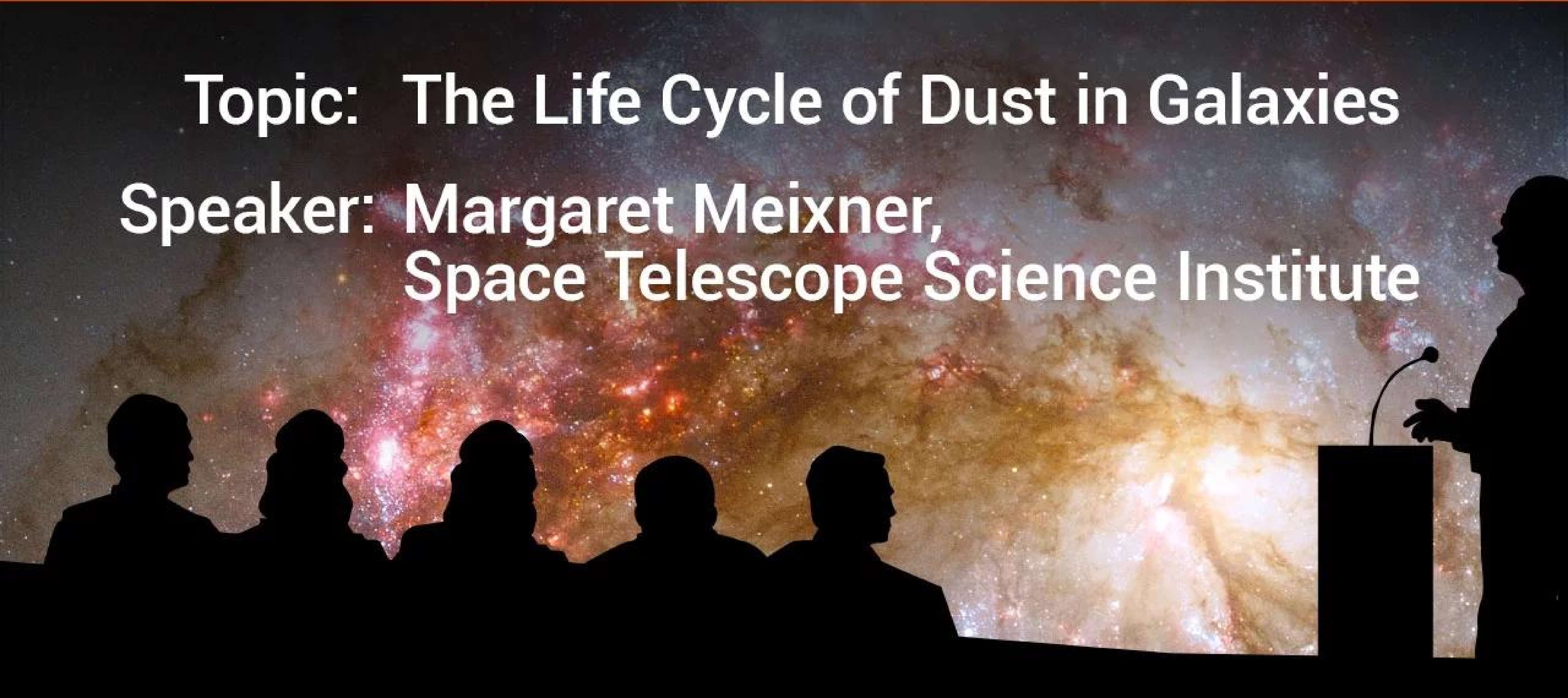
Hubble Public Lecture Series



1
00:00:07,519 --> 00:00:02,899
our talk tonight is the life cycle of

2
00:00:08,810 --> 00:00:07,529
dust in galaxies we have an astronomer

3
00:00:11,930 --> 00:00:08,820
in the office of public outreach who

4
00:00:13,280 --> 00:00:11,940
studies dust and I got to say that some

5
00:00:14,660 --> 00:00:13,290
of the other astronomers you know give

6
00:00:16,519 --> 00:00:14,670
him a little bit of a hard time like aha

7
00:00:17,870 --> 00:00:16,529
you're looking at dust out there you

8
00:00:20,990 --> 00:00:17,880
know a can a pledge could wipe you out

9
00:00:22,460 --> 00:00:21,000
well this is actually one of the most

10
00:00:24,380 --> 00:00:22,470
important things in astronomy and

11
00:00:26,689 --> 00:00:24,390
Margaret will be able to show you if the

12
00:00:30,380 --> 00:00:26,699
splendors of dust in the universe

13
00:00:32,900 --> 00:00:30,390

tonight upcoming next month Tom Brown

14
00:00:34,400 --> 00:00:32,910
who was a gracious and postponed news

15
00:00:36,620 --> 00:00:34,410
talk when we had a special guest speaker

16
00:00:38,990 --> 00:00:36,630
a few months ago will talk about on the

17
00:00:42,440 --> 00:00:39,000
trail of the missing galaxies the oldest

18
00:00:45,979 --> 00:00:42,450
stars in the neighborhood in our local

19
00:00:48,139 --> 00:00:45,989
galactic neighborhood October Bill Blair

20
00:00:51,139 --> 00:00:48,149
of from across the street Johns Hopkins

21
00:00:54,170 --> 00:00:51,149
will do present a multi-wavelength view

22
00:00:56,500 --> 00:00:54,180
of stellar life and death in Messier 83

23
00:00:58,729 --> 00:00:56,510
or another talk actually he had about

24
00:01:00,979 --> 00:00:58,739
writing another title he had like four

25
00:01:02,720 --> 00:01:00,989
different titles he was suggesting this

26
00:01:04,160 --> 00:01:02,730
is the one that I said oh this sounds

27
00:01:05,359 --> 00:01:04,170
good bill but he hasn't got back to me

28
00:01:08,270 --> 00:01:05,369
as to which one you'll actually choose

29
00:01:11,359 --> 00:01:08,280
but it'll be about supernovae in the

30
00:01:13,660 --> 00:01:11,369
galaxy Messier 83 in November

31
00:01:16,940 --> 00:01:13,670
unfortunately our speaker TVA is back

32
00:01:19,789 --> 00:01:16,950
and he keeps popping up every now and

33
00:01:21,920 --> 00:01:19,799
then this I will note is on November 1st

34
00:01:24,289 --> 00:01:21,930
it's not on election night election

35
00:01:25,850 --> 00:01:24,299
night will be November 8th so the week

36
00:01:28,219 --> 00:01:25,860
before election night maybe we're gonna

37
00:01:30,649 --> 00:01:28,229
have a debate you know no no no no

38
00:01:33,499 --> 00:01:30,659

absolutely not we don't do politics here

39
00:01:35,630 --> 00:01:33,509
but please come the week before you vote

40
00:01:38,920 --> 00:01:35,640
to our public lecture series

41
00:01:42,440 --> 00:01:38,930
I'll have that speaker for you in a bit

42
00:01:44,359 --> 00:01:42,450
deconstruction as you know San Martin

43
00:01:47,149 --> 00:01:44,369
drives south of STScI will be closed

44
00:01:49,190 --> 00:01:47,159
until approximately September 2016

45
00:01:50,990 --> 00:01:49,200
so to get here tonight you had to

46
00:01:53,240 --> 00:01:51,000
approach STS yeah I from the north

47
00:01:56,870 --> 00:01:53,250
however you'll notice that September

48
00:01:59,569 --> 00:01:56,880
2016 so by the next month things might

49
00:02:01,880 --> 00:01:59,579
have changed if you go to this website

50
00:02:05,170 --> 00:02:01,890
it says that phase 1 is scheduled to be

51
00:02:08,059 --> 00:02:05,180
completed the end of August with phase 2

52
00:02:11,360 --> 00:02:08,069
to begin immediately afterward that

53
00:02:13,790 --> 00:02:11,370
means that next time we have this it

54
00:02:15,980 --> 00:02:13,800
could be see all this

55
00:02:18,290 --> 00:02:15,990
stuff here that's currently closed it

56
00:02:21,140 --> 00:02:18,300
could be then that then the red stuff

57
00:02:22,790 --> 00:02:21,150
and the yellow stuff will be closed so

58
00:02:25,640 --> 00:02:22,800
instead of coming from University

59
00:02:28,550 --> 00:02:25,650
Parkway south to STScI you will have to

60
00:02:31,640 --> 00:02:28,560
come from Wyman Park Drive to come north

61
00:02:34,190 --> 00:02:31,650
to us okay so approach us from the south

62
00:02:36,320 --> 00:02:34,200
so next month I expect I will have this

63
00:02:38,630 --> 00:02:36,330

one that between September and December

64
00:02:41,750 --> 00:02:38,640
the north part will be closed so

65
00:02:44,720 --> 00:02:41,760
approach from Wyman Park Drive if you

66
00:02:46,850 --> 00:02:44,730
are on our email list I will the day or

67
00:02:48,860 --> 00:02:46,860
both of the lecture or before the

68
00:02:50,720 --> 00:02:48,870
lecture make sure that you get the

69
00:02:52,880 --> 00:02:50,730
proper instructions as to whether come

70
00:02:55,370 --> 00:02:52,890
from the north or from the South okay or

71
00:02:58,670 --> 00:02:55,380
you can just to check this website for

72
00:03:02,030 --> 00:02:58,680
yourself our website where you get

73
00:03:03,620 --> 00:03:02,040
information like this is well if you

74
00:03:04,940 --> 00:03:03,630
just search Hubble public talks you'll

75
00:03:07,460 --> 00:03:04,950
find it in your favorite search engine

76
00:03:09,800 --> 00:03:07,470
at Hubble site we have a Golding Hubble

77
00:03:12,890 --> 00:03:09,810
site or go talks you get the list of the

78
00:03:16,280 --> 00:03:12,900
upcoming lectures you have links to the

79
00:03:18,920 --> 00:03:16,290
live YouTube and STS a webcasting feeds

80
00:03:21,860 --> 00:03:18,930
as well as the past lectures on YouTube

81
00:03:24,890 --> 00:03:21,870
and the STS a webcasting and the easiest

82
00:03:27,229 --> 00:03:24,900
way to sign up for our email list you

83
00:03:30,979 --> 00:03:27,239
can subscribe or even unsubscribe here

84
00:03:33,080 --> 00:03:30,989
all right our e-mail announcements if

85
00:03:35,479 --> 00:03:33,090
you don't want to use our web page can

86
00:03:39,080 --> 00:03:35,489
be found at mail list at stsci dot edu

87
00:03:41,620 --> 00:03:39,090
is called public lecture announce last

88
00:03:44,570 --> 00:03:41,630

thing if you have questions or cut

89
00:03:46,790 --> 00:03:44,580
social media we are on Facebook we had

90
00:03:49,600 --> 00:03:46,800
two Twitter accounts we're on Google+

91
00:03:53,600 --> 00:03:49,610
we have Pinterest I'm also on Facebook

92
00:03:58,370 --> 00:03:53,610
Google+ and Twitter occasionally and I

93
00:04:00,470 --> 00:03:58,380
have a blog on Hubbell site alright

94
00:04:02,780 --> 00:04:00,480
the observatory the weather appears to

95
00:04:04,880 --> 00:04:02,790
be permitting so it looks like there

96
00:04:06,979 --> 00:04:04,890
will be observing tonight this is the

97
00:04:08,570 --> 00:04:06,989
Maryland Space Grant Observatory which

98
00:04:10,640 --> 00:04:08,580
is on top of the physics and astronomy

99
00:04:12,590 --> 00:04:10,650
building across the street here in

100
00:04:16,130 --> 00:04:12,600
Hopkins so you can go up and do a little

101
00:04:18,289 --> 00:04:16,140
bit observing afterwards Duncan will

102
00:04:20,270 --> 00:04:18,299
probably be here at the end if I forget

103
00:04:22,219 --> 00:04:20,280
somebody remind me hey hey what about

104
00:04:24,320 --> 00:04:22,229
the observing because you'll just sort

105
00:04:26,529 --> 00:04:24,330
of meet if you cannot go over by

106
00:04:28,040 --> 00:04:26,539
yourself you got to go over with Duncan

107
00:04:30,499 --> 00:04:28,050
because you got

108
00:04:31,879 --> 00:04:30,509
through some some get into the building

109
00:04:34,719 --> 00:04:31,889
and through some stairs and up and you

110
00:04:38,540 --> 00:04:34,729
have to go as a group okay all right

111
00:04:40,580 --> 00:04:38,550
news from the universe for August 2016

112
00:04:42,260 --> 00:04:40,590
and I will apologize it's gonna be a

113
00:04:43,580 --> 00:04:42,270

little abbreviated because we've been

114
00:04:45,290 --> 00:04:43,590
really busy in the office of public

115
00:04:47,210 --> 00:04:45,300
outreach lately I didn't have enough

116
00:04:49,089 --> 00:04:47,220
time to prepare full stories but I do

117
00:04:52,999 --> 00:04:49,099
have two short stories for you tonight

118
00:04:58,520 --> 00:04:53,009
our first story the final frontier of

119
00:05:00,260 --> 00:04:58,530
the universe if you keep up with popular

120
00:05:04,159 --> 00:05:00,270
culture you know that this year is the

121
00:05:07,339 --> 00:05:04,169
50th anniversary of Star Trek the Star

122
00:05:09,110 --> 00:05:07,349
Trek series 50 years ago how many

123
00:05:13,370 --> 00:05:09,120
seasons did the original Star Trek TV

124
00:05:15,980 --> 00:05:13,380
show last just three it's amazing that

125
00:05:17,899 --> 00:05:15,990
this franchise has lasted so long but

126
00:05:22,189 --> 00:05:17,909
the original TV series is only three

127
00:05:24,620 --> 00:05:22,199
seasons well we here at Hubble and NASA

128
00:05:27,999 --> 00:05:24,630
like to get in on a good pop culture

129
00:05:30,140 --> 00:05:28,009
reference so well we don't have

130
00:05:33,320 --> 00:05:30,150
spaceships that can explore the universe

131
00:05:37,219 --> 00:05:33,330
we don't have warp drive to boost us to

132
00:05:39,499 --> 00:05:37,229
the far side of the galaxy but we do

133
00:05:43,219 --> 00:05:39,509
explore the universe and we use a

134
00:05:46,969 --> 00:05:43,229
version of nature's own warp drive what

135
00:05:49,490 --> 00:05:46,979
we do have is gravitational lensing the

136
00:05:51,950 --> 00:05:49,500
mass of giant clusters of galaxies

137
00:05:55,839 --> 00:05:51,960
actually warps the fabric of space

138
00:05:58,459 --> 00:05:55,849

around them and using that spatial warp

139
00:06:02,450 --> 00:05:58,469
the light that passes through it is

140
00:06:07,120 --> 00:06:02,460
redirected such that the light actually

141
00:06:09,170 --> 00:06:07,130
lens acts like a lens and focuses and

142
00:06:13,219 --> 00:06:09,180
amplifies the light that passes through

143
00:06:15,589 --> 00:06:13,229
it so we have gravitational lensing that

144
00:06:18,140 --> 00:06:15,599
we can use to look at the most distant

145
00:06:20,749 --> 00:06:18,150
regions of universe and we have done so

146
00:06:24,260 --> 00:06:20,759
in a project called the frontier fields

147
00:06:27,200 --> 00:06:24,270
and for the press release that we did

148
00:06:28,850 --> 00:06:27,210
celebrating in honor of stark the new

149
00:06:31,580 --> 00:06:28,860
Star Trek movie in Star Trek's 50th

150
00:06:36,139 --> 00:06:31,590
anniversary we released the last the

151
00:06:40,310 --> 00:06:36,149
final of our frontier fields a bell s106

152
00:06:41,980 --> 00:06:40,320
3 so what you are seeing here is this

153
00:06:44,740 --> 00:06:41,990
giant cluster of

154
00:06:47,680 --> 00:06:44,750
sees all these galaxies here that are so

155
00:06:50,620 --> 00:06:47,690
massive - combined that they warp the

156
00:06:52,210 --> 00:06:50,630
space around it and then the galaxies

157
00:06:54,520 --> 00:06:52,220
that are behind it the light that passes

158
00:06:57,190 --> 00:06:54,530
through gets warped it becomes distorted

159
00:06:59,650 --> 00:06:57,200
you can see these long streaky Archy

160
00:07:02,170 --> 00:06:59,660
things those are gravitationally lens

161
00:07:04,180 --> 00:07:02,180
arcs they are the images of galaxies

162
00:07:05,650 --> 00:07:04,190
behind the cluster that have become

163
00:07:08,440 --> 00:07:05,660

stretched out as the light passes

164
00:07:08,680 --> 00:07:08,450
through that cluster of galaxies all

165
00:07:11,500 --> 00:07:08,690
right

166
00:07:14,050 --> 00:07:11,510
it also amplifies the light makes it

167
00:07:16,570 --> 00:07:14,060
brighter so that we can see fainter

168
00:07:19,870 --> 00:07:16,580
galaxies by looking through this cluster

169
00:07:21,610 --> 00:07:19,880
than we otherwise could all right the

170
00:07:24,130 --> 00:07:21,620
frontier fields project is one of the

171
00:07:27,130 --> 00:07:24,140
largest projects ever to get time on

172
00:07:30,250 --> 00:07:27,140
Hubble and it not only observes these

173
00:07:31,330 --> 00:07:30,260
giant clusters but while one instrument

174
00:07:34,030 --> 00:07:31,340
is observing these giant clusters

175
00:07:36,730 --> 00:07:34,040
another instrument is observing a random

176
00:07:39,130 --> 00:07:36,740
field relatively nearby and so we also

177
00:07:42,220 --> 00:07:39,140
have these deep fields that we can

178
00:07:44,530 --> 00:07:42,230
release because we process two images at

179
00:07:46,870 --> 00:07:44,540
the same time one of the cluster one of

180
00:07:49,510 --> 00:07:46,880
this parallel field and these parallel

181
00:07:51,640 --> 00:07:49,520
fields are very deep images of the night

182
00:07:55,240 --> 00:07:51,650
skies like the Hubble Deep Field and

183
00:07:58,330 --> 00:07:55,250
Hubble ultra-deep field so using the

184
00:08:01,150 --> 00:07:58,340
nature's warp drive we are exploring the

185
00:08:03,790 --> 00:08:01,160
frontiers of the universe with the

186
00:08:06,610 --> 00:08:03,800
frontier fields project and if you think

187
00:08:08,200 --> 00:08:06,620
that sort of play on words was bad you

188
00:08:10,450 --> 00:08:08,210

ought to read the press releases because

189
00:08:12,880 --> 00:08:10,460
they gets really bad in terms of trying

190
00:08:14,980 --> 00:08:12,890
to use the play on words but there was a

191
00:08:17,560 --> 00:08:14,990
way of connecting with the the Star Trek

192
00:08:19,780 --> 00:08:17,570
50th anniversary and showing off the

193
00:08:20,800 --> 00:08:19,790
deep deep images we are getting of the

194
00:08:24,790 --> 00:08:20,810
universe with the frontier fields

195
00:08:28,450 --> 00:08:24,800
project our second story tonight is

196
00:08:31,720 --> 00:08:28,460
about the heart of the Crab Nebula now

197
00:08:34,740 --> 00:08:31,730
in 2000 or 2001 we released this image

198
00:08:37,840 --> 00:08:34,750
of the Crab Nebula the Crab Nebula is a

199
00:08:39,790 --> 00:08:37,850
supernova remnant this is a star that

200
00:08:42,520 --> 00:08:39,800
was observed by chinese astronomers to

201
00:08:45,960 --> 00:08:42,530
have exploded from our point of view a

202
00:08:49,390 --> 00:08:45,970
thousand years ago we saw the star

203
00:08:51,130 --> 00:08:49,400
brightened a thousand years ago it was

204
00:08:53,680 --> 00:08:51,140
bright enough to be observed in the

205
00:08:54,440 --> 00:08:53,690
daytime for about a month okay

206
00:08:56,090 --> 00:08:54,450
and

207
00:08:58,220 --> 00:08:56,100
we look in that same spot in the sky

208
00:08:59,990 --> 00:08:58,230
these days this is what we see we see

209
00:09:02,900 --> 00:09:00,000
the guts of the star just blown out

210
00:09:05,750 --> 00:09:02,910
across space and so this is Hubble's

211
00:09:08,360 --> 00:09:05,760
image from but this is probably this is

212
00:09:10,640 --> 00:09:08,370
a with pictu image of the Crab Nebula

213
00:09:12,520 --> 00:09:10,650

and you can see all of the the material

214
00:09:15,650 --> 00:09:12,530
of the star that blows out into space

215
00:09:17,960 --> 00:09:15,660
now at the center of the Crab Nebula the

216
00:09:21,290 --> 00:09:17,970
beating heart of the Crab Nebula is

217
00:09:23,990 --> 00:09:21,300
something called a pulsar and so we just

218
00:09:26,210 --> 00:09:24,000
released in this month this image of a

219
00:09:28,400 --> 00:09:26,220
core of the Crab Nebula all right you

220
00:09:30,680 --> 00:09:28,410
can see that filamentary structure but

221
00:09:32,990 --> 00:09:30,690
you can also see these rings around here

222
00:09:36,410 --> 00:09:33,000
circling around at the center which is

223
00:09:39,560 --> 00:09:36,420
where the pulsar is now a pulsar is a

224
00:09:42,560 --> 00:09:39,570
neutron star that is spinning okay and a

225
00:09:44,690 --> 00:09:42,570
neutron star is basically an atomic

226
00:09:47,450 --> 00:09:44,700
nucleus all right that weighs as much as

227
00:09:49,310 --> 00:09:47,460
the Sun right because all of the

228
00:09:51,980 --> 00:09:49,320
material at the end of the supernova

229
00:09:54,440 --> 00:09:51,990
explosion collapses that the core of it

230
00:09:57,770 --> 00:09:54,450
collapses to become there's really super

231
00:10:00,770 --> 00:09:57,780
dense neutron star at the core and it is

232
00:10:03,790 --> 00:10:00,780
spinning so fast that the heart of the

233
00:10:06,890 --> 00:10:03,800
crowd nebula spins 30 times every second

234
00:10:12,170 --> 00:10:06,900
this was a signal that was discovered by

235
00:10:13,190 --> 00:10:12,180
radio astronomers in 1960 1961 called

236
00:10:16,480 --> 00:10:13,200
lgm1

237
00:10:19,040 --> 00:10:16,490
as in little green men number one

238
00:10:21,770 --> 00:10:19,050

because we didn't know what it was back

239
00:10:24,230 --> 00:10:21,780
in the 60s we now know that it is a

240
00:10:26,930 --> 00:10:24,240
neutron star spinning 30 times a second

241
00:10:29,180 --> 00:10:26,940
and it has intense intense magnetic

242
00:10:31,400 --> 00:10:29,190
field and here you can actually see the

243
00:10:33,740 --> 00:10:31,410
rings around here our material that is

244
00:10:36,560 --> 00:10:33,750
actually moving away and you can see the

245
00:10:37,880 --> 00:10:36,570
material and we actually have time-lapse

246
00:10:40,640 --> 00:10:37,890
of this where we can actually watch the

247
00:10:42,590 --> 00:10:40,650
material move away from the Crab Nebula

248
00:10:44,870 --> 00:10:42,600
one of the few things in astronomy that

249
00:10:48,290 --> 00:10:44,880
changes during our lifetime

250
00:10:50,960 --> 00:10:48,300
there was no science new science result

251
00:10:52,820 --> 00:10:50,970
released with this image this was just a

252
00:10:56,900 --> 00:10:52,830
reprocessing of other data that we had

253
00:11:00,260 --> 00:10:56,910
gotten but going in deeper and seeing

254
00:11:02,330 --> 00:11:00,270
the heart of the Crab Nebula okay that

255
00:11:10,030 --> 00:11:02,340
was our Hubble heritage release for July

256
00:11:16,940 --> 00:11:12,890
well if I go back to this image the

257
00:11:18,980 --> 00:11:16,950
neutron star is about in here okay

258
00:11:20,930 --> 00:11:18,990
the two images are actually at slightly

259
00:11:24,140 --> 00:11:20,940
different orientation okay I think the

260
00:11:26,900 --> 00:11:24,150
the image is rotated about 110 degrees

261
00:11:28,040 --> 00:11:26,910
from from this image I was gonna line

262
00:11:31,340 --> 00:11:28,050
them up but I didn't quite have time

263
00:11:33,500 --> 00:11:31,350

today to do that sorry about right but

264
00:11:36,530 --> 00:11:33,510
yeah it is it is it is in the in the

265
00:11:40,820 --> 00:11:36,540
core of that by the way this nebula here

266
00:11:43,040 --> 00:11:40,830
is about ten light years across okay so

267
00:11:45,350 --> 00:11:43,050
it's gone from being a single star to

268
00:11:48,400 --> 00:11:45,360
being about ten light years across over

269
00:11:51,770 --> 00:11:48,410
the course of a thousand years all right

270
00:11:55,100 --> 00:11:51,780
okay so now we go to our featured

271
00:11:57,890 --> 00:11:55,110
speaker and our featured speaker tonight

272
00:12:00,170 --> 00:11:57,900
is Margaret Meixner she and I first met

273
00:12:02,600 --> 00:12:00,180
at the University of California Berkeley

274
00:12:04,850 --> 00:12:02,610
where we were doing our graduate school

275
00:12:07,970 --> 00:12:04,860
together back at Berkeley they're

276
00:12:09,920 --> 00:12:07,980
actually several from from our group of

277
00:12:11,000 --> 00:12:09,930
astronomers going through grad students

278
00:12:12,830 --> 00:12:11,010
going through Berkeley that are working

279
00:12:14,450 --> 00:12:12,840
here at Space Telescope so obviously we

280
00:12:17,330 --> 00:12:14,460
were just an amazing group of grad

281
00:12:20,780 --> 00:12:17,340
students right several of us ended up

282
00:12:23,180 --> 00:12:20,790
here Margaret however was Mark was the

283
00:12:26,480 --> 00:12:23,190
most exceptional of all of us as

284
00:12:30,860 --> 00:12:26,490
evidenced by after she graduated and got

285
00:12:32,900 --> 00:12:30,870
her PhD she didn't go to a postdoc she

286
00:12:34,670 --> 00:12:32,910
was offered an associate assistant

287
00:12:36,650 --> 00:12:34,680
professorship at the University of

288
00:12:39,170 --> 00:12:36,660

Illinois she went straight from grad

289
00:12:41,660 --> 00:12:39,180
school to being a professor that just

290
00:12:42,760 --> 00:12:41,670
almost never happens okay that tells you

291
00:12:44,810 --> 00:12:42,770
how special she is

292
00:12:47,930 --> 00:12:44,820
fortunately University of Illinois

293
00:12:49,760 --> 00:12:47,940
couldn't keep her alright and in 2002

294
00:12:52,340 --> 00:12:49,770
she came here to the whole Space

295
00:12:54,110 --> 00:12:52,350
Telescope Science Institute and has been

296
00:12:59,300 --> 00:12:54,120
here for I guess 14 years now that makes

297
00:13:02,510 --> 00:12:59,310
it yeah she is an expert in dust of

298
00:13:05,000 --> 00:13:02,520
course but she's also really really good

299
00:13:08,210 --> 00:13:05,010
at doing very large observations very

300
00:13:09,970 --> 00:13:08,220
large survey observations the last talk

301
00:13:12,830 --> 00:13:09,980
you gave here was on planetary nebula

302
00:13:15,680 --> 00:13:12,840
right but you've gay you've done since

303
00:13:17,929 --> 00:13:15,690
then done a number of very large surveys

304
00:13:19,339 --> 00:13:17,939
and she's done them so well

305
00:13:21,139 --> 00:13:19,349
they've actually made her put her in

306
00:13:23,779 --> 00:13:21,149
charge a lot of things and her current

307
00:13:25,069 --> 00:13:23,789
position as as deputy of the instruments

308
00:13:27,169 --> 00:13:25,079
division here

309
00:13:28,909 --> 00:13:27,179
I think she's pleased to be able to talk

310
00:13:30,889 --> 00:13:28,919
about the science work that she loves so

311
00:13:48,710 --> 00:13:30,899
much so ladies and gentlemen dr.

312
00:13:50,239 --> 00:13:48,720
Margaret Meixner can you hear me if you

313
00:13:54,319 --> 00:13:50,249

can in the back wave your hand

314
00:13:56,689 --> 00:13:54,329
all right good all right so I'm gonna

315
00:13:59,479 --> 00:13:56,699
talk to you about the life cycle of dust

316
00:14:01,999 --> 00:13:59,489
and galaxies and the subtitle here is

317
00:14:03,849 --> 00:14:02,009
from these large surveys that Frank was

318
00:14:06,669 --> 00:14:03,859
telling you that I that I'd love to do

319
00:14:09,409 --> 00:14:06,679
insights from Spitzer and Herschel

320
00:14:13,460 --> 00:14:09,419
Spitzer and Herschel are two infrared

321
00:14:16,609 --> 00:14:13,470
space observatories that flew Spitzer

322
00:14:18,409 --> 00:14:16,619
Stoll still out there and I used it to

323
00:14:19,399 --> 00:14:18,419
survey the Magellanic Clouds how many

324
00:14:27,139 --> 00:14:19,409
people have heard of the Magellanic

325
00:14:28,460 --> 00:14:27,149
Clouds before Wow very well all right so

326
00:14:30,999 --> 00:14:28,470
this is a picture of the Large

327
00:14:38,179 --> 00:14:31,009
Magellanic Cloud that's a combination of

328
00:14:39,859 --> 00:14:38,189
both Spitzer and Herschel data and it

329
00:14:42,499 --> 00:14:39,869
looks very disc II it has all this

330
00:14:45,189 --> 00:14:42,509
frothy very colorful things and I look

331
00:14:50,299 --> 00:14:45,199
at it it's like wow this is beautiful

332
00:14:52,129 --> 00:14:50,309
isn't that beautiful and I look at it I

333
00:14:54,439 --> 00:14:52,139
said this is beautiful but I can't help

334
00:14:56,179 --> 00:14:54,449
but thinking about all the dust that's

335
00:14:57,649 --> 00:14:56,189
in it that's causing it because all this

336
00:15:01,099 --> 00:14:57,659
emission you see here is actually from

337
00:15:03,169 --> 00:15:01,109
the dust in these galaxies in particular

338
00:15:08,659 --> 00:15:03,179

I asked myself the question of why does

339
00:15:10,279 --> 00:15:08,669
this galaxy have dust because as you may

340
00:15:12,109 --> 00:15:10,289
have heard in these forums the whole

341
00:15:13,879 --> 00:15:12,119
universe began is mostly hydrogen and

342
00:15:16,339 --> 00:15:13,889
helium it may be a few other elements

343
00:15:20,029 --> 00:15:16,349
but we've got dust now so how did it get

344
00:15:22,579 --> 00:15:20,039
there so what I'm gonna be talking to

345
00:15:24,019 --> 00:15:22,589
you about is the life cycle of dust in

346
00:15:27,769 --> 00:15:24,029
galaxies and I'm going to use this

347
00:15:30,049 --> 00:15:27,779
cartoon to describe how dust gets there

348
00:15:30,750 --> 00:15:30,059
or the processes in there and also how

349
00:15:33,630 --> 00:15:30,760
much

350
00:15:34,980 --> 00:15:33,640
a little we know about it so let me go

351
00:15:36,600 --> 00:15:34,990
through this because I'm gonna use this

352
00:15:40,230 --> 00:15:36,610
as a narrative tool throughout the whole

353
00:15:43,530 --> 00:15:40,240
talk so at the center here we have what

354
00:15:45,990 --> 00:15:43,540
I call the origin of dust so dust can be

355
00:15:48,600 --> 00:15:46,000
formed in the atmospheres of AGB stars

356
00:15:50,580 --> 00:15:48,610
so AG B stands for asymptotic giant

357
00:15:53,160 --> 00:15:50,590
branch stars these are dying stars like

358
00:15:57,480 --> 00:15:53,170
our Sun will become an Ag B star and

359
00:15:59,820 --> 00:15:57,490
they blow winds and send out dust dust

360
00:16:01,110 --> 00:15:59,830
dust may also arise in supernovae so

361
00:16:04,260 --> 00:16:01,120
Frank just talked to you about the Crab

362
00:16:07,440 --> 00:16:04,270
Nebula the crab has dust in it and

363
00:16:10,260 --> 00:16:07,450

that's the pipe to supernova that's when

364
00:16:13,440 --> 00:16:10,270
a massive star explodes type 1a

365
00:16:14,820 --> 00:16:13,450
supernovas are being looked at but

366
00:16:16,980 --> 00:16:14,830
there's that's more like a white dwarf

367
00:16:19,500 --> 00:16:16,990
pair exploding so anyway these are where

368
00:16:21,630 --> 00:16:19,510
the new grains come from and they get

369
00:16:26,040 --> 00:16:21,640
injected out drifts out into the

370
00:16:28,200 --> 00:16:26,050
interstellar medium and they're in the

371
00:16:30,930 --> 00:16:28,210
interstellar medium they get processed a

372
00:16:33,210 --> 00:16:30,940
lot so these same supernovae that create

373
00:16:34,890 --> 00:16:33,220
dust will also send huge shock waves in

374
00:16:38,160 --> 00:16:34,900
the interstellar medium and they'll

375
00:16:40,410 --> 00:16:38,170
shatter the grains and then these grains

376
00:16:42,810 --> 00:16:40,420
will drift around because the is M

377
00:16:48,000 --> 00:16:42,820
drifts around into the inter cloud

378
00:16:49,890 --> 00:16:48,010
medium clouds will form out of these and

379
00:16:53,040 --> 00:16:49,900
the dust kind of gets dragged along with

380
00:16:55,530 --> 00:16:53,050
the gas in there and then they become

381
00:16:59,190 --> 00:16:55,540
cold clouds and maybe in the cold clouds

382
00:17:01,320 --> 00:16:59,200
you get growth of dust that as the

383
00:17:03,480 --> 00:17:01,330
grains grow bigger because they're cold

384
00:17:05,720 --> 00:17:03,490
and they get Mantle's around them and

385
00:17:08,400 --> 00:17:05,730
maybe they just start sticking and grow

386
00:17:11,340 --> 00:17:08,410
and then from and then this this whole

387
00:17:13,770 --> 00:17:11,350
cycle out here the is M can happen

388
00:17:16,590 --> 00:17:13,780

around but also from these dense clouds

389
00:17:19,680 --> 00:17:16,600
you can form young stars and so young

390
00:17:21,480 --> 00:17:19,690
stars form and then you know they they

391
00:17:23,910 --> 00:17:21,490
grow up to main sequence stars and then

392
00:17:25,199 --> 00:17:23,920
the whole process to Stiles starts over

393
00:17:28,550 --> 00:17:25,209
again so that's why we call it a life

394
00:17:31,530 --> 00:17:28,560
cycle because stars have a life cycle

395
00:17:33,180 --> 00:17:31,540
and because stars have a life cycle on

396
00:17:38,400 --> 00:17:33,190
the air in some sense the sources and

397
00:17:42,370 --> 00:17:40,780
all right so let me talk a little bit

398
00:17:46,720 --> 00:17:42,380
about the Magellanic Clouds and why I

399
00:17:49,300 --> 00:17:46,730
chose them for this study first of all

400
00:17:51,610 --> 00:17:49,310
they're nearby so so proximity is

401
00:17:55,570 --> 00:17:51,620
helpful the Large Magellanic Clouds

402
00:17:58,750 --> 00:17:55,580
about 50 kiloparsecs away the small

403
00:18:00,790 --> 00:17:58,760
Magellanic Clouds about 60 and you

404
00:18:03,010 --> 00:18:00,800
multiply that by kind of 3.3 to get

405
00:18:04,990 --> 00:18:03,020
light-years but if you can ever go to

406
00:18:06,670 --> 00:18:05,000
the southern hemisphere you can see the

407
00:18:08,110 --> 00:18:06,680
Magellanic Clouds with your own eye at

408
00:18:12,340 --> 00:18:08,120
night it's quite a sight they're

409
00:18:14,820 --> 00:18:12,350
beautiful visions to see the Large

410
00:18:17,890 --> 00:18:14,830
Magellanic Cloud which I'm going to be

411
00:18:19,660 --> 00:18:17,900
because I am affiliated with NASA I love

412
00:18:21,910 --> 00:18:19,670
acronyms so I'm going to call it LM C

413
00:18:23,410 --> 00:18:21,920

for Large Magellanic Clouds it's kind of

414
00:18:24,490 --> 00:18:23,420
nearly face on remember that first

415
00:18:27,670 --> 00:18:24,500
picture I showed you is kind of

416
00:18:29,470 --> 00:18:27,680
disc-like so it's nearly face on and the

417
00:18:31,210 --> 00:18:29,480
combination of both these things the

418
00:18:33,690 --> 00:18:31,220
fact that they're kind of close by and

419
00:18:37,350 --> 00:18:33,700
the LM scene particulars kind of face on

420
00:18:40,330 --> 00:18:37,360
you can separate the stars from the

421
00:18:42,520 --> 00:18:40,340
interstellar clouds and then watch their

422
00:18:44,230 --> 00:18:42,530
in monitor their interaction between

423
00:18:47,200 --> 00:18:44,240
each other because you can separate them

424
00:18:48,670 --> 00:18:47,210
and because it's nearly face-on you can

425
00:18:50,230 --> 00:18:48,680
kind of look at a dust cloud and say

426
00:18:51,730 --> 00:18:50,240
well I think it's really associated with

427
00:18:55,570 --> 00:18:51,740
this gas cloud and stuff so there's a

428
00:18:58,480 --> 00:18:55,580
lot of clarity and information you can

429
00:19:00,640 --> 00:18:58,490
get from these from these systems now

430
00:19:02,200 --> 00:19:00,650
the Magellanic Clouds are I've been

431
00:19:04,110 --> 00:19:02,210
interested for a lot of reasons

432
00:19:06,400 --> 00:19:04,120
throughout the the history of astronomy

433
00:19:09,870 --> 00:19:06,410
they're sort of a stepping stone between

434
00:19:13,120 --> 00:19:09,880
galactic and extra galactic studies

435
00:19:15,730 --> 00:19:13,130
they're mean metallicity which means how

436
00:19:19,930 --> 00:19:15,740
many metals and metals is anything

437
00:19:23,470 --> 00:19:19,940
heavier than helium really is the LMC

438
00:19:26,050 --> 00:19:23,480

it's about 1/2 solar so it's less half

439
00:19:28,270 --> 00:19:26,060
half of the metallicity of our own Sun

440
00:19:30,460 --> 00:19:28,280
in our own solar system and the small

441
00:19:33,700 --> 00:19:30,470
Magellanic Cloud is 0.2 times that's

442
00:19:35,980 --> 00:19:33,710
sort of 1/5 so it's less and this

443
00:19:39,310 --> 00:19:35,990
metallicity is interesting because the

444
00:19:42,730 --> 00:19:39,320
is Emer the interstellar medium in the

445
00:19:45,370 --> 00:19:42,740
universe had a in in galaxies in the

446
00:19:49,450 --> 00:19:45,380
universe had a peak star formation epoch

447
00:19:50,670 --> 00:19:49,460
and a Z about 1.5 but the mean

448
00:19:54,390 --> 00:19:50,680
mentallity the Magellanic

449
00:19:55,980 --> 00:19:54,400
is actually brackets what happened

450
00:19:58,650 --> 00:19:55,990
during the peak star formation effect so

451
00:20:00,240 --> 00:19:58,660
if you study sort of the Astrophysical

452
00:20:01,530 --> 00:20:00,250
processes in the Magellanic Clouds you

453
00:20:03,480 --> 00:20:01,540
might get some insight of what was

454
00:20:06,660 --> 00:20:03,490
happening during this major event in our

455
00:20:09,510 --> 00:20:06,670
universe of star formation and then the

456
00:20:13,770 --> 00:20:09,520
dust content that is what we call the

457
00:20:17,340 --> 00:20:13,780
dust to gas ratio is lower than our own

458
00:20:20,640 --> 00:20:17,350
galaxy again about half the Milky of the

459
00:20:25,020 --> 00:20:20,650
Milky Way's dust content and for the SMC

460
00:20:26,940 --> 00:20:25,030
it's about a tenth and then some other

461
00:20:29,430 --> 00:20:26,950
interesting aspects to the large and

462
00:20:31,140 --> 00:20:29,440
small Magellanic Cloud have known tidal

463
00:20:35,430 --> 00:20:31,150

interactions between each other there

464
00:20:38,190 --> 00:20:35,440
they're a pair and possibly the Milky

465
00:20:40,740 --> 00:20:38,200
Way and they've had a very long history

466
00:20:42,360 --> 00:20:40,750
of studies of all sorts of studies

467
00:20:44,610 --> 00:20:42,370
they've been a proving ground for lots

468
00:20:46,590 --> 00:20:44,620
of studies I mean for example the whole

469
00:20:48,690 --> 00:20:46,600
thing is cepheid's relation which people

470
00:20:50,160 --> 00:20:48,700
use for distance indicators that was

471
00:20:53,460 --> 00:20:50,170
first established in the Magellanic

472
00:20:56,760 --> 00:20:53,470
Clouds and so for a member of reasons

473
00:21:03,900 --> 00:20:56,770
this is sort of an ideal case study for

474
00:21:07,410 --> 00:21:03,910
galaxy evolution alright so what I did

475
00:21:09,450 --> 00:21:07,420
is I led to large surveys and the work

476
00:21:11,640 --> 00:21:09,460
I'm showing is actually from a team of

477
00:21:15,480 --> 00:21:11,650
sort of over a hundred scientists

478
00:21:18,390 --> 00:21:15,490
worldwide but I helped I helped organize

479
00:21:20,340 --> 00:21:18,400
the effort with Spitzer we call that

480
00:21:22,260 --> 00:21:20,350
surveying the agents of galaxy evolution

481
00:21:24,840 --> 00:21:22,270
the agents are the stars in the

482
00:21:27,240 --> 00:21:24,850
interstellar medium that really create

483
00:21:29,040 --> 00:21:27,250
the environment and we also called it

484
00:21:30,780 --> 00:21:29,050
the Herschel inventory of the agents of

485
00:21:34,680 --> 00:21:30,790
galaxy evolution so we call them sage

486
00:21:36,720 --> 00:21:34,690
and heritage and what we have here are

487
00:21:38,490 --> 00:21:36,730
what we call spectral energy

488
00:21:41,130 --> 00:21:38,500

distributions so this is sort of the

489
00:21:44,100 --> 00:21:41,140
energy or flux coming out of the galaxy

490
00:21:45,900 --> 00:21:44,110
on the y-axis and on the x-axis we have

491
00:21:47,820 --> 00:21:45,910
the wavelength in microns because

492
00:21:53,430 --> 00:21:47,830
infrared astronomers like myself like to

493
00:21:55,470 --> 00:21:53,440
think about microns this is ten a

494
00:21:58,230 --> 00:21:55,480
hundred a thousand and then kind of

495
00:22:01,710 --> 00:21:58,240
shaded in here is the range over which

496
00:22:04,350 --> 00:22:01,720
the Spitzer Space Observatory covered so

497
00:22:06,030 --> 00:22:04,360
it goes all the way from there to there

498
00:22:08,340 --> 00:22:06,040
and Hershel covers from here to there

499
00:22:11,190 --> 00:22:08,350
and so together you actually get the

500
00:22:13,080 --> 00:22:11,200
whole thing yeah if you get a little bit

501
00:22:15,750 --> 00:22:13,090
of the stars but the whole thing about

502
00:22:18,270 --> 00:22:15,760
the dust you get the warm dust with

503
00:22:19,740 --> 00:22:18,280
Spitzer with Herschel you get the colder

504
00:22:21,630 --> 00:22:19,750
dust you get the whole complete picture

505
00:22:23,490 --> 00:22:21,640
with it and what I'm going to talk to

506
00:22:26,640 --> 00:22:23,500
you about is the complete picture that

507
00:22:31,289 --> 00:22:26,650
we're learning from these these

508
00:22:32,910 --> 00:22:31,299
observations so this this image here I

509
00:22:36,120 --> 00:22:32,920
like this image because it kind of shows

510
00:22:39,000 --> 00:22:36,130
that whole lot dust lifecycle with the

511
00:22:41,340 --> 00:22:39,010
three colors so this is from Spitzer

512
00:22:44,730 --> 00:22:41,350
sage of the Large Magellanic Cloud and

513
00:22:47,310 --> 00:22:44,740

in purple here this is from the Spitzer

514
00:22:49,260 --> 00:22:47,320
Iraq camera at three point six microns

515
00:22:51,810 --> 00:22:49,270
and you can see all this blue here you

516
00:22:53,669 --> 00:22:51,820
can see kind of a faint glow of a bar

517
00:22:57,120 --> 00:22:53,679
and if you look in the optical the bar

518
00:22:59,549 --> 00:22:57,130
is very prominent but here it's it's a

519
00:23:03,299 --> 00:22:59,559
little fainter compared to the other

520
00:23:05,820 --> 00:23:03,309
dust things but here what we're tracing

521
00:23:08,340 --> 00:23:05,830
here is what I call the old stellar

522
00:23:10,049 --> 00:23:08,350
population the the old and dying stars

523
00:23:12,990 --> 00:23:10,059
and these are the stars remember that

524
00:23:16,169 --> 00:23:13,000
are producing the origin of dust so this

525
00:23:18,659 --> 00:23:16,179
blue glow here is sort of where lots of

526
00:23:21,960 --> 00:23:18,669
dust is originating from and then in

527
00:23:24,180 --> 00:23:21,970
green is sort of a tracer of the dust in

528
00:23:27,360 --> 00:23:24,190
the interstellar medium itself so that's

529
00:23:30,690 --> 00:23:27,370
the is M processing growth destruction

530
00:23:33,810 --> 00:23:30,700
that's the I rec eat micron emission and

531
00:23:36,030 --> 00:23:33,820
then in bright red here this is this

532
00:23:38,970 --> 00:23:36,040
MEPs 24 micron camera that's picks up

533
00:23:40,980 --> 00:23:38,980
sort of hot spots where massive stars

534
00:23:43,200 --> 00:23:40,990
are being formed in this galaxy and so

535
00:23:48,180 --> 00:23:43,210
this is one image kind of shows this

536
00:23:49,710 --> 00:23:48,190
whole life cycle now just to show you a

537
00:23:51,630 --> 00:23:49,720
compliment I'm going to be showing

538
00:23:53,460 --> 00:23:51,640

pictures of the SMC and the ellison this

539
00:23:56,220 --> 00:23:53,470
is the small magellanic cloud this is

540
00:23:58,610 --> 00:23:56,230
the Herschel heritage image and and

541
00:24:00,810 --> 00:23:58,620
Herschel remember all we're seeing is

542
00:24:02,400 --> 00:24:00,820
sort of dust emission from the

543
00:24:05,130 --> 00:24:02,410
interstellar medium that second pump

544
00:24:06,780 --> 00:24:05,140
it's all interstellar medium dust and

545
00:24:09,750 --> 00:24:06,790
you can see some brighter spots sort of

546
00:24:14,430 --> 00:24:09,760
where the dust is warmer redder spots

547
00:24:17,100 --> 00:24:14,440
were it's it's cooler all right so let's

548
00:24:18,220 --> 00:24:17,110
go back to our problem at him about why

549
00:24:21,340 --> 00:24:18,230
do galaxies have

550
00:24:24,190 --> 00:24:21,350
dust so this is first of all I we might

551
00:24:25,870 --> 00:24:24,200
we ask the question and how much dust

552
00:24:28,060 --> 00:24:25,880
are we talking about I mean how much do

553
00:24:31,260 --> 00:24:28,070
we actually need to keep there per

554
00:24:35,440 --> 00:24:31,270
galaxies to have dust well in the LMC

555
00:24:37,690 --> 00:24:35,450
it's 7.3 times plus or minus 1 times 10

556
00:24:40,780 --> 00:24:37,700
to the 5 solar masses of dust over the

557
00:24:42,730 --> 00:24:40,790
whole galaxy so that's how much dust is

558
00:24:44,740 --> 00:24:42,740
in this galaxy and this life cycle in

559
00:24:47,800 --> 00:24:44,750
some sense has to maintain our balance

560
00:24:51,340 --> 00:24:47,810
to keep it and in a small Magellanic

561
00:24:53,710 --> 00:24:51,350
Cloud it's less everything is smaller in

562
00:24:55,690 --> 00:24:53,720
the small Magellanic Cloud it's 8.3 plus

563
00:24:58,060 --> 00:24:55,700

minus one times 10 to the 4 so it's

564
00:24:59,740 --> 00:24:58,070
about a factor of 10 and everything

565
00:25:02,890 --> 00:24:59,750
about the small Magellanic Clouds about

566
00:25:06,190 --> 00:25:02,900
a factor of 10 smaller than the Large

567
00:25:09,040 --> 00:25:06,200
Magellanic Cloud all right let's go back

568
00:25:11,560 --> 00:25:09,050
to this life cycle of deaths and I want

569
00:25:13,510 --> 00:25:11,570
to show you what we've learned from

570
00:25:15,670 --> 00:25:13,520
these from these surveys over the past

571
00:25:20,080 --> 00:25:15,680
gosh almost 10 years I started this

572
00:25:23,500 --> 00:25:20,090
about 10 years ago and first we're gonna

573
00:25:25,150 --> 00:25:23,510
start off with the origin of dust so

574
00:25:27,370 --> 00:25:25,160
where does this come from what have we

575
00:25:31,330 --> 00:25:27,380
learn from these surveys that tell us

576
00:25:33,970 --> 00:25:31,340
about how dust is produced and polluting

577
00:25:35,950 --> 00:25:33,980
the galaxies so first I'm going to talk

578
00:25:38,380 --> 00:25:35,960
about asymptotic giant branch stores eg

579
00:25:40,150 --> 00:25:38,390
B stars and this is my favorite picture

580
00:25:41,800 --> 00:25:40,160
of an Ag bestir it's actually from one

581
00:25:44,080 --> 00:25:41,810
of the hottest new observatories the

582
00:25:47,320 --> 00:25:44,090
Alma Observatory the radio Observatory

583
00:25:49,840 --> 00:25:47,330
in the southern hemisphere in Chile and

584
00:25:51,520 --> 00:25:49,850
it just shows it looks kind of circular

585
00:25:54,970 --> 00:25:51,530
but there's also a spiral pattern and

586
00:25:59,110 --> 00:25:54,980
it's just puffing out the dust I'm along

587
00:26:01,510 --> 00:25:59,120
with molecular gas in this star in

588
00:26:04,900 --> 00:26:01,520

addition to the egb stars a more massive

589
00:26:07,390 --> 00:26:04,910
star things that go boom and explode is

590
00:26:11,050 --> 00:26:07,400
a red supergiant and this is a Hubble

591
00:26:14,200 --> 00:26:11,060
image of V Y Canis Majoris showing sort

592
00:26:16,150 --> 00:26:14,210
of the heart of it in reflected and all

593
00:26:17,980 --> 00:26:16,160
this light here is basically starlight

594
00:26:23,590 --> 00:26:17,990
reflected in the dust by the dust

595
00:26:27,550 --> 00:26:23,600
surrounding this star alright so in the

596
00:26:30,280 --> 00:26:27,560
large LMC and small Magellanic Cloud we

597
00:26:33,730 --> 00:26:30,290
had to identify which of the stars are

598
00:26:35,860 --> 00:26:33,740
actually dust producers and we do that

599
00:26:38,440 --> 00:26:35,870
using these diagrams called

600
00:26:40,840 --> 00:26:38,450
color-magnitude diagram and so what this

601
00:26:44,200 --> 00:26:40,850
is is we measure the flux every star in

602
00:26:48,880 --> 00:26:44,210
the galaxy and then we plot that flux

603
00:26:50,890 --> 00:26:48,890
used this system astronomer system

604
00:26:54,850 --> 00:26:50,900
called magnitudes and so this is 8

605
00:26:57,400 --> 00:26:54,860
micron emission in magnitudes and this

606
00:26:59,830 --> 00:26:57,410
is the color so this is j-man so this is

607
00:27:01,480 --> 00:26:59,840
about 1 micron minus 8 microns and so as

608
00:27:04,600 --> 00:27:01,490
you go to the right you're getting to a

609
00:27:06,460 --> 00:27:04,610
redder and redder star and as you go up

610
00:27:11,170 --> 00:27:06,470
I'm you're getting to a brighter

611
00:27:13,960 --> 00:27:11,180
brighter star and the pattern of this

612
00:27:16,960 --> 00:27:13,970
contour is sort of the location a sort

613
00:27:18,820 --> 00:27:16,970

of a density plot of all the stars in

614
00:27:20,410 --> 00:27:18,830
these respective galaxies and what we've

615
00:27:22,360 --> 00:27:20,420
identified here there are all sorts of

616
00:27:24,550 --> 00:27:22,370
features there structure in this contour

617
00:27:27,910 --> 00:27:24,560
plot and that structure is actually

618
00:27:30,970 --> 00:27:27,920
different types and types of objects red

619
00:27:34,180 --> 00:27:30,980
supergiant I'm sorry red supergiant's

620
00:27:35,830 --> 00:27:34,190
and the egb stars are there in that but

621
00:27:38,200 --> 00:27:35,840
there's a lot of other things and so the

622
00:27:40,540 --> 00:27:38,210
first tack job is to find out and

623
00:27:45,360 --> 00:27:40,550
identify those sources that are the AGB

624
00:27:47,710 --> 00:27:45,370
stars in the red supergiant's and then

625
00:27:49,570 --> 00:27:47,720
and then you have to sort of model how

626
00:27:53,140 --> 00:27:49,580
much dust is around them and for that

627
00:27:55,000 --> 00:27:53,150
because we have all the measurements for

628
00:27:57,070 --> 00:27:55,010
the dust is we can again create a

629
00:28:00,430 --> 00:27:57,080
spectral energy distribution for every

630
00:28:02,590 --> 00:28:00,440
star in the galaxy every AGB star again

631
00:28:04,720 --> 00:28:02,600
this is how much flux or energy that's

632
00:28:08,770 --> 00:28:04,730
coming out versus wavelength there's 1

633
00:28:11,110 --> 00:28:08,780
to 10 microns and this is a case of a an

634
00:28:14,520 --> 00:28:11,120
oxygen-rich source and how do we know

635
00:28:18,670 --> 00:28:14,530
it's oxygen-rich we look at its spectrum

636
00:28:21,790 --> 00:28:18,680
and what we've I call this thing grams

637
00:28:23,530 --> 00:28:21,800
because to calculate all the dusts in

638
00:28:25,480 --> 00:28:23,540

all these stars there were a lot of

639
00:28:28,150 --> 00:28:25,490
stars there like tens of thousands of

640
00:28:29,770 --> 00:28:28,160
them so we created a grid of red

641
00:28:32,530 --> 00:28:29,780
supergiant asymptotic giant branch

642
00:28:36,070 --> 00:28:32,540
models we call them grams because we

643
00:28:38,410 --> 00:28:36,080
were weighing to dust and we use this

644
00:28:40,930 --> 00:28:38,420
particular source to figure out the type

645
00:28:43,080 --> 00:28:40,940
of dust and so this spectrum there's a

646
00:28:47,250 --> 00:28:43,090
little feature here and there and this

647
00:28:48,990 --> 00:28:47,260
indicative of silicates in the star so

648
00:28:50,520 --> 00:28:49,000
you can take a spectrum of silicates

649
00:28:51,990 --> 00:28:50,530
turn around galaxy you would see the

650
00:28:53,520 --> 00:28:52,000
same it's already in our own

651
00:28:55,380 --> 00:28:53,530
laboratories and you see these features

652
00:29:00,240 --> 00:28:55,390
and so we know it's silicates from the

653
00:29:03,240 --> 00:29:00,250
spectrum and then we model the energy in

654
00:29:05,970 --> 00:29:03,250
silicates here and from that modeling we

655
00:29:08,520 --> 00:29:05,980
can determine the luminosity of the star

656
00:29:10,680 --> 00:29:08,530
and what we call a dust mask loss rate

657
00:29:12,360 --> 00:29:10,690
and so this is the luminosity so it's

658
00:29:14,190 --> 00:29:12,370
five thousand eighty eight times the

659
00:29:16,380 --> 00:29:14,200
luminosity of our Sun it's much much

660
00:29:19,890 --> 00:29:16,390
more luminous than our Sun and our Sun

661
00:29:22,410 --> 00:29:19,900
will get this luminous when it dies and

662
00:29:24,810 --> 00:29:22,420
then this is the amount of dust it's

663
00:29:28,860 --> 00:29:24,820

producing per year this one star two

664
00:29:29,190 --> 00:29:28,870
times ten to the minus nine per year all

665
00:29:32,310 --> 00:29:29,200
right

666
00:29:34,440 --> 00:29:32,320
so that was the very nitrogen rich start

667
00:29:37,080 --> 00:29:34,450
where does carbon dust come from things

668
00:29:40,350 --> 00:29:37,090
like polycyclic aromatic hydrocarbons

669
00:29:42,450 --> 00:29:40,360
and carbonaceous dust and soot that

670
00:29:45,780 --> 00:29:42,460
comes from things called carbon stars

671
00:29:47,970 --> 00:29:45,790
and a carbon star again is an asymptotic

672
00:29:51,150 --> 00:29:47,980
giant branch star in which the innards

673
00:29:53,010 --> 00:29:51,160
of the star has turned out enough to

674
00:29:54,960 --> 00:29:53,020
change the chemistry on the surface of

675
00:29:56,940 --> 00:29:54,970
the star from oxygen-rich which is

676
00:30:00,240 --> 00:29:56,950
pretty much what the universe is to

677
00:30:02,310 --> 00:30:00,250
something carbonaceous and we know that

678
00:30:04,260 --> 00:30:02,320
these stars have carbonaceous dust

679
00:30:05,910 --> 00:30:04,270
because they're mostly features except

680
00:30:09,660 --> 00:30:05,920
there's a little feature here from a

681
00:30:12,570 --> 00:30:09,670
silicon carbide feature si si and so

682
00:30:15,540 --> 00:30:12,580
again we used grams and we modeled what

683
00:30:18,690 --> 00:30:15,550
is coming from the star with a spectral

684
00:30:20,550 --> 00:30:18,700
energy distribution and we find out that

685
00:30:23,250 --> 00:30:20,560
it's also over five thousand solar

686
00:30:26,510 --> 00:30:23,260
luminosities and it's about 2.6 times

687
00:30:29,160 --> 00:30:26,520
minus nine solar masses of dust per year

688
00:30:31,980 --> 00:30:29,170

all right so those are two example stars

689
00:30:36,660 --> 00:30:31,990
and the types of dust that we get from

690
00:30:38,760 --> 00:30:36,670
them but again we have like thousands

691
00:30:41,370 --> 00:30:38,770
tens of thousands 30 thousands of these

692
00:30:44,010 --> 00:30:41,380
stars and so what we did was we created

693
00:30:46,050 --> 00:30:44,020
this grid and this is a representation

694
00:30:50,060 --> 00:30:46,060
of the grid on a color magnitude diagram

695
00:30:53,220 --> 00:30:50,070
of the eight versus three point six

696
00:30:56,290 --> 00:30:53,230
minus eight and in grayer all the models

697
00:30:57,910 --> 00:30:56,300
we created and then in blue

698
00:31:00,820 --> 00:30:57,920
are all the sources in the large

699
00:31:04,570 --> 00:31:00,830
magellanic cloud so blue is where all

700
00:31:07,000 --> 00:31:04,580
the LMC oxygen-rich sources are and in

701
00:31:09,280 --> 00:31:07,010
red are the carbon rich sources because

702
00:31:14,230 --> 00:31:09,290
there's two types of dust carbonaceous

703
00:31:19,750 --> 00:31:14,240
and silica based dust and they all go

704
00:31:21,190 --> 00:31:19,760
out all right so what are the things

705
00:31:25,150 --> 00:31:21,200
that we've learned about these stars

706
00:31:27,370 --> 00:31:25,160
well I mentioned the oxygen rich sources

707
00:31:30,130 --> 00:31:27,380
the carbon rich sources and then this

708
00:31:32,790 --> 00:31:30,140
shows in some sense the luminosity

709
00:31:35,440 --> 00:31:32,800
function I was telling you that we have

710
00:31:37,030 --> 00:31:35,450
sources that are 5000 solar luminosities

711
00:31:41,950 --> 00:31:37,040
we have some that are even greater than

712
00:31:44,950 --> 00:31:41,960
that so in the purple the blue here is

713
00:31:47,380 --> 00:31:44,960

the oxygen rich sources and the solid

714
00:31:50,470 --> 00:31:47,390
line the SMC it's been scaled up but

715
00:31:54,130 --> 00:31:50,480
that's for the SMC and again for the LMC

716
00:31:55,990 --> 00:31:54,140
we have the red solid line for the

717
00:31:58,060 --> 00:31:56,000
carbon sources and the dashed line for

718
00:32:00,310 --> 00:31:58,070
thee for the SMC and then what I've

719
00:32:03,790 --> 00:32:00,320
shown here is sort of a it's a dashed

720
00:32:05,410 --> 00:32:03,800
line of the separating what we call the

721
00:32:08,380 --> 00:32:05,420
eg B or the asymptotic giant branch

722
00:32:11,710 --> 00:32:08,390
stars from the red supergiant's and this

723
00:32:13,450 --> 00:32:11,720
is important because these types of

724
00:32:15,070 --> 00:32:13,460
stars on the right are the stars that

725
00:32:17,530 --> 00:32:15,080
explode as supernovae those are the

726
00:32:22,210 --> 00:32:17,540
massive stars that explode whereas those

727
00:32:25,510 --> 00:32:22,220
on the left are the ones that are going

728
00:32:28,120 --> 00:32:25,520
to die quietly like like white dwarfs

729
00:32:29,800 --> 00:32:28,130
and planetary nebulae and one point I

730
00:32:34,120 --> 00:32:29,810
want to make here is that you can see

731
00:32:36,370 --> 00:32:34,130
that the carbonaceous winds only come

732
00:32:39,880 --> 00:32:36,380
from the AGB stars red supergiant's

733
00:32:42,130 --> 00:32:39,890
don't turn up carbon so a lot of people

734
00:32:44,680 --> 00:32:42,140
think a lot of the carbonaceous dust in

735
00:32:50,350 --> 00:32:44,690
the universe comes from stars like our

736
00:32:52,750 --> 00:32:50,360
Sun when they die alright so we've

737
00:32:54,550 --> 00:32:52,760
applied these grams models through all

738
00:32:56,650 --> 00:32:54,560

the populations in the Large Magellanic

739
00:32:58,240 --> 00:32:56,660
Cloud and Small Magellanic Cloud and it

740
00:33:02,440 --> 00:32:58,250
said okay well how much dust are we

741
00:33:04,630 --> 00:33:02,450
producing so this is what on the y axis

742
00:33:07,750 --> 00:33:04,640
we call cumulative dust production rate

743
00:33:09,850 --> 00:33:07,760
in solar masses per year so this is ten

744
00:33:14,169 --> 00:33:09,860
the minus five solar masses

745
00:33:17,650 --> 00:33:14,179
- six and what I show here in the black

746
00:33:21,400 --> 00:33:17,660
are all the sources in the LMC red is

747
00:33:24,100 --> 00:33:21,410
again carbon sources blue it's oxygen

748
00:33:26,980 --> 00:33:24,110
rich sources and again you can see the

749
00:33:30,700 --> 00:33:26,990
SMC is smaller than the LMC by a factor

750
00:33:32,530 --> 00:33:30,710
of 10 just to show you what some of the

751
00:33:35,289 --> 00:33:32,540
numbers are concrete ly so there have

752
00:33:38,560 --> 00:33:35,299
been a couple of papers by former

753
00:33:40,900 --> 00:33:38,570
students of mine one by RIBA where he

754
00:33:43,570 --> 00:33:40,910
says the total dust produced in the LMC

755
00:33:45,909 --> 00:33:43,580
now by these stars the stellar winds is

756
00:33:49,799 --> 00:33:45,919
2.1 times in the mines five solar masses

757
00:33:53,110 --> 00:33:49,809
per year it's quite a lot and the SMC

758
00:33:55,210 --> 00:33:53,120
it's about eight point nine times ten to

759
00:33:58,870 --> 00:33:55,220
the minus seven solar masses per year

760
00:34:02,020 --> 00:33:58,880
and then what is the breakdown so in the

761
00:34:04,090 --> 00:34:02,030
LMC it seems to be dominated by carbon

762
00:34:05,890 --> 00:34:04,100
rich dust production so we have more

763
00:34:09,190 --> 00:34:05,900

carbon rich dust being produced by these

764
00:34:14,080 --> 00:34:09,200
stars than the oxygen rich dust and the

765
00:34:15,909 --> 00:34:14,090
S&C it seems to be more 5050 and then

766
00:34:18,700 --> 00:34:15,919
when you look at the oxygen rich dusts

767
00:34:20,680 --> 00:34:18,710
remember you can have sort of the lower

768
00:34:24,310 --> 00:34:20,690
mass stars like the AGB stars in the red

769
00:34:27,820 --> 00:34:24,320
supergiant's so the red supergiant's

770
00:34:29,740 --> 00:34:27,830
it's only about 9% in the LMC and the

771
00:34:34,659 --> 00:34:29,750
SMC it seems to be about half and half

772
00:34:36,159 --> 00:34:34,669
25% red supergiant 25% a GB so you kind

773
00:34:38,200 --> 00:34:36,169
of look at the red supergiant scene

774
00:34:39,700 --> 00:34:38,210
you're thinking well the massive stars

775
00:34:41,530 --> 00:34:39,710
really aren't doing very much it seems

776
00:34:45,780 --> 00:34:41,540
to be all these kind of lower mass solar

777
00:34:52,599 --> 00:34:50,349
okay this is okay but the truth is maybe

778
00:34:55,990 --> 00:34:52,609
things happen later in the massive

779
00:34:58,390 --> 00:34:56,000
star's life and it turns out that as the

780
00:35:01,450 --> 00:34:58,400
massive star gets closer to death it has

781
00:35:03,340 --> 00:35:01,460
more phases than the lower mass stars so

782
00:35:04,840 --> 00:35:03,350
this for example is what's called a

783
00:35:07,210 --> 00:35:04,850
luminous blue variable and this is the

784
00:35:10,270 --> 00:35:07,220
iconic one from the Hubble image of a to

785
00:35:12,160 --> 00:35:10,280
Carina this is not in the LMC but there

786
00:35:14,770 --> 00:35:12,170
are objects like that in the LMC and

787
00:35:17,460 --> 00:35:14,780
this is one of the more famous luminous

788
00:35:20,020 --> 00:35:17,470

blue variable objects r71

789
00:35:22,120 --> 00:35:20,030
it has a dust mask of eight times to the

790
00:35:23,500 --> 00:35:22,130
minus seven solar masses per year and

791
00:35:26,530 --> 00:35:23,510
there are five

792
00:35:28,330 --> 00:35:26,540
BB's in the SMC and it's possible that

793
00:35:30,430 --> 00:35:28,340
if all of them each of them have that

794
00:35:32,920 --> 00:35:30,440
much dust production you actually get a

795
00:35:35,020 --> 00:35:32,930
pretty hefty amount of dust coming from

796
00:35:39,340 --> 00:35:35,030
these lb B's four times ten minus six

797
00:35:43,360 --> 00:35:39,350
solar masses per year but you know it

798
00:35:52,839 --> 00:35:43,370
turns out that see if I can get this to

799
00:35:59,529 --> 00:35:55,809
here we go turns out that the mass of

800
00:36:03,670 --> 00:35:59,539
stars really do produce a lot of dust

801
00:36:18,890 --> 00:36:03,680
and when it happens those at the very

802
00:36:26,390 --> 00:36:22,370
so Frank's talk about the heart of the

803
00:36:28,460 --> 00:36:26,400
Crab Nebula this is sort of a movie

804
00:36:30,380 --> 00:36:28,470
version of how that Crab Nebula was was

805
00:36:34,040 --> 00:36:30,390
created it's basically a star exploding

806
00:36:37,580 --> 00:36:34,050
in and dying and one of the largest

807
00:36:39,710 --> 00:36:37,590
surprises for us in the Magellanic Cloud

808
00:36:43,580 --> 00:36:39,720
search was that we actually detected

809
00:36:45,830 --> 00:36:43,590
dustin87 a it was pretty much a

810
00:36:48,320 --> 00:36:45,840
discovery I mean in it that people are

811
00:36:51,770 --> 00:36:48,330
rapidly following up on so this is

812
00:36:53,900 --> 00:36:51,780
supernova 1987a this is a Hubble image

813
00:36:58,160 --> 00:36:53,910

of it it's still the manager by Hubble

814
00:37:01,730 --> 00:36:58,170
and it Hubble launched shortly after you

815
00:37:04,580 --> 00:37:01,740
know this thing exploded and this is a

816
00:37:06,590 --> 00:37:04,590
picture of the field and Hubble and this

817
00:37:10,850 --> 00:37:06,600
is a picture of our Herschel heritage

818
00:37:13,160 --> 00:37:10,860
image and we found it and I remember the

819
00:37:15,140 --> 00:37:13,170
phone conversation when we were trying

820
00:37:17,720 --> 00:37:15,150
to pick follow-up sources of supernova

821
00:37:19,610 --> 00:37:17,730
remnants to follow up on with the

822
00:37:22,250 --> 00:37:19,620
spectroscopy capability of Herschel and

823
00:37:26,360 --> 00:37:22,260
a postdoc was going through and she says

824
00:37:28,310 --> 00:37:26,370
oh we have and 49 that's like yeah ok n

825
00:37:30,620 --> 00:37:28,320
1 3 2 is like ok that's exciting and we

826
00:37:32,240 --> 00:37:30,630
have 87 I said well hold it there we

827
00:37:34,340 --> 00:37:32,250
don't have 87 me we're not supposed to

828
00:37:36,950 --> 00:37:34,350
see it she says well I'm sorry but we

829
00:37:42,140 --> 00:37:36,960
see it and I was like ok well that's

830
00:37:44,180 --> 00:37:42,150
very very interesting and the

831
00:37:48,110 --> 00:37:44,190
interesting thing about it is here we

832
00:37:50,660 --> 00:37:48,120
have a close-up of 87a here's the ring

833
00:37:51,890 --> 00:37:50,670
this ring was created by the prior

834
00:37:53,600 --> 00:37:51,900
remember I was talking about the stellar

835
00:37:55,520 --> 00:37:53,610
winds and the red supergiant's creating

836
00:37:58,930 --> 00:37:55,530
those winds that material drifts out

837
00:38:02,600 --> 00:37:58,940
that's what the ring is it's that prior

838
00:38:05,060 --> 00:38:02,610

progenitor star wind and at the heart of

839
00:38:08,330 --> 00:38:05,070
it is the ejecta so this is the exploded

840
00:38:10,610 --> 00:38:08,340
star and this is the star from the prior

841
00:38:16,130 --> 00:38:10,620
wind and here it is in x-rays as well

842
00:38:20,000 --> 00:38:16,140
and when we were proposing to observe

843
00:38:21,680 --> 00:38:20,010
the LMC with Herschel we said well can

844
00:38:23,240 --> 00:38:21,690
we see 80 70 because it's such a famous

845
00:38:25,250 --> 00:38:23,250
object if we can see it we should tell

846
00:38:27,470 --> 00:38:25,260
them we're gonna see it and at the time

847
00:38:29,300 --> 00:38:27,480
this is what we knew ok well here is you

848
00:38:31,400 --> 00:38:29,310
know here's what we got with spitzer and

849
00:38:32,070 --> 00:38:31,410
spitzer went up and then up Spitzer's

850
00:38:35,200 --> 00:38:32,080
came down

851
00:38:37,060 --> 00:38:35,210
and so we said well you follow this line

852
00:38:38,470 --> 00:38:37,070
down again this is one of these spectral

853
00:38:40,990 --> 00:38:38,480
energy distribution where you have the

854
00:38:42,640 --> 00:38:41,000
amount of energy and wavelength and you

855
00:38:44,440 --> 00:38:42,650
keep going down and well here's where

856
00:38:46,810 --> 00:38:44,450
Herschel started and we were on this

857
00:38:49,450 --> 00:38:46,820
yellow I was like there is no way we're

858
00:38:51,640 --> 00:38:49,460
going to detect this object and so when

859
00:38:55,090 --> 00:38:51,650
we detected it we're like wow what is

860
00:38:57,370 --> 00:38:55,100
this and so what it is is you can see

861
00:39:01,110 --> 00:38:57,380
sort of two peaks of dust the ring dust

862
00:39:04,270 --> 00:39:01,120
we said this has got to be in the ejecta

863
00:39:07,540 --> 00:39:04,280

with it the ejecta really well you know

864
00:39:10,680 --> 00:39:07,550
how much dust would you need to create

865
00:39:14,560 --> 00:39:10,690
this much emission in the floor infrared

866
00:39:16,420 --> 00:39:14,570
and it turns out it's about 0.4 to 0.7

867
00:39:18,190 --> 00:39:16,430
solar masses of dust and there's a large

868
00:39:20,650 --> 00:39:18,200
uncertainty because we don't know the

869
00:39:22,390 --> 00:39:20,660
composition of this dust yet that's

870
00:39:25,360 --> 00:39:22,400
actually something I hope to tackle with

871
00:39:27,730 --> 00:39:25,370
James Webb that's a lot of dust I mean

872
00:39:29,560 --> 00:39:27,740
no one has ever seen that much dust in a

873
00:39:31,150 --> 00:39:29,570
supernova remnant before most of the

874
00:39:33,400 --> 00:39:31,160
dust people see is like 10 to minus

875
00:39:35,020 --> 00:39:33,410
three solar masses of dust from prior

876
00:39:38,230 --> 00:39:35,030
measurements so this was really really

877
00:39:40,180 --> 00:39:38,240
quite remarkable and we published it in

878
00:39:42,430 --> 00:39:40,190
science and people got all excited but

879
00:39:44,230 --> 00:39:42,440
they kind of said look you know you got

880
00:39:46,780 --> 00:39:44,240
some kind of fluff there you really you

881
00:39:48,700 --> 00:39:46,790
know you don't have the resolution you

882
00:39:51,190 --> 00:39:48,710
know I don't think it's I don't think

883
00:39:52,720 --> 00:39:51,200
it's a supernova you're like okay okay

884
00:39:55,120 --> 00:39:52,730
we're gonna go look at it with this hot

885
00:39:58,690 --> 00:39:55,130
new telescope called Alma and we're

886
00:40:01,450 --> 00:39:58,700
gonna measure from the ring emission to

887
00:40:03,670 --> 00:40:01,460
dust and see if it's there we think it's

888
00:40:06,760 --> 00:40:03,680

going to be there so but they got the

889
00:40:08,470 --> 00:40:06,770
time and this is what it looked like

890
00:40:10,720 --> 00:40:08,480
going it from these longer wavelengths

891
00:40:12,970 --> 00:40:10,730
so this is really trust testing they

892
00:40:16,510 --> 00:40:12,980
were finding the ring emission there's a

893
00:40:20,560 --> 00:40:16,520
lot of synchrotron emission and then as

894
00:40:22,480 --> 00:40:20,570
you go to the shorter wavelengths you

895
00:40:24,790 --> 00:40:22,490
get more into the dust emission you can

896
00:40:26,410 --> 00:40:24,800
see well there's a ring and hold it

897
00:40:28,360 --> 00:40:26,420
there's something in the center and when

898
00:40:30,100 --> 00:40:28,370
you go to the highest line it's in the

899
00:40:31,720 --> 00:40:30,110
center and so this very clearly it

900
00:40:33,940 --> 00:40:31,730
silenced all the critics they said oh

901
00:40:35,830 --> 00:40:33,950
yeah gosh you do have a lot of dust

902
00:40:38,310 --> 00:40:35,840
there and all the theorists are running

903
00:40:42,100 --> 00:40:38,320
madly around trying to figure out why

904
00:40:44,440 --> 00:40:42,110
all right so that's the story of of dust

905
00:40:45,700 --> 00:40:44,450
of dust production so let's talk a

906
00:40:47,530 --> 00:40:45,710
little bit about

907
00:40:51,700 --> 00:40:47,540
what happens when these dust grains go

908
00:40:54,370 --> 00:40:51,710
out into the interstellar medium all

909
00:40:57,849 --> 00:40:54,380
right so here's a supernova remnant in

910
00:41:00,760 --> 00:40:57,859
the Large Magellanic Cloud and 49 this

911
00:41:03,310 --> 00:41:00,770
is a beautiful composite HST glorious

912
00:41:08,349 --> 00:41:03,320
detail with Chandra in the blue because

913
00:41:10,660 --> 00:41:08,359

it's a hot plasma and so because of the

914
00:41:12,070 --> 00:41:10,670
87 a discovery there's a student at

915
00:41:13,599 --> 00:41:12,080
Keele what she said well I'm gonna look

916
00:41:15,220 --> 00:41:13,609
around at all the supernova remnants to

917
00:41:18,280 --> 00:41:15,230
see if they have dust in them and so she

918
00:41:20,050 --> 00:41:18,290
looked and here's n 49 and these plots

919
00:41:24,280 --> 00:41:20,060
these color plots I'm showing you here

920
00:41:27,280 --> 00:41:24,290
is her study showing on the left here

921
00:41:28,599 --> 00:41:27,290
this is dust mass and on the right this

922
00:41:31,870 --> 00:41:28,609
is dust temperature so it's like a

923
00:41:37,030 --> 00:41:31,880
little map around and 49 which is in the

924
00:41:37,890 --> 00:41:37,040
circle here and on the top is cold sort

925
00:41:40,570 --> 00:41:37,900
of cold dust

926
00:41:44,290 --> 00:41:40,580
this is warm dust those two components

927
00:41:45,970 --> 00:41:44,300
she she modeled and so here at the

928
00:41:48,310 --> 00:41:45,980
center you can see that well on coal

929
00:41:51,670 --> 00:41:48,320
dust there's doesn't really seem to be

930
00:41:56,710 --> 00:41:51,680
much there there seems to be some warm

931
00:42:00,750 --> 00:41:56,720
dust some mass and warm dust and and

932
00:42:02,980 --> 00:42:00,760
here again this is cold and this is warm

933
00:42:04,630 --> 00:42:02,990
but really when she looked at all the

934
00:42:06,609 --> 00:42:04,640
whole samples she really did not find

935
00:42:09,400 --> 00:42:06,619
much dust at the center of these things

936
00:42:12,280 --> 00:42:09,410
and some of that is could be a limit to

937
00:42:15,010 --> 00:42:12,290
the sensitivity for Herschel and mostly

938
00:42:18,250 --> 00:42:15,020

what she measured then was what happened

939
00:42:20,140 --> 00:42:18,260
to the surrounding part and she found

940
00:42:21,579 --> 00:42:20,150
that really well gosh these supernovae

941
00:42:23,560 --> 00:42:21,589
room knows as they go out they're really

942
00:42:26,349 --> 00:42:23,570
destroying the dust and so her paper

943
00:42:29,320 --> 00:42:26,359
showed that there's some dust

944
00:42:31,329 --> 00:42:29,330
destruction and then we did a slightly

945
00:42:33,099 --> 00:42:31,339
more rigorous calculation on the

946
00:42:35,050 --> 00:42:33,109
supernova remnants in large magellanic

947
00:42:43,320 --> 00:42:35,060
cloud here's all of them in the in the

948
00:42:46,030 --> 00:42:43,330
red circles and this is sort of the

949
00:42:47,500 --> 00:42:46,040
amount of dust that's destroyed by them

950
00:42:50,290 --> 00:42:47,510
so this is the number of supernova

951
00:42:52,030 --> 00:42:50,300
remnants and this is how effectively

952
00:42:53,859 --> 00:42:52,040
they are destroying the carbonaceous

953
00:42:55,730 --> 00:42:53,869
stuff in the interstellar medium or the

954
00:42:57,500 --> 00:42:55,740
silicate dust and

955
00:42:59,240 --> 00:42:57,510
or seller medium you can see that the

956
00:43:03,410 --> 00:42:59,250
silica dust is actually more readily

957
00:43:05,359 --> 00:43:03,420
destroyed than the carbonaceous dust in

958
00:43:07,430 --> 00:43:05,369
fact you can kind of figure out what is

959
00:43:09,170 --> 00:43:07,440
the average lifetime for dust grains so

960
00:43:10,550 --> 00:43:09,180
these stars produce the dust and they

961
00:43:13,430 --> 00:43:10,560
kind of hover out in the interstellar

962
00:43:16,220 --> 00:43:13,440
medium how long can they possibly last

963
00:43:18,650 --> 00:43:16,230

given all these supernovae in them and

964
00:43:21,680 --> 00:43:18,660
remnant sweeping through so this is dust

965
00:43:23,420 --> 00:43:21,690
lifetime this is a parameter sort of how

966
00:43:26,480 --> 00:43:23,430
effective the LMC along the line of

967
00:43:28,280 --> 00:43:26,490
sight this is the LM seeing the SMC so

968
00:43:29,930 --> 00:43:28,290
to get a dust lifetime you say well how

969
00:43:31,250 --> 00:43:29,940
much is the total mass of dust and now

970
00:43:32,630 --> 00:43:31,260
there was the number I gave you at the

971
00:43:34,970 --> 00:43:32,640
beginning of this talk how much is the

972
00:43:37,670 --> 00:43:34,980
total mass in the in the galaxy of dust

973
00:43:40,690 --> 00:43:37,680
and then what is the average amount of

974
00:43:42,470 --> 00:43:40,700
dust destroyed per supernova remnant

975
00:43:44,450 --> 00:43:42,480
that comes from a theoretical

976
00:43:46,099 --> 00:43:44,460
calculation and then this is the rate of

977
00:43:47,540 --> 00:43:46,109
supernovae which is just sort of the

978
00:43:51,290 --> 00:43:47,550
rate at which stars are formed at a

979
00:43:53,420 --> 00:43:51,300
massive mess that can explode and when

980
00:43:56,570 --> 00:43:53,430
you get in the LMC is that well silica

981
00:44:00,500 --> 00:43:56,580
dust grains can only live 26 to 42

982
00:44:04,310 --> 00:44:00,510
million years really really short I mean

983
00:44:11,089 --> 00:44:04,320
remember how old is our Sun anyone know

984
00:44:12,680 --> 00:44:11,099
that billions five billion right and

985
00:44:16,310 --> 00:44:12,690
it's gonna get it's gonna get up to ten

986
00:44:18,290 --> 00:44:16,320
billion before it dies so here's 42

987
00:44:23,150 --> 00:44:18,300
million so a lot lot shorter than that

988
00:44:26,750 --> 00:44:23,160

than the lifetime of one of our stars so

989
00:44:29,990 --> 00:44:26,760
so dust is destroyed in the interstellar

990
00:44:35,390 --> 00:44:30,000
medium and the question is do we have

991
00:44:38,599 --> 00:44:35,400
any evidence that it grows back and here

992
00:44:39,859 --> 00:44:38,609
we've been looking at maps of dusty gas

993
00:44:41,810 --> 00:44:39,869
eration so we're using the Herschel

994
00:44:44,210 --> 00:44:41,820
images or figuring and we get a total

995
00:44:46,640 --> 00:44:44,220
map of the dust I showed you that at the

996
00:44:47,870 --> 00:44:46,650
beginning and my colleague Julie Roman

997
00:44:51,140 --> 00:44:47,880
de balón said okay well I'm going to

998
00:44:56,240 --> 00:44:51,150
compare it to the gas and look at how

999
00:44:58,430 --> 00:44:56,250
the gas to dust ratio that's N and here

1000
00:45:00,770 --> 00:44:58,440
in the SMC in particular you can see

1001
00:45:03,410 --> 00:45:00,780
that here's here's a gas cloud that's

1002
00:45:08,089 --> 00:45:03,420
showed here in the contours and you can

1003
00:45:09,200 --> 00:45:08,099
see that the gas to dust ratio appears

1004
00:45:12,819 --> 00:45:09,210
to be

1005
00:45:16,910 --> 00:45:12,829
Louis that is the amount of gas per dust

1006
00:45:20,150 --> 00:45:16,920
is lower when you get to these gas

1007
00:45:21,829 --> 00:45:20,160
clouds so just to flip that around that

1008
00:45:24,019 --> 00:45:21,839
means there's more dust

1009
00:45:29,180 --> 00:45:24,029
apparently more dust in these clouds

1010
00:45:30,920 --> 00:45:29,190
than gas in these denser clouds so the

1011
00:45:32,329 --> 00:45:30,930
tricky thing is though that it's a hard

1012
00:45:33,829 --> 00:45:32,339
thing to prove with these measurements

1013
00:45:35,630 --> 00:45:33,839

because they're kind of course they're

1014
00:45:37,609 --> 00:45:35,640
the measurements are you know they're

1015
00:45:40,309 --> 00:45:37,619
factors of two or three and certainty

1016
00:45:43,069 --> 00:45:40,319
because we're using all these model fits

1017
00:45:44,839 --> 00:45:43,079
and stuff and so we said whoa Kay let's

1018
00:45:48,950 --> 00:45:44,849
use a more precise tool let's use

1019
00:45:51,589 --> 00:45:48,960
spectroscopy and so we another way of

1020
00:45:53,720 --> 00:45:51,599
studying what we're dust is is what we

1021
00:45:56,510 --> 00:45:53,730
call metal depletion onto dust grains so

1022
00:45:58,160 --> 00:45:56,520
what is dust made of so we you know we

1023
00:46:00,019 --> 00:45:58,170
kind of think of the dust bunnies on our

1024
00:46:02,120 --> 00:46:00,029
carpet but actually if you analyze those

1025
00:46:04,940 --> 00:46:02,130
maybe it would be similar but it's

1026
00:46:07,279 --> 00:46:04,950
basically anything that has metals so it

1027
00:46:10,099 --> 00:46:07,289
could be iron it could be carbon the

1028
00:46:13,430 --> 00:46:10,109
oxygen silicon all bound together in

1029
00:46:15,200 --> 00:46:13,440
these complex solid features so it's

1030
00:46:20,870 --> 00:46:15,210
made of metals these have things much

1031
00:46:22,940 --> 00:46:20,880
heavier than than helium and if you look

1032
00:46:24,559 --> 00:46:22,950
along the line of sight towards a star

1033
00:46:28,130 --> 00:46:24,569
you can look in reflection and you can

1034
00:46:31,220 --> 00:46:28,140
see how much how many metals are there

1035
00:46:34,099 --> 00:46:31,230
and you can compare it to what we know

1036
00:46:36,380 --> 00:46:34,109
should be there and then the depletion

1037
00:46:41,120 --> 00:46:36,390
is basically the metals that are missing

1038
00:46:42,680 --> 00:46:41,130

from the interstellar medium all right

1039
00:46:44,779 --> 00:46:42,690
so let me just walk you through this a

1040
00:46:47,990 --> 00:46:44,789
bit more so here's one of the stars we

1041
00:46:49,789 --> 00:46:48,000
looked at here's a spectrum from an

1042
00:46:51,890 --> 00:46:49,799
ultraviolet spectrum so these are

1043
00:46:56,029 --> 00:46:51,900
measurements taken with Hubble and with

1044
00:46:59,599 --> 00:46:56,039
the with fuse and it shows again here's

1045
00:47:01,309 --> 00:46:59,609
wavelengths and here's here's flexes and

1046
00:47:04,160 --> 00:47:01,319
you can see these dips here this is

1047
00:47:07,220 --> 00:47:04,170
absorption dips from gas and the

1048
00:47:12,380 --> 00:47:07,230
interstellar medium and its absorption

1049
00:47:15,170 --> 00:47:12,390
debts due to iron or silicon or thing

1050
00:47:17,870 --> 00:47:15,180
for magnesium or chromium and all these

1051
00:47:21,470 --> 00:47:17,880
are trace heavy metals that we use to

1052
00:47:23,900 --> 00:47:21,480
understand and trace where dust where

1053
00:47:25,970 --> 00:47:23,910
dust is forming

1054
00:47:28,789 --> 00:47:25,980
so we measured these for a number of

1055
00:47:30,859 --> 00:47:28,799
different species so this is iron and

1056
00:47:34,490 --> 00:47:30,869
silicon and zinc and chromium and

1057
00:47:39,430 --> 00:47:34,500
phosphorus this is in the SMC and we

1058
00:47:42,380 --> 00:47:39,440
plot basically how much stuff is missing

1059
00:47:46,190 --> 00:47:42,390
compared to sort of a rolled-up number

1060
00:47:48,289 --> 00:47:46,200
on that roll it up depletion so this is

1061
00:47:51,470 --> 00:47:48,299
more depletion that is you have more of

1062
00:47:54,500 --> 00:47:51,480
the metals in dust and then less

1063
00:47:57,609 --> 00:47:54,510

depletion less metals and dust and black

1064
00:48:00,920 --> 00:47:57,619
this black line here is what happens in

1065
00:48:03,079 --> 00:48:00,930
the milky way so this is comparing the

1066
00:48:07,760 --> 00:48:03,089
small Magellanic Cloud to the Milky Way

1067
00:48:10,279 --> 00:48:07,770
and by summing up all this all these

1068
00:48:14,569 --> 00:48:10,289
metals that are missing you can estimate

1069
00:48:16,430 --> 00:48:14,579
gas to dust ratios from basically what's

1070
00:48:18,829 --> 00:48:16,440
missing in a in a much more precise way

1071
00:48:23,210 --> 00:48:18,839
than we can with with the maps and so

1072
00:48:26,240 --> 00:48:23,220
it's a good check and so what we have

1073
00:48:29,420 --> 00:48:26,250
here is the hydrogen to dust mass ratio

1074
00:48:33,079 --> 00:48:29,430
the gas the dust ratio for the SMC the

1075
00:48:35,900 --> 00:48:33,089
LMC in the milky way and we can see that

1076
00:48:37,940 --> 00:48:35,910
it changes you have lines the sites that

1077
00:48:40,490 --> 00:48:37,950
they're things are more depleted that is

1078
00:48:42,380 --> 00:48:40,500
there's much more dust and you have

1079
00:48:44,960 --> 00:48:42,390
regions that are less depleted and so

1080
00:48:47,420 --> 00:48:44,970
this is other confirmation that there

1081
00:48:49,670 --> 00:48:47,430
are actually real variations of how much

1082
00:48:51,230 --> 00:48:49,680
dust is contained in different parts of

1083
00:48:53,120 --> 00:48:51,240
the galaxy there's real processing out

1084
00:48:55,490 --> 00:48:53,130
there it's both destroyed by the

1085
00:48:57,019 --> 00:48:55,500
supernova remnants as I showed but then

1086
00:48:59,859 --> 00:48:57,029
also in the colder clouds it really

1087
00:49:02,120 --> 00:48:59,869
seems that they it is growing again now

1088
00:49:05,450 --> 00:49:02,130

this is shorter of evidence that that

1089
00:49:08,299 --> 00:49:05,460
exists in existence proof but we are not

1090
00:49:10,190 --> 00:49:08,309
as far along in terms of coming up with

1091
00:49:12,859 --> 00:49:10,200
a rate like I showed you nice dust

1092
00:49:15,170 --> 00:49:12,869
production rates by the Evolve stars but

1093
00:49:17,240 --> 00:49:15,180
all we've done so far but I think it's a

1094
00:49:19,730 --> 00:49:17,250
big step forward is to show that yeah

1095
00:49:21,260 --> 00:49:19,740
actually this this stuff happens we

1096
00:49:22,789 --> 00:49:21,270
don't know how fast it happens how

1097
00:49:25,819 --> 00:49:22,799
effective it is but it's certainly

1098
00:49:27,680 --> 00:49:25,829
happening all right so let me go on to

1099
00:49:29,930 --> 00:49:27,690
the last loop here the young stars

1100
00:49:32,390 --> 00:49:29,940
forming the stars now in terms of the

1101
00:49:33,910 --> 00:49:32,400
life cycle of dust how this is important

1102
00:49:35,510 --> 00:49:33,920
is that the dust grains actually

1103
00:49:36,830 --> 00:49:35,520
disappear because

1104
00:49:39,440 --> 00:49:36,840
when you form a star it kind of takes

1105
00:49:41,750 --> 00:49:39,450
all the gas all the dust and it makes

1106
00:49:45,950 --> 00:49:41,760
them all atoms exactly highly ionized

1107
00:49:48,680 --> 00:49:45,960
atoms when it forms the star this is a

1108
00:49:50,990 --> 00:49:48,690
again a beautiful Hubble image of a

1109
00:49:53,000 --> 00:49:51,000
beautiful forming or young stellar

1110
00:49:54,850 --> 00:49:53,010
object because that's what we found in

1111
00:49:57,650 --> 00:49:54,860
the Magellanic Clouds you accelerate

1112
00:50:03,170 --> 00:49:57,660
s106 showing these beautiful bipolar

1113
00:50:04,880 --> 00:50:03,180

nebulas and why it's those or yang

1114
00:50:08,900 --> 00:50:04,890
stellar objects have different kinds of

1115
00:50:11,470 --> 00:50:08,910
evolutionary stages that we learn about

1116
00:50:15,080 --> 00:50:11,480
and can pick up with these observatories

1117
00:50:19,610 --> 00:50:15,090
here's a young protostar mean accreting

1118
00:50:21,980 --> 00:50:19,620
phase stage zero it's basically just a

1119
00:50:24,050 --> 00:50:21,990
bunch of cloud condensing onto thing

1120
00:50:28,010 --> 00:50:24,060
it's very cold it's really only seeing

1121
00:50:29,510 --> 00:50:28,020
with Herschel so we were good at finding

1122
00:50:31,820 --> 00:50:29,520
these types of objects and then we have

1123
00:50:34,550 --> 00:50:31,830
stage one object this is sort of an

1124
00:50:37,310 --> 00:50:34,560
accreting protostar where you have a

1125
00:50:40,310 --> 00:50:37,320
disc it's getting it's turned on

1126
00:50:43,220 --> 00:50:40,320
you have been frit excesses and then

1127
00:50:45,140 --> 00:50:43,230
stage two is when basically that

1128
00:50:47,270 --> 00:50:45,150
envelope is gone but you still have this

1129
00:50:49,700 --> 00:50:47,280
disk and planets will start forming in

1130
00:50:53,900 --> 00:50:49,710
stage three which I won't be talking

1131
00:50:55,430 --> 00:50:53,910
about at all really two or three stage

1132
00:51:00,470 --> 00:50:55,440
three is where basically you have

1133
00:51:02,740 --> 00:51:00,480
planets and and there you're seeing a

1134
00:51:06,320 --> 00:51:02,750
book sort of Kuiper belt type objects

1135
00:51:08,030 --> 00:51:06,330
all right so small Magellanic Cloud

1136
00:51:09,680 --> 00:51:08,040
why so Canada so again how do we find

1137
00:51:12,200 --> 00:51:09,690
these so I talk to you a little bit

1138
00:51:14,480 --> 00:51:12,210

these this is maybe somewhat familiar

1139
00:51:17,870 --> 00:51:14,490
we use these color-magnitude diagram yet

1140
00:51:21,980 --> 00:51:17,880
again this is eight versus eight minus

1141
00:51:25,610 --> 00:51:21,990
24 and the thing with the why shows is

1142
00:51:28,010 --> 00:51:25,620
that before the launch of spitzer there

1143
00:51:29,960 --> 00:51:28,020
was only one known in a small magellanic

1144
00:51:32,480 --> 00:51:29,970
cloud and in the large magellanic cloud

1145
00:51:34,130 --> 00:51:32,490
there were only 20 so to really

1146
00:51:36,350 --> 00:51:34,140
understand this we actually had to find

1147
00:51:38,090 --> 00:51:36,360
all the all the young stellar objects

1148
00:51:39,860 --> 00:51:38,100
know this was a big discovery just

1149
00:51:42,320 --> 00:51:39,870
trying to find them and identify them

1150
00:51:44,560 --> 00:51:42,330
for the first time so it was pretty

1151
00:51:47,840 --> 00:51:44,570
exciting this is a lot of cool stuff

1152
00:51:49,499 --> 00:51:47,850
what I want to show over here is these

1153
00:51:50,879 --> 00:51:49,509
are all the evolved stars

1154
00:51:52,739 --> 00:51:50,889
use all the ones I talked about at the

1155
00:51:54,839 --> 00:51:52,749
beginning of the talk the ones that are

1156
00:51:56,789 --> 00:51:54,849
dying there's confusion with the ones

1157
00:51:59,879 --> 00:51:56,799
that are being born because they both

1158
00:52:02,579 --> 00:51:59,889
power stars with dust around it and

1159
00:52:04,529 --> 00:52:02,589
here's the young ones these are the ones

1160
00:52:06,749 --> 00:52:04,539
where we were after and there were some

1161
00:52:09,419 --> 00:52:06,759
studies done before tonight to show some

1162
00:52:12,239 --> 00:52:09,429
of them and then this is what we this is

1163
00:52:14,009 --> 00:52:12,249

this was our guidance so in grey here

1164
00:52:15,809 --> 00:52:14,019
and all the things are it's basically

1165
00:52:17,069 --> 00:52:15,819
the whole catalog for the element for

1166
00:52:20,489 --> 00:52:17,079
the small Magellanic Cloud the whole

1167
00:52:24,389 --> 00:52:20,499
catalog of all the sources and in amber

1168
00:52:26,370 --> 00:52:24,399
here is the model predictions of where

1169
00:52:29,309 --> 00:52:26,380
do you expect to find them in the

1170
00:52:31,469 --> 00:52:29,319
color-magnitude space and then here well

1171
00:52:32,549 --> 00:52:31,479
this is a problem the problem here is

1172
00:52:36,029 --> 00:52:32,559
that there are a lot of background

1173
00:52:38,069 --> 00:52:36,039
galaxies to the LMC that confuse us with

1174
00:52:41,069 --> 00:52:38,079
whether it's a star or a galaxy

1175
00:52:43,319 --> 00:52:41,079
so the initial survey is the one

1176
00:52:47,249 --> 00:52:43,329
published by this former postdoc of mine

1177
00:52:49,169 --> 00:52:47,259
marta Savio basically went for the easy

1178
00:52:50,699 --> 00:52:49,179
stuff the really dusty stuff and the

1179
00:52:54,539 --> 00:52:50,709
bright stuffs are kind of the more

1180
00:52:58,019 --> 00:52:54,549
massive young stellar objects and so

1181
00:53:01,499 --> 00:52:58,029
what we did is we found actually 1100

1182
00:53:03,389 --> 00:53:01,509
yso candidates in the SMC that's a

1183
00:53:06,029 --> 00:53:03,399
thousand times more than we we knew

1184
00:53:09,509 --> 00:53:06,039
before before the survey was done a

1185
00:53:13,709 --> 00:53:09,519
thousand times more objects and this is

1186
00:53:15,629 --> 00:53:13,719
the location of all of them so what are

1187
00:53:17,789 --> 00:53:15,639
some of the things that are interesting

1188
00:53:19,469 --> 00:53:17,799

particularly with respect to this dust

1189
00:53:22,799 --> 00:53:19,479
lifecycle is well you can start making

1190
00:53:25,169 --> 00:53:22,809
plots histogram of the stellar mass here

1191
00:53:28,109 --> 00:53:25,179
you can see we're kind of biased to the

1192
00:53:31,109 --> 00:53:28,119
more massive ones here's the luminosity

1193
00:53:32,909 --> 00:53:31,119
plot again the more luminous ones but

1194
00:53:35,219 --> 00:53:32,919
there been lots of theoretical studies

1195
00:53:36,779 --> 00:53:35,229
shown of figuring out what an initial

1196
00:53:38,429 --> 00:53:36,789
mass function is and this is a

1197
00:53:40,259 --> 00:53:38,439
characteristic initial mass function

1198
00:53:42,569 --> 00:53:40,269
that we just fit over the part that

1199
00:53:45,179 --> 00:53:42,579
we're most confident with when we figure

1200
00:53:47,279 --> 00:53:45,189
out how much how many stars are being

1201
00:53:50,669 --> 00:53:47,289
born now and from that we can come up

1202
00:53:53,099 --> 00:53:50,679
with a star formation rate or asfr and

1203
00:53:56,459 --> 00:53:53,109
that star formation rate in the SMC is

1204
00:53:58,079 --> 00:53:56,469
0.06 solar masses per year and so that's

1205
00:53:59,549 --> 00:53:58,089
the real which stars are forming if you

1206
00:54:01,079 --> 00:53:59,559
have a guess the dust' ratio you can

1207
00:54:02,150 --> 00:54:01,089
also say well how much dust is

1208
00:54:08,920 --> 00:54:02,160
disappearing

1209
00:54:11,089 --> 00:54:08,930
forming these stars alright going to the

1210
00:54:14,990 --> 00:54:11,099
less-evolved the young stellar object

1211
00:54:17,509 --> 00:54:15,000
and dust calms we got those from the

1212
00:54:21,049 --> 00:54:17,519
Herschel Heritage Survey so this is H

1213
00:54:23,839 --> 00:54:21,059

alpha spire 250 microns and this is our

1214
00:54:26,539 --> 00:54:23,849
band merge catalog and then bottom here

1215
00:54:29,029 --> 00:54:26,549
you can see where we think all the Y

1216
00:54:32,599 --> 00:54:29,039
shows are located and then we also found

1217
00:54:34,970 --> 00:54:32,609
kind of preforming stars sort of dense

1218
00:54:36,650 --> 00:54:34,980
clump things and then you can see we

1219
00:54:38,180 --> 00:54:36,660
have lots of contamination from the

1220
00:54:39,980 --> 00:54:38,190
background galaxies at these wavelengths

1221
00:54:42,380 --> 00:54:39,990
so this was a very tricky problem to

1222
00:54:43,759 --> 00:54:42,390
separate what's really distant in high

1223
00:54:47,089 --> 00:54:43,769
redshift and what is part of the

1224
00:54:51,680 --> 00:54:47,099
galaxies but we ended up with you can

1225
00:54:55,910 --> 00:54:51,690
see on the order of almost 800 young

1226
00:54:58,009 --> 00:54:55,920
stellar objects with Herschel alright so

1227
00:54:58,970 --> 00:54:58,019
so this is kind of a little bit at the

1228
00:55:01,069 --> 00:54:58,980
end of my story

1229
00:55:04,190 --> 00:55:01,079
so I've stepped you through that whole

1230
00:55:04,609 --> 00:55:04,200
life cycle now but then what is the

1231
00:55:08,390 --> 00:55:04,619
ledger

1232
00:55:10,220 --> 00:55:08,400
beginning I said okay what is how much

1233
00:55:13,460 --> 00:55:10,230
dust is in the is m and so in this

1234
00:55:15,680 --> 00:55:13,470
column here it's always the LMC this is

1235
00:55:19,670 --> 00:55:15,690
always the SMC I'm going to focus on the

1236
00:55:21,980 --> 00:55:19,680
LMC numbers and quote those and remember

1237
00:55:25,309 --> 00:55:21,990
the SMC you'll see is about factor of 10

1238
00:55:27,499 --> 00:55:25,319

lower so the dust mass seven point three

1239
00:55:30,650 --> 00:55:27,509
times ten to the five solar masses of

1240
00:55:32,900 --> 00:55:30,660
dust how much dust is being returned

1241
00:55:35,329 --> 00:55:32,910
from these stellar winds from egb stars

1242
00:55:37,910 --> 00:55:35,339
where it supergiant's LBB masses if you

1243
00:55:42,740 --> 00:55:37,920
sum all that up you have 2.5 times 10 of

1244
00:55:45,680 --> 00:55:42,750
-5 solar masses per year and then here

1245
00:55:48,499 --> 00:55:45,690
you have supernova dust production this

1246
00:55:51,829 --> 00:55:48,509
was based on the 87 a result 2 times 10

1247
00:55:54,740 --> 00:55:51,839
to minus three solar masses per year and

1248
00:55:59,210 --> 00:55:54,750
then you have dust destruction by

1249
00:56:00,620 --> 00:55:59,220
supernovae 2 times 10 to minus 2 solar

1250
00:56:03,769 --> 00:56:00,630
masses per year so you can see the

1251
00:56:08,269 --> 00:56:03,779
destruction seems to be bigger star

1252
00:56:09,259 --> 00:56:08,279
formation rate 0.1 times 10.1 solar

1253
00:56:10,940 --> 00:56:09,269
masses per year

1254
00:56:13,039 --> 00:56:10,950
stellar astray ssin of death so that's

1255
00:56:15,620 --> 00:56:13,049
sort of multiplying this time to dust

1256
00:56:17,150 --> 00:56:15,630
the gas ratio so this is how much dust

1257
00:56:19,610 --> 00:56:17,160
appears because we're just warming stars

1258
00:56:22,760 --> 00:56:19,620
two times some of mines for solar masses

1259
00:56:27,440 --> 00:56:22,770
per year so what we have here is a net

1260
00:56:29,600 --> 00:56:27,450
loss of dust at 1.8 times 10 to minus 2

1261
00:56:32,420 --> 00:56:29,610
solar masses per year it's that's kind

1262
00:56:34,970 --> 00:56:32,430
of a high rate of deaths now you'll note

1263
00:56:38,660 --> 00:56:34,980

that I don't have a calculation for the

1264
00:56:40,880 --> 00:56:38,670
dust grouse in the is M because we don't

1265
00:56:42,410 --> 00:56:40,890
have ways to measure that yet we know

1266
00:56:45,890 --> 00:56:42,420
something's happening but we don't know

1267
00:56:50,930 --> 00:56:45,900
what the rate but because this number is

1268
00:56:55,720 --> 00:56:50,940
negative I still ask this question of

1269
00:56:58,280 --> 00:56:55,730
why does this galaxy have dust and

1270
00:57:00,260 --> 00:56:58,290
before I take your questions I just want

1271
00:57:02,270 --> 00:57:00,270
to point out that doing this type of

1272
00:57:04,580 --> 00:57:02,280
work I mean the amount of discoveries we

1273
00:57:06,440 --> 00:57:04,590
made in these programs is tremendous and

1274
00:57:08,900 --> 00:57:06,450
it's been really rewarding but it is not

1275
00:57:11,830 --> 00:57:08,910
possible without a large team of people

1276
00:57:18,080 --> 00:57:11,840
because all these calculations and work

1277
00:57:34,900 --> 00:57:18,090
requires many hands so anyway I thank

1278
00:57:34,910 --> 00:57:52,579
Yeah right

1279
00:57:58,640 --> 00:57:54,769
in terms of interaction physical

1280
00:58:01,489 --> 00:57:58,650
dynamical interaction not not as

1281
00:58:04,940 --> 00:58:01,499
intensely as the LMC the SMC do with

1282
00:58:08,210 --> 00:58:04,950
each other and this type of study of

1283
00:58:09,950 --> 00:58:08,220
dust evolution has not been done in the

1284
00:58:12,710 --> 00:58:09,960
mini Andromeda galaxy although I'm

1285
00:58:15,170 --> 00:58:12,720
thinking about it with James Webb when

1286
00:58:16,819 --> 00:58:15,180
James why but the the two satellite

1287
00:58:18,650 --> 00:58:16,829
galaxies of Andromeda are mostly

1288
00:58:23,089 --> 00:58:18,660

ellipticals do they have significant

1289
00:58:25,789 --> 00:58:23,099
dust and ice the close-in ones are too

1290
00:58:28,069 --> 00:58:25,799
elliptical with dwarf ellipticals yeah I

1291
00:58:29,180 --> 00:58:28,079
don't know my postdoc Libby's actually

1292
00:58:31,549 --> 00:58:29,190
going to try to measure the dust

1293
00:58:32,779 --> 00:58:31,559
production for him 32 okay

1294
00:58:34,789 --> 00:58:32,789
I'm just to see what's being produced

1295
00:58:36,579 --> 00:58:34,799
but there is not a lot of gas and dust

1296
00:58:39,229 --> 00:58:36,589
there's not a lot of interstellar medium

1297
00:58:46,080 --> 00:58:39,239
so it's hard to measure what's what's in

1298
00:58:57,000 --> 00:58:55,650
oh right okay we need to repeat the

1299
00:58:59,460 --> 00:58:57,010
question for though oh right for the eye

1300
00:59:02,820 --> 00:58:59,470
okay so the question was you mentioned

1301
00:59:06,120 --> 00:59:02,830
that supernovae destroyed us but in 1987

1302
00:59:09,840 --> 00:59:06,130
au seed us so why do you see it in that

1303
00:59:11,660 --> 00:59:09,850
case and so the difference or maybe I

1304
00:59:15,120 --> 00:59:11,670
didn't make very clear is that the

1305
00:59:18,630 --> 00:59:15,130
supernova 1987a the ejecta from the star

1306
00:59:22,080 --> 00:59:18,640
I mean the explosion has created dust

1307
00:59:24,420 --> 00:59:22,090
that much dust and it is but it's the

1308
00:59:26,220 --> 00:59:24,430
shockwave of the supernova remnant going

1309
00:59:28,800 --> 00:59:26,230
out that is destroying the dust outside

1310
00:59:32,520 --> 00:59:28,810
of that so it's destroying the dust in

1311
00:59:36,180 --> 00:59:32,530
the interstellar medium so that's that's

1312
00:59:38,340 --> 00:59:36,190
why we saw it also it's very young super

1313
00:59:39,690 --> 00:59:38,350

number 87 a is really experienced what

1314
00:59:41,070 --> 00:59:39,700
they call a reverse shock where the

1315
00:59:43,320 --> 00:59:41,080
shocks that would come back and so a lot

1316
00:59:44,670 --> 00:59:43,330
of people say okay well to have solar

1317
00:59:45,900 --> 00:59:44,680
massive dust but all of its gonna go

1318
00:59:47,640 --> 00:59:45,910
away with the reverse shock well that's

1319
00:59:50,460 --> 00:59:47,650
something we'll be able to explore

1320
00:59:52,650 --> 00:59:50,470
actually over the next decade how much

1321
00:59:54,270 --> 00:59:52,660
how much does get destroyed so you're

1322
00:59:56,670 --> 00:59:54,280
expecting the reverse shot to hit in the

1323
01:00:00,330 --> 00:59:56,680
next decade that's what someone was

1324
01:00:02,820 --> 01:00:00,340
telling me yeah I just find 87 is so fun

1325
01:00:04,650 --> 01:00:02,830
it is we have to watch things happen in

1326
01:00:06,690 --> 01:00:04,660
real time that you've never been able to

1327
01:00:08,430 --> 01:00:06,700
see so with James Webb I'm gonna use

1328
01:00:10,230 --> 01:00:08,440
some of my guaranteed time to actually

1329
01:00:11,760 --> 01:00:10,240
try to get a spectrum of that dust to

1330
01:00:22,410 --> 01:00:11,770
figure out what is it made of because

1331
01:00:25,020 --> 01:00:22,420
it's limiting our models yes it means

1332
01:00:27,780 --> 01:00:25,030
that well dust is it's sort of all these

1333
01:00:29,550 --> 01:00:27,790
metals that are solid in a solid form so

1334
01:00:33,330 --> 01:00:29,560
when you mean destroyed it means it's

1335
01:00:35,250 --> 01:00:33,340
shattered all into the atoms so that's

1336
01:00:37,020 --> 01:00:35,260
why these depletion measurements we're

1337
01:00:39,840 --> 01:00:37,030
just looking at how many how many how

1338
01:00:41,600 --> 01:00:39,850

much atoms of iron is there in the gas

1339
01:00:44,700 --> 01:00:41,610
and how much should there be in that's

1340
01:00:48,210 --> 01:00:44,710
the fact that whatever's missing sort of

1341
01:00:50,640 --> 01:00:48,220
the missing so we had a question from

1342
01:00:52,890 --> 01:00:50,650
online yes they wanted to know our dust

1343
01:00:55,410 --> 01:00:52,900
grains positively or negatively charged

1344
01:00:58,109 --> 01:00:55,420
are they mostly neutral oh that's a very

1345
01:01:02,579 --> 01:00:58,119
good question very sophisticated

1346
01:01:04,799 --> 01:01:02,589
they are neutral inside the dense clouds

1347
01:01:06,809 --> 01:01:04,809
but near the surfaces where their shine

1348
01:01:20,759 --> 01:01:06,819
by light they tend to be positively

1349
01:01:23,849 --> 01:01:20,769
charged questions from the room right so

1350
01:01:26,609 --> 01:01:23,859
hydrogen's the bulk of it but then it's

1351
01:01:28,499 --> 01:01:26,619
like healing there's some fraction of it

1352
01:01:33,059 --> 01:01:28,509
that's helium that we that we correct

1353
01:01:35,339 --> 01:01:33,069
for no I mean hydrogen I mean basically

1354
01:01:37,620 --> 01:01:35,349
if you can account for all the hydrogen

1355
01:01:39,569 --> 01:01:37,630
atoms and then correct for the helium

1356
01:01:42,239 --> 01:01:39,579
you you pretty much know how much gas is

1357
01:01:45,120 --> 01:01:42,249
there I mean we use all sorts of gas

1358
01:01:47,730 --> 01:01:45,130
tracers to help us like for the cold

1359
01:01:52,620 --> 01:01:47,740
molecular gas for h2 we can't really

1360
01:01:54,089 --> 01:01:52,630
trace that very well with well with the

1361
01:01:56,099 --> 01:01:54,099
transitions because it's a diatomic

1362
01:01:59,099 --> 01:01:56,109
molecule so we tend to use carbon

1363
01:02:01,769 --> 01:01:59,109

monoxide or Co because it's asymmetric

1364
01:02:04,620 --> 01:02:01,779
we can trace its rotational lines at a

1365
01:02:09,259 --> 01:02:04,630
low temperature and be able to use it as

1366
01:02:11,579 --> 01:02:09,269
a tracer for the molecular hydrogen is

1367
01:02:15,569 --> 01:02:11,589
that's part of the uncertainty and that

1368
01:02:19,229 --> 01:02:15,579
gas to dust ratio map that I showed you

1369
01:02:22,109 --> 01:02:19,239
is it's very difficult to to map where

1370
01:02:24,089 --> 01:02:22,119
the hydrogen is okay so we have another

1371
01:02:25,769 --> 01:02:24,099
question from online wanting to know

1372
01:02:27,630 --> 01:02:25,779
about the dust clouds themselves what

1373
01:02:29,339 --> 01:02:27,640
are the it's like the average density in

1374
01:02:30,779 --> 01:02:29,349
these dust clouds I guess they'd

1375
01:02:33,779 --> 01:02:30,789
probably want to know the temperature -

1376
01:02:38,309 --> 01:02:33,789
okay the temperature in the clouds in

1377
01:02:42,120 --> 01:02:38,319
the largeman jóhanna around 25 Kelvin 22

1378
01:02:44,489 --> 01:02:42,130
Kelvin so I mean really cold but it's

1379
01:02:46,559 --> 01:02:44,499
colder than 3 Kelvin which is the Cosmic

1380
01:02:50,309 --> 01:02:46,569
Microwave Background but that's still

1381
01:02:52,710 --> 01:02:50,319
minus 250 or so yeah you wouldn't

1382
01:02:59,970 --> 01:02:52,720
centigrade there which is around minus

1383
01:03:03,509 --> 01:02:59,980
500 yeah it's not it's not like being at

1384
01:03:05,339 --> 01:03:03,519
the beach or something I mean actually

1385
01:03:07,920 --> 01:03:05,349
sand grains is kind of an analogy to all

1386
01:03:09,970 --> 01:03:07,930
the silicate grains and stuff but the

1387
01:03:15,160 --> 01:03:09,980
densities it's very low

1388
01:03:16,930 --> 01:03:15,170

gosh I mean some of the desk clouds you

1389
01:03:20,319 --> 01:03:16,940
know and I'm going to trace this in

1390
01:03:22,920 --> 01:03:20,329
terms of the hydrogen content right it

1391
01:03:26,109 --> 01:03:22,930
could be like there might be a hundred

1392
01:03:28,060 --> 01:03:26,119
per cubic centimeter right that's I mean

1393
01:03:29,980 --> 01:03:28,070
it's really I mean it's rarified it's

1394
01:03:32,230 --> 01:03:29,990
more rarefied than any vacuum that we

1395
01:03:34,180 --> 01:03:32,240
can create on earth it's just very it's

1396
01:03:36,250 --> 01:03:34,190
very rarefied and the reason we can see

1397
01:03:39,910 --> 01:03:36,260
is that we see large columns of it and

1398
01:03:42,220 --> 01:03:39,920
you map it because there's just lots it

1399
01:03:44,829 --> 01:03:42,230
the clouds big it's massive but it's

1400
01:03:47,200 --> 01:03:44,839
very diffused right so it's like colder

1401
01:03:48,880 --> 01:03:47,210
than anything on earth and more rarefied

1402
01:04:02,109 --> 01:03:48,890
than anything on earth but let me call

1403
01:04:03,040 --> 01:04:02,119
it this these giant dust clouds yes it

1404
01:04:05,589 --> 01:04:03,050
does

1405
01:04:07,000 --> 01:04:05,599
I mean our earth is made of dust grains

1406
01:04:10,300 --> 01:04:07,010
these dust grains they've been floating

1407
01:04:13,810 --> 01:04:10,310
around but that's it creates things only

1408
01:04:15,640 --> 01:04:13,820
when it gets gathered up right it

1409
01:04:17,559 --> 01:04:15,650
creates a lot of hassle for all my

1410
01:04:19,420 --> 01:04:17,569
optical Astronomy buddies in the house

1411
01:04:21,190 --> 01:04:19,430
in this building because they're like ah

1412
01:04:23,410 --> 01:04:21,200
that's I've gotta correct for it cuz

1413
01:04:26,170 --> 01:04:23,420

it's reddening my observations and it's

1414
01:04:29,589 --> 01:04:26,180
making it dimmer so it causes a nuisance

1415
01:04:33,370 --> 01:04:29,599
that way but in terms of creating things

1416
01:04:35,140 --> 01:04:33,380
when a stars formed I showed you that

1417
01:04:37,059 --> 01:04:35,150
disk and planets form around it and the

1418
01:04:39,880 --> 01:04:37,069
planets are really formed from the dust

1419
01:04:43,120 --> 01:04:39,890
the dust condenses nicely at the center

1420
01:04:44,440 --> 01:04:43,130
settles better than the gas and it and

1421
01:04:45,730 --> 01:04:44,450
that's actually a different mystery as

1422
01:04:47,620 --> 01:04:45,740
someone else can talk to you about but

1423
01:04:49,569 --> 01:04:47,630
how do you get these grains to build up

1424
01:04:51,700 --> 01:04:49,579
to fill to create plant if they actually

1425
01:04:54,069 --> 01:04:51,710
haven't figured that out yet because

1426
01:04:56,200 --> 01:04:54,079
it's hard to go from okay you can

1427
01:04:57,640 --> 01:04:56,210
coagulate in there bigger bigger but at

1428
01:04:59,859 --> 01:04:57,650
that certain point they can't figure out

1429
01:05:02,530 --> 01:04:59,869
how they stick well enough together to

1430
01:05:12,680 --> 01:05:02,540
build something bigger that's a that's a

1431
01:05:22,950 --> 01:05:20,220
no no you mean to imply you mean to a

1432
01:05:25,740 --> 01:05:22,960
planet is ever to me no I wouldn't call

1433
01:05:27,750 --> 01:05:25,750
that destruction to me right I would say

1434
01:05:31,830 --> 01:05:27,760
that's creating into a really large dust

1435
01:05:36,540 --> 01:05:31,840
grain you live on a giant doesn't

1436
01:05:53,760 --> 01:05:36,550
everybody know because it's still a

1437
01:05:53,770 --> 01:05:59,270
they won't write

1438
01:06:04,500 --> 01:06:02,040

okay so I'll have two answers one is

1439
01:06:06,690 --> 01:06:04,510
that I mean we we certainly observe dust

1440
01:06:09,150 --> 01:06:06,700
and gas clouds in our solar neighborhood

1441
01:06:10,890 --> 01:06:09,160
that you know people have observed in

1442
01:06:13,049 --> 01:06:10,900
fact this whole depletion stuff I talked

1443
01:06:15,150 --> 01:06:13,059
about all of that has been done very

1444
01:06:19,290 --> 01:06:15,160
local to this to the Sun because it's

1445
01:06:21,839 --> 01:06:19,300
difficult to go beyond that I think in

1446
01:06:24,660 --> 01:06:21,849
terms of our solar system sweeping

1447
01:06:26,099 --> 01:06:24,670
through next hundred years well I don't

1448
01:06:30,210 --> 01:06:26,109
know I mean we might be passing through

1449
01:06:33,620 --> 01:06:30,220
something now I did hear a paper where

1450
01:06:37,109 --> 01:06:33,630
someone used the Voyager spacecraft data

1451
01:06:38,819 --> 01:06:37,119
to understand interstellar grain dust

1452
01:06:42,059 --> 01:06:38,829
grains that were coming into the solar

1453
01:06:45,660 --> 01:06:42,069
system so it's it's quite possible that

1454
01:06:48,030 --> 01:06:45,670
you know we are getting I mean that we

1455
01:06:50,880 --> 01:06:48,040
are getting bombarded but it's and it's

1456
01:06:53,099 --> 01:06:50,890
difficult that it was a fascinating

1457
01:06:57,120 --> 01:06:53,109
paper because somehow they were able to

1458
01:06:59,520 --> 01:06:57,130
know it was clouds coming out the Oort

1459
01:07:01,859 --> 01:06:59,530
cloud Oh with the with the Kuiper belt

1460
01:07:03,690 --> 01:07:01,869
objects and stuff like that I mean that

1461
01:07:06,150 --> 01:07:03,700
but that's part of the solar system I

1462
01:07:08,849 --> 01:07:06,160
mean so that I think he was asking like

1463
01:07:23,059 --> 01:07:08,859

a different interstellar cloud that a

1464
01:07:29,849 --> 01:07:26,089
it would be I mean and actually

1465
01:07:32,210 --> 01:07:29,859
something there's a group in University

1466
01:07:33,930 --> 01:07:32,220
of Washington in st. Louis that is

1467
01:07:35,760 --> 01:07:33,940
internationally famous they have a

1468
01:07:38,099 --> 01:07:35,770
meteoroid lab in which they take

1469
01:07:39,809 --> 01:07:38,109
meteorites and they smash them out to

1470
01:07:41,420 --> 01:07:39,819
little parts and they try to identify

1471
01:07:45,150 --> 01:07:41,430
which dust grains are what they call

1472
01:07:49,529 --> 01:07:45,160
pre-solar grains and so they've actually

1473
01:07:53,549 --> 01:07:49,539
have found and analyzed dust grains that

1474
01:07:55,620 --> 01:07:53,559
were formed in an Ag B star wind and

1475
01:07:58,079 --> 01:07:55,630
they're able to identify it because the

1476
01:08:01,140 --> 01:07:58,089
isotopic ratio of like a carbon star has

1477
01:08:04,140 --> 01:08:01,150
a very unique signature when you dredge

1478
01:08:07,170 --> 01:08:04,150
up the carbon the carbon 12 to carbon 13

1479
01:08:09,000 --> 01:08:07,180
ratio is very different than you know

1480
01:08:11,279 --> 01:08:09,010
what we find normally in the in the

1481
01:08:12,660 --> 01:08:11,289
universe and so they're able to identify

1482
01:08:15,240 --> 01:08:12,670
that and actually study those grains

1483
01:08:17,550 --> 01:08:15,250
incident that's probably the closest

1484
01:08:20,160 --> 01:08:17,560
that I know where you come to try to

1485
01:08:22,530 --> 01:08:20,170
study something that was created outside

1486
01:08:24,840 --> 01:08:22,540
and actually somehow survived all the

1487
01:08:28,499 --> 01:08:24,850
processing I've talked about I mean I

1488
01:08:29,729 --> 01:08:28,509

think people were floored when they

1489
01:08:32,579 --> 01:08:29,739
heard what do you mean you found

1490
01:08:34,380 --> 01:08:32,589
something that that pre-existed the

1491
01:08:37,380 --> 01:08:34,390
solar system and wasn't smashed to

1492
01:08:40,320 --> 01:08:37,390
smithereens and rebuilt yeah and let me

1493
01:08:42,870 --> 01:08:40,330
just set timescale the Sun moves around

1494
01:08:46,019 --> 01:08:42,880
the center of our galaxy in about 200 to

1495
01:08:47,459 --> 01:08:46,029
220 million years so a hundred years is

1496
01:08:47,939 --> 01:08:47,469
nothing to the sun's motion through the

1497
01:08:50,640 --> 01:08:47,949
galaxy

1498
01:08:52,649 --> 01:08:50,650
so so we well I'm sure that in our

1499
01:08:53,880 --> 01:08:52,659
travels we've made about eighteen orbits

1500
01:08:56,610 --> 01:08:53,890
around the center of the galaxy we have

1501
01:08:58,320 --> 01:08:56,620
passed through dust clouds right but

1502
01:08:59,999 --> 01:08:58,330
it's not something that a hundred years

1503
01:09:03,630 --> 01:09:00,009
is going to make a lot of difference to

1504
01:09:31,870 --> 01:09:03,640
our position in the galaxy okay other

1505
01:09:35,320 --> 01:09:33,550
okay you have to summarize that for the

1506
01:09:37,450 --> 01:09:35,330
online cousin up to here at the front

1507
01:09:39,670 --> 01:09:37,460
right so what I hear and please correct

1508
01:09:42,400 --> 01:09:39,680
me if I'm ever mind you're asking that

1509
01:09:43,780 --> 01:09:42,410
you imagine different stars different

1510
01:09:48,390 --> 01:09:43,790
masses will have different explosive

1511
01:09:51,970 --> 01:09:48,400
forces and that's completely true and

1512
01:09:53,620 --> 01:09:51,980
how does that how does it affect is it

1513
01:09:55,720 --> 01:09:53,630

because there's this difference in the

1514
01:10:07,480 --> 01:09:55,730
carbon and silicon destruction does that

1515
01:10:10,120 --> 01:10:07,490
affect right so the question was do we

1516
01:10:12,100 --> 01:10:10,130
have evidence of how the dust get right

1517
01:10:14,350 --> 01:10:12,110
is there a correlation between this

1518
01:10:17,650 --> 01:10:14,360
supernova explosion and the type of

1519
01:10:19,720 --> 01:10:17,660
destruction that it does all I can tell

1520
01:10:21,940 --> 01:10:19,730
you is that not as much evidence as we

1521
01:10:23,560 --> 01:10:21,950
would like I mean there are a couple of

1522
01:10:26,140 --> 01:10:23,570
supernova remnants that have been

1523
01:10:30,430 --> 01:10:26,150
studied in some detail to show that dust

1524
01:10:33,640 --> 01:10:30,440
is destroyed but a lot of what a lot of

1525
01:10:36,070 --> 01:10:33,650
what is modeled is very theoretical and

1526
01:10:38,080 --> 01:10:36,080
that's why there's this whole huge

1527
01:10:40,420 --> 01:10:38,090
uncertainty like I've told you this

1528
01:10:44,070 --> 01:10:40,430
death destruction so some people in the

1529
01:10:47,410 --> 01:10:44,080
in in the field say well okay but that's

1530
01:10:49,150 --> 01:10:47,420
that this is really a calculation this

1531
01:10:52,350 --> 01:10:49,160
is really a theoretical count it's not

1532
01:10:55,120 --> 01:10:52,360
as not as known as well as we might like

1533
01:10:59,140 --> 01:10:55,130
and so some people dispute that this

1534
01:11:00,850 --> 01:10:59,150
dust is destroyed this efficiently other

1535
01:11:07,000 --> 01:11:00,860
people believe this is gospel that's

1536
01:11:08,440 --> 01:11:07,010
mainly the theorists and the you know

1537
01:11:10,780 --> 01:11:08,450
then they say and the theorists say well

1538
01:11:13,360 --> 01:11:10,790

what this proves is that dust has to

1539
01:11:15,550 --> 01:11:13,370
grow in the is M at a rate to nullify

1540
01:11:17,830 --> 01:11:15,560
that so basically things are steady

1541
01:11:21,640 --> 01:11:17,840
state and hence we have dust in a galaxy

1542
01:11:23,800 --> 01:11:21,650
but I think I mean this I would like to

1543
01:11:25,630 --> 01:11:23,810
see more observational investigation

1544
01:11:27,760 --> 01:11:25,640
today I mean we could do what you just

1545
01:11:30,670 --> 01:11:27,770
said and can we find a correlation

1546
01:11:33,460 --> 01:11:30,680
between a massive explosion and how much

1547
01:11:36,190 --> 01:11:33,470
dust is destroyed and really find har

1548
01:11:37,300 --> 01:11:36,200
vêtements or that that would be that

1549
01:11:39,790 --> 01:11:37,310
would be really good that would be a

1550
01:11:40,580 --> 01:11:39,800
huge step forward in my opinion we could

1551
01:11:42,260 --> 01:11:40,590
do that

1552
01:11:55,160 --> 01:11:42,270
but we don't we don't quite have that

1553
01:12:00,470 --> 01:11:55,170
yet let's see well a couple things it's

1554
01:12:03,470 --> 01:12:00,480
a bit of a secure Espace for me I was it

1555
01:12:05,180 --> 01:12:03,480
was a bit random how I got here in the

1556
01:12:08,300 --> 01:12:05,190
sense that I was always interested in

1557
01:12:11,390 --> 01:12:08,310
astronomy as a as a child like in age 13

1558
01:12:13,040 --> 01:12:11,400
I took a science course and I have to

1559
01:12:15,109 --> 01:12:13,050
say middle school teachers if any of you

1560
01:12:17,419 --> 01:12:15,119
are out there you have probably the most

1561
01:12:21,290 --> 01:12:17,429
impact on the kids the career career

1562
01:12:22,669 --> 01:12:21,300
decision but I took a class and every

1563
01:12:25,339 --> 01:12:22,679

everything they talked to me about was

1564
01:12:26,959 --> 01:12:25,349
like meteorology a meteorologist or Ino

1565
01:12:28,310 --> 01:12:26,969
jealous oh I want to be a geologist and

1566
01:12:30,350 --> 01:12:28,320
we ended with astronomy and I was like

1567
01:12:33,859 --> 01:12:30,360
oh man I've got to be an astronomer and

1568
01:12:35,810 --> 01:12:33,869
and then I found I then I took physics

1569
01:12:37,430 --> 01:12:35,820
I think the following year and I thought

1570
01:12:39,800 --> 01:12:37,440
you know it's quite good I was good at

1571
01:12:44,750 --> 01:12:39,810
math and physics less good at English

1572
01:12:46,280 --> 01:12:44,760
and then when I went to school I kind of

1573
01:12:49,760 --> 01:12:46,290
I went to University of Maryland College

1574
01:12:51,410 --> 01:12:49,770
Park actually undergrad I said well you

1575
01:12:53,000 --> 01:12:51,420
can't get a job as an astronomer so I

1576
01:12:54,410 --> 01:12:53,010
went into logical engineering I have a

1577
01:12:58,160 --> 01:12:54,420
degree in electrical engineering and

1578
01:13:00,109 --> 01:12:58,170
mathematics but a neighbor of mine who

1579
01:13:01,820 --> 01:13:00,119
was an astronomer you know as a bright

1580
01:13:03,459 --> 01:13:01,830
student and said hey do you want to work

1581
01:13:06,680 --> 01:13:03,469
with me and over the summer I was like

1582
01:13:09,589 --> 01:13:06,690
okay and so I worked at Goddard in some

1583
01:13:11,899 --> 01:13:09,599
internships and that was really cool

1584
01:13:14,390 --> 01:13:11,909
that was fun and exciting and then when

1585
01:13:16,520 --> 01:13:14,400
I neared the end of undergrad I had to

1586
01:13:18,229 --> 01:13:16,530
do an engineering honors thesis and

1587
01:13:20,450 --> 01:13:18,239
again a friend of mine who was an

1588
01:13:22,250 --> 01:13:20,460

astronomy major told his professor and

1589
01:13:24,290 --> 01:13:22,260
he called me up and says how would you

1590
01:13:26,959 --> 01:13:24,300
like to do it in in astronomy I was like

1591
01:13:28,520 --> 01:13:26,969
okay it has to have some engineering so

1592
01:13:30,770 --> 01:13:28,530
how about a Radio Astronomy that's like

1593
01:13:33,020 --> 01:13:30,780
okay so I did a radio astronomy project

1594
01:13:35,000 --> 01:13:33,030
and it was really cool I thought wow

1595
01:13:38,870 --> 01:13:35,010
well you know I think I want to go into

1596
01:13:41,750 --> 01:13:38,880
grad school this is pretty cool maybe

1597
01:13:43,280 --> 01:13:41,760
I'll try it out for a year so I tried it

1598
01:13:44,780 --> 01:13:43,290
out for a year in grad school and said

1599
01:13:46,970 --> 01:13:44,790
if no if I really don't like it I'm just

1600
01:13:47,299 --> 01:13:46,980
I'm just gonna move over but I really

1601
01:13:51,020 --> 01:13:47,309
like

1602
01:13:52,609 --> 01:13:51,030
so I stuck with it you know all right

1603
01:13:55,850 --> 01:13:52,619
that sounds like a wonderful finish

1604
01:13:58,430 --> 01:13:55,860
point I am sorry to tell you that clouds

1605
01:14:00,649 --> 01:13:58,440
have come in and Duncan sent me an email

1606
01:14:04,669 --> 01:14:00,659
and we are not going across the street

1607
01:14:07,689 --> 01:14:04,679
to the observatory however I did go out

1608
01:14:11,149 --> 01:14:07,699
during market stalk and get you a

1609
01:14:13,399 --> 01:14:11,159
picture for tonight pillar in the Korean

1610
01:14:17,020 --> 01:14:13,409
and nebula all sorts of information on

1611
01:14:19,430 --> 01:14:17,030
the back some over there some here

1612
01:14:21,140 --> 01:14:19,440
remember to check the website for

1613
01:14:23,510 --> 01:14:21,150

whether or not the south or the north is

1614
01:14:25,790 --> 01:14:23,520
closed next month I'll send it out on

1615
01:14:27,140 --> 01:14:25,800
the email thank you all for coming we'll

1616
01:14:40,200 --> 01:14:27,150
see you in September

1617
01:14:49,979 --> 01:14:44,400
I wonder if I might an average basis

1618
01:14:51,630 --> 01:14:49,989
with even someone for a large or could