1
00:02:45,209 --> 00:02:43,619
good afternoon welcome to Goddard Space

2
00:02:47,940 --> 00:02:45,219
Flight Center and todays space astronomy

3
00:02:49,410 --> 00:02:47,950
update where we will have today some of

4
00:02:51,270 --> 00:02:49,420
the most dramatic pictures yet from the

5
00:02:54,030 --> 00:02:51,280
Hubble Space Telescope and here to tell

6
00:02:56,489 --> 00:02:54,040
us about it and the findings is our

7
00:02:58,379 --> 00:02:56,499
distinguished panel and our host Steve

8
00:03:00,360 --> 00:02:58,389
marant an astronomer from Goddard Space

9
00:03:01,920 --> 00:03:00,370
Flight Center Steve thanks Don and

10
00:03:04,559 --> 00:03:01,930
welcome to space astronomy update

11
00:03:05,550 --> 00:03:04,569
everybody originating today from Goddard

12
00:03:08,490 --> 00:03:05,560
Space Flight Center in Greenbelt

13
00:03:11,819 --> 00:03:08,500

Maryland and with us today to discuss

14
00:03:15,690 --> 00:03:11,829
the birth pangs of stars like the Sun

15
00:03:18,119 --> 00:03:15,700
and its solar system are three experts

16
00:03:19,640 --> 00:03:18,129
have been investigating these objects

17
00:03:22,949 --> 00:03:19,650
with the Hubble Space Telescope

18
00:03:25,170 --> 00:03:22,959
professor Jeff Hester from the arizona

19
00:03:27,689 --> 00:03:25,180
state university in tempe an

20
00:03:29,789 --> 00:03:27,699
investigator of nebulae of some

21
00:03:31,920 --> 00:03:29,799
distinction and a member of the original

22
00:03:34,470 --> 00:03:31,930
wide field and planetary camera team for

23
00:03:36,809 --> 00:03:34,480
the Hubble Space Telescope and also

24
00:03:39,959 --> 00:03:36,819
we're glad to have a young postdoctoral

25
00:03:42,300 --> 00:03:39,969
researcher dr. John Morse of the Space

26
00:03:44,789 --> 00:03:42,310
Telescope Science Institute in Baltimore

27
00:03:46,920 --> 00:03:44,799
did his PhD on these objects at

28
00:03:49,259 --> 00:03:46,930
University of North Carolina a Harvard

29
00:03:51,330 --> 00:03:49,269
graduate and welcome back to space

30
00:03:53,309 --> 00:03:51,340
astronomy update one of the optics

31
00:03:54,960 --> 00:03:53,319
experts of the Hubble Space Telescope a

32
00:03:58,229 --> 00:03:54,970
member of the wide field and planetary

33
00:03:59,819 --> 00:03:58,239
camera 2 team from the European Space

34
00:04:02,580 --> 00:03:59,829
Agency in Space Telescope Science

35
00:04:06,199 --> 00:04:02,590
Institute Chris burrows dr. Chris

36
00:04:08,610 --> 00:04:06,209
burrows and our independent panelist

37
00:04:11,729 --> 00:04:08,620
chairman of the department of astronomy

38
00:04:13,949 --> 00:04:11,739

University of Washington in Seattle dr.

39
00:04:15,990 --> 00:04:13,959
Bruce margon who is the chairman of the

40
00:04:18,300 --> 00:04:16,000
board of the Astrophysical research

41
00:04:20,310 --> 00:04:18,310
consortium and just appointed as the

42
00:04:22,350 --> 00:04:20,320
next chairman of the board of the

43
00:04:25,200 --> 00:04:22,360
Association of universities for research

44
00:04:26,790 --> 00:04:25,210
in astronomy head of two boards but he

45
00:04:28,740 --> 00:04:26,800
won't leave anyone bored because he's

46
00:04:31,290 --> 00:04:28,750
one of the brilliant communicators of

47
00:04:33,209 --> 00:04:31,300
the astronomical research now we're

48
00:04:36,029 --> 00:04:33,219
talking about her big harrow objects and

49
00:04:37,909 --> 00:04:36,039
Jeff Hester what are they and what have

50
00:04:40,260 --> 00:04:37,919
you seen with the Hubble telescope well

51
00:04:41,879 --> 00:04:40,270
I'll back up a little bit and first

52
00:04:44,149 --> 00:04:41,889
start talking about why it is that star

53
00:04:47,120 --> 00:04:44,159
formation is such a fascinating question

54
00:04:49,080 --> 00:04:47,130
when we look at stars forming

55
00:04:51,390 --> 00:04:49,090
astronomers never get a chance to

56
00:04:53,610 --> 00:04:51,400
actually see stars for me but what we

57
00:04:54,930 --> 00:04:53,620
can do instead is look out at different

58
00:04:56,250 --> 00:04:54,940
objects and catch them

59
00:04:59,190 --> 00:04:56,260
different stages in the formation

60
00:05:01,620 --> 00:04:59,200
process and then use what we know with

61
00:05:03,450 --> 00:05:01,630
physics and of our local environment to

62
00:05:05,280 --> 00:05:03,460
put those together into a story which is

63
00:05:07,680 --> 00:05:05,290

becoming a remarkably clean story

64
00:05:09,450 --> 00:05:07,690
actually and this is exciting because

65
00:05:11,760 --> 00:05:09,460
really what we're seeing here is what

66
00:05:13,830 --> 00:05:11,770
happened five billion years ago when our

67
00:05:16,170 --> 00:05:13,840
own son and our own solar system came

68
00:05:17,760 --> 00:05:16,180
into being and so when we look at what

69
00:05:19,770 --> 00:05:17,770
we're going to be looking at today it's

70
00:05:22,410 --> 00:05:19,780
a bit of a time machine that lets us see

71
00:05:24,960 --> 00:05:22,420
into our own history and some of the why

72
00:05:27,620 --> 00:05:24,970
behind our own existence we could look

73
00:05:30,270 --> 00:05:27,630
at the first graphic a very important

74
00:05:33,210 --> 00:05:30,280
piece of this story was discovered in

75
00:05:35,100 --> 00:05:33,220
the 1950s by two astronomers by the name

76
00:05:38,850 --> 00:05:35,110
of George her big and Guillermo hello

77
00:05:41,670 --> 00:05:38,860
and what they found were Jets of glowing

78
00:05:44,310 --> 00:05:41,680
gas such as the jet here and the jet

79
00:05:47,010 --> 00:05:44,320
here clumps of glowing gas rather moving

80
00:05:49,470 --> 00:05:47,020
rapidly through space but we now

81
00:05:51,330 --> 00:05:49,480
understand is happening is that right

82
00:05:53,610 --> 00:05:51,340
about where the cross is now there's a

83
00:05:56,490 --> 00:05:53,620
brand new star that's forming material

84
00:05:59,190 --> 00:05:56,500
is flowing away from that star in two

85
00:06:01,080 --> 00:05:59,200
Jet's one in this direction and one in

86
00:06:03,870 --> 00:06:01,090
this direction it's called a bipolar

87
00:06:06,450 --> 00:06:03,880
outflow that material is streaming away

88
00:06:08,909 --> 00:06:06,460

from that forming star and then up in

89
00:06:10,920 --> 00:06:08,919
this area and down in this area it's

90
00:06:13,740 --> 00:06:10,930
running into ambient material the

91
00:06:15,540 --> 00:06:13,750
material that was around that star this

92
00:06:18,180 --> 00:06:15,550
is a Space Telescope picture of an

93
00:06:19,710 --> 00:06:18,190
object called h81 to which is one of

94
00:06:22,740 --> 00:06:19,720
four different objects that we're going

95
00:06:23,880 --> 00:06:22,750
to see images of today a nice thing

96
00:06:25,260 --> 00:06:23,890
about what we're going to see today

97
00:06:27,240 --> 00:06:25,270
we're going to see images of four

98
00:06:29,040 --> 00:06:27,250
separate objects and yet the story

99
00:06:31,980 --> 00:06:29,050
that's being told in those four separate

100
00:06:33,659 --> 00:06:31,990
objects is a common story you put it all

101
00:06:35,880 --> 00:06:33,669
together and you start to get a clear

102
00:06:38,190 --> 00:06:35,890
picture that answers some fundamental

103
00:06:40,710 --> 00:06:38,200
questions about how it is that stars

104
00:06:42,270 --> 00:06:40,720
form for example we're going to see some

105
00:06:45,300 --> 00:06:42,280
data that shows us the immediate

106
00:06:47,340 --> 00:06:45,310
environment around a forming star the

107
00:06:49,470 --> 00:06:47,350
things that might lead to solar systems

108
00:06:51,570 --> 00:06:49,480
and such as that we're going to see new

109
00:06:53,550 --> 00:06:51,580
information that tells us about the

110
00:06:55,800 --> 00:06:53,560
material flowing away from those stars

111
00:06:58,950 --> 00:06:55,810
and in particular tells us that that

112
00:07:00,750 --> 00:06:58,960
material brings with it the history of

113
00:07:03,150 --> 00:07:00,760

what was happening with the star itself

114
00:07:05,070 --> 00:07:03,160
and finally we're going to see a story

115
00:07:06,990 --> 00:07:05,080
about how that material goes out and

116
00:07:08,800 --> 00:07:07,000
interacts with the surroundings of the

117
00:07:10,690 --> 00:07:08,810
star which might be an

118
00:07:13,420 --> 00:07:10,700
piece of answering the question of what

119
00:07:16,210 --> 00:07:13,430
makes stars the size that they are if I

120
00:07:19,240 --> 00:07:16,220
could have the next graphic this is an

121
00:07:20,830 --> 00:07:19,250
object called HH 34 and this is a

122
00:07:22,990 --> 00:07:20,840
different object from the last one that

123
00:07:25,960 --> 00:07:23,000
we showed you and what you see here

124
00:07:28,150 --> 00:07:25,970
again is right down at about this

125
00:07:30,970 --> 00:07:28,160
location right at the tip of that little

126
00:07:33,610 --> 00:07:30,980
arrow shape is where the star itself is

127
00:07:36,640 --> 00:07:33,620
the light that you see right around that

128
00:07:38,620 --> 00:07:36,650
is light that's being reflected from the

129
00:07:41,650 --> 00:07:38,630
cloud and the disk from which that star

130
00:07:45,640 --> 00:07:41,660
is forming coming out away from that

131
00:07:47,290 --> 00:07:45,650
star is an exceedingly thin jet and one

132
00:07:49,659 --> 00:07:47,300
of the new results that will be talking

133
00:07:52,330 --> 00:07:49,669
about today is the fact that that jet is

134
00:07:53,710 --> 00:07:52,340
so very very thin right at its tip that

135
00:07:56,770 --> 00:07:53,720
tells us it's coming from the star

136
00:07:58,780 --> 00:07:56,780
itself almost that material then comes

137
00:08:01,750 --> 00:07:58,790
streaming out through interstellar space

138
00:08:04,659 --> 00:08:01,760

and if you see each of these knots along

139
00:08:07,270 --> 00:08:04,669
here they sort of look like a train of

140
00:08:09,219 --> 00:08:07,280
motorboats each of which has its own

141
00:08:11,680 --> 00:08:09,229
little bow wave and that's a very

142
00:08:13,360 --> 00:08:11,690
exciting new result when astronomers

143
00:08:16,060 --> 00:08:13,370
first looked at these jets they

144
00:08:17,770 --> 00:08:16,070
understood that they were clumpy but

145
00:08:20,529 --> 00:08:17,780
many astronomers believe that those

146
00:08:22,960 --> 00:08:20,539
clumps were in fact due to a smooth flow

147
00:08:25,600 --> 00:08:22,970
in the jet that had some sort of funny

148
00:08:27,010 --> 00:08:25,610
internal structure in it for those of

149
00:08:28,240 --> 00:08:27,020
you who've watched a space shuttle take

150
00:08:30,100 --> 00:08:28,250
off you might notice that there are

151
00:08:32,230 --> 00:08:30,110
little diamond-shaped features behind

152
00:08:34,120 --> 00:08:32,240
the shuttle main engines we now know

153
00:08:36,520 --> 00:08:34,130
that's not what's going on in these jets

154
00:08:38,500 --> 00:08:36,530
that in fact each one of these knots is

155
00:08:40,839 --> 00:08:38,510
a separate little puff of material

156
00:08:43,060 --> 00:08:40,849
bursts of material that came off of the

157
00:08:45,400 --> 00:08:43,070
forming star and we can look at those

158
00:08:49,630 --> 00:08:45,410
bursts and find out not only about the

159
00:08:53,590 --> 00:08:49,640
jet itself but about the source finally

160
00:08:56,500 --> 00:08:53,600
to to close up a few opening thoughts we

161
00:08:58,270 --> 00:08:56,510
see jets in these forming stars but the

162
00:09:00,220 --> 00:08:58,280
jets that we see in these forming stars

163
00:09:02,130 --> 00:09:00,230

are also very similar to the jets that

164
00:09:04,300 --> 00:09:02,140
astronomers see when they study

165
00:09:07,210 --> 00:09:04,310
quasi-stellar objects when they study

166
00:09:09,850 --> 00:09:07,220
radio galaxies when they study jets that

167
00:09:11,650 --> 00:09:09,860
cover millions of light-years of

168
00:09:13,690 --> 00:09:11,660
interstellar space and when they talk

169
00:09:16,300 --> 00:09:13,700
about massive black holes at the Centers

170
00:09:18,910 --> 00:09:16,310
of galaxies here we're looking at the

171
00:09:20,890 --> 00:09:18,920
very same types of phenomena that now

172
00:09:22,289 --> 00:09:20,900
close by where we can study them in more

173
00:09:28,089 --> 00:09:22,299
d

174
00:09:30,400 --> 00:09:28,099
Morris what have you seen of these

175
00:09:32,829 --> 00:09:30,410
objects with bubble well aside from

176
00:09:35,650 --> 00:09:32,839
investigating the origin of the Jets we

177
00:09:37,509 --> 00:09:35,660
might also ask how these Jets interact

178
00:09:40,139 --> 00:09:37,519
with their environments and how

179
00:09:44,019 --> 00:09:40,149
important they an impact they may have

180
00:09:45,999 --> 00:09:44,029
these new hubble space telescope images

181
00:09:48,429 --> 00:09:46,009
show us for the first time the details

182
00:09:51,909 --> 00:09:48,439
of the interactions between the Jets and

183
00:09:55,479 --> 00:09:51,919
the interstellar gas first of all the

184
00:09:57,729 --> 00:09:55,489
Jets travel at very high speeds hundreds

185
00:10:00,069 --> 00:09:57,739
of kilometers per second and shockwaves

186
00:10:01,929 --> 00:10:00,079
form along the flow where it interacts

187
00:10:04,889 --> 00:10:01,939
with the interstellar gas causing the

188
00:10:08,439 --> 00:10:04,899

jet and that interstellar gas to glow

189
00:10:12,339 --> 00:10:08,449
the shockwaves sweep away material from

190
00:10:14,409 --> 00:10:12,349
the protostar and may in fact restrict

191
00:10:18,129 --> 00:10:14,419
how much material is available to build

192
00:10:20,769 --> 00:10:18,139
the star secondly the Jets propagate for

193
00:10:24,609 --> 00:10:20,779
very large distances at least several

194
00:10:26,889 --> 00:10:24,619
yard light years in some cases they

195
00:10:29,319 --> 00:10:26,899
deposit considerable energy into the gas

196
00:10:33,279 --> 00:10:29,329
clouds which are forming stars and so

197
00:10:34,869 --> 00:10:33,289
somewhat ironically if you have a gas

198
00:10:37,989 --> 00:10:34,879
cloud which is sitting there forming

199
00:10:41,469 --> 00:10:37,999
stars the actual process of star

200
00:10:44,529 --> 00:10:41,479
formation may wind up destroying the gas

201
00:10:47,679 --> 00:10:44,539
cloud for example let's look at the HH

202
00:10:52,329 --> 00:10:47,689
47 system if we can bring up the first

203
00:10:54,909 --> 00:10:52,339
graphic this is a ground-based image

204
00:10:58,389 --> 00:10:54,919
taken by bo raipur at the european

205
00:11:00,609 --> 00:10:58,399
southern observatory this is the outline

206
00:11:02,619 --> 00:11:00,619
of the cloud here and there's a single

207
00:11:04,960 --> 00:11:02,629
star which is forming down in the cloud

208
00:11:08,889 --> 00:11:04,970
the star is located about right here

209
00:11:12,429 --> 00:11:08,899
it's invisible in the optical but we can

210
00:11:14,799 --> 00:11:12,439
detect it in the infrared this jet is

211
00:11:16,989 --> 00:11:14,809
driving two Jet's one to the Northeast

212
00:11:18,999 --> 00:11:16,999
which is up here which is slightly

213
00:11:20,710 --> 00:11:19,009

inclined towards us so it comes out of

214
00:11:23,889 --> 00:11:20,720
the cloud and we can see it the other

215
00:11:28,300 --> 00:11:23,899
jet we can faintly see right here and it

216
00:11:37,530 --> 00:11:32,260
mawlid zoom in on the details that the

217
00:11:42,850 --> 00:11:40,420
first of all we see that the jet has

218
00:11:44,829 --> 00:11:42,860
carved a hole in the gas cloud remember

219
00:11:47,170 --> 00:11:44,839
the stars about right here and this jet

220
00:11:49,360 --> 00:11:47,180
is speeding off to the northeast

221
00:11:52,090 --> 00:11:49,370
direction here these white filaments are

222
00:11:54,190 --> 00:11:52,100
the walls of the cavity and it's just

223
00:11:55,840 --> 00:11:54,200
reflecting light from the star which is

224
00:11:59,440 --> 00:11:55,850
here which is shining through the hole

225
00:12:03,670 --> 00:11:59,450
carved out by the Jets the real news in

226
00:12:06,490 --> 00:12:03,680
this story is that we can see these thin

227
00:12:09,100 --> 00:12:06,500
shox structures along the edges of the

228
00:12:11,290 --> 00:12:09,110
jet highlighted in blue green here

229
00:12:13,240 --> 00:12:11,300
there's a series of them associated with

230
00:12:16,780 --> 00:12:13,250
these knots and there's a big one up

231
00:12:18,820 --> 00:12:16,790
here associated with the bow wave now

232
00:12:21,430 --> 00:12:18,830
these thin structures had never been

233
00:12:22,780 --> 00:12:21,440
seen before in exquisite detail that

234
00:12:26,260 --> 00:12:22,790
we're seeing here and this is the first

235
00:12:29,040 --> 00:12:26,270
time we've been able to tell how the jet

236
00:12:35,829 --> 00:12:29,050
will transfer momentum to the gas cloud

237
00:12:39,220 --> 00:12:35,839
okay Thank You Johnny Chris burrows you

238
00:12:42,280 --> 00:12:39,230

were with us last when we discover these

239
00:12:44,950 --> 00:12:42,290
or obtain a beautiful images of three

240
00:12:47,800 --> 00:12:44,960
rings around supernova 1987a want to

241
00:12:50,110 --> 00:12:47,810
know what you have to top it well in

242
00:12:54,310 --> 00:12:50,120
some ways this desktop it what we see

243
00:12:56,740 --> 00:12:54,320
with Hubble now is an image of star in

244
00:12:58,329 --> 00:12:56,750
the closest star forming region so here

245
00:13:00,250 --> 00:12:58,339
we have a unique opportunity this is the

246
00:13:01,660 --> 00:13:00,260
closest star forming region to us and

247
00:13:04,210 --> 00:13:01,670
we're looking at it with the most

248
00:13:10,060 --> 00:13:04,220
powerful telescope available to humans

249
00:13:11,890 --> 00:13:10,070
and what we see is is around the star we

250
00:13:14,590 --> 00:13:11,900
see the disk of material that's falling

251
00:13:17,079 --> 00:13:14,600
in to form the start and we see the jet

252
00:13:21,010 --> 00:13:17,089
being formed this is the image that

253
00:13:22,900 --> 00:13:21,020
we've obtained and you can see this disc

254
00:13:24,430 --> 00:13:22,910
here this is the top surface of the disc

255
00:13:25,660 --> 00:13:24,440
the back of the disc and this is the

256
00:13:27,579 --> 00:13:25,670
front of the disc these are both being

257
00:13:29,680 --> 00:13:27,589
lit up by the star that's forming in the

258
00:13:31,660 --> 00:13:29,690
middle here now we can't see the star at

259
00:13:34,470 --> 00:13:31,670
all because it's obscured behind the

260
00:13:37,780 --> 00:13:34,480
disc itself it's there's a very dense

261
00:13:39,850 --> 00:13:37,790
band of dust between us and the star and

262
00:13:41,860 --> 00:13:39,860
in fact only one in a hundred billion

263
00:13:43,900 --> 00:13:41,870

billion photons that come from that

264
00:13:46,090 --> 00:13:43,910
star actually make it back out to us

265
00:13:47,620 --> 00:13:46,100
directly but quite a few as you can see

266
00:13:49,540 --> 00:13:47,630
a reflective from the disc so you can

267
00:13:52,180 --> 00:13:49,550
see the shape of the disc and we're able

268
00:13:54,460 --> 00:13:52,190
to quantitatively model it then we're

269
00:13:56,920 --> 00:13:54,470
also able to see the jet as it comes out

270
00:13:58,930 --> 00:13:56,930
from the star and it's as the disc

271
00:14:02,019 --> 00:13:58,940
collapse on collapses to form the star

272
00:14:03,640 --> 00:14:02,029
it's super heated and the jet is

273
00:14:06,700 --> 00:14:03,650
material that's escaping and the only

274
00:14:09,700 --> 00:14:06,710
free path perpendicular to the disk gets

275
00:14:12,070 --> 00:14:09,710
jetted out in both directions and we're

276
00:14:13,810 --> 00:14:12,080
able to see it as a very fine stream

277
00:14:15,760 --> 00:14:13,820
coming right from the star it's

278
00:14:18,280 --> 00:14:15,770
unresolved even by hubble clothes into

279
00:14:20,410 --> 00:14:18,290
the star which means it's got the scales

280
00:14:23,590 --> 00:14:20,420
of less than the size of our solar

281
00:14:25,540 --> 00:14:23,600
system our solar system itself would fit

282
00:14:27,880 --> 00:14:25,550
in this image at about that size there

283
00:14:30,070 --> 00:14:27,890
across there so you can see that we're

284
00:14:32,410 --> 00:14:30,080
seeing now on the scale of our own solar

285
00:14:35,050 --> 00:14:32,420
system a star in the form in the process

286
00:14:36,970 --> 00:14:35,060
of forming and indeed when this star has

287
00:14:40,570 --> 00:14:36,980
formed the material that is left behind

288
00:14:45,310 --> 00:14:40,580

in the disk could well eventually form

289
00:14:47,800 --> 00:14:45,320
planets so okay Thank You Kris and Bruce

290
00:14:50,050 --> 00:14:47,810
marg on these are amazing pictures of

291
00:14:52,420 --> 00:14:50,060
jets and all I'm sure most people

292
00:14:55,150 --> 00:14:52,430
haven't thought of phenomena like this

293
00:14:56,800 --> 00:14:55,160
very much in there people read about how

294
00:14:59,290 --> 00:14:56,810
the Sun might have formed it stars from

295
00:15:01,810 --> 00:14:59,300
how does this fit with our solar system

296
00:15:03,940 --> 00:15:01,820
good got into being well you're right

297
00:15:06,670 --> 00:15:03,950
Steve that when people think about these

298
00:15:10,269 --> 00:15:06,680
narrowly focused jets and astronomy they

299
00:15:12,070 --> 00:15:10,279
normally think about a larger scale far

300
00:15:13,870 --> 00:15:12,080
more violent events in astronomy like

301
00:15:16,090 --> 00:15:13,880
quasi-stellar objects that are ejecting

302
00:15:18,100 --> 00:15:16,100
huge amounts of material over scales and

303
00:15:20,350 --> 00:15:18,110
millions of light years here we're

304
00:15:22,150 --> 00:15:20,360
talking about a far more common

305
00:15:24,850 --> 00:15:22,160
phenomenon indeed a phenomena every star

306
00:15:27,519 --> 00:15:24,860
has to undergo namely collapsing from a

307
00:15:30,910 --> 00:15:27,529
diffuse cloud to become a star and yet

308
00:15:33,190 --> 00:15:30,920
we see that these Jets still occur and

309
00:15:35,410 --> 00:15:33,200
they occur remarkably even though the

310
00:15:37,240 --> 00:15:35,420
scale is far far smaller with the same

311
00:15:41,800 --> 00:15:37,250
very very fine pointing in collimation

312
00:15:43,480 --> 00:15:41,810
and perhaps most remarkably of all we

313
00:15:47,410 --> 00:15:43,490

see these accretion disks these

314
00:15:50,470 --> 00:15:47,420
flattened pancakes of gas that expel

315
00:15:52,990 --> 00:15:50,480
these Jets now the most remarkable thing

316
00:15:54,550 --> 00:15:53,000
that I've seen thus far is this very

317
00:15:55,689 --> 00:15:54,560
most recent image that Christian shows

318
00:16:00,269 --> 00:15:55,699
maybe we could put it back up

319
00:16:04,509 --> 00:16:00,279
and if I were asked to draw on a napkin

320
00:16:07,030 --> 00:16:04,519
for a student a disk of gas that is

321
00:16:09,159 --> 00:16:07,040
falling on to something and some jets

322
00:16:10,869 --> 00:16:09,169
that were then expelled out this is

323
00:16:13,239 --> 00:16:10,879
exactly the drawing that I would make

324
00:16:15,579 --> 00:16:13,249
but this is not a drawing this is a

325
00:16:17,409 --> 00:16:15,589
picture this is an image obtained by the

326
00:16:19,869 --> 00:16:17,419
Hubble Space Telescope of an accretion

327
00:16:22,449 --> 00:16:19,879
disk accretion is a fundamental property

328
00:16:24,789 --> 00:16:22,459
in astronomy the water can't fall right

329
00:16:26,650 --> 00:16:24,799
down the bathtub drain the water has to

330
00:16:29,259 --> 00:16:26,660
swirl around first no matter what the

331
00:16:31,059 --> 00:16:29,269
environment in astronomy is the gas

332
00:16:33,189 --> 00:16:31,069
can't fall right on to something that's

333
00:16:35,199 --> 00:16:33,199
to swirl around for us to shed its spin

334
00:16:36,970 --> 00:16:35,209
times to shut its angular momentum so

335
00:16:38,499 --> 00:16:36,980
everyone is always said these disks must

336
00:16:40,929 --> 00:16:38,509
form and you draw this little cartoon

337
00:16:42,999 --> 00:16:40,939
but here we actually have an image of it

338
00:16:44,590 --> 00:16:43,009

this is really in my mind the picture

339
00:16:46,900 --> 00:16:44,600
that's worth a thousand words because

340
00:16:48,819 --> 00:16:46,910
this object is close enough that we can

341
00:16:51,129 --> 00:16:48,829
actually photograph this accretion disk

342
00:16:54,639 --> 00:16:51,139
did we not see a year or two ago from

343
00:16:58,030 --> 00:16:54,649
Hubble and this very program some dark

344
00:16:59,590 --> 00:16:58,040
disk in the galaxy NGC 4261 or there

345
00:17:01,629 --> 00:16:59,600
have been when object or another there

346
00:17:04,419 --> 00:17:01,639
have been previous Hubble images of

347
00:17:06,610 --> 00:17:04,429
active galaxies like NGC 4261 and

348
00:17:10,289 --> 00:17:06,620
another one is Messier 87 where the

349
00:17:13,990 --> 00:17:10,299
image shows a large donate donut shape

350
00:17:15,879 --> 00:17:14,000
structure of gas and dust but those are

351
00:17:19,480 --> 00:17:15,889
not accretion disks those are sort of

352
00:17:22,419 --> 00:17:19,490
the reservoirs of gas on a much larger

353
00:17:24,970 --> 00:17:22,429
spatial scale waiting their turn to fall

354
00:17:27,309 --> 00:17:24,980
in and in those external galaxies the

355
00:17:30,519 --> 00:17:27,319
actual accretion disk is much much too

356
00:17:31,779 --> 00:17:30,529
small to be seen because as both Chris

357
00:17:32,919 --> 00:17:31,789
and Jeff have indicated we're talking

358
00:17:35,769 --> 00:17:32,929
about structures about the size of our

359
00:17:38,529 --> 00:17:35,779
solar system here this object is close

360
00:17:40,990 --> 00:17:38,539
enough and Hubble's angular resolution

361
00:17:43,450 --> 00:17:41,000
ability to take sharp images is fine

362
00:17:46,779 --> 00:17:43,460
enough that we can actually see the

363
00:17:48,610 --> 00:17:46,789

pancake itself not the worst 830 picture

364
00:17:50,590 --> 00:17:48,620
is the first real picture of an

365
00:17:52,269 --> 00:17:50,600
accretion is certainly the first one of

366
00:17:54,279 --> 00:17:52,279
which I'm aware and so on the one hand

367
00:17:55,750 --> 00:17:54,289
everyone has always predicted this but

368
00:17:57,730 --> 00:17:55,760
on the other hand to actually be able to

369
00:18:00,789 --> 00:17:57,740
see it and have it come out so simply

370
00:18:02,230 --> 00:18:00,799
and such hey an imitation of the cartoon

371
00:18:04,720 --> 00:18:02,240
that you would draw to me is really

372
00:18:07,029 --> 00:18:04,730
remarkable right well I think we've got

373
00:18:08,889 --> 00:18:07,039
to go back to Chris burrows and find out

374
00:18:09,420 --> 00:18:08,899
some more tell us tell us more about

375
00:18:11,580 --> 00:18:09,430
what

376
00:18:15,750 --> 00:18:11,590
design and the center of these stars

377
00:18:18,710 --> 00:18:15,760
information well the these images

378
00:18:22,560 --> 00:18:18,720
actually were were first captured in

379
00:18:24,270 --> 00:18:22,570
January of a fabulet last year and we

380
00:18:25,800 --> 00:18:24,280
were so excited to see this object but

381
00:18:27,240 --> 00:18:25,810
we had to come back to it with Hubble

382
00:18:31,050 --> 00:18:27,250
and get a second image so one thing I'm

383
00:18:32,340 --> 00:18:31,060
going to show you is is an image this is

384
00:18:34,710 --> 00:18:32,350
actually the second image we've taken

385
00:18:36,630 --> 00:18:34,720
and it's another version of the image

386
00:18:38,850 --> 00:18:36,640
you just saw just displayed in a

387
00:18:40,890 --> 00:18:38,860
different way and you can clearly see

388
00:18:43,500 --> 00:18:40,900

here these knots of material coming out

389
00:18:45,270 --> 00:18:43,510
from the star in the jet and again each

390
00:18:47,850 --> 00:18:45,280
pixel in this image each little square

391
00:18:50,340 --> 00:18:47,860
block that you see is about 14

392
00:18:53,190 --> 00:18:50,350
astronomical units across so that the

393
00:18:54,960 --> 00:18:53,200
our solar system's 80 astronomical units

394
00:18:57,690 --> 00:18:54,970
across so our solar system fits right in

395
00:19:00,090 --> 00:18:57,700
there so we're seeing the material that

396
00:19:01,740 --> 00:19:00,100
might eventually form a planetary system

397
00:19:03,620 --> 00:19:01,750
around this star and we're seeing the

398
00:19:06,630 --> 00:19:03,630
jet as it comes out from this disk

399
00:19:08,810 --> 00:19:06,640
directly for the first time and it's

400
00:19:11,280 --> 00:19:08,820
also clear I guess that the jet

401
00:19:13,740 --> 00:19:11,290
collimation that the thing that can find

402
00:19:14,850 --> 00:19:13,750
the jet in this pencil beam really

403
00:19:17,070 --> 00:19:14,860
doesn't have very much to do with the

404
00:19:18,270 --> 00:19:17,080
shape of the disk as had been theorized

405
00:19:19,770 --> 00:19:18,280
it this has to be something that's

406
00:19:22,800 --> 00:19:19,780
happening much closer to the star than

407
00:19:25,830 --> 00:19:22,810
than the disc itself this is much

408
00:19:27,450 --> 00:19:25,840
narrower than the Thunder and the cavity

409
00:19:30,240 --> 00:19:27,460
in the disk right and the little black

410
00:19:32,310 --> 00:19:30,250
spots along the red jet are the

411
00:19:34,080 --> 00:19:32,320
individual little lumps no that was

412
00:19:36,570 --> 00:19:34,090
actually the red jet itself maybe we can

413
00:19:40,560 --> 00:19:36,580

put the image up a moment the red the

414
00:19:42,420 --> 00:19:40,570
jet the red spots you see a knot in the

415
00:19:44,160 --> 00:19:42,430
jet that are propagating away from the

416
00:19:46,230 --> 00:19:44,170
star and then you can see a hint here of

417
00:19:47,430 --> 00:19:46,240
the of the jet on the other side so

418
00:19:49,470 --> 00:19:47,440
these blobs we actually know are moving

419
00:19:52,320 --> 00:19:49,480
the other direction perhaps to visualize

420
00:19:53,490 --> 00:19:52,330
this in three dimensions with John

421
00:19:56,310 --> 00:19:53,500
Christie at the Space Telescope

422
00:19:58,620 --> 00:19:56,320
Institute Kyle snapple felt at JPL and

423
00:20:00,440 --> 00:19:58,630
Alan Watson at lowell observatory I made

424
00:20:03,570 --> 00:20:00,450
a simulation which I'd like to show

425
00:20:04,800 --> 00:20:03,580
which illustrates in perhaps in three

426
00:20:07,530 --> 00:20:04,810
dimensions and this is a full physical

427
00:20:09,210 --> 00:20:07,540
model of what's going on what you see

428
00:20:11,040 --> 00:20:09,220
here is a rotator is the whole system

429
00:20:13,650 --> 00:20:11,050
rotating so you can see it from many

430
00:20:15,270 --> 00:20:13,660
different angles and this is we've been

431
00:20:17,130 --> 00:20:15,280
able to describe in three dimensions

432
00:20:18,960 --> 00:20:17,140
what the distribution of material in the

433
00:20:20,670 --> 00:20:18,970
disc looks like and you can see that the

434
00:20:23,190 --> 00:20:20,680
model fits very nicely onto the data

435
00:20:25,019 --> 00:20:23,200
that we've got so we're understanding

436
00:20:26,700 --> 00:20:25,029
in detail what's happening in this in

437
00:20:28,080 --> 00:20:26,710
the system we're understanding you know

438
00:20:29,879 --> 00:20:28,090

what the density is a function of

439
00:20:31,259 --> 00:20:29,889
position and then that will help us to

440
00:20:33,330 --> 00:20:31,269
build models which will explain how

441
00:20:37,470 --> 00:20:33,340
eventually you could build planets for

442
00:20:39,889 --> 00:20:37,480
example okay well we've seen Jeff Hess

443
00:20:43,289 --> 00:20:39,899
sir we've seen a at least four different

444
00:20:45,419 --> 00:20:43,299
her big arrow objects to the uninitiated

445
00:20:47,340 --> 00:20:45,429
like myself they all look their friend I

446
00:20:48,899 --> 00:20:47,350
suspect we'll see some more before we're

447
00:20:50,700 --> 00:20:48,909
done today there ain't commonality in

448
00:20:52,019 --> 00:20:50,710
all of this is well that's that's really

449
00:20:54,779 --> 00:20:52,029
one of the exciting things about these

450
00:20:56,610 --> 00:20:54,789
data often in astronomy we go and look

451
00:20:58,200 --> 00:20:56,620
at this object and say wow that's wild

452
00:21:00,720 --> 00:20:58,210
and then we look at this object and say

453
00:21:02,340 --> 00:21:00,730
wow that's wild but here we're looking

454
00:21:04,500 --> 00:21:02,350
at a number of different objects and

455
00:21:06,029 --> 00:21:04,510
we're getting the same common picture

456
00:21:07,680 --> 00:21:06,039
out of all of them and tells us that

457
00:21:09,870 --> 00:21:07,690
we're really seeing not special

458
00:21:12,990 --> 00:21:09,880
circumstances but really we're seeing a

459
00:21:14,820 --> 00:21:13,000
picture of how it is that stars form as

460
00:21:16,889 --> 00:21:14,830
a way of seeing that Chris was just

461
00:21:19,169 --> 00:21:16,899
showing you a model of what's going on

462
00:21:21,090 --> 00:21:19,179
in HH 30 with the disc and such as that

463
00:21:25,320 --> 00:21:21,100

and if we could have the next graphic

464
00:21:28,200 --> 00:21:25,330
here this is exactly the same model the

465
00:21:30,149 --> 00:21:28,210
Chris was showing you for HH 30 except

466
00:21:32,159 --> 00:21:30,159
this model has been turned on in the

467
00:21:35,669 --> 00:21:32,169
little bit and so if you look at this

468
00:21:38,519 --> 00:21:35,679
model what you see now is you see the

469
00:21:40,649 --> 00:21:38,529
jet coming out away from the start very

470
00:21:42,950 --> 00:21:40,659
narrow at the end you then see what

471
00:21:45,509 --> 00:21:42,960
appears to be kind of a conical

472
00:21:47,669 --> 00:21:45,519
reflection nebula here that's the top of

473
00:21:49,379 --> 00:21:47,679
the disk and then you don't see the jet

474
00:21:52,070 --> 00:21:49,389
on the other side because on the other

475
00:21:55,470 --> 00:21:52,080
side the jet is in fact hiding behind

476
00:21:57,960 --> 00:21:55,480
the material on the disk when we look at

477
00:22:00,990 --> 00:21:57,970
HH 34 which was the same object that we

478
00:22:03,539 --> 00:22:01,000
looked at before we see a picture that

479
00:22:07,080 --> 00:22:03,549
looks very much like this model we can

480
00:22:08,879 --> 00:22:07,090
have that graphic please in HH 34 keep

481
00:22:11,220 --> 00:22:08,889
the model that you just saw in mind and

482
00:22:13,649 --> 00:22:11,230
look at what we have here down at one

483
00:22:17,190 --> 00:22:13,659
end the star itself is at this location

484
00:22:19,590 --> 00:22:17,200
and we see kind of a conical reflection

485
00:22:21,600 --> 00:22:19,600
nebula which is exactly what we saw in

486
00:22:24,690 --> 00:22:21,610
that model of HH 30 when we turned it on

487
00:22:27,240 --> 00:22:24,700
end we then see the jet coming out again

488
00:22:29,430 --> 00:22:27,250

very very thin right down at the tip and

489
00:22:31,769 --> 00:22:29,440
expanding somewhat as it moves out

490
00:22:34,529 --> 00:22:31,779
through interstellar space again just as

491
00:22:36,419 --> 00:22:34,539
we saw in the model of HH 30 and finally

492
00:22:36,840 --> 00:22:36,429
we see the difference between this model

493
00:22:39,420 --> 00:22:36,850
in nature

494
00:22:41,970 --> 00:22:39,430
30 is that there is no jet here on the

495
00:22:44,010 --> 00:22:41,980
other side it's actually there it's just

496
00:22:46,560 --> 00:22:44,020
that we can't see it because it's hiding

497
00:22:49,500 --> 00:22:46,570
behind that very dense disk from which

498
00:22:50,970 --> 00:22:49,510
the star itself is forming while this

499
00:22:52,710 --> 00:22:50,980
picture is up the other thing that I'll

500
00:22:54,480 --> 00:22:52,720
talk about that's common between these

501
00:22:56,790 --> 00:22:54,490
observations is the picture that we're

502
00:22:58,920 --> 00:22:56,800
getting of these knots again I mentioned

503
00:23:00,750 --> 00:22:58,930
in my opening comments that many

504
00:23:03,960 --> 00:23:00,760
astronomers thought for a long time that

505
00:23:06,270 --> 00:23:03,970
just a smooth flow of material was

506
00:23:08,400 --> 00:23:06,280
coming out from the star and that the

507
00:23:09,990 --> 00:23:08,410
knots that they saw from the ground were

508
00:23:12,720 --> 00:23:10,000
things that were kind of happening

509
00:23:15,450 --> 00:23:12,730
inside that smooth flow of material here

510
00:23:18,270 --> 00:23:15,460
though we clearly see for example here a

511
00:23:20,700 --> 00:23:18,280
clump with its own little bow wave or

512
00:23:23,700 --> 00:23:20,710
hear a clump with its own little bow

513
00:23:25,410 --> 00:23:23,710

wave and if you look at all of the jets

514
00:23:28,650 --> 00:23:25,420
that we see today you get that same

515
00:23:30,900 --> 00:23:28,660
basic picture that these are bursts that

516
00:23:33,720 --> 00:23:30,910
are happening that the star does

517
00:23:35,970 --> 00:23:33,730
something and it spits out material and

518
00:23:37,890 --> 00:23:35,980
so these bursts are not talking is

519
00:23:40,140 --> 00:23:37,900
telling us something about you know some

520
00:23:42,450 --> 00:23:40,150
esoteric piece of gas dynamics that

521
00:23:44,910 --> 00:23:42,460
happens as Jets travel through

522
00:23:47,670 --> 00:23:44,920
interstellar space instead it's telling

523
00:23:49,320 --> 00:23:47,680
us that stars when they form for reasons

524
00:23:52,410 --> 00:23:49,330
that are not entirely clear to us yet

525
00:23:54,300 --> 00:23:52,420
stars when they form from the very inner

526
00:23:58,110 --> 00:23:54,310
most part of that disc in the star

527
00:24:00,450 --> 00:23:58,120
itself are episodic they do something

528
00:24:02,190 --> 00:24:00,460
for a while and then they go burst and

529
00:24:04,200 --> 00:24:02,200
they send out a burst of material and

530
00:24:05,910 --> 00:24:04,210
understanding the physics of why that

531
00:24:07,920 --> 00:24:05,920
happens is going to be something that

532
00:24:09,600 --> 00:24:07,930
any successful model of star formation

533
00:24:13,920 --> 00:24:09,610
is going to have to come to grips with

534
00:24:15,900 --> 00:24:13,930
okay now thanks Jeff talking about these

535
00:24:18,450 --> 00:24:15,910
moving knots I think Chris burrows you

536
00:24:20,430 --> 00:24:18,460
have couple images that blink them for

537
00:24:22,260 --> 00:24:20,440
us right well I was how you measured

538
00:24:24,240 --> 00:24:22,270

their motion yeah I actually mentioned

539
00:24:26,340 --> 00:24:24,250
we saw this intriguing object laughs

540
00:24:28,440 --> 00:24:26,350
februari and we were determined to come

541
00:24:30,090 --> 00:24:28,450
back and take a second look so the first

542
00:24:33,030 --> 00:24:30,100
look that we got actually is on the

543
00:24:35,310 --> 00:24:33,040
screen now and we could take a look at

544
00:24:37,230 --> 00:24:35,320
it what you see here these arrows are

545
00:24:39,690 --> 00:24:37,240
pointing to some knots in the jet that

546
00:24:43,440 --> 00:24:39,700
we saw this was in January of 90 in

547
00:24:45,390 --> 00:24:43,450
February of 94 and then we took another

548
00:24:47,610 --> 00:24:45,400
image in January this year and this is

549
00:24:49,480 --> 00:24:47,620
the image that we saw then and you can

550
00:24:51,070 --> 00:24:49,490
see that the knots have moved

551
00:24:53,410 --> 00:24:51,080
in fact if you blink backwards and

552
00:24:55,419 --> 00:24:53,420
forwards between these two images you

553
00:24:58,330 --> 00:24:55,429
can see the knots are moving and because

554
00:25:00,460 --> 00:24:58,340
we know how long ago that far apart in

555
00:25:02,470 --> 00:25:00,470
time the images were taken and how far

556
00:25:05,320 --> 00:25:02,480
away this object is we can compute how

557
00:25:07,419 --> 00:25:05,330
fast the jet is moving it turns out for

558
00:25:10,090 --> 00:25:07,429
example that the top job not there which

559
00:25:13,090 --> 00:25:10,100
is the one moving fastest is moving at

560
00:25:15,280 --> 00:25:13,100
something like 300 miles a second which

561
00:25:17,169 --> 00:25:15,290
is if you like a thousandth of the speed

562
00:25:18,520 --> 00:25:17,179
of light so these are very energetic

563
00:25:20,049 --> 00:25:18,530

outflows that we're seeing which is why

564
00:25:24,520 --> 00:25:20,059
they're able to propagate for hundreds

565
00:25:27,430 --> 00:25:24,530
of billions of miles so now it's not a

566
00:25:30,190 --> 00:25:27,440
matter of some kind of indirect esoteric

567
00:25:31,690 --> 00:25:30,200
a guess and how quickly these blobs are

568
00:25:33,310 --> 00:25:31,700
coasting out you're actually just

569
00:25:34,930 --> 00:25:33,320
watching the motion from month to month

570
00:25:36,580 --> 00:25:34,940
a month and measuring it directly is

571
00:25:38,380 --> 00:25:36,590
that right that that's right although

572
00:25:39,910 --> 00:25:38,390
we've been able to do this on the ground

573
00:25:41,620 --> 00:25:39,920
but it's always taken years and years

574
00:25:43,180 --> 00:25:41,630
before you'd have to look so that you

575
00:25:45,190 --> 00:25:43,190
could detect this motion from the ground

576
00:25:46,750 --> 00:25:45,200
and that may take five or ten years now

577
00:25:48,940 --> 00:25:46,760
we're able to just measure it directly

578
00:25:50,620 --> 00:25:48,950
in the space of 12 months and that means

579
00:25:52,690 --> 00:25:50,630
that we can follow individual block

580
00:25:54,669 --> 00:25:52,700
blobs through the you know through the

581
00:25:57,190 --> 00:25:54,679
the kinks in the Jets and see how they

582
00:25:58,870 --> 00:25:57,200
behave during those during those changes

583
00:26:00,850 --> 00:25:58,880
in direction one of the one of the

584
00:26:03,190 --> 00:26:00,860
mysteries which was Jeff may come back

585
00:26:05,140 --> 00:26:03,200
to is why there are these kinks in the

586
00:26:06,940 --> 00:26:05,150
Jets what's causing them now we'll be

587
00:26:08,680 --> 00:26:06,950
able to literally take a video of the of

588
00:26:10,630 --> 00:26:08,690

these knots as they go through the kinks

589
00:26:11,770 --> 00:26:10,640
and understand better whether the knots

590
00:26:14,110 --> 00:26:11,780
always keep going in the same direction

591
00:26:15,820 --> 00:26:14,120
or whether they deviate and follow along

592
00:26:17,200 --> 00:26:15,830
the jet as it bends through space and

593
00:26:18,790 --> 00:26:17,210
what would this why hasn't this been

594
00:26:20,110 --> 00:26:18,800
done before what would this image look

595
00:26:21,820 --> 00:26:20,120
like if you took it from a ground-based

596
00:26:25,360 --> 00:26:21,830
telescope well from the ground you

597
00:26:26,830 --> 00:26:25,370
simply the central the central disc that

598
00:26:30,310 --> 00:26:26,840
you're seeing this yellow and the in the

599
00:26:32,290 --> 00:26:30,320
image would be would be unresolved you'd

600
00:26:34,060 --> 00:26:32,300
see a fuzzy blob but you wouldn't be

601
00:26:36,940 --> 00:26:34,070
able to tell that it wasn't just a point

602
00:26:39,850 --> 00:26:36,950
star and in the knots here remember this

603
00:26:41,320 --> 00:26:39,860
is the closest example the knots here

604
00:26:42,970 --> 00:26:41,330
from the ground will be very difficult

605
00:26:44,650 --> 00:26:42,980
to resolve there are only a few tenths

606
00:26:45,940 --> 00:26:44,660
of an arcsecond department so the whole

607
00:26:47,650 --> 00:26:45,950
thing what Billy just look like one

608
00:26:48,850 --> 00:26:47,660
fuzzy mushroom right you'd see that

609
00:26:50,320 --> 00:26:48,860
there was a jet there but you wouldn't

610
00:26:51,640 --> 00:26:50,330
be able to resolve easily the individual

611
00:26:53,520 --> 00:26:51,650
components and unfortunate that the

612
00:26:55,990 --> 00:26:53,530
nearest one has just the ideal

613
00:26:58,120 --> 00:26:56,000

orientation to our view that it's in

614
00:26:59,830 --> 00:26:58,130
profile we learnt there are a number of

615
00:27:01,750 --> 00:26:59,840
stars in this star forming region we've

616
00:27:03,020 --> 00:27:01,760
looked at this is easily the best

617
00:27:04,910 --> 00:27:03,030
example I see

618
00:27:07,790 --> 00:27:04,920
okay I think we want to look into the

619
00:27:10,070 --> 00:27:07,800
physics a little and ask Jeff fester and

620
00:27:11,630 --> 00:27:10,080
John Morse you know what do you think

621
00:27:14,330 --> 00:27:11,640
makes these things come out at

622
00:27:15,920 --> 00:27:14,340
methodically and and if you want to get

623
00:27:17,720 --> 00:27:15,930
into the kinks tell us about that too

624
00:27:19,970 --> 00:27:17,730
well the the physics is the right word

625
00:27:22,130 --> 00:27:19,980
the you know one of the very most

626
00:27:24,740 --> 00:27:22,140
exciting things about this is that we're

627
00:27:27,020 --> 00:27:24,750
finally getting a close enough look at

628
00:27:29,300 --> 00:27:27,030
what's going on that we can start doing

629
00:27:32,030 --> 00:27:29,310
some physics for some years people have

630
00:27:33,950 --> 00:27:32,040
been calculating models using computers

631
00:27:37,310 --> 00:27:33,960
to do simulations of what should be

632
00:27:38,990 --> 00:27:37,320
happening in these Jets and they've been

633
00:27:40,370 --> 00:27:39,000
calculating these models and we all go

634
00:27:42,230 --> 00:27:40,380
off to meetings and look at them and say

635
00:27:43,820 --> 00:27:42,240
oh that's very pretty but then we've

636
00:27:46,010 --> 00:27:43,830
been turning through our data and our

637
00:27:48,770 --> 00:27:46,020
data been of such a quality that we just

638
00:27:50,420 --> 00:27:48,780

couldn't do a real comparison between

639
00:27:52,520 --> 00:27:50,430
what we were seeing in the models in

640
00:27:54,140 --> 00:27:52,530
between what we were seeing in the real

641
00:27:55,910 --> 00:27:54,150
universe have more detailed in the

642
00:27:57,920 --> 00:27:55,920
picture Jerry had more details in the

643
00:27:59,960 --> 00:27:57,930
pictures the exciting thing here is that

644
00:28:02,360 --> 00:27:59,970
we're finally actually able to see the

645
00:28:05,450 --> 00:28:02,370
real objects well enough to start doing

646
00:28:07,010 --> 00:28:05,460
that comparison we have a simulation

647
00:28:09,920 --> 00:28:07,020
here in fact this is a simulation that

648
00:28:12,290 --> 00:28:09,930
was carried out by a gemstone is at the

649
00:28:16,250 --> 00:28:12,300
University of Maryland and what he did

650
00:28:18,470 --> 00:28:16,260
is calculate what happens when a jet a

651
00:28:20,930 --> 00:28:18,480
pulse jet consisting of lots of little

652
00:28:23,450 --> 00:28:20,940
bursts comes flying out into the

653
00:28:25,580 --> 00:28:23,460
surrounding interstellar gas and what

654
00:28:26,870 --> 00:28:25,590
you see here these individual if I could

655
00:28:28,970 --> 00:28:26,880
have a cursor on please a little

656
00:28:31,460 --> 00:28:28,980
motorboat the little motor boats exactly

657
00:28:33,890 --> 00:28:31,470
these individual knots are the pulses

658
00:28:36,500 --> 00:28:33,900
that are coming out from the source and

659
00:28:39,200 --> 00:28:36,510
you see that as they move along each one

660
00:28:41,510 --> 00:28:39,210
has its own little bow wave just like a

661
00:28:43,040 --> 00:28:41,520
motor boat has its little bow wave which

662
00:28:44,840 --> 00:28:43,050
is exactly the kind of structure that

663
00:28:47,210 --> 00:28:44,850

we're seeing when we're looking at these

664
00:28:48,830 --> 00:28:47,220
jets and so all you have to do it was

665
00:28:50,750 --> 00:28:48,840
when we got these data it was really

666
00:28:53,110 --> 00:28:50,760
exciting because we had seen these

667
00:28:55,400 --> 00:28:53,120
models for the past several years and

668
00:28:57,350 --> 00:28:55,410
when you first looked at the hubble

669
00:28:59,390 --> 00:28:57,360
space telescope images of these jets it

670
00:29:01,490 --> 00:28:59,400
was like saying WOW I've seen that

671
00:29:03,170 --> 00:29:01,500
picture before except it wasn't a

672
00:29:04,820 --> 00:29:03,180
picture of something in space really

673
00:29:06,650 --> 00:29:04,830
instead it was a picture of somebody's

674
00:29:08,360 --> 00:29:06,660
calculation of what should be in space

675
00:29:10,040 --> 00:29:08,370
and that's the kind of thing that when

676
00:29:12,440 --> 00:29:10,050
it happens for an astronomer it's really

677
00:29:13,910 --> 00:29:12,450
very very exciting because it tells you

678
00:29:16,040 --> 00:29:13,920
just almost instantly that there's

679
00:29:18,500 --> 00:29:16,050
something that now you understand that

680
00:29:20,330 --> 00:29:18,510
or you didn't another piece of that

681
00:29:23,110 --> 00:29:20,340
model that you just saw was the

682
00:29:26,360 --> 00:29:23,120
individual blobs of gas coming along and

683
00:29:28,070 --> 00:29:26,370
running into the bow wave at the end so

684
00:29:29,900 --> 00:29:28,080
this material was coming along and one

685
00:29:32,270 --> 00:29:29,910
not hit smack and then the next not

686
00:29:34,370 --> 00:29:32,280
caught up with it and smack over and

687
00:29:37,430 --> 00:29:34,380
over again well when you look at another

688
00:29:39,650 --> 00:29:37,440

object this is a HH one if I could have

689
00:29:42,710 --> 00:29:39,660
the next graphic please another very

690
00:29:45,020 --> 00:29:42,720
exciting thing was that we saw exactly

691
00:29:46,610 --> 00:29:45,030
the same phenomena there this is another

692
00:29:48,350 --> 00:29:46,620
Hubble Space toss this is another Hubble

693
00:29:49,700 --> 00:29:48,360
Space Telescope image this is in fact a

694
00:29:52,430 --> 00:29:49,710
blow-up of the first Hubble Space

695
00:29:53,960 --> 00:29:52,440
Telescope image that I showed you and if

696
00:29:55,880 --> 00:29:53,970
I could have the graphic in the and the

697
00:29:59,030 --> 00:29:55,890
cursor again please what you're seeing

698
00:30:02,000 --> 00:29:59,040
here is the jet is coming in from this

699
00:30:04,520 --> 00:30:02,010
direction and it's smacking into the

700
00:30:06,890 --> 00:30:04,530
interstellar gas right here and so these

701
00:30:10,130 --> 00:30:06,900
individual pulses are coming in over and

702
00:30:12,230 --> 00:30:10,140
over again wham wham wham and what we

703
00:30:15,560 --> 00:30:12,240
saw here that was really fascinating is

704
00:30:18,140 --> 00:30:15,570
that right up here at the very front of

705
00:30:21,380 --> 00:30:18,150
this is the bow wave of one of those

706
00:30:24,710 --> 00:30:21,390
pulses and then immediately behind it

707
00:30:26,750 --> 00:30:24,720
coming right up on its wake is the bow

708
00:30:28,940 --> 00:30:26,760
wave of another one of those pulses and

709
00:30:31,240 --> 00:30:28,950
so not only are we getting to see the

710
00:30:33,740 --> 00:30:31,250
detailed physics of the jet itself and

711
00:30:35,540 --> 00:30:33,750
speculate about what that jet tells us

712
00:30:37,400 --> 00:30:35,550
about the star and the star formation

713
00:30:39,230 --> 00:30:37,410

we're also getting to look at the other

714
00:30:41,450 --> 00:30:39,240
end of it and seeing the effects of

715
00:30:43,550 --> 00:30:41,460
these individual pulses coming in and

716
00:30:45,260 --> 00:30:43,560
one after the other running into the

717
00:30:47,990 --> 00:30:45,270
clouds of interstellar gas that's around

718
00:30:50,180 --> 00:30:48,000
this object so it's really very exciting

719
00:30:54,980 --> 00:30:50,190
stuff John Morris what what causes those

720
00:30:58,010 --> 00:30:54,990
pulses well I wouldn't know but there

721
00:31:03,590 --> 00:30:58,020
are people who might have an idea out

722
00:31:05,780 --> 00:31:03,600
there determining that a the jet comes

723
00:31:07,820 --> 00:31:05,790
from a very narrow region close to the

724
00:31:10,520 --> 00:31:07,830
star is a huge result in these

725
00:31:14,230 --> 00:31:10,530
observations secondly determining that

726
00:31:17,510 --> 00:31:14,240
the jet is intrinsically pulsed is

727
00:31:19,790 --> 00:31:17,520
another huge result it means that wild

728
00:31:23,360 --> 00:31:19,800
matter is what falling down in the star

729
00:31:24,200 --> 00:31:23,370
there's some sort of episodic phenomenon

730
00:31:28,670 --> 00:31:24,210
occurring

731
00:31:32,870 --> 00:31:28,680
now what that phenomenon is is open to

732
00:31:35,720 --> 00:31:32,880
debate there are objects such as dwarf

733
00:31:38,030 --> 00:31:35,730
novae which people know our binary

734
00:31:43,490 --> 00:31:38,040
systems which involve accretion disks

735
00:31:45,940 --> 00:31:43,500
onto a white dwarf and these objects

736
00:31:49,430 --> 00:31:45,950
which have accretion disk around them

737
00:31:51,770 --> 00:31:49,440
actually go through unstable periods and

738
00:31:53,960 --> 00:31:51,780

they have outburst and so matter might

739
00:31:55,760 --> 00:31:53,970
build up and then it would release and

740
00:31:58,070 --> 00:31:55,770
then for a time the matter would build

741
00:32:03,230 --> 00:31:58,080
up again and release again so you might

742
00:32:06,860 --> 00:32:03,240
get episodic ejections or outbursts with

743
00:32:09,410 --> 00:32:06,870
a disk phenomenon now the other

744
00:32:11,810 --> 00:32:09,420
interesting analogy with that object is

745
00:32:14,270 --> 00:32:11,820
that those objects don't always have the

746
00:32:16,490 --> 00:32:14,280
same size outbursts sometimes the

747
00:32:18,080 --> 00:32:16,500
outbursts are big sometimes the

748
00:32:20,210 --> 00:32:18,090
outbursts are small and we do see

749
00:32:21,680 --> 00:32:20,220
evidence for that in these stellar Jets

750
00:32:24,470 --> 00:32:21,690
that there are different sizes of

751
00:32:28,810 --> 00:32:24,480
outbursts perhaps we might debate that a

752
00:32:34,220 --> 00:32:31,760
another phenomenon we see is that all of

753
00:32:36,800 --> 00:32:34,230
the Jets that we've imaged although

754
00:32:38,960 --> 00:32:36,810
they're straight and narrow which and

755
00:32:42,320 --> 00:32:38,970
how narrow they are is quite remarkable

756
00:32:44,540 --> 00:32:42,330
all of the Jets show signs or some sort

757
00:32:46,340 --> 00:32:44,550
of wiggling motion that they don't go

758
00:32:48,800 --> 00:32:46,350
perfectly straight they tend to bend

759
00:32:52,940 --> 00:32:48,810
around a little bit now if we can bring

760
00:32:56,720 --> 00:32:52,950
up the HH 47 HST image we could actually

761
00:33:01,640 --> 00:32:56,730
see global Telescope image that's right

762
00:33:04,070 --> 00:33:01,650
the wiggling in this particular jet is

763
00:33:05,900 --> 00:33:04,080

more exaggerated than the other ones we

764
00:33:07,970 --> 00:33:05,910
saw to remind you again the star is

765
00:33:12,320 --> 00:33:07,980
right here in the cloud and the jet is

766
00:33:16,190 --> 00:33:12,330
moving off to the upper left there's a

767
00:33:18,890 --> 00:33:16,200
wiggle here another one over here it's

768
00:33:20,870 --> 00:33:18,900
hard to say whether the jet actually

769
00:33:22,820 --> 00:33:20,880
bounces back and forth here or whether

770
00:33:25,730 --> 00:33:22,830
we're just seeing emission on the

771
00:33:28,540 --> 00:33:25,740
surface of the jet which is actually

772
00:33:31,280 --> 00:33:28,550
moving along here but there are clearly

773
00:33:34,010 --> 00:33:31,290
lots of Wiggles and curves in here when

774
00:33:35,630 --> 00:33:34,020
people look at this image the first

775
00:33:37,850 --> 00:33:35,640
thing they think of is like a corkscrew

776
00:33:40,400 --> 00:33:37,860
it looks like the jet may actually

777
00:33:42,669 --> 00:33:40,410
spirally the gas are there and we know

778
00:33:47,180 --> 00:33:42,679
that's definitely not what's occurring

779
00:33:51,980 --> 00:33:47,190
so this jet goes fast down the middle

780
00:33:57,130 --> 00:33:51,990
and slow at the edges and we have curb

781
00:34:01,850 --> 00:33:59,600
well John couldn't it be what's going on

782
00:34:04,460 --> 00:34:01,860
is that the nozzle that's ejecting the

783
00:34:08,149 --> 00:34:04,470
jet is itself undergoing these gyrations

784
00:34:10,129 --> 00:34:08,159
it's it's possible and immediately when

785
00:34:12,859 --> 00:34:10,139
you think of precession or some sort of

786
00:34:15,139 --> 00:34:12,869
motion of the source you have to bring

787
00:34:18,260 --> 00:34:15,149
in a component especially when the axis

788
00:34:21,800 --> 00:34:18,270

wobbles around you have to bring in

789
00:34:23,510 --> 00:34:21,810
another another star into the picture it

790
00:34:27,649 --> 00:34:23,520
is known that many of the sources of

791
00:34:30,109 --> 00:34:27,659
these Jets are in fact binaries but

792
00:34:32,090 --> 00:34:30,119
whether all of them are is open to

793
00:34:34,580 --> 00:34:32,100
question yet one of the one of the

794
00:34:36,290 --> 00:34:34,590
exciting things as we've been getting

795
00:34:37,490 --> 00:34:36,300
ready for this presentation in the last

796
00:34:39,590 --> 00:34:37,500
couple of days and we've been arguing

797
00:34:41,930 --> 00:34:39,600
among ourselves what it means they're

798
00:34:44,419 --> 00:34:41,940
all manner of models that you can come

799
00:34:45,859 --> 00:34:44,429
up with unless one or two okay you look

800
00:34:47,810 --> 00:34:45,869
for example if you look at the time

801
00:34:50,210 --> 00:34:47,820
scales for these pulses they range

802
00:34:52,520 --> 00:34:50,220
anywhere from a few years to a few tens

803
00:34:54,680 --> 00:34:52,530
of years and that's the same kind of

804
00:34:56,629 --> 00:34:54,690
time that it takes say for a large

805
00:34:58,640 --> 00:34:56,639
planet to orbit around the star or the

806
00:35:00,920 --> 00:34:58,650
kind of time that it takes for two stars

807
00:35:03,170 --> 00:35:00,930
to orbit around each other but it's also

808
00:35:05,750 --> 00:35:03,180
the kind of time that it takes say for

809
00:35:07,640 --> 00:35:05,760
the sun's magnetic field to change

810
00:35:09,620 --> 00:35:07,650
directions and we know that there's a

811
00:35:12,230 --> 00:35:09,630
good chance that these disks or that

812
00:35:14,630 --> 00:35:12,240
these disks and jets are strongly

813
00:35:18,080 --> 00:35:14,640

magnetic and that that's a major part of

814
00:35:19,730 --> 00:35:18,090
it lots of other speculation and again

815
00:35:21,859 --> 00:35:19,740
we're not giving you answers today but

816
00:35:23,780 --> 00:35:21,869
instead we're saying that there's lots

817
00:35:25,490 --> 00:35:23,790
of neat stuff in here and before we

818
00:35:28,250 --> 00:35:25,500
really say that we understand star

819
00:35:30,050 --> 00:35:28,260
formation we're going to have to say

820
00:35:31,609 --> 00:35:30,060
that we understand all these phenomena

821
00:35:34,310 --> 00:35:31,619
that we're speculating about today I'd

822
00:35:36,950 --> 00:35:34,320
like to interject first that actually we

823
00:35:40,160 --> 00:35:36,960
do not have direct evidence that the

824
00:35:42,200 --> 00:35:40,170
Jets are strongly magnetic we have in

825
00:35:45,740 --> 00:35:42,210
fact no evidence that the Jets are

826
00:35:48,170 --> 00:35:45,750
strongly magnetic we know we believe

827
00:35:51,109 --> 00:35:48,180
some work I did on my thesis I made

828
00:35:53,660 --> 00:35:51,119
estimates that there are at least some

829
00:35:55,849 --> 00:35:53,670
moderate magnetic fields far out in the

830
00:35:57,290 --> 00:35:55,859
Jets way far away from the star now

831
00:35:59,930 --> 00:35:57,300
those magnetic fields might be much

832
00:36:02,599 --> 00:35:59,940
larger near the star were the whole

833
00:36:04,880 --> 00:36:02,609
structures are compressed okay but i

834
00:36:07,400 --> 00:36:04,890
would say that proudly magnetic fields

835
00:36:10,880 --> 00:36:07,410
as far as the dynamics of the Jets don't

836
00:36:12,770 --> 00:36:10,890
have much to do with the real shape of

837
00:36:14,780 --> 00:36:12,780
well but there's a there's a response to

838
00:36:16,609 --> 00:36:14,790

that I'll get off pretty quickly there's

839
00:36:18,200 --> 00:36:16,619
a response to that and that is that we

840
00:36:19,910 --> 00:36:18,210
can see where the gas is there are two

841
00:36:22,010 --> 00:36:19,920
basic models for how these Jets are

842
00:36:24,109 --> 00:36:22,020
collimated one of those models is that

843
00:36:26,480 --> 00:36:24,119
there are magnetic fields that force the

844
00:36:28,190 --> 00:36:26,490
gas to flow along in that direction the

845
00:36:30,770 --> 00:36:28,200
other model is to say that there's gas

846
00:36:32,270 --> 00:36:30,780
around that contains the Jets and when

847
00:36:34,940 --> 00:36:32,280
you look at these pictures for example

848
00:36:37,160 --> 00:36:34,950
both the HH 34 and chris is HH 30

849
00:36:39,109 --> 00:36:37,170
observations you see that there isn't

850
00:36:40,609 --> 00:36:39,119
gas right around the Jets like that in

851
00:36:42,770 --> 00:36:40,619
fact that you see things are pretty well

852
00:36:44,330 --> 00:36:42,780
wide open and this jet comes screaming

853
00:36:45,920 --> 00:36:44,340
right out of the middle of it and it's

854
00:36:48,230 --> 00:36:45,930
hard for me to imagine how you're going

855
00:36:50,180 --> 00:36:48,240
to do that without invoking some strong

856
00:36:52,310 --> 00:36:50,190
role for magnetic field well I would say

857
00:36:55,870 --> 00:36:52,320
the role of the magnetic fields might be

858
00:36:58,820 --> 00:36:55,880
very important by those are all right

859
00:37:00,859 --> 00:36:58,830
return to in another five years or so

860
00:37:02,210 --> 00:37:00,869
there's going to be a new camera on the

861
00:37:04,070 --> 00:37:02,220
Hubble telescope will get even better

862
00:37:06,230 --> 00:37:04,080
pictures and maybe we'll hear more about

863
00:37:09,290 --> 00:37:06,240

it before then but right now I want to

864
00:37:12,680 --> 00:37:09,300
thank all the panelists and give this

865
00:37:15,170 --> 00:37:12,690
back to our announcer Don Savage Thank

866
00:37:20,050 --> 00:37:15,180
You Steven panelists will start taking

867
00:37:26,440 --> 00:37:22,970
up scheming please Kate wait for the

868
00:37:29,300 --> 00:37:26,450
microphone so we can get you picked up

869
00:37:34,550 --> 00:37:29,310
and a please state your name and

870
00:37:35,900 --> 00:37:34,560
affiliation thank you what are to the

871
00:37:38,599 --> 00:37:35,910
extent that it can be understood the

872
00:37:40,460 --> 00:37:38,609
range of masses either of the jets or of

873
00:37:41,990 --> 00:37:40,470
the proto stars that are forming if this

874
00:37:43,760 --> 00:37:42,000
is truly a common phenomenon the

875
00:37:46,670 --> 00:37:43,770
presumably of a range of masses that

876
00:37:48,680 --> 00:37:46,680
you're dealing with here yes the the

877
00:37:52,250 --> 00:37:48,690
protostars that we're all looking at

878
00:37:54,700 --> 00:37:52,260
probably have masses similar to those of

879
00:37:58,070 --> 00:37:54,710
our Sun or in fact may be much smaller

880
00:37:59,500 --> 00:37:58,080
these are all low mass stars as the

881
00:38:06,400 --> 00:37:59,510
range of stellar masses

882
00:38:09,670 --> 00:38:06,410
the masses in the Jets are yes much less

883
00:38:13,180 --> 00:38:09,680
but they're about 110 million of a solar

884
00:38:17,110 --> 00:38:13,190
mass lost per year in one of these Jets

885
00:38:18,820 --> 00:38:17,120
so in order to get an appreciable amount

886
00:38:21,280 --> 00:38:18,830
of mass loss in one of these Jets the

887
00:38:23,020 --> 00:38:21,290
Jets would have to be very old and like

888
00:38:25,510 --> 00:38:23,030

millions of years but they really aren't

889
00:38:29,160 --> 00:38:25,520
there maybe a hundred thousand years old

890
00:38:32,260 --> 00:38:29,170
at the most so the masses are very tiny

891
00:38:35,800 --> 00:38:32,270
now what fraction of the mass that's

892
00:38:37,870 --> 00:38:35,810
ejected in the jet as a fraction of how

893
00:38:39,460 --> 00:38:37,880
much is falling onto the star that still

894
00:38:41,800 --> 00:38:39,470
not real clear we know it's at least

895
00:38:44,080 --> 00:38:41,810
probably about ten percent but but maybe

896
00:38:46,180 --> 00:38:44,090
higher could be more and could explain

897
00:38:47,710 --> 00:38:46,190
why why you don't make much way you

898
00:38:50,200 --> 00:38:47,720
don't make massive stories you only make

899
00:38:52,180 --> 00:38:50,210
low mass stars this way in fact I think

900
00:38:56,140 --> 00:38:52,190
one of the most interesting things about

901
00:38:58,270 --> 00:38:56,150
these pictures is for years guided only

902
00:38:59,890 --> 00:38:58,280
by the extra galactic cases the flashy

903
00:39:02,170 --> 00:38:59,900
exploding galaxies that have jets

904
00:39:04,030 --> 00:39:02,180
astronomers are how are these jets made

905
00:39:05,890 --> 00:39:04,040
the details look so complicated and all

906
00:39:08,260 --> 00:39:05,900
that now I think we're beginning to

907
00:39:10,000 --> 00:39:08,270
realize that the answer is why doesn't

908
00:39:12,460 --> 00:39:10,010
everything have a jet that is it seems

909
00:39:15,130 --> 00:39:12,470
like that this the process of accretion

910
00:39:17,110 --> 00:39:15,140
is almost inevitably accompanied by the

911
00:39:19,390 --> 00:39:17,120
process of this narrow collimated

912
00:39:20,500 --> 00:39:19,400
expulsion the question is not how do you

913
00:39:21,970 --> 00:39:20,510

make Jetts it seems to be any the

914
00:39:24,100 --> 00:39:21,980
question is how do you avoid making Jets

915
00:39:26,400 --> 00:39:24,110
because here we look at the very closest

916
00:39:28,750 --> 00:39:26,410
cases of accretion that we can see

917
00:39:29,950 --> 00:39:28,760
anywhere in the universe named we think

918
00:39:32,320 --> 00:39:29,960
that are happening quite close to the

919
00:39:34,060 --> 00:39:32,330
Sun and we see these things that we used

920
00:39:36,910 --> 00:39:34,070
to think we're very exotic these over

921
00:39:39,310 --> 00:39:36,920
here at the birth of the Sun Bruce you

922
00:39:41,980 --> 00:39:39,320
would have seen an amazing fire rocket

923
00:39:43,990 --> 00:39:41,990
going up I i think the conclusion is

924
00:39:46,210 --> 00:39:44,000
becoming inescapable that you don't get

925
00:39:49,090 --> 00:39:46,220
accretion disks without also getting

926
00:39:50,950 --> 00:39:49,100
these narrow ejected fire hoses on all

927
00:39:54,010 --> 00:39:50,960
different spatial scales whether they

928
00:39:55,630 --> 00:39:54,020
are calm quiet formations of low-mass

929
00:39:58,600 --> 00:39:55,640
stars or whether there are these very

930
00:40:01,720 --> 00:39:58,610
violent accretion onto mass of nuclei of

931
00:40:03,520 --> 00:40:01,730
entire galaxies though even these events

932
00:40:06,670 --> 00:40:03,530
are not that common quiet given that the

933
00:40:09,040 --> 00:40:06,680
materials blasted off this as ionized

934
00:40:11,500 --> 00:40:09,050
plasma at hundreds of kilometers a

935
00:40:13,180 --> 00:40:11,510
second so we're talking a very energetic

936
00:40:14,829 --> 00:40:13,190
thing which is far more energy

937
00:40:15,760 --> 00:40:14,839
thick than the star is when it's finally

938
00:40:19,960 --> 00:40:15,770

been formed I wouldn't want to be

939
00:40:24,309 --> 00:40:19,970
standing in the way any further

940
00:40:25,720 --> 00:40:24,319
questions here at Goddard okay thank you

941
00:40:28,300 --> 00:40:25,730
understand that there are no questions

942
00:40:30,370 --> 00:40:28,310
from the other centers thank you for

943
00:40:33,040 --> 00:40:30,380
joining us today and thank you panelist