

1  
00:00:00,030 --> 00:00:04,290  
okay now that I've got your attention

2  
00:00:01,199 --> 00:00:06,508  
because they're changing pictures I'd

3  
00:00:04,290 --> 00:00:10,440  
like to welcome everybody to our July

4  
00:00:06,509 --> 00:00:12,120  
open night your guests usual host Frank

5  
00:00:10,439 --> 00:00:14,250  
summers is on travel

6  
00:00:12,119 --> 00:00:16,649  
that means you'll get home early enough

7  
00:00:14,250 --> 00:00:18,809  
to let the cat out tonight I'm just

8  
00:00:16,649 --> 00:00:21,778  
teasing and there won't be a quiz after

9  
00:00:18,809 --> 00:00:23,099  
the talk my name is Ray Vallarta I'm the

10  
00:00:21,778 --> 00:00:25,589  
news director here at the Space

11  
00:00:23,100 --> 00:00:28,230  
Telescope Institute we've got a

12  
00:00:25,589 --> 00:00:30,719  
fascinating talk tonight dealing with

13  
00:00:28,230 --> 00:00:34,859  
our cosmic origins the origin of the

14  
00:00:30,719 --> 00:00:37,079  
solar system and the planets the Frank

15  
00:00:34,859 --> 00:00:38,789  
usually gives you the big Hubble news

16  
00:00:37,079 --> 00:00:41,549  
rundown I have the Reader's Digest

17  
00:00:38,789 --> 00:00:43,738  
version and I'm going to show you one

18  
00:00:41,549 --> 00:00:45,929  
item and I wanted to show you this

19  
00:00:43,738 --> 00:00:50,399  
tonight because it dovetails with what

20  
00:00:45,929 --> 00:00:53,039  
our guests will be talking about but the

21  
00:00:50,399 --> 00:00:55,469  
the the news just came out today so you

22  
00:00:53,039 --> 00:00:56,910  
may not have heard about it so I'm not

23  
00:00:55,469 --> 00:01:04,439  
going to give you a quiz but who can

24  
00:00:56,909 --> 00:01:12,560  
tell me what spacecraft is that now

25  
00:01:04,438 --> 00:01:15,239  
you're off by 40 years nobody okay

26  
00:01:12,560 --> 00:01:19,978  
no but you're getting warmer

27  
00:01:15,239 --> 00:01:21,658  
or should I say colder come on you guys

28  
00:01:19,978 --> 00:01:24,170  
paid a billion dollars for this

29

00:01:21,659 --> 00:01:26,820  
spacecraft

30  
00:01:24,170 --> 00:01:31,079  
oh you're getting colder you keep track

31  
00:01:26,819 --> 00:01:33,599  
for any money goes yes not Voyager

32  
00:01:31,078 --> 00:01:34,889  
that's way the hell out and it's I don't

33  
00:01:33,599 --> 00:01:39,000  
think it's beyond the edge of the solar

34  
00:01:34,890 --> 00:01:42,060  
system that's my person right here okay

35  
00:01:39,000 --> 00:01:46,170  
I will because times going this is the

36  
00:01:42,060 --> 00:01:47,670  
New Horizons craft headed for Pluto it

37  
00:01:46,170 --> 00:01:51,060  
is controlled here at the Applied

38  
00:01:47,670 --> 00:01:54,990  
Physics lab down outside of Columbia and

39  
00:01:51,060 --> 00:01:56,879  
this craft was launched 10 years ago it

40  
00:01:54,989 --> 00:02:00,030  
is the fastest man-made object ever

41  
00:01:56,879 --> 00:02:03,149  
built and this is a trajectory as of

42  
00:02:00,030 --> 00:02:05,129  
today it is a marathon runner it has

43  
00:02:03,149 --> 00:02:08,219

sprinted across the orbits of all the

44

00:02:05,129 --> 00:02:10,429

major planets it is a year from flying

45

00:02:08,219 --> 00:02:12,829

by the planet Pluto

46

00:02:10,429 --> 00:02:17,628

and with Frank not here I can say planet

47

00:02:12,829 --> 00:02:20,719

tweet are actually was Pluto is a dwarf

48

00:02:17,628 --> 00:02:23,840

binary planet an interesting idea which

49

00:02:20,719 --> 00:02:25,219

gets lost in all the silly fight over

50

00:02:23,840 --> 00:02:27,709

the semantics of what to call it

51

00:02:25,219 --> 00:02:31,878

whatever Pluto is it's very interesting

52

00:02:27,709 --> 00:02:33,979

it will reach Pluto in July but the

53

00:02:31,878 --> 00:02:37,039

people running new horizons would like

54

00:02:33,979 --> 00:02:40,818

to go farther they'd like to boldly go

55

00:02:37,039 --> 00:02:44,060

even deeper into the solar system so the

56

00:02:40,818 --> 00:02:47,149

outer rim of the solar system is a vast

57

00:02:44,060 --> 00:02:49,900

undiscovered country stretching from 3

58  
00:02:47,150 --> 00:02:52,819  
billion to 5 billion miles from the Sun

59  
00:02:49,900 --> 00:02:55,188  
it contains primordial debris going back

60  
00:02:52,818 --> 00:02:58,098  
to the birth of our solar system 4.6

61  
00:02:55,188 --> 00:03:00,560  
billion years ago we've never been there

62  
00:02:58,098 --> 00:03:04,729  
and we only know it about objects out

63  
00:03:00,560 --> 00:03:06,650  
there since the 1990s the folks on the

64  
00:03:04,729 --> 00:03:09,138  
new Horizons probe after they fly by

65  
00:03:06,650 --> 00:03:11,950  
Pluto wanted to visit a Kuiper belt

66  
00:03:09,139 --> 00:03:14,629  
object these are objects that range in a

67  
00:03:11,949 --> 00:03:16,729  
variety of sizes typically the one that

68  
00:03:14,628 --> 00:03:19,429  
the one they want to fly by is about the

69  
00:03:16,729 --> 00:03:22,250  
size of Manhattan Island but we have to

70  
00:03:19,430 --> 00:03:24,139  
find it and only Hubble only Hubble not

71  
00:03:22,250 --> 00:03:26,269  
any ground-based telescope has the

72  
00:03:24,139 --> 00:03:29,030  
ability to look for targets for the new

73  
00:03:26,269 --> 00:03:31,519  
Horizons probe so just released today

74  
00:03:29,030 --> 00:03:34,848  
our pictures of two Kuiper belt objects

75  
00:03:31,519 --> 00:03:36,408  
these are extraordinarily faint they're

76  
00:03:34,848 --> 00:03:38,658  
about as faint as the glow of a

77  
00:03:36,408 --> 00:03:41,298  
flashlight on the moon if you could see

78  
00:03:38,658 --> 00:03:43,548  
it from Earth now how do we know that

79  
00:03:41,299 --> 00:03:47,379  
these are Kuiper belt objects because

80  
00:03:43,549 --> 00:03:47,379  
God put little green circles around them

81  
00:03:49,379 --> 00:03:56,139  
god these are these two objects are four

82  
00:03:53,050 --> 00:03:57,400  
billion miles from the Sun well how do

83  
00:03:56,139 --> 00:03:59,409  
we know they belong in the Kuiper belt

84  
00:03:57,400 --> 00:04:01,689  
because they're moving against the

85  
00:03:59,409 --> 00:04:03,579  
background of stars that background is

86

00:04:01,689 --> 00:04:05,500  
in the summer constellation Sagittarius

87  
00:04:03,580 --> 00:04:08,770  
so finding these was like playing a game

88  
00:04:05,500 --> 00:04:11,020  
of Where's Waldo it was it was a needle

89  
00:04:08,770 --> 00:04:13,060  
in haystack search we announced today

90  
00:04:11,020 --> 00:04:15,520  
that we found two of them this means

91  
00:04:13,060 --> 00:04:17,410  
that more than 140 Hubble orbits will be

92  
00:04:15,520 --> 00:04:19,209  
dedicated to looking for more Kuiper

93  
00:04:17,410 --> 00:04:23,470  
belt objects which would be suitable

94  
00:04:19,209 --> 00:04:26,709  
targets for new horizons so but probably

95  
00:04:23,470 --> 00:04:29,680  
by the year 2020 if we find if that team

96  
00:04:26,709 --> 00:04:31,599  
finds a suitable Kuiper belt object it

97  
00:04:29,680 --> 00:04:34,269  
will fly by that object and what this

98  
00:04:31,600 --> 00:04:35,860  
will be this will complete mankind's

99  
00:04:34,269 --> 00:04:38,459  
initial reconnaissance of the solar

100  
00:04:35,860 --> 00:04:40,810

system going back to the early 60s

101

00:04:38,459 --> 00:04:43,029

because these Kuiper belt objects are

102

00:04:40,810 --> 00:04:45,459

the last class of object in the solar

103

00:04:43,029 --> 00:04:48,099

system we will have completed the

104

00:04:45,459 --> 00:04:59,159

chapter of our initial exploration of

105

00:04:48,100 --> 00:05:01,770

that yes yes yeah why was right no they

106

00:04:59,160 --> 00:05:04,419

the Hubble survey finds an ideal target

107

00:05:01,769 --> 00:05:07,779

the new horizons will be redirected

108

00:05:04,418 --> 00:05:10,478

after it passes Pluto to flyby this

109

00:05:07,779 --> 00:05:12,489

object again finding these is like

110

00:05:10,478 --> 00:05:15,219

trying to find a said Manhattan Island

111

00:05:12,490 --> 00:05:19,930

but imagine Manhattan Island covered in

112

00:05:15,220 --> 00:05:26,530

black velvet four billion miles away and

113

00:05:19,930 --> 00:05:28,418

Hubble found it the almighty Hubble no

114

00:05:26,529 --> 00:05:31,799

that's about our clouds like your away



115  
00:05:28,418 --> 00:05:35,079  
so unless you invent immortality it's

116  
00:05:31,800 --> 00:05:37,410  
the I don't want to digress with the

117  
00:05:35,079 --> 00:05:40,120  
Voyager spacecraft that that sound the

118  
00:05:37,410 --> 00:05:42,960  
on the way out it'll take it I think

119  
00:05:40,120 --> 00:05:45,610  
10,000 years to reach the earth clap so

120  
00:05:42,959 --> 00:05:48,789  
again that's about 50,000 astronomical

121  
00:05:45,610 --> 00:05:51,819  
units Kuiper belt is no more than five

122  
00:05:48,790 --> 00:05:54,939  
astronomical units now I wanted to bring

123  
00:05:51,819 --> 00:05:57,459  
this up because the talk tonight deals

124  
00:05:54,939 --> 00:05:59,860  
with disks around other stars for

125  
00:05:57,459 --> 00:06:01,019  
planets are forming so this is a Hubble

126  
00:05:59,860 --> 00:06:02,970  
picture and nobody

127  
00:06:01,019 --> 00:06:05,848  
to ink on it they just blocked out the

128  
00:06:02,970 --> 00:06:08,520  
star but this is a Kuiper belt like disc

129  
00:06:05,848 --> 00:06:10,889  
around another star and it's really

130  
00:06:08,519 --> 00:06:13,859  
evidence circumstantial evidence for the

131  
00:06:10,889 --> 00:06:16,168  
formation of planets around other stars

132  
00:06:13,860 --> 00:06:18,180  
and that's really the talk tonight and I

133  
00:06:16,168 --> 00:06:20,490  
think these discs are important they've

134  
00:06:18,180 --> 00:06:23,699  
only been known about for about 15 years

135  
00:06:20,490 --> 00:06:24,810  
or so you know if you ask a child where

136  
00:06:23,699 --> 00:06:27,300  
did they come from they'll say the

137  
00:06:24,810 --> 00:06:31,379  
hospital but studying the Kuiper belt

138  
00:06:27,300 --> 00:06:34,050  
discs go back to 4.6 billion years word

139  
00:06:31,379 --> 00:06:36,419  
of the solar system comes from so we

140  
00:06:34,050 --> 00:06:38,788  
have a wonderfully of enthusiastic

141  
00:06:36,418 --> 00:06:41,939  
speaker tonight andrea

142  
00:06:38,788 --> 00:06:43,918  
ben sati who has specialized in the

143

00:06:41,939 --> 00:06:46,379  
chemistry and physics of how planets

144  
00:06:43,918 --> 00:06:49,560  
form inside these circumstellar disks

145  
00:06:46,379 --> 00:06:52,288  
he's a postdoctoral fellow here at the

146  
00:06:49,560 --> 00:06:55,379  
Space Telescope Institute now he got his

147  
00:06:52,288 --> 00:06:58,978  
PhD from the Institute for technology

148  
00:06:55,379 --> 00:07:00,689  
and Europe in Zurich Switzerland I

149  
00:06:58,978 --> 00:07:04,889  
forget the name of that right

150  
00:07:00,689 --> 00:07:07,889  
close sir Institute for technology in

151  
00:07:04,889 --> 00:07:09,269  
astronomy he got his master's working at

152  
00:07:07,889 --> 00:07:13,259  
the European Southern Observatory's

153  
00:07:09,269 --> 00:07:17,758  
headquarters in Garching Germany and he

154  
00:07:13,259 --> 00:07:22,430  
got his masters and bachelor's in Italy

155  
00:07:17,759 --> 00:07:22,430  
with that please welcome dr. Ben's Adi

156  
00:07:25,839 --> 00:07:55,329  
Oh is another Kuiper belt I see 100 G hi

157  
00:07:49,329 --> 00:07:57,579

hello hello okay so I have different

158

00:07:55,329 --> 00:08:02,168

instruments here I think I need only

159

00:07:57,579 --> 00:08:05,680

this one from now so Frank is not here

160

00:08:02,168 --> 00:08:09,009

tonight but actually he's the inventor

161

00:08:05,680 --> 00:08:10,780

of the name he made up the the title of

162

00:08:09,009 --> 00:08:13,449

this talk building new words in

163

00:08:10,779 --> 00:08:14,829

protoplanetary discs I simply told him

164

00:08:13,449 --> 00:08:17,259

that I was working for information and

165

00:08:14,829 --> 00:08:20,069

we came up with this appealing title and

166

00:08:17,259 --> 00:08:22,899

we did when he told me this this title I

167

00:08:20,069 --> 00:08:27,719

actually felt a bit of vertigo and the

168

00:08:22,899 --> 00:08:27,719

end value because this is actually do

169

00:08:46,470 --> 00:09:04,870

you hear me okay okay so I was saying

170

00:09:00,669 --> 00:09:07,029

that I I was tempted so Frank made up

171

00:09:04,870 --> 00:09:08,679

this this time the title of his talk and

172  
00:09:07,029 --> 00:09:10,299  
I was telling some wanted to change it

173  
00:09:08,679 --> 00:09:16,569  
then to narrow it down on the capital of

174  
00:09:10,299 --> 00:09:18,729  
things on which I am working on but in

175  
00:09:16,570 --> 00:09:23,410  
the end I decided to keep the challenge

176  
00:09:18,730 --> 00:09:25,690  
and keep the title for for one reason

177  
00:09:23,409 --> 00:09:27,399  
mainly I thought about it and for one

178  
00:09:25,690 --> 00:09:31,480  
reason I decided to keep the title as

179  
00:09:27,399 --> 00:09:34,720  
broad as it is because of the mystery

180  
00:09:31,480 --> 00:09:37,959  
I feel attracted to I know that even

181  
00:09:34,720 --> 00:09:38,759  
with an entire life dedicated to working

182  
00:09:37,958 --> 00:09:40,469  
on

183  
00:09:38,759 --> 00:09:44,309  
formation I will not solve this mister

184  
00:09:40,470 --> 00:09:46,320  
and yet I feel attracted to it like for

185  
00:09:44,309 --> 00:09:48,689  
example like Shahrukh Khan's who cannot

186  
00:09:46,320 --> 00:09:51,120  
stay away from intriguing facts that he

187  
00:09:48,690 --> 00:09:52,860  
reads on newspapers okay and like

188  
00:09:51,120 --> 00:09:55,289  
Sherlock Holmes I like to go on the

189  
00:09:52,860 --> 00:09:57,000  
crime scene to see what what happened

190  
00:09:55,289 --> 00:09:59,819  
okay

191  
00:09:57,000 --> 00:10:03,029  
in other words I am an observer I like

192  
00:09:59,820 --> 00:10:06,150  
to look at facts collect hints and try

193  
00:10:03,029 --> 00:10:10,139  
to see the story hidden beyond the

194  
00:10:06,149 --> 00:10:14,220  
appearance of things I think that all of

195  
00:10:10,139 --> 00:10:16,649  
you understand the kind of investigative

196  
00:10:14,220 --> 00:10:18,930  
our president talking about because this

197  
00:10:16,649 --> 00:10:21,600  
is not something for astronomers or for

198  
00:10:18,929 --> 00:10:23,609  
scientists only otherwise you will not

199  
00:10:21,600 --> 00:10:27,149  
be here tonight this is something that

200

00:10:23,610 --> 00:10:29,250  
we discover in our cells at least at

201  
00:10:27,149 --> 00:10:31,829  
some point in life at least where we are

202  
00:10:29,250 --> 00:10:36,659  
kids okay and and in fact astronomers

203  
00:10:31,830 --> 00:10:38,070  
are a kind of never growing kids but

204  
00:10:36,659 --> 00:10:41,819  
what is the mystery that I'm talking

205  
00:10:38,070 --> 00:10:47,640  
about so let's imagine for a moment that

206  
00:10:41,820 --> 00:10:50,370  
we are Sherlock Holmes it's the morning

207  
00:10:47,639 --> 00:10:52,379  
and after a delicate British breakfast

208  
00:10:50,370 --> 00:10:56,490  
we are ready to read the daily

209  
00:10:52,379 --> 00:10:58,889  
newspapers okay since we are experienced

210  
00:10:56,490 --> 00:11:01,669  
investigators we know that the news we

211  
00:10:58,889 --> 00:11:04,649  
can be in big capitals on the front page

212  
00:11:01,669 --> 00:11:07,169  
they are the least reliable the most

213  
00:11:04,649 --> 00:11:10,049  
contaminated so as experienced

214  
00:11:07,169 --> 00:11:13,110

investigators we go for the news with a

215

00:11:10,049 --> 00:11:15,000

small in the corner those news that are

216

00:11:13,110 --> 00:11:17,310

dedicated a few paragraphs at the end of

217

00:11:15,000 --> 00:11:18,990

the newspaper okay the section that you

218

00:11:17,309 --> 00:11:20,579

would read on if you have a lot of spare

219

00:11:18,990 --> 00:11:26,220

time during the day and be happy because

220

00:11:20,580 --> 00:11:28,920

we are Sherlock Holmes we have not so

221

00:11:26,220 --> 00:11:32,519

today this morning we open the newspaper

222

00:11:28,919 --> 00:11:37,349

and we read a title it title written

223

00:11:32,519 --> 00:11:40,110

small catches our attention a title the

224

00:11:37,350 --> 00:11:42,960

wheels a story the begins in a

225

00:11:40,110 --> 00:11:45,960

breathhtaking beauty and then in an

226

00:11:42,960 --> 00:11:48,240

unexpected way unexpected this is this

227

00:11:45,960 --> 00:11:50,639

is for eyes so we immediately go to the

228

00:11:48,240 --> 00:11:51,000

section section Bly at the end of the



229  
00:11:50,639 --> 00:11:57,208  
news

230  
00:11:51,000 --> 00:12:07,970  
okay and this is what we will do let me

231  
00:11:57,208 --> 00:12:07,969  
see before reading okay

232  
00:12:09,470 --> 00:12:14,790  
with increasing telescopic capabilities

233  
00:12:12,600 --> 00:12:17,459  
it turned out that the interstellar

234  
00:12:14,789 --> 00:12:20,490  
space is not as black and empty as it

235  
00:12:17,458 --> 00:12:22,919  
looks to human hands from earth diffuse

236  
00:12:20,490 --> 00:12:25,409  
gas and dust are present everywhere in

237  
00:12:22,919 --> 00:12:28,229  
our galaxy we then use a mission that can

238  
00:12:25,409 --> 00:12:31,588  
be seen with modern telescopes like the

239  
00:12:28,230 --> 00:12:34,560  
NASA Hubble Space Telescope these

240  
00:12:31,589 --> 00:12:38,519  
regions are primarily made of gas 99% in

241  
00:12:34,559 --> 00:12:40,559  
mass with only 1% is more dust grains it

242  
00:12:38,519 --> 00:12:43,139  
is from the interplay of gas and dust

243  
00:12:40,559 --> 00:12:46,078  
and the surrounding radiation that

244  
00:12:43,139 --> 00:12:48,600  
amazing figures are carved deep into the

245  
00:12:46,078 --> 00:12:50,818  
interstellar space providing undoubtedly

246  
00:12:48,600 --> 00:12:54,990  
some of the most beautiful images of the

247  
00:12:50,818 --> 00:12:58,259  
local universe driven by observational

248  
00:12:54,990 --> 00:13:00,930  
evidence scientists propose that stars

249  
00:12:58,259 --> 00:13:05,159  
are formed by collapse of droplets of

250  
00:13:00,929 --> 00:13:07,708  
material in these regions for reasons

251  
00:13:05,159 --> 00:13:09,778  
that are not yet fully understood at

252  
00:13:07,708 --> 00:13:11,188  
some point dense cores become

253  
00:13:09,778 --> 00:13:15,230  
gravitationally unstable and rapidly

254  
00:13:11,188 --> 00:13:17,730  
collapse in a flattened rotating disc

255  
00:13:15,230 --> 00:13:22,459  
which in turn a clump of material on to

256  
00:13:17,730 --> 00:13:25,399  
form a star a protostar at the center

257

00:13:22,458 --> 00:13:29,549  
the reading sorry

258  
00:13:25,399 --> 00:13:32,009  
with time disks disappear and the

259  
00:13:29,549 --> 00:13:35,219  
newborn star is ready for its mature

260  
00:13:32,009 --> 00:13:37,769  
phases on the main sequence burning

261  
00:13:35,220 --> 00:13:40,290  
heavier and heavier elements in its core

262  
00:13:37,769 --> 00:13:43,438  
and eventually releasing them back into

263  
00:13:40,289 --> 00:13:44,849  
the interstellar space but this is

264  
00:13:43,438 --> 00:13:48,719  
another story and we shall not get

265  
00:13:44,850 --> 00:13:50,790  
distracted as it is right now the we

266  
00:13:48,720 --> 00:13:54,180  
unexpectedly knot is something that was

267  
00:13:50,789 --> 00:13:56,519  
not previously under focus scientists

268  
00:13:54,179 --> 00:14:01,828  
proposed that this physics would let us

269  
00:13:56,519 --> 00:14:04,179  
believe that the surco stellar matter is

270  
00:14:01,828 --> 00:14:06,459  
quickly accreted onto the star

271  
00:14:04,179 --> 00:14:09,370

or dispersed by high-energy radiation

272

00:14:06,460 --> 00:14:13,149

and this has been largely confirmed by

273

00:14:09,370 --> 00:14:15,210

observations but the sequence teller

274

00:14:13,149 --> 00:14:18,750

material does not completely disappear

275

00:14:15,210 --> 00:14:21,730

some spherical bodies solid and gaseous

276

00:14:18,750 --> 00:14:25,720

rotate in orbits flatten on a plane that

277

00:14:21,730 --> 00:14:27,778

resembles the initial disc so at the end

278

00:14:25,720 --> 00:14:31,269

of the star formation process we find

279

00:14:27,778 --> 00:14:32,980

planets the reader could gently remind

280

00:14:31,269 --> 00:14:34,838

us that this is not surprising and then

281

00:14:32,980 --> 00:14:36,730

if that were not true

282

00:14:34,839 --> 00:14:40,390

we would not be here for soon with these

283

00:14:36,730 --> 00:14:42,370

maps nor with any other we would then

284

00:14:40,389 --> 00:14:44,649

gently remind the reader that it was

285

00:14:42,370 --> 00:14:47,169

only yesterday that planets have been

286  
00:14:44,649 --> 00:14:49,899  
found to be the natural outcome of star

287  
00:14:47,169 --> 00:14:52,059  
formation and scientists are still

288  
00:14:49,899 --> 00:14:54,580  
struggling to find a comprehensive way

289  
00:14:52,059 --> 00:14:58,269  
to make this happen naturally in their

290  
00:14:54,580 --> 00:15:00,550  
models this is why circumstellar disks

291  
00:14:58,269 --> 00:15:03,669  
are increasingly dedicated efforts in

292  
00:15:00,549 --> 00:15:06,490  
astronomical research today to unveil

293  
00:15:03,669 --> 00:15:09,729  
what they secretly do inside themselves

294  
00:15:06,490 --> 00:15:11,889  
in order to build new world and such a

295  
00:15:09,730 --> 00:15:14,950  
variety of words that can be so

296  
00:15:11,889 --> 00:15:17,679  
different from our own a challenging

297  
00:15:14,950 --> 00:15:20,259  
task if we consider that since the

298  
00:15:17,679 --> 00:15:22,169  
beginning this field of research has

299  
00:15:20,259 --> 00:15:25,689  
been driven by observations and

300  
00:15:22,169 --> 00:15:28,059  
unexpected discoveries but challenges

301  
00:15:25,690 --> 00:15:30,490  
and the unexpected are the two pillars

302  
00:15:28,059 --> 00:15:35,319  
of cutting-edge research and triggers

303  
00:15:30,490 --> 00:15:37,060  
for investigative Minds so let me now

304  
00:15:35,320 --> 00:15:42,100  
draw let's now drop the Sherlock Holmes

305  
00:15:37,059 --> 00:15:46,000  
character and get back into myself if I

306  
00:15:42,100 --> 00:15:50,019  
can distinguish the two I choose this

307  
00:15:46,000 --> 00:15:51,940  
article - to set the stage of the of the

308  
00:15:50,019 --> 00:15:54,100  
topic of the night of the mystery that

309  
00:15:51,940 --> 00:15:56,800  
we address tonight how planets and not

310  
00:15:54,100 --> 00:16:00,399  
only planets but worlds can form inside

311  
00:15:56,799 --> 00:16:08,229  
protoplanetary disks and the crime scene

312  
00:16:00,399 --> 00:16:10,000  
that we need to go to our second stellar

313  
00:16:08,230 --> 00:16:11,500  
disk or protoplanet at least likely like

314

00:16:10,000 --> 00:16:14,139  
those that we see this beautiful he

315  
00:16:11,500 --> 00:16:16,000  
image of the of the of the Hubble from

316  
00:16:14,139 --> 00:16:19,149  
from the Hubble Space Telescope here you

317  
00:16:16,000 --> 00:16:23,559  
see images and there you see an artist's

318  
00:16:19,149 --> 00:16:26,230  
impression and so the mystery we address

319  
00:16:23,559 --> 00:16:28,569  
tonight is a story that begins in a

320  
00:16:26,230 --> 00:16:31,230  
breathtaking beauty and thence in an

321  
00:16:28,570 --> 00:16:31,230  
unexpected way

322  
00:16:31,559 --> 00:16:49,929  
so as a first team let's let's look

323  
00:16:47,440 --> 00:16:52,270  
first at this at a couple of of things

324  
00:16:49,929 --> 00:16:55,028  
to understand better what what we read

325  
00:16:52,269 --> 00:16:58,179  
in the article okay and let's start from

326  
00:16:55,028 --> 00:17:00,009  
where shallow cones would serve as well

327  
00:16:58,179 --> 00:17:02,588  
as any astronomer would start where

328  
00:17:00,009 --> 00:17:06,669

where when we address a new unknown

329

00:17:02,589 --> 00:17:08,500

problem the library okay my I remember

330

00:17:06,669 --> 00:17:11,110

my PhD supervisor used to tell me that

331

00:17:08,500 --> 00:17:14,828

when he started in astronomy some 25

332

00:17:11,109 --> 00:17:22,808

years ago he used to to go am I going to

333

00:17:14,828 --> 00:17:25,869

- so I still remember then my PhD

334

00:17:22,808 --> 00:17:30,029

supervisor told me that when he started

335

00:17:25,869 --> 00:17:33,729

in astronomy some twenty-five years ago

336

00:17:30,029 --> 00:17:36,808

he used to go regularly to the library

337

00:17:33,730 --> 00:17:39,640

physically and be able to read all

338

00:17:36,808 --> 00:17:43,649

astronomy papers would the deck they

339

00:17:39,640 --> 00:17:46,390

were published worldwide okay now it's

340

00:17:43,650 --> 00:17:49,240

more difficult because something like a

341

00:17:46,390 --> 00:17:52,090

hundred new papers in astronomy every

342

00:17:49,240 --> 00:17:54,960

day so if you spend your time reading



343  
00:17:52,089 --> 00:17:59,889  
them you spend your life reading them

344  
00:17:54,960 --> 00:18:01,929  
but now we have a wonderful online tool

345  
00:17:59,890 --> 00:18:05,620  
which is an online library where we can

346  
00:18:01,929 --> 00:18:09,580  
search for papers even back in history

347  
00:18:05,619 --> 00:18:11,739  
using keywords and this is what we are

348  
00:18:09,579 --> 00:18:15,308  
going to do now okay so let's use two

349  
00:18:11,740 --> 00:18:17,549  
keywords using the things that we have

350  
00:18:15,308 --> 00:18:20,619  
that were mentioned in the article

351  
00:18:17,549 --> 00:18:23,289  
psycho stellar disk and exoplanet okay

352  
00:18:20,619 --> 00:18:26,619  
in this plot you see the number of

353  
00:18:23,289 --> 00:18:30,809  
published papers in force lots of years

354  
00:18:26,619 --> 00:18:30,809  
over the last 35 years okay

355  
00:18:31,048 --> 00:18:36,339  
let's look at exoplanets what happened

356  
00:18:33,970 --> 00:18:37,808  
at the exoplanet so these are papers

357  
00:18:36,339 --> 00:18:42,398  
they were published within the planet in

358  
00:18:37,808 --> 00:18:52,418  
the title sorry but we are going to stay

359  
00:18:42,398 --> 00:18:54,428  
here for two hours if I don't so this is

360  
00:18:52,419 --> 00:18:56,940  
what happened in the field of exoplanets

361  
00:18:54,429 --> 00:18:59,830  
what do we see from here that the

362  
00:18:56,940 --> 00:19:04,860  
interest in exoplanet has grown

363  
00:18:59,829 --> 00:19:04,859  
enormously over the last 20 years okay

364  
00:19:06,630 --> 00:19:11,710  
this is what we find okay so while we

365  
00:19:10,538 --> 00:19:14,200  
see that the interest in exoplanet

366  
00:19:11,710 --> 00:19:15,819  
hasn't blown along it seems that the

367  
00:19:14,200 --> 00:19:18,220  
interest the number of publications

368  
00:19:15,819 --> 00:19:20,439  
interesting circumstellar disk is is not

369  
00:19:18,220 --> 00:19:22,808  
really growing anymore actually we can

370  
00:19:20,440 --> 00:19:24,940  
imagine from this become conclude that

371

00:19:22,808 --> 00:19:27,329  
the interest in circle stellar disk is

372  
00:19:24,940 --> 00:19:32,230  
going to die very soon because

373  
00:19:27,329 --> 00:19:34,898  
exoplanets are the sexy thing now that

374  
00:19:32,230 --> 00:19:37,419  
we want to look at okay and here is

375  
00:19:34,898 --> 00:19:39,729  
where an investigative mind is triggered

376  
00:19:37,419 --> 00:19:41,980  
because maybe we don't have the full

377  
00:19:39,730 --> 00:19:46,569  
evidence in front of us maybe we are

378  
00:19:41,980 --> 00:19:49,750  
asking the wrong question you have heard

379  
00:19:46,569 --> 00:19:52,210  
the day in the title that here I'm

380  
00:19:49,750 --> 00:19:54,519  
talking about circumstellar disks but

381  
00:19:52,210 --> 00:19:58,028  
they are now more known with the name

382  
00:19:54,519 --> 00:20:01,659  
protoplanetary okay and this word was

383  
00:19:58,028 --> 00:20:03,880  
created to suggest the idea that planets

384  
00:20:01,659 --> 00:20:05,350  
are formed inside circle solid discs

385  
00:20:03,880 --> 00:20:08,289

okay we are talking about the same thing

386

00:20:05,349 --> 00:20:11,469

okay but they are called saku Stella or

387

00:20:08,288 --> 00:20:13,869

protoplanet okay and this idea that

388

00:20:11,470 --> 00:20:17,019

planets are form a circle solid disk is

389

00:20:13,869 --> 00:20:19,538

much older than exoplanets that they did

390

00:20:17,019 --> 00:20:23,019

the discoveries of exoplanets okay and

391

00:20:19,538 --> 00:20:25,629

was born by by considering the an

392

00:20:23,019 --> 00:20:27,940

interesting similarity between the the

393

00:20:25,630 --> 00:20:30,010

orbits of the planets of our own solar

394

00:20:27,940 --> 00:20:32,830

system that are flattened on on a plane

395

00:20:30,009 --> 00:20:35,798

and the first images of protoplanet of

396

00:20:32,829 --> 00:20:37,599

circumstellar disk that where a disk so

397

00:20:35,798 --> 00:20:41,058

flattened on a plane

398

00:20:37,599 --> 00:20:49,750

so now let's look at papers publications

399

00:20:41,058 --> 00:20:52,910

with protoplanetary discs so this is

400  
00:20:49,750 --> 00:20:57,319  
interesting because it's telling us one

401  
00:20:52,910 --> 00:20:59,058  
thing well two things first we find what

402  
00:20:57,319 --> 00:21:00,859  
the article was saying so indeed the

403  
00:20:59,058 --> 00:21:03,558  
interest in protoplanetary discs

404  
00:21:00,859 --> 00:21:05,719  
Israelis is increasing and has been

405  
00:21:03,558 --> 00:21:10,240  
increasing a lot lately okay in the last

406  
00:21:05,720 --> 00:21:13,880  
two decades and second thing is that

407  
00:21:10,240 --> 00:21:17,029  
exoplanets seems to be the driving the

408  
00:21:13,880 --> 00:21:21,110  
driving force shifting the focus from

409  
00:21:17,029 --> 00:21:22,579  
the origin of stars in the in the world

410  
00:21:21,109 --> 00:21:24,500  
that silk Estella to the origin of

411  
00:21:22,579 --> 00:21:26,419  
planets now we are talking about the

412  
00:21:24,500 --> 00:21:28,609  
same thing but now instead of calling it

413  
00:21:26,420 --> 00:21:30,950  
circles that we call it protoplanet okay

414  
00:21:28,609 --> 00:21:33,319  
so this strongly suggest that we see

415  
00:21:30,950 --> 00:21:36,019  
indeed you see that the rise of the

416  
00:21:33,319 --> 00:21:41,210  
protoplanetary name the use of the name

417  
00:21:36,019 --> 00:21:45,889  
is together with okay but now let me ask

418  
00:21:41,210 --> 00:21:47,929  
you this question if by now if right now

419  
00:21:45,890 --> 00:21:50,960  
there is a huge interest in exoplanets

420  
00:21:47,929 --> 00:21:54,140  
and if by now its upper end it's clear

421  
00:21:50,960 --> 00:21:56,929  
that exoplanets are common around other

422  
00:21:54,140 --> 00:22:04,190  
stars why should we care how they form

423  
00:21:56,929 --> 00:22:07,640  
no they simply are and to address this

424  
00:22:04,190 --> 00:22:11,420  
question let's go let me let me bring

425  
00:22:07,640 --> 00:22:15,650  
you to the big today back in time to the

426  
00:22:11,420 --> 00:22:18,470  
time when the curves here stars start to

427  
00:22:15,650 --> 00:22:21,380  
diverge to the early 1990s when the

428

00:22:18,470 --> 00:22:23,089  
first exoplanets were well found here

429  
00:22:21,380 --> 00:22:26,750  
you find here you see the first two

430  
00:22:23,089 --> 00:22:29,750  
papers 1992 and 1995 that we are

431  
00:22:26,750 --> 00:22:32,660  
presenting they the first example

432  
00:22:29,750 --> 00:22:36,829  
discovers okay and now to understand the

433  
00:22:32,660 --> 00:22:39,259  
key point of these two papers I want to

434  
00:22:36,829 --> 00:22:41,710  
do an experiment with you and they need

435  
00:22:39,259 --> 00:22:45,129  
one or two volunteers

436  
00:22:41,710 --> 00:22:53,600  
who feel like dr. Watson they want to

437  
00:22:45,130 --> 00:23:11,000  
play with Rochelle bombs come in even

438  
00:22:53,599 --> 00:23:13,730  
two people spam there is one test you

439  
00:23:11,000 --> 00:23:26,900  
have to pass to participate to this test

440  
00:23:13,730 --> 00:23:29,710  
to this experiment what is this okay you

441  
00:23:26,900 --> 00:23:29,710  
go and you stay

442  
00:23:49,589 --> 00:23:57,548

so this favorite I want to do is to we

443

00:23:54,880 --> 00:24:01,900

have our star this is as you see it's a

444

00:23:57,548 --> 00:24:12,339

star and now we take the material of

445

00:24:01,900 --> 00:24:14,288

which the star is made which is so we

446

00:24:12,339 --> 00:24:16,028

are using the same material to make the

447

00:24:14,288 --> 00:24:18,819

disc because this time is made from the

448

00:24:16,028 --> 00:24:21,369

disk okay so I'm allowed to do that okay

449

00:24:18,819 --> 00:24:24,069

so we use the material of which the star

450

00:24:21,369 --> 00:24:26,589

is made let's do it you you make two

451

00:24:24,069 --> 00:24:29,829

rings one very close one very close so

452

00:24:26,589 --> 00:24:33,459

put it here and the other one as far as

453

00:24:29,829 --> 00:24:42,668

you can to within the limits of this

454

00:24:33,460 --> 00:24:44,259

table that's for this time okay so in

455

00:24:42,669 --> 00:24:47,110

the and so you do this small one you do

456

00:24:44,259 --> 00:24:51,788

the large one doesn't matter if it's not



457  
00:24:47,109 --> 00:24:55,769  
super okay and please pay attention

458  
00:24:51,788 --> 00:24:55,769  
because this is BA realize nothing

459  
00:24:55,869 --> 00:25:01,069  
so in the meantime I have something also

460  
00:24:58,910 --> 00:25:04,870  
for the rest of the audience you can you

461  
00:25:01,069 --> 00:25:04,869  
can try to guess my country of origin

462  
00:25:42,910 --> 00:25:53,150  
alright now next step I want you to form

463  
00:25:48,619 --> 00:25:54,500  
two clans at the two distances from the

464  
00:25:53,150 --> 00:25:56,840  
start that we have here where we have

465  
00:25:54,500 --> 00:25:58,009  
material ok using only the material that

466  
00:25:56,839 --> 00:26:23,029  
we have at that radius

467  
00:25:58,009 --> 00:26:26,029  
ok so let's do that let's assume the

468  
00:26:23,029 --> 00:26:34,910  
baby let's assume that plan for measure

469  
00:26:26,029 --> 00:26:37,490  
works better than this ok now in this

470  
00:26:34,910 --> 00:26:39,769  
kind of scenario where would you form

471  
00:26:37,490 --> 00:26:44,720  
the most massive planet and where would

472  
00:26:39,769 --> 00:26:50,179  
you form the least massive planet for

473  
00:26:44,720 --> 00:26:53,440  
the ratio for the radius Y you can also

474  
00:26:50,179 --> 00:26:53,440  
tune because you have more

475  
00:27:07,750 --> 00:27:12,259  
wait wait wait don't go too far let's go

476  
00:27:10,880 --> 00:27:16,460  
let's go step by step

477  
00:27:12,259 --> 00:27:18,319  
okay so in if this were a scaled version

478  
00:27:16,460 --> 00:27:18,950  
of our solar system where would you from

479  
00:27:18,319 --> 00:27:26,500  
Jupiter

480  
00:27:18,950 --> 00:27:32,720  
well would you form mercury or wonderful

481  
00:27:26,500 --> 00:27:35,410  
now push back now let's look at the

482  
00:27:32,720 --> 00:27:38,350  
90-95 what they differ

483  
00:27:35,410 --> 00:27:43,279  
they found the jupiter-mass companion

484  
00:27:38,349 --> 00:27:47,539  
well inside the orbit of mercury this

485

00:27:43,279 --> 00:27:49,759  
was very unexpected I can tell you that

486  
00:27:47,539 --> 00:27:53,420  
I had the pleasure you stay here

487  
00:27:49,759 --> 00:27:57,140  
the pleasure of two personal meetings

488  
00:27:53,420 --> 00:27:58,850  
with this guy here it's from Switzerland

489  
00:27:57,140 --> 00:28:02,240  
I did my business bits alone for a

490  
00:27:58,849 --> 00:28:05,509  
reason well imagine there and then a

491  
00:28:02,240 --> 00:28:10,700  
very heard from him the story and he the

492  
00:28:05,509 --> 00:28:13,279  
solar to be scorned and he has a

493  
00:28:10,700 --> 00:28:15,890  
wonderful story to tell about finding

494  
00:28:13,279 --> 00:28:18,589  
something unexpected something that for

495  
00:28:15,890 --> 00:28:22,460  
the theories at that time was completely

496  
00:28:18,589 --> 00:28:24,799  
impossible was impossible such that when

497  
00:28:22,460 --> 00:28:29,450  
they started to have the idea of what

498  
00:28:24,799 --> 00:28:33,529  
they were finding was at the time he was

499  
00:28:29,450 --> 00:28:35,660

very young he was worried because he

500

00:28:33,529 --> 00:28:38,029

said this is not possible if it cannot

501

00:28:35,660 --> 00:28:39,740

be a Jupiter around the Stars so close

502

00:28:38,029 --> 00:28:41,559

to the star it's impossible nobody

503

00:28:39,740 --> 00:28:45,769

nobody would believe that because

504

00:28:41,559 --> 00:28:47,480

theories cannot explain that okay but I

505

00:28:45,769 --> 00:28:50,930

need turned out to be true and now we

506

00:28:47,480 --> 00:28:51,870

have many ok let's go back to our

507

00:28:50,930 --> 00:29:02,009

experiment

508

00:28:51,869 --> 00:29:05,129

now so now let's say that at some point

509

00:29:02,009 --> 00:29:08,210

the star explodes in a supernova what do

510

00:29:05,130 --> 00:29:08,210

you think would happen today

511

00:29:48,130 --> 00:29:51,520

this is what

512

00:30:24,299 --> 00:30:31,029

so let's move 1992 paper what did they

513

00:30:28,299 --> 00:30:34,839

find they found not not not one but two

514  
00:30:31,029 --> 00:30:37,599  
planets where around a pulsar a pulsar

515  
00:30:34,839 --> 00:30:40,209  
is the neutron star the neutron remnant

516  
00:30:37,599 --> 00:30:46,659  
star after supernova supernova explosion

517  
00:30:40,210 --> 00:30:49,329  
and even back then so you cannot say

518  
00:30:46,660 --> 00:30:50,980  
well optimistically I was they are far

519  
00:30:49,329 --> 00:30:53,230  
enough out that they don't feel the

520  
00:30:50,980 --> 00:30:55,089  
supernova supernova explosion they were

521  
00:30:53,230 --> 00:30:58,839  
very close inside the orbit of Earth

522  
00:30:55,089 --> 00:31:02,500  
they would be destroyed for sure so what

523  
00:30:58,839 --> 00:31:05,319  
was what is the point that I that I for

524  
00:31:02,500 --> 00:31:09,490  
which we we we made the this experiment

525  
00:31:05,319 --> 00:31:11,889  
I made to make here one thing that since

526  
00:31:09,490 --> 00:31:13,990  
the very beginning the field of

527  
00:31:11,890 --> 00:31:19,150  
exoplanet research has been the reign of

528  
00:31:13,990 --> 00:31:22,089  
the unexpected okay and it is so even

529  
00:31:19,150 --> 00:31:26,650  
now let's look for example at this plot

530  
00:31:22,089 --> 00:31:29,139  
that is more recent this is 2013 when we

531  
00:31:26,650 --> 00:31:31,570  
see a representation of the population

532  
00:31:29,140 --> 00:31:34,420  
of planets that the exoplanets that we

533  
00:31:31,569 --> 00:31:37,319  
have been detected so far this is going

534  
00:31:34,420 --> 00:31:37,320  
to be significant

535  
00:31:42,278 --> 00:31:49,298  
so even here you see that the known

536  
00:31:45,589 --> 00:31:52,579  
population of exoplanets we have a

537  
00:31:49,298 --> 00:31:54,829  
population here of planets that are more

538  
00:31:52,579 --> 00:31:57,499  
massive than Earth this is the mass and

539  
00:31:54,829 --> 00:32:00,710  
this is the peer proportion today they

540  
00:31:57,499 --> 00:32:02,749  
are the distance from the star okay so

541  
00:32:00,710 --> 00:32:05,899  
this planets here are more massive than

542

00:32:02,749 --> 00:32:07,639  
Earth but close the ring and this kind

543  
00:32:05,898 --> 00:32:09,199  
of super day they are called super

544  
00:32:07,638 --> 00:32:11,329  
Earths because they are more massive and

545  
00:32:09,200 --> 00:32:13,278  
they seem to be really the rule in plan

546  
00:32:11,329 --> 00:32:17,358  
formation it seems that every EXO

547  
00:32:13,278 --> 00:32:19,038  
planetary system has one okay and we

548  
00:32:17,358 --> 00:32:21,528  
have a population also of Jupiter's

549  
00:32:19,038 --> 00:32:24,048  
which are called hot Jupiters well

550  
00:32:21,528 --> 00:32:27,138  
especially this one that are closer win

551  
00:32:24,048 --> 00:32:29,898  
again then our Jupiter okay here we have

552  
00:32:27,138 --> 00:32:33,108  
our Jupiter here we have been a very

553  
00:32:29,898 --> 00:32:34,908  
nice honor okay and this is just

554  
00:32:33,108 --> 00:32:38,118  
considering two properties of the

555  
00:32:34,909 --> 00:32:42,159  
planets the mass and the distance from

556  
00:32:38,118 --> 00:32:44,868

the star okay many scientists say that

557

00:32:42,159 --> 00:32:48,019

when we will be able to study more

558

00:32:44,868 --> 00:32:51,228

details the composition of the planets

559

00:32:48,019 --> 00:32:54,019

of the atmospheres and the bulk

560

00:32:51,229 --> 00:32:57,909

composition of the of the core we will

561

00:32:54,019 --> 00:33:00,858

be very likely surprised by unexpected

562

00:32:57,909 --> 00:33:02,869

discoveries at this point we expect to

563

00:33:00,858 --> 00:33:06,259

be surprised by the unexpected in this

564

00:33:02,868 --> 00:33:08,829

field okay so let me answer now the

565

00:33:06,259 --> 00:33:10,940

question why should we care about

566

00:33:08,829 --> 00:33:13,728

protoplanetary discs why should we study

567

00:33:10,940 --> 00:33:16,009

them because we are surprised by the

568

00:33:13,729 --> 00:33:19,249

unexpected discoveries in the exoplanet

569

00:33:16,009 --> 00:33:22,220

field and so we would like to understand

570

00:33:19,249 --> 00:33:24,589

how we can form such a variety of



571  
00:33:22,220 --> 00:33:26,899  
different exoplanets as well as

572  
00:33:24,589 --> 00:33:32,199  
understand how our own planets and our

573  
00:33:26,898 --> 00:33:32,199  
own solar system can be form okay so

574  
00:33:32,348 --> 00:33:37,939  
let's now go step by step what do we

575  
00:33:36,169 --> 00:33:41,559  
know about the planet formation process

576  
00:33:37,940 --> 00:33:41,558  
and let's start simple

577  
00:33:44,569 --> 00:33:51,149  
from the composition okay let's look at

578  
00:33:48,599 --> 00:33:55,829  
our the most familiar case of our solar

579  
00:33:51,150 --> 00:33:59,370  
system we have the star the Sun mostly

580  
00:33:55,829 --> 00:34:01,980  
made by hydrogen and helium and the the

581  
00:33:59,369 --> 00:34:03,539  
gas giants in our solar system as well

582  
00:34:01,980 --> 00:34:06,990  
they are mostly made by hydrogen and

583  
00:34:03,539 --> 00:34:10,340  
helium ok so our little experiment that

584  
00:34:06,990 --> 00:34:15,960  
we did here see it's a simplified

585  
00:34:10,340 --> 00:34:18,179  
version for me might have probably

586  
00:34:15,960 --> 00:34:22,800  
worked ok we are using the same material

587  
00:34:18,179 --> 00:34:23,789  
to form big planets in the disk ok but

588  
00:34:22,800 --> 00:34:26,910  
we have a problem

589  
00:34:23,789 --> 00:34:30,480  
for these planets here their composition

590  
00:34:26,909 --> 00:34:34,199  
is instead is very dissimilar from this

591  
00:34:30,480 --> 00:34:37,829  
stuff so if the disk has the same

592  
00:34:34,199 --> 00:34:39,928  
composition this planets are peculiar

593  
00:34:37,829 --> 00:34:41,940  
because they are mainly first they are

594  
00:34:39,929 --> 00:34:46,039  
mainly solid and they they they have a

595  
00:34:41,940 --> 00:34:49,168  
composition that is mostly made by

596  
00:34:46,039 --> 00:34:54,179  
compounds of iron oxygen silicon and

597  
00:34:49,168 --> 00:34:56,190  
magnesium okay in in in in short it they

598  
00:34:54,179 --> 00:35:01,050  
are mainly solid this is the evident

599

00:34:56,190 --> 00:35:04,260  
okay gas giants solid rocky if you think

600  
00:35:01,050 --> 00:35:09,330  
that this approach is trivial to start

601  
00:35:04,260 --> 00:35:10,830  
from the bulk composition ok please

602  
00:35:09,329 --> 00:35:13,559  
consider that this is what we are still

603  
00:35:10,829 --> 00:35:15,900  
doing now with exoplanets this is a very

604  
00:35:13,559 --> 00:35:17,909  
recent paper where we have the planet

605  
00:35:15,900 --> 00:35:20,550  
the planet radius here in the planet

606  
00:35:17,909 --> 00:35:26,069  
Mars on this axis ok this this one is a

607  
00:35:20,550 --> 00:35:28,680  
zooming in this the plot when we are

608  
00:35:26,070 --> 00:35:32,400  
able to measure the mass and the radius

609  
00:35:28,679 --> 00:35:35,659  
of an exoplanet we can measure a mean

610  
00:35:32,400 --> 00:35:39,240  
density mass divided by the volume and

611  
00:35:35,659 --> 00:35:41,639  
from the mean density we can estimate

612  
00:35:39,239 --> 00:35:44,729  
the bulk composition as if the planet

613  
00:35:41,639 --> 00:35:47,489

was made by a single thing okay so for

614

00:35:44,730 --> 00:35:49,650

example we can see a planet made of

615

00:35:47,489 --> 00:35:50,829

water the time of water would lie on

616

00:35:49,650 --> 00:35:54,099

this curve depend

617

00:35:50,829 --> 00:35:56,409

on the mass and they reduce okay Oliver

618

00:35:54,099 --> 00:35:59,829

Oliver I know I run eccentric setter

619

00:35:56,409 --> 00:36:02,319

here we have for example the in this

620

00:35:59,829 --> 00:36:05,799

paper they were presenting a discovery

621

00:36:02,320 --> 00:36:09,010

of one of the most earth-like planets in

622

00:36:05,800 --> 00:36:11,289

terms of bulk composition okay you see

623

00:36:09,010 --> 00:36:14,500

that the planets that they found is here

624

00:36:11,289 --> 00:36:16,809

Earth and Venus okay and so it's it's

625

00:36:14,500 --> 00:36:23,500

the closest compared to other kepler

626

00:36:16,809 --> 00:36:25,539

planet okay so historically and

627

00:36:23,500 --> 00:36:30,400

classically the problem of planet

628  
00:36:25,539 --> 00:36:34,210  
formation is a problem of solids so the

629  
00:36:30,400 --> 00:36:36,660  
property to build bodies of at least the

630  
00:36:34,210 --> 00:36:39,010  
kilometers inside a kilometer in size

631  
00:36:36,659 --> 00:36:40,629  
starting from the dust grains that at

632  
00:36:39,010 --> 00:36:42,520  
the beginning of the story we said in

633  
00:36:40,630 --> 00:36:44,170  
the planet formation regions in this

634  
00:36:42,519 --> 00:36:47,710  
nebula planet formation which is a well

635  
00:36:44,170 --> 00:36:51,190  
that we observe the the size of this

636  
00:36:47,710 --> 00:36:53,740  
dust grains that we observe there is one

637  
00:36:51,190 --> 00:36:57,550  
micron or less 10 to the minus 6 meters

638  
00:36:53,739 --> 00:37:05,079  
okay so this is a jump of at least nine

639  
00:36:57,550 --> 00:37:06,910  
orders of magnitude okay in size think

640  
00:37:05,079 --> 00:37:10,719  
for example of going to the to the beach

641  
00:37:06,909 --> 00:37:13,179  
and if you take sand of grain it's the

642  
00:37:10,719 --> 00:37:16,269  
it's even more than the jump from that

643  
00:37:13,179 --> 00:37:19,389  
send of grain and and earth even more

644  
00:37:16,269 --> 00:37:23,469  
than that because grains here are

645  
00:37:19,389 --> 00:37:28,449  
smaller than the same weights so we are

646  
00:37:23,469 --> 00:37:31,089  
just history yes because we know of

647  
00:37:28,449 --> 00:37:33,189  
thousands of exoplanets but we still

648  
00:37:31,090 --> 00:37:37,170  
haven't figured out the details of how

649  
00:37:33,190 --> 00:37:41,230  
this job happens of this process happens

650  
00:37:37,170 --> 00:37:44,139  
what we know however is that at least

651  
00:37:41,230 --> 00:37:46,860  
the first step happens in protoplanetary

652  
00:37:44,139 --> 00:37:49,869  
disk in circumstellar disks because

653  
00:37:46,860 --> 00:37:52,630  
scientists have been able to measure the

654  
00:37:49,869 --> 00:37:56,199  
size of dust grains in these discs and

655  
00:37:52,630 --> 00:37:59,110  
found one millimeter one centimeter okay

656

00:37:56,199 --> 00:38:01,239  
so it's it's it's an increase of three

657  
00:37:59,110 --> 00:38:03,160  
four orders of magnitude and I've been

658  
00:38:01,239 --> 00:38:03,578  
working when I was in Germany these oh I

659  
00:38:03,159 --> 00:38:06,548  
was

660  
00:38:03,579 --> 00:38:08,759  
on this this field measuring the the

661  
00:38:06,548 --> 00:38:12,579  
signs of the quincy protoplanetary disk

662  
00:38:08,759 --> 00:38:15,969  
it's a first step and yet we still have

663  
00:38:12,579 --> 00:38:24,099  
to grow at least six orders of magnitude

664  
00:38:15,969 --> 00:38:27,159  
more good so i said this is still an

665  
00:38:24,099 --> 00:38:29,950  
unsolved mystery you know strong me but

666  
00:38:27,159 --> 00:38:32,078  
huh is it possible that I mean again we

667  
00:38:29,949 --> 00:38:35,949  
know of so many exoplanets and we still

668  
00:38:32,079 --> 00:38:39,068  
don't know of this which is like if you

669  
00:38:35,949 --> 00:38:42,368  
cannot grow this the solids you cannot

670  
00:38:39,068 --> 00:38:45,818

be black we we still don't know because

671

00:38:42,369 --> 00:38:48,930

of due to problems mainly the first

672

00:38:45,818 --> 00:38:52,630

problem is a problem of observations

673

00:38:48,929 --> 00:38:54,608

while gas is mainly optically thin in

674

00:38:52,630 --> 00:38:56,528

these regions okay this is the artists

675

00:38:54,608 --> 00:39:00,159

impression of a protoplanetary disk okay

676

00:38:56,528 --> 00:39:01,798

so while gas is primarily optically thin

677

00:39:00,159 --> 00:39:04,629

so we can see through it

678

00:39:01,798 --> 00:39:07,199

duster is instead of instead of tucume

679

00:39:04,630 --> 00:39:11,619

thick so we cannot see inside the disk

680

00:39:07,199 --> 00:39:13,329

exactly where planets are formed okay to

681

00:39:11,619 --> 00:39:15,910

give you an analogy imagine that you are

682

00:39:13,329 --> 00:39:18,278

driving in the fog and you are trying to

683

00:39:15,909 --> 00:39:21,548

guess if what you have in front of you

684

00:39:18,278 --> 00:39:24,130

is a car a motorcycle or a deer okay



685  
00:39:21,548 --> 00:39:27,248  
for the same reason in protoplanetary

686  
00:39:24,130 --> 00:39:30,430  
disk we even though the small dust

687  
00:39:27,248 --> 00:39:32,879  
grains are small implants that are

688  
00:39:30,429 --> 00:39:35,649  
forming there are possibly already big

689  
00:39:32,880 --> 00:39:38,920  
they the opacity is dominated by the

690  
00:39:35,650 --> 00:39:41,079  
small grains and so we see only do only

691  
00:39:38,920 --> 00:39:44,289  
them and we cannot see the big bodies

692  
00:39:41,079 --> 00:39:47,109  
okay and all consider in addition to

693  
00:39:44,289 --> 00:39:50,229  
that that given the distance of these

694  
00:39:47,108 --> 00:39:52,208  
disks from Arthur they look to our eyes

695  
00:39:50,228 --> 00:39:53,498  
very small in the sky like in these

696  
00:39:52,208 --> 00:39:58,228  
images from the Hubble Space Telescope

697  
00:39:53,498 --> 00:40:02,198  
ok and what we are trying to find to see

698  
00:39:58,228 --> 00:40:04,118  
forming planets inside them at most a

699  
00:40:02,199 --> 00:40:08,440  
hundred thousand times smaller than

700  
00:40:04,119 --> 00:40:11,740  
these blobs ok so no way

701  
00:40:08,440 --> 00:40:14,159  
but I said that this moon disgraces that

702  
00:40:11,739 --> 00:40:16,809  
became measure know the size I said

703  
00:40:14,159 --> 00:40:19,059  
stromer's have been able to measure the

704  
00:40:16,809 --> 00:40:21,849  
signs of the Samantha's grains for the

705  
00:40:19,059 --> 00:40:23,799  
same reason why did the small that's why

706  
00:40:21,849 --> 00:40:27,579  
the small particles in the form they

707  
00:40:23,800 --> 00:40:30,100  
dominate in opacity okay and for example

708  
00:40:27,579 --> 00:40:33,789  
with the VLE in New Mexico or the Alma

709  
00:40:30,099 --> 00:40:35,559  
on unmanned chillin nowadays we are able

710  
00:40:33,789 --> 00:40:37,570  
to measure the thermal emission from

711  
00:40:35,559 --> 00:40:39,519  
this model screens and measure this and

712  
00:40:37,570 --> 00:40:44,530  
estimate their Sciences okay you find

713

00:40:39,519 --> 00:40:48,519  
again the K visa has for some

714  
00:40:44,530 --> 00:40:51,820  
microgreens in the nebula second problem

715  
00:40:48,519 --> 00:40:54,789  
we have the chroming of timescales so

716  
00:40:51,820 --> 00:40:57,190  
one transformation happens very very

717  
00:40:54,789 --> 00:41:01,199  
quickly it's very fast compared to the

718  
00:40:57,190 --> 00:41:04,539  
to the lifetime of star it's very slow

719  
00:41:01,199 --> 00:41:07,079  
compared to our lifetime okay so we

720  
00:41:04,539 --> 00:41:09,719  
would have to leave 10000 times an

721  
00:41:07,079 --> 00:41:13,690  
entire human life to be able to follow

722  
00:41:09,719 --> 00:41:18,069  
planet formation a planet forming okay

723  
00:41:13,690 --> 00:41:21,849  
all the stages so we have to two ways

724  
00:41:18,070 --> 00:41:24,370  
out when when we can know when we cannot

725  
00:41:21,849 --> 00:41:27,339  
directly see what we are looking for

726  
00:41:24,369 --> 00:41:29,349  
either we we try to imagine it to in

727  
00:41:27,340 --> 00:41:33,820

making models we try to imagine how that

728

00:41:29,349 --> 00:41:35,679

could happen or we try to look at the

729

00:41:33,820 --> 00:41:39,190

same object but in different phases of

730

00:41:35,679 --> 00:41:40,829

evolution okay and then we try to

731

00:41:39,190 --> 00:41:43,210

connect the points and build a story

732

00:41:40,829 --> 00:41:44,259

okay and these two approaches the

733

00:41:43,210 --> 00:41:46,210

theoretical approach and the

734

00:41:44,260 --> 00:41:48,220

observational approach are both are both

735

00:41:46,210 --> 00:41:52,240

fundamental and they sustain and help

736

00:41:48,219 --> 00:41:53,019

each other to build the the story of

737

00:41:52,239 --> 00:41:56,099

planet formation

738

00:41:53,019 --> 00:41:59,769

okay let's look for example at how

739

00:41:56,099 --> 00:42:03,639

theories theoretical models trying to

740

00:41:59,769 --> 00:42:06,639

explain how we can grow dustin disks

741

00:42:03,639 --> 00:42:09,009

from the dust from from the small sizes

742  
00:42:06,639 --> 00:42:12,190  
of 1 micron as i said 10 to the minus 6

743  
00:42:09,010 --> 00:42:13,450  
meters up to planet sizes of more than

744  
00:42:12,190 --> 00:42:16,300  
economic ok

745  
00:42:13,449 --> 00:42:17,929  
this is from a recent review where a

746  
00:42:16,300 --> 00:42:20,839  
number of models are put

747  
00:42:17,929 --> 00:42:26,088  
gather you know the twist plain how it

748  
00:42:20,838 --> 00:42:28,699  
may be possible to to to climb this

749  
00:42:26,088 --> 00:42:30,858  
ladder in Sciences and go for dust two

750  
00:42:28,699 --> 00:42:34,068  
planets okay in in the in the so called

751  
00:42:30,858 --> 00:42:37,400  
the core accretion scenario so I cannot

752  
00:42:34,068 --> 00:42:40,940  
go into the details here but this is to

753  
00:42:37,400 --> 00:42:44,000  
give you an idea that we have we have at

754  
00:42:40,940 --> 00:42:46,700  
least a few ideas how with following

755  
00:42:44,000 --> 00:42:49,039  
steps ok different different processes

756  
00:42:46,699 --> 00:42:52,368  
one after the other or probably

757  
00:42:49,039 --> 00:42:55,039  
happening the same time the different

758  
00:42:52,369 --> 00:42:56,750  
Vaidya in the disk again we can go from

759  
00:42:55,039 --> 00:43:00,380  
dust to to two planets okay

760  
00:42:56,750 --> 00:43:02,630  
the first step this one number one that

761  
00:43:00,380 --> 00:43:06,318  
that brings the dust from from here to

762  
00:43:02,630 --> 00:43:09,349  
millimeter in sizes is believed to be

763  
00:43:06,318 --> 00:43:11,420  
the one responsible for the emission

764  
00:43:09,349 --> 00:43:14,119  
that we see with interferometers as i

765  
00:43:11,420 --> 00:43:17,539  
said before okay so the millimeter sized

766  
00:43:14,119 --> 00:43:19,700  
grains that we measure in the be

767  
00:43:17,539 --> 00:43:21,769  
detecting in protoplanetary disk are

768  
00:43:19,699 --> 00:43:25,068  
probably formed by speaking of small

769  
00:43:21,769 --> 00:43:27,588  
part okay for the rest the the next

770

00:43:25,068 --> 00:43:29,480  
steps are very much still unconstrained

771  
00:43:27,588 --> 00:43:32,328  
and a mostly theoretical and they are

772  
00:43:29,480 --> 00:43:34,190  
very difficult to go through a classical

773  
00:43:32,329 --> 00:43:38,298  
problem this scenario is for example

774  
00:43:34,190 --> 00:43:40,280  
they so-called meter-sized earlier in

775  
00:43:38,298 --> 00:43:44,269  
this models it is expected that the soon

776  
00:43:40,280 --> 00:43:46,940  
as dust grains stick together and they

777  
00:43:44,269 --> 00:43:50,509  
grow in sizes enough and they reach the

778  
00:43:46,940 --> 00:43:53,000  
meter one meter inside as an order of

779  
00:43:50,510 --> 00:43:55,670  
magnitude at one you the distance of

780  
00:43:53,000 --> 00:43:58,849  
Earth from the Sun they would start to

781  
00:43:55,670 --> 00:44:00,798  
feel a gas drag that would such that

782  
00:43:58,849 --> 00:44:04,369  
they would be sucked onto the star very

783  
00:44:00,798 --> 00:44:06,380  
quickly okay so we have a problem of

784  
00:44:04,369 --> 00:44:08,450

time scales here because the the

785

00:44:06,380 --> 00:44:11,030

material of which planets are made need

786

00:44:08,449 --> 00:44:14,509

to stay in the disk long enough for the

787

00:44:11,030 --> 00:44:16,099

planets to to be to be made okay if you

788

00:44:14,510 --> 00:44:18,980

suck all the material to start to

789

00:44:16,099 --> 00:44:21,750

quickly nothing is left no then you

790

00:44:18,980 --> 00:44:24,750

cannot from the planet

791

00:44:21,750 --> 00:44:29,940

but with this with these other

792

00:44:24,750 --> 00:44:32,519

mechanisms here there is the hypothesis

793

00:44:29,940 --> 00:44:35,190

that there can't that there are over

794

00:44:32,519 --> 00:44:38,340

densities in over densities of on

795

00:44:35,190 --> 00:44:44,720

material in disks okay or the so called

796

00:44:38,340 --> 00:44:44,720

the dust traps that may allow to to jump

797

00:44:45,019 --> 00:44:53,429

and once the the planet did these solids

798

00:44:49,889 --> 00:44:56,699

bodies grow enough okay at some point



799  
00:44:53,429 --> 00:44:58,529  
gravity kicks in strongly and so all the

800  
00:44:56,699 --> 00:45:01,529  
smaller bodies are fitted onto this

801  
00:44:58,530 --> 00:45:03,780  
planet a similar protoplanet and at some

802  
00:45:01,530 --> 00:45:05,640  
point also also and also the gas

803  
00:45:03,780 --> 00:45:09,000  
participate with this flow so that you

804  
00:45:05,639 --> 00:45:11,789  
can it is expected that you can build a

805  
00:45:09,000 --> 00:45:15,030  
rocky planet with also another gases

806  
00:45:11,789 --> 00:45:18,449  
atmosphere okay and now very recently

807  
00:45:15,030 --> 00:45:22,380  
this is of the last few years these dust

808  
00:45:18,449 --> 00:45:24,929  
traps start to be seen so they they may

809  
00:45:22,380 --> 00:45:27,510  
they may show us that they did indeed

810  
00:45:24,929 --> 00:45:28,980  
some kind of things some of these models

811  
00:45:27,510 --> 00:45:30,450  
that proposed these dust traps are

812  
00:45:28,980 --> 00:45:32,099  
really happening in viscous so to

813  
00:45:30,449 --> 00:45:35,519  
allowed to jump from one side to the

814  
00:45:32,099 --> 00:45:38,130  
other and then okay for example this

815  
00:45:35,519 --> 00:45:44,130  
observation is from Alma this is the

816  
00:45:38,130 --> 00:45:48,410  
location of they detected millimeter

817  
00:45:44,130 --> 00:45:50,519  
sized grains only in this vision okay

818  
00:45:48,409 --> 00:45:54,809  
showing that these grains are not

819  
00:45:50,519 --> 00:45:58,530  
distributed on on a disk as ingeniously

820  
00:45:54,809 --> 00:46:01,679  
okay as one would expect but they are

821  
00:45:58,530 --> 00:46:04,619  
sort of trapped by some mechanism in

822  
00:46:01,679 --> 00:46:06,690  
that region and these regions called the

823  
00:46:04,619 --> 00:46:08,789  
straps are believed to be regions of

824  
00:46:06,690 --> 00:46:12,030  
efficient planet formation because they

825  
00:46:08,789 --> 00:46:14,909  
you bring solids on on a smaller portion

826  
00:46:12,030 --> 00:46:20,460  
of the disk and and you you increase the

827

00:46:14,909 --> 00:46:24,989  
probability of interactions and and the

828  
00:46:20,460 --> 00:46:28,050  
build-up of larger bodies okay now so

829  
00:46:24,989 --> 00:46:29,309  
while this first step is observed these

830  
00:46:28,050 --> 00:46:33,200  
intermediate steps

831  
00:46:29,309 --> 00:46:37,079  
maybe they start to be observed an

832  
00:46:33,199 --> 00:46:39,659  
Australian at the very end the final

833  
00:46:37,079 --> 00:46:43,250  
accretion of gas and material on the DS

834  
00:46:39,659 --> 00:46:49,199  
and on the plan on the protoplanet

835  
00:46:43,250 --> 00:46:52,079  
is only very very recently that we

836  
00:46:49,199 --> 00:46:54,569  
started to see also the last steps and

837  
00:46:52,079 --> 00:46:57,809  
this is a very exciting observations

838  
00:46:54,570 --> 00:47:01,470  
that it's from was published in 2013

839  
00:46:57,809 --> 00:47:03,840  
actually Sasha once he was a colleague

840  
00:47:01,469 --> 00:47:08,009  
of mine at the ETH in Zurich in

841  
00:47:03,840 --> 00:47:10,980

Switzerland so what they were they

842

00:47:08,010 --> 00:47:14,460

showed here this is an op Hubble image

843

00:47:10,980 --> 00:47:17,550

of this protoplanetary disc they started

844

00:47:14,460 --> 00:47:19,740

to detect kind of point like not not

845

00:47:17,550 --> 00:47:22,440

exactly point like plane by small

846

00:47:19,739 --> 00:47:25,319

sources of emission inside the disc

847

00:47:22,440 --> 00:47:28,789

still embedded ok and they interpret

848

00:47:25,320 --> 00:47:32,010

these these observations as observing

849

00:47:28,789 --> 00:47:35,519

protoplanets where the disc material is

850

00:47:32,010 --> 00:47:38,850

still tweeting ok onto the protoplanet

851

00:47:35,519 --> 00:47:42,150

and these new observations are starting

852

00:47:38,849 --> 00:47:47,039

to connect the two ends of the story

853

00:47:42,150 --> 00:47:49,889

that until couple of years ago were the

854

00:47:47,039 --> 00:47:53,159

only things we have see coastal discs

855

00:47:49,889 --> 00:47:55,379

and exoplanet okay in between again the

856  
00:47:53,159 --> 00:47:57,659  
stories very still very unknown because

857  
00:47:55,380 --> 00:48:00,240  
we cannot see inside discs it seems that

858  
00:47:57,659 --> 00:48:02,399  
we start in some cases to be able to see

859  
00:48:00,239 --> 00:48:04,259  
also the emission of some protoplanets

860  
00:48:02,400 --> 00:48:06,150  
this is still a candidate okay it's not

861  
00:48:04,260 --> 00:48:08,640  
confirmed yet but I believe that

862  
00:48:06,150 --> 00:48:11,510  
observations like this will will

863  
00:48:08,639 --> 00:48:16,079  
increase in number in the near future

864  
00:48:11,510 --> 00:48:19,470  
ok let's say that now we are able to

865  
00:48:16,079 --> 00:48:21,539  
overcome the problems and the barriers

866  
00:48:19,469 --> 00:48:23,069  
that are in our theoretical

867  
00:48:21,539 --> 00:48:28,039  
understanding and we're able to form

868  
00:48:23,070 --> 00:48:28,039  
rocky balls in disks ok

869  
00:48:29,269 --> 00:48:41,690  
still we don't have yet

870  
00:48:35,030 --> 00:48:44,390  
planets okay the next step from rocky

871  
00:48:41,690 --> 00:48:46,940  
balls and define rocky balls to planets

872  
00:48:44,389 --> 00:48:51,319  
let's address the composition in a bit

873  
00:48:46,940 --> 00:48:55,150  
in more details okay and let's look

874  
00:48:51,320 --> 00:48:58,309  
again at our solar system in this scale

875  
00:48:55,150 --> 00:49:00,260  
representation one of the first things

876  
00:48:58,309 --> 00:49:03,679  
that struck me when I when I look at

877  
00:49:00,260 --> 00:49:10,100  
this representation is what you see

878  
00:49:03,679 --> 00:49:16,480  
immediately so gas giants rocky planets

879  
00:49:10,099 --> 00:49:20,779  
in rocky planets small gas giants big

880  
00:49:16,480 --> 00:49:22,610  
there are solid bodies all over the the

881  
00:49:20,780 --> 00:49:24,380  
solar system okay we heard them even

882  
00:49:22,610 --> 00:49:26,390  
into in the introduction okay all over

883  
00:49:24,380 --> 00:49:29,059  
even in the outer regions but as far as

884

00:49:26,389 --> 00:49:34,579  
planets are concerned the rocky planets

885  
00:49:29,059 --> 00:49:40,969  
are the gas giants around so there seems

886  
00:49:34,579 --> 00:49:42,230  
to be something there between the rocky

887  
00:49:40,969 --> 00:49:46,519  
and the giant it seems to give

888  
00:49:42,230 --> 00:49:49,369  
discontinuity some critical change

889  
00:49:46,519 --> 00:49:52,130  
between the inside and the outside so

890  
00:49:49,369 --> 00:49:54,950  
the simple idea that this visualization

891  
00:49:52,130 --> 00:49:59,869  
seems to suggest was proposed in a paper

892  
00:49:54,949 --> 00:50:02,210  
in 1981 where and here I'm showing the

893  
00:49:59,869 --> 00:50:03,920  
key figure where we have the density of

894  
00:50:02,210 --> 00:50:08,090  
material in the disk and the distance

895  
00:50:03,920 --> 00:50:10,130  
from the Sun where any spill an

896  
00:50:08,090 --> 00:50:13,070  
experiment similar to what we did here

897  
00:50:10,130 --> 00:50:15,410  
but reversed was done which is to take

898  
00:50:13,070 --> 00:50:17,660

the mass that is nowadays in the planet

899

00:50:15,409 --> 00:50:21,969

okay in our solar system planets and

900

00:50:17,659 --> 00:50:24,409

spread it all the rings of material

901

00:50:21,969 --> 00:50:27,259

assuming that every planet contributes

902

00:50:24,409 --> 00:50:30,319

only to enameled and at its distance on

903

00:50:27,260 --> 00:50:32,350

the star from the Sun okay so to build a

904

00:50:30,320 --> 00:50:34,940

representation of what our own

905

00:50:32,349 --> 00:50:38,659

protoplanetary disk would probably

906

00:50:34,940 --> 00:50:41,159

possibly have looked like and what they

907

00:50:38,659 --> 00:50:44,338

what he found

908

00:50:41,159 --> 00:50:46,889

is a discontinued

909

00:50:44,338 --> 00:50:49,078

okay this is the density of material and

910

00:50:46,889 --> 00:50:51,358

you see but if you connect the points

911

00:50:49,079 --> 00:50:54,298

here we have a discontinuity between the

912

00:50:51,358 --> 00:50:58,288

rocky planets and the giant planet and



913  
00:50:54,298 --> 00:51:00,838  
this discontinuity was in the in that

914  
00:50:58,289 --> 00:51:04,380  
paper attributed to a so called snow

915  
00:51:00,838 --> 00:51:06,568  
line as which is the line marking the

916  
00:51:04,380 --> 00:51:11,630  
separation between regions where water

917  
00:51:06,568 --> 00:51:14,159  
is in the is in the is in the ice phase

918  
00:51:11,630 --> 00:51:16,048  
outside of this line and in the gas

919  
00:51:14,159 --> 00:51:18,420  
phase inside because of the temperature

920  
00:51:16,048 --> 00:51:20,639  
okay when the temperature that decreases

921  
00:51:18,420 --> 00:51:24,059  
with the distance from the star drops

922  
00:51:20,639 --> 00:51:26,038  
enough so to water to freeze out then

923  
00:51:24,059 --> 00:51:27,539  
you have on the ice on one side and an

924  
00:51:26,039 --> 00:51:30,720  
angle on the other one okay

925  
00:51:27,539 --> 00:51:35,539  
such that inside inside the snow line

926  
00:51:30,719 --> 00:51:37,828  
only compounds and molecules more

927

00:51:35,539 --> 00:51:40,920  
resistant to heat then water could

928

00:51:37,829 --> 00:51:44,369  
survive okay like silicates for example

929

00:51:40,920 --> 00:51:45,838  
and and so only rocky bodies were formed

930

00:51:44,369 --> 00:51:48,960  
with the material the solid material

931

00:51:45,838 --> 00:51:53,608  
inside outside is tell is that rock and

932

00:51:48,960 --> 00:51:57,269  
ice would have allowed for larger faster

933

00:51:53,608 --> 00:52:01,130  
buildup of planetary cores and then a

934

00:51:57,269 --> 00:52:03,900  
faster accretion of gas to be the big

935

00:52:01,130 --> 00:52:10,019  
gas atmospheres of the gas giants

936

00:52:03,900 --> 00:52:13,950  
okay now this simplified story that I

937

00:52:10,019 --> 00:52:17,250  
just told still still very much assumed

938

00:52:13,949 --> 00:52:19,489  
nowadays okay and it has important

939

00:52:17,250 --> 00:52:23,489  
implications on what we can learn about

940

00:52:19,489 --> 00:52:26,879  
exoplanet composition by looking at from

941

00:52:23,489 --> 00:52:29,338  
looking at protoplanetary discs so let's

942  
00:52:26,880 --> 00:52:30,990  
look at the section of a protein from

943  
00:52:29,338 --> 00:52:37,858  
the vendor disc okay let's take it and

944  
00:52:30,989 --> 00:52:39,868  
let's take a section star and here and

945  
00:52:37,858 --> 00:52:42,659  
let's summarize in a cartoon the

946  
00:52:39,869 --> 00:52:45,480  
ingredients the factors that the process

947  
00:52:42,659 --> 00:52:47,699  
that we have taught so far okay so we

948  
00:52:45,480 --> 00:52:50,670  
have the dust grains small dust grains

949  
00:52:47,699 --> 00:52:52,828  
that grow in sizes okay at some point

950  
00:52:50,670 --> 00:52:53,700  
that they grow enough to fill a gas

951  
00:52:52,829 --> 00:52:55,920  
track and they

952  
00:52:53,699 --> 00:52:58,649  
feel they feel aghast ragged they

953  
00:52:55,920 --> 00:53:01,769  
migrate inward toward was the toward the

954  
00:52:58,650 --> 00:53:04,200  
star at some point for because of some

955  
00:53:01,769 --> 00:53:05,789

processes they are kept they are stopped

956

00:53:04,199 --> 00:53:10,409

in their migration some of them are

957

00:53:05,789 --> 00:53:13,019

stopped and and they in this for example

958

00:53:10,409 --> 00:53:15,149

in these dust traps okay so that they

959

00:53:13,019 --> 00:53:18,030

can stay there long enough to build

960

00:53:15,150 --> 00:53:19,769

beginning mass and reached the

961

00:53:18,030 --> 00:53:22,320

planetesimals side the kilometer size

962

00:53:19,769 --> 00:53:24,809

and then start Procrit also also gaseous

963

00:53:22,320 --> 00:53:26,460

atmospheres okay those ways that make it

964

00:53:24,809 --> 00:53:29,130

to be inside the what is known I mean

965

00:53:26,460 --> 00:53:30,900

here has this strange because of the

966

00:53:29,130 --> 00:53:32,970

thermal temperature and density

967

00:53:30,900 --> 00:53:35,099

structure of the disk which is more

968

00:53:32,969 --> 00:53:37,769

complicated than a simple mind okay

969

00:53:35,099 --> 00:53:48,960

inside we have we have a separation so

970  
00:53:37,769 --> 00:53:52,559  
on will agree on for example of so while

971  
00:53:48,960 --> 00:53:54,539  
the processes that happen in the planet

972  
00:53:52,559 --> 00:53:56,880  
formation region inside the disk are

973  
00:53:54,539 --> 00:54:02,159  
hidden to our eyes we cannot see them

974  
00:53:56,880 --> 00:54:04,740  
okay we can observe the molecular gas in

975  
00:54:02,159 --> 00:54:08,339  
the inner disk through the infrared

976  
00:54:04,739 --> 00:54:14,009  
radiation of the gas okay and it is very

977  
00:54:08,340 --> 00:54:18,090  
recent in the last years that warm water

978  
00:54:14,010 --> 00:54:20,100  
and emission from molecules with carbon

979  
00:54:18,090 --> 00:54:22,500  
inside has been discovered in

980  
00:54:20,099 --> 00:54:24,779  
protoplanetary disk and another this is

981  
00:54:22,500 --> 00:54:26,610  
another achieved an achievement of

982  
00:54:24,780 --> 00:54:29,070  
another NASA Telescope the Spitzer Space

983  
00:54:26,610 --> 00:54:30,420  
Telescope okay and here you see here we

984  
00:54:29,070 --> 00:54:34,200  
use the trois copy inference

985  
00:54:30,420 --> 00:54:36,180  
spectroscopy to identify the molecules

986  
00:54:34,199 --> 00:54:39,179  
in the gas that produced the emission

987  
00:54:36,179 --> 00:54:41,250  
okay we have here the observations and

988  
00:54:39,179 --> 00:54:43,319  
here a model where you basically see

989  
00:54:41,250 --> 00:54:45,389  
that all the Wiggles you see well the

990  
00:54:43,320 --> 00:54:49,500  
majority of the Wiggles are due to water

991  
00:54:45,389 --> 00:54:53,639  
vapour and this colored ones are due to

992  
00:54:49,500 --> 00:54:56,880  
molecules that contain carbon okay so

993  
00:54:53,639 --> 00:54:59,519  
this tells us that now we are able to

994  
00:54:56,880 --> 00:55:00,990  
trace some molecules and not some

995  
00:54:59,519 --> 00:55:04,610  
irrelevant ones we are talking about

996  
00:55:00,989 --> 00:55:08,239  
water and carbon carbon B molecules okay

997  
00:55:04,610 --> 00:55:10,430  
back when they were in the disk okay and

998

00:55:08,239 --> 00:55:13,699  
we can try to come to make a spirit to

999  
00:55:10,429 --> 00:55:17,199  
connect them to the composition of the

1000  
00:55:13,699 --> 00:55:19,789  
exoplanets okay let's see what we can do

1001  
00:55:17,199 --> 00:55:21,980  
one one example what what we can do with

1002  
00:55:19,789 --> 00:55:24,920  
these kind of observations for example

1003  
00:55:21,980 --> 00:55:28,369  
let's take the composition of one of our

1004  
00:55:24,920 --> 00:55:34,220  
earth and the Sun okay and let's compare

1005  
00:55:28,369 --> 00:55:39,199  
them so the the black line here is where

1006  
00:55:34,219 --> 00:55:41,059  
all elements that we consider would lie

1007  
00:55:39,199 --> 00:55:42,679  
they would lie on this land is the

1008  
00:55:41,059 --> 00:55:45,230  
composition of Earth and the Sun is

1009  
00:55:42,679 --> 00:55:50,359  
exactly the same okay and we see that

1010  
00:55:45,230 --> 00:55:54,559  
this is this is true for many elements

1011  
00:55:50,360 --> 00:55:55,990  
lie at least close to this line okay but

1012  
00:55:54,559 --> 00:55:59,210

some do not

1013

00:55:55,989 --> 00:56:02,569

for example let me draw your attention

1014

00:55:59,210 --> 00:56:05,210

to carbon that is under a bundle toward

1015

00:56:02,570 --> 00:56:07,340

okay if it is lower than the line it

1016

00:56:05,210 --> 00:56:11,539

means that this under abundant north by

1017

00:56:07,340 --> 00:56:14,809

it by at most by almost a factor 10,000

1018

00:56:11,539 --> 00:56:16,969

okay if you think how much carbon is is

1019

00:56:14,809 --> 00:56:19,610

essential for for life on Earth you may

1020

00:56:16,969 --> 00:56:22,869

be you may be surprised by by by seeing

1021

00:56:19,610 --> 00:56:31,099

how little carbon there is on earth okay

1022

00:56:22,869 --> 00:56:33,859

now this may find an explanation in the

1023

00:56:31,099 --> 00:56:37,759

observations of protoplanetary discs and

1024

00:56:33,860 --> 00:56:40,820

in particular in the in the imprint that

1025

00:56:37,760 --> 00:56:43,160

is given by no lines in protoplanetary

1026

00:56:40,820 --> 00:56:46,640

discs to the composition of exoplanets



1027  
00:56:43,159 --> 00:56:50,359  
let's look at this plot from people in

1028  
00:56:46,639 --> 00:56:54,049  
2011 so far I've talked only about only

1029  
00:56:50,360 --> 00:56:56,210  
of one snow line the water snow line but

1030  
00:56:54,050 --> 00:56:58,640  
actually in in protoplanetary discs

1031  
00:56:56,210 --> 00:57:01,550  
every molecule has its own stone on

1032  
00:56:58,639 --> 00:57:04,609  
which is the location in the disk okay

1033  
00:57:01,550 --> 00:57:05,190  
the star is here we go further round the

1034  
00:57:04,610 --> 00:57:07,608  
temperature

1035  
00:57:05,190 --> 00:57:14,519  
Croesus in this direction the star okay

1036  
00:57:07,608 --> 00:57:17,219  
so all every molecule has its own snow

1037  
00:57:14,519 --> 00:57:20,489  
line where on one side further from the

1038  
00:57:17,219 --> 00:57:23,689  
star it's a nice only nice for him in

1039  
00:57:20,489 --> 00:57:27,358  
the ice form and closely easing the gas

1040  
00:57:23,690 --> 00:57:28,800  
okay so you have it for example waters

1041  
00:57:27,358 --> 00:57:32,489  
you to a co okay

1042  
00:57:28,800 --> 00:57:34,920  
co freezes at much lower temperatures

1043  
00:57:32,489 --> 00:57:38,088  
than water so there's no line of CO is

1044  
00:57:34,920 --> 00:57:43,289  
much further out okay in the disk and

1045  
00:57:38,088 --> 00:57:46,230  
co2 in between water as you so in this

1046  
00:57:43,289 --> 00:57:47,909  
plot here that is really a very

1047  
00:57:46,230 --> 00:57:51,420  
interesting result from the last years

1048  
00:57:47,909 --> 00:57:55,108  
and even this one will grow in interest

1049  
00:57:51,420 --> 00:58:00,079  
and in related papers in the next years

1050  
00:57:55,108 --> 00:58:04,380  
for sure we see that the composition the

1051  
00:58:00,079 --> 00:58:08,339  
composition of the gas this line and the

1052  
00:58:04,380 --> 00:58:11,220  
solids the solid grains in the disk this

1053  
00:58:08,338 --> 00:58:14,969  
this one line the composition in terms

1054  
00:58:11,219 --> 00:58:17,939  
of karbala balances as compared to

1055

00:58:14,969 --> 00:58:20,608  
oxygen amount the number of carbon atoms

1056  
00:58:17,940 --> 00:58:23,190  
compared to oxygen atoms okay the

1057  
00:58:20,608 --> 00:58:28,108  
composition changes every time that

1058  
00:58:23,190 --> 00:58:30,179  
there is no line okay because a in any

1059  
00:58:28,108 --> 00:58:32,219  
given location of the disk we have

1060  
00:58:30,179 --> 00:58:34,348  
different contributions to the gas to

1061  
00:58:32,219 --> 00:58:35,939  
the solids depending on which molecules

1062  
00:58:34,349 --> 00:58:38,000  
are in the gas phase only the solid

1063  
00:58:35,940 --> 00:58:41,659  
phase okay

1064  
00:58:38,000 --> 00:58:45,179  
such that we can imagine that if

1065  
00:58:41,659 --> 00:58:47,848  
depending on where in exoplanet

1066  
00:58:45,179 --> 00:58:50,519  
forms in the linker it will have a

1067  
00:58:47,849 --> 00:58:52,260  
different composition okay depending on

1068  
00:58:50,519 --> 00:58:55,559  
the location where it forms in the disk

1069  
00:58:52,260 --> 00:58:57,690

and not only the planet but also plan

1070

00:58:55,559 --> 00:59:01,199

the planet atmosphere as compared to the

1071

00:58:57,690 --> 00:59:09,659

planet surface in particular we will

1072

00:59:01,199 --> 00:59:12,868

have carbon rich atmospheres for for for

1073

00:59:09,659 --> 00:59:15,838

a large extent in radii while we will

1074

00:59:12,869 --> 00:59:17,280

have carbon poor surfaces for foreign

1075

00:59:15,838 --> 00:59:22,269

foreign

1076

00:59:17,280 --> 00:59:25,210

okay and this could explain a recent

1077

00:59:22,269 --> 00:59:27,519

exotic example the pizza panel was well

1078

00:59:25,210 --> 00:59:30,309

being who was proposed to have looking

1079

00:59:27,519 --> 00:59:34,719

at its atmosphere it's not Jupiter this

1080

00:59:30,309 --> 00:59:36,460

one looking at it at my atmosphere it

1081

00:59:34,719 --> 00:59:39,009

was proposed that the seat wall ratio

1082

00:59:36,460 --> 00:59:42,220

the composition in terms of siendo was

1083

00:59:39,010 --> 00:59:44,829

close to one must be close to one okay

1084  
00:59:42,219 --> 00:59:47,019  
this was what was proposed and this is

1085  
00:59:44,829 --> 00:59:48,460  
very exotic very strange compared to

1086  
00:59:47,019 --> 00:59:50,798  
what we find in the in the solar system

1087  
00:59:48,460 --> 00:59:54,220  
this is the seat wall the composition of

1088  
00:59:50,798 --> 00:59:56,679  
the Sun okay in terms of siendo and and

1089  
00:59:54,219 --> 00:59:59,318  
the the an exoplanet like this could be

1090  
00:59:56,679 --> 01:00:02,048  
explained if it formed in a location in

1091  
00:59:59,318 --> 01:00:05,619  
a comparable location in its own

1092  
01:00:02,048 --> 01:00:12,038  
protoplanetary disk okay this could also

1093  
01:00:05,619 --> 01:00:14,410  
explain maybe why is carbon poor okay if

1094  
01:00:12,039 --> 01:00:17,339  
it formed in a location of the proto

1095  
01:00:14,409 --> 01:00:20,048  
plant our protoplanetary disk where

1096  
01:00:17,338 --> 01:00:23,759  
carbon was primarily in the gas phase

1097  
01:00:20,048 --> 01:00:27,099  
not in the solid phase for example in co

1098  
01:00:23,760 --> 01:00:33,640  
so this is where we are going now in

1099  
01:00:27,099 --> 01:00:35,440  
this field we are working on finding a

1100  
01:00:33,639 --> 01:00:38,230  
link between the composition of

1101  
01:00:35,440 --> 01:00:40,510  
protoplanetary disks and the composition

1102  
01:00:38,230 --> 01:00:42,519  
of planets exoplanets and plants that

1103  
01:00:40,510 --> 01:00:45,579  
phone is a protoplanetary disc in an

1104  
01:00:42,519 --> 01:00:46,960  
attempt to build a story to build to

1105  
01:00:45,579 --> 01:00:50,500  
build a scenario where ever we

1106  
01:00:46,960 --> 01:00:52,690  
understand why and how certain kinds of

1107  
01:00:50,500 --> 01:00:55,358  
planets can form in certain discs and

1108  
01:00:52,690 --> 01:01:00,389  
why not others for example it's very

1109  
01:00:55,358 --> 01:01:05,500  
early in this okay

1110  
01:01:00,389 --> 01:01:11,578  
and now we are at the end so we made it

1111  
01:01:05,500 --> 01:01:11,579  
somehow to form a rocky ball in the disk

1112

01:01:12,090 --> 01:01:19,980  
a rocket ball let's say even with

1113  
01:01:14,670 --> 01:01:21,780  
another sphere okay second step we

1114  
01:01:19,980 --> 01:01:23,639  
addressed also the composition so we

1115  
01:01:21,780 --> 01:01:25,680  
don't have only a rocket ball but we

1116  
01:01:23,639 --> 01:01:29,159  
have something that we can call a planet

1117  
01:01:25,679 --> 01:01:31,799  
okay and we saw how the composition of

1118  
01:01:29,159 --> 01:01:33,389  
the natural disk may imprint the

1119  
01:01:31,800 --> 01:01:37,710  
composition of the exoplanet of the

1120  
01:01:33,389 --> 01:01:41,460  
planet but the talk tonight the title

1121  
01:01:37,710 --> 01:01:46,740  
says new worlds not simply planets okay

1122  
01:01:41,460 --> 01:01:49,740  
and the end world suggests something

1123  
01:01:46,739 --> 01:01:53,699  
more than simply a rocky ball with some

1124  
01:01:49,739 --> 01:01:57,889  
composition floating into space world

1125  
01:01:53,699 --> 01:02:01,500  
suggests complexity diversity and life

1126  
01:01:57,889 --> 01:02:04,559

so at the end of this talk I have to at

1127

01:02:01,500 --> 01:02:06,239

least mention an interesting symposium

1128

01:02:04,559 --> 01:02:09,079

that we had just a couple of months ago

1129

01:02:06,239 --> 01:02:12,389

here a space telescope in this room

1130

01:02:09,079 --> 01:02:15,539

called habitable worlds across time and

1131

01:02:12,389 --> 01:02:18,029

space we talked for days and we

1132

01:02:15,539 --> 01:02:20,940

discussed for days about the details and

1133

01:02:18,030 --> 01:02:24,690

many facets of the of this exciting

1134

01:02:20,940 --> 01:02:28,829

topic and that day I was I was surprised

1135

01:02:24,690 --> 01:02:32,070

that the final discussion we found

1136

01:02:28,829 --> 01:02:34,679

ourselves still addressing some

1137

01:02:32,070 --> 01:02:38,070

fundamental questions what is

1138

01:02:34,679 --> 01:02:40,139

habitability how can we define it for it

1139

01:02:38,070 --> 01:02:44,010

so planets and how can we search for

1140

01:02:40,139 --> 01:02:48,389

life beyond Earth and the all these



1141  
01:02:44,010 --> 01:02:50,610  
questions are still very often so if the

1142  
01:02:48,389 --> 01:02:54,299  
mystery addressed tonight was not enough

1143  
01:02:50,610 --> 01:02:57,180  
intriguing so far the problem of

1144  
01:02:54,300 --> 01:03:00,780  
habitability makes it the challenge that

1145  
01:02:57,179 --> 01:03:02,399  
we that is and will drive research for

1146  
01:03:00,780 --> 01:03:05,370  
for many years to come and also the

1147  
01:03:02,400 --> 01:03:08,269  
interest of the public for sure and no

1148  
01:03:05,369 --> 01:03:12,239  
doubt that we will be surprised

1149  
01:03:08,269 --> 01:03:15,269  
respectively scholars but desperately in

1150  
01:03:12,239 --> 01:03:17,399  
the article challenges and the

1151  
01:03:15,269 --> 01:03:20,610  
unexpected are the two pillars of

1152  
01:03:17,400 --> 01:03:23,450  
cutting-edge research and triggers for

1153  
01:03:20,610 --> 01:03:23,450  
investigative minds

1154  
01:03:23,760 --> 01:03:26,880  
thank you

1155  
01:03:47,489 --> 01:03:57,299  
anyway we've got time for some questions

1156  
01:03:49,829 --> 01:04:04,980  
please raise your hands if you want to

1157  
01:03:57,300 --> 01:04:10,380  
repeat experiment please okay let me try

1158  
01:04:04,980 --> 01:04:11,130  
one of the gas giant Saturn how does it

1159  
01:04:10,380 --> 01:04:13,200  
get stirred

1160  
01:04:11,130 --> 01:04:15,720  
what's down inside this draws the gas

1161  
01:04:13,199 --> 01:04:20,399  
it they probably have trouble keeping

1162  
01:04:15,719 --> 01:04:23,069  
gas on Mars because it's too light so

1163  
01:04:20,400 --> 01:04:26,099  
you're asking what's inside and settle

1164  
01:04:23,070 --> 01:04:33,590  
just a loser get started and what's

1165  
01:04:26,099 --> 01:04:36,630  
there so the idea is that you made or

1166  
01:04:33,590 --> 01:04:42,180  
rocky terrestrial planets in the inner

1167  
01:04:36,630 --> 01:04:45,030  
disk closer to the star and apply rocky

1168  
01:04:42,179 --> 01:04:47,669  
cores for the four giant planets if they

1169

01:04:45,030 --> 01:04:50,460  
have rocky cores III don't think it's

1170  
01:04:47,670 --> 01:04:52,860  
still super clear for our own giant

1171  
01:04:50,460 --> 01:04:55,800  
plants so it's not clear in general but

1172  
01:04:52,860 --> 01:04:58,620  
the idea is that even even gas giants

1173  
01:04:55,800 --> 01:05:14,400  
have a rocky calling in in them that

1174  
01:04:58,619 --> 01:05:17,519  
maybe the size of the of the rocky rocky

1175  
01:05:14,400 --> 01:05:21,059  
fast enough to to form when there is

1176  
01:05:17,519 --> 01:05:23,550  
still a lot of gas around then as I said

1177  
01:05:21,059 --> 01:05:27,029  
at some point the gravity kicks in a lot

1178  
01:05:23,550 --> 01:05:29,160  
and so you create a lot of gas from from

1179  
01:05:27,030 --> 01:05:31,500  
the surrounding from from the wing of

1180  
01:05:29,159 --> 01:05:34,289  
material okay at that location

1181  
01:05:31,500 --> 01:05:36,780  
okay and so it's a problem also of

1182  
01:05:34,289 --> 01:05:39,599  
timescales how fast you can build up

1183  
01:05:36,780 --> 01:05:41,970

this course okay so in in the reaches

1184

01:05:39,599 --> 01:05:46,519

outside this simplified view of there's

1185

01:05:41,969 --> 01:05:50,579

no line being their eyes other than rock

1186

01:05:46,519 --> 01:05:53,969

solid material rock and ice

1187

01:05:50,579 --> 01:05:56,730

it's it's also seen by from experiments

1188

01:05:53,969 --> 01:05:58,739

that dyes helps a lot in building up

1189

01:05:56,730 --> 01:06:01,650

material because it's more sticky there

1190

01:05:58,739 --> 01:06:04,109

are a lot of experiments done with this

1191

01:06:01,650 --> 01:06:06,300

little quiz and try to see how they

1192

01:06:04,110 --> 01:06:08,789

stick and if they stick or not depending

1193

01:06:06,300 --> 01:06:11,400

on the velocity and but it seems that

1194

01:06:08,789 --> 01:06:13,380

the ice helps a lot okay so if if

1195

01:06:11,400 --> 01:06:16,769

outside of is known and you can build up

1196

01:06:13,380 --> 01:06:21,119

quickly a rocky core made of rock and

1197

01:06:16,769 --> 01:06:25,440

and dies then there is a runaway process

1198  
01:06:21,119 --> 01:06:56,279  
that accretes gas and this is a way to

1199  
01:06:25,440 --> 01:06:59,610  
explain everything you can think of is

1200  
01:06:56,280 --> 01:07:01,710  
there so I cannot tell you a specific

1201  
01:06:59,610 --> 01:07:12,019  
example we can look it up afterwards

1202  
01:07:01,710 --> 01:07:12,019  
each one but the nature is must more

1203  
01:07:12,679 --> 01:07:22,980  
created by NASA so the dead I'm sure we

1204  
01:07:17,519 --> 01:07:26,190  
can find one we have now so we can find

1205  
01:07:22,980 --> 01:07:31,650  
one there is really a big large variety

1206  
01:07:26,190 --> 01:07:34,320  
of compositions and size unless the

1207  
01:07:31,650 --> 01:07:38,150  
universe is not stranger than we

1208  
01:07:34,320 --> 01:07:38,150  
imagined a stranger than we can

1209  
01:07:39,119 --> 01:07:47,650  
the the moons of Saturn and Jupiter are

1210  
01:07:43,900 --> 01:07:58,119  
they considered mainly rocky or are they

1211  
01:07:47,650 --> 01:08:02,400  
mostly they mix dynamics so some of very

1212  
01:07:58,119 --> 01:08:06,670  
much eyes some rocky with with yeah

1213  
01:08:02,400 --> 01:08:23,170  
actually interestingly in in the plot

1214  
01:08:06,670 --> 01:08:26,770  
that I showed here this one here the the

1215  
01:08:23,170 --> 01:08:29,050  
green points and III it's hidden okay

1216  
01:08:26,770 --> 01:08:31,780  
because I wanted to make it simpler but

1217  
01:08:29,050 --> 01:08:34,630  
the green points are the satellites of

1218  
01:08:31,779 --> 01:08:36,909  
gas giants so there is an interesting

1219  
01:08:34,630 --> 01:08:41,859  
overlap between the super Earths

1220  
01:08:36,909 --> 01:08:50,849  
population and the gas giant satellite

1221  
01:08:41,859 --> 01:08:54,069  
population there is this interesting

1222  
01:08:50,850 --> 01:09:00,930  
similarity that may suggest of a similar

1223  
01:08:54,069 --> 01:09:00,929  
process of formation but only so

1224  
01:09:07,630 --> 01:09:15,500  
it's a planetary system and these super

1225  
01:09:10,698 --> 01:09:19,399  
rods and then here the mass is scared

1226

01:09:15,500 --> 01:09:21,798  
with the rate with the mass of the star

1227  
01:09:19,399 --> 01:09:23,719  
and for the giant line satellites is

1228  
01:09:21,798 --> 01:09:26,509  
scaled with the mass of the giant gas

1229  
01:09:23,719 --> 01:09:29,798  
giant okay so there is some story behind

1230  
01:09:26,509 --> 01:09:32,229  
that but but there is this seminar

1231  
01:09:29,798 --> 01:09:41,569  
hinting at the possibility in our

1232  
01:09:32,229 --> 01:09:43,158  
process there are first time yes yes so

1233  
01:09:41,569 --> 01:09:47,569  
you might have mentioned this but like

1234  
01:09:43,158 --> 01:09:49,848  
you said when they for like was it 1

1235  
01:09:47,569 --> 01:09:54,199  
meter bigots some of them get like

1236  
01:09:49,849 --> 01:09:57,739  
sucked into the start yeah what-what

1237  
01:09:54,198 --> 01:10:06,618  
exactly softly all all the planets that

1238  
01:09:57,738 --> 01:10:10,368  
were formed so what exactly we don't

1239  
01:10:06,618 --> 01:10:11,658  
know okay but we have to again we have

1240  
01:10:10,368 --> 01:10:13,729

the theoretical approach and the

1241

01:10:11,658 --> 01:10:20,198

observation approach observationally

1242

01:10:13,729 --> 01:10:20,198

we have evidence for this clumps of

1243

01:10:20,260 --> 01:10:26,210

millimeter sized grains that are not

1244

01:10:24,219 --> 01:10:28,849

homogeneously distributed in the disk

1245

01:10:26,210 --> 01:10:31,219

but clamped in one region okay so that

1246

01:10:28,849 --> 01:10:34,219

that thing that observation is telling

1247

01:10:31,219 --> 01:10:36,889

us that there is some process that is it

1248

01:10:34,219 --> 01:10:38,599

that is keeping them there okay even if

1249

01:10:36,889 --> 01:10:40,880

we don't know what it is okay

1250

01:10:38,599 --> 01:10:42,380

on the theoretical side that there there

1251

01:10:40,880 --> 01:10:44,690

have been a lot of creativity and

1252

01:10:42,380 --> 01:10:47,329

imagination to try to explain that okay

1253

01:10:44,689 --> 01:10:50,598

and so that the idea is that that there

1254

01:10:47,329 --> 01:10:53,960

that there are these regions of over



1255  
01:10:50,599 --> 01:10:55,819  
density over densities in in that is

1256  
01:10:53,960 --> 01:11:00,469  
such that the density is not the same

1257  
01:10:55,819 --> 01:11:03,649  
okay so these these these grains while

1258  
01:11:00,469 --> 01:11:06,198  
they for example one is this I said one

1259  
01:11:03,649 --> 01:11:08,849  
is the snowline okay there's no name is

1260  
01:11:06,198 --> 01:11:10,769  
the region where you have

1261  
01:11:08,850 --> 01:11:13,200  
one side ice and the other side gas okay

1262  
01:11:10,770 --> 01:11:15,120  
if you have a sharp region where on the

1263  
01:11:13,199 --> 01:11:17,489  
on one side you have a lot of gas on the

1264  
01:11:15,119 --> 01:11:20,550  
other side you you don't you have the

1265  
01:11:17,489 --> 01:11:22,500  
same matter the same monole for the

1266  
01:11:20,550 --> 01:11:27,239  
river water but in solid there is a

1267  
01:11:22,500 --> 01:11:29,100  
discontinuity so in in density of gas

1268  
01:11:27,239 --> 01:11:30,809  
material okay because on one side you

1269  
01:11:29,100 --> 01:11:34,050  
have a lot on the absolute you have less

1270  
01:11:30,810 --> 01:11:38,370  
okay that would be a a density region

1271  
01:11:34,050 --> 01:11:41,610  
where when the swings could be stopped

1272  
01:11:38,369 --> 01:11:43,800  
okay even though some still make it

1273  
01:11:41,609 --> 01:11:45,809  
through and produce the gas that is seen

1274  
01:11:43,800 --> 01:11:47,550  
in the inner disk of the in the in

1275  
01:11:45,810 --> 01:11:49,410  
England disk because they evaporate ice

1276  
01:11:47,550 --> 01:11:51,779  
is evaporate there and then there is

1277  
01:11:49,409 --> 01:11:55,859  
this proposed that there is a pre

1278  
01:11:51,779 --> 01:11:57,479  
diffusion of gas outside beyond the

1279  
01:11:55,859 --> 01:11:59,909  
stone and again building up again

1280  
01:11:57,479 --> 01:12:04,019  
freezing out water for example and

1281  
01:11:59,909 --> 01:12:07,739  
building up again material the solid

1282  
01:12:04,020 --> 01:12:09,180  
bodies beyond this one okay we don't

1283

01:12:07,739 --> 01:12:11,119  
have a clear idea that there are many

1284  
01:12:09,180 --> 01:12:14,159  
complicated models to try to explain how

1285  
01:12:11,119 --> 01:12:16,920  
you can stop this grains there okay but

1286  
01:12:14,159 --> 01:12:25,489  
we have evidence that that happens okay

1287  
01:12:16,920 --> 01:12:25,489  
so we know that it that it happens yes

1288  
01:12:52,578 --> 01:13:09,179  
the answer to his question ishow two

1289  
01:13:07,078 --> 01:13:13,469  
unexpected things but Denis explain them

1290  
01:13:09,179 --> 01:13:19,288  
okay and actually one is still very

1291  
01:13:13,469 --> 01:13:21,179  
mysterious the idea is that and a lot of

1292  
01:13:19,288 --> 01:13:24,269  
development has been done even at that

1293  
01:13:21,179 --> 01:13:31,288  
time when these two Swiss guys were able

1294  
01:13:24,270 --> 01:13:33,420  
to from the theoretical side they had to

1295  
01:13:31,288 --> 01:13:36,658  
come up with something okay because they

1296  
01:13:33,420 --> 01:13:39,868  
had to explain it in some way and the

1297  
01:13:36,658 --> 01:13:42,149

idea was that the the planet forms outer

1298

01:13:39,868 --> 01:13:44,848  
for further out in the disk but then

1299

01:13:42,149 --> 01:13:47,368  
migrates in okay I talked about the

1300

01:13:44,849 --> 01:13:50,239  
migration of the small solids but the

1301

01:13:47,368 --> 01:13:54,689  
similar migration may happen for

1302

01:13:50,238 --> 01:13:56,428  
protoplanets or all planets okay by

1303

01:13:54,689 --> 01:13:58,439  
interaction with the gas again so the

1304

01:13:56,429 --> 01:14:00,449  
idea to explain there to explain the

1305

01:13:58,439 --> 01:14:04,049  
population of hot Jupiter is that they

1306

01:14:00,448 --> 01:14:04,698  
migrate towards the star after they are

1307

01:14:04,050 --> 01:14:12,210  
formed

1308

01:14:04,698 --> 01:14:16,219  
that's the sorry back there yes the

1309

01:14:12,210 --> 01:14:20,489  
given radius from any Sun in this early

1310

01:14:16,219 --> 01:14:22,170  
formation time are they all going at the

1311

01:14:20,488 --> 01:14:25,109  
same rate of speed or do they go at

1312  
01:14:22,170 --> 01:14:28,319  
different speed I'm sorry can you did

1313  
01:14:25,109 --> 01:14:32,399  
the particles going which might vary in

1314  
01:14:28,319 --> 01:14:34,558  
terms of size do they end composition do

1315  
01:14:32,399 --> 01:14:38,069  
they all go at the same speed at a given

1316  
01:14:34,559 --> 01:14:42,119  
radius from some star or do they go at

1317  
01:14:38,069 --> 01:14:45,288  
different speeds it's an interesting

1318  
01:14:42,118 --> 01:14:45,288  
point yes so

1319  
01:14:46,800 --> 01:14:54,880  
they go at different speeds when it

1320  
01:14:51,158 --> 01:14:57,279  
frozen when the soil particles are still

1321  
01:14:54,880 --> 01:14:59,560  
in random in the gas so when the disk is

1322  
01:14:57,279 --> 01:15:04,300  
still in the early phases and you have

1323  
01:14:59,560 --> 01:15:06,310  
gas and dust together at that point when

1324  
01:15:04,300 --> 01:15:08,800  
the particles the solid particles are

1325  
01:15:06,310 --> 01:15:15,760  
small enough they simply follow the gas

1326  
01:15:08,800 --> 01:15:18,489  
okay the reason why there is this

1327  
01:15:15,760 --> 01:15:23,650  
meter-sized barrier problem one of the

1328  
01:15:18,488 --> 01:15:26,468  
reasons is that when the solid particles

1329  
01:15:23,649 --> 01:15:33,698  
stick together and grow enough in size

1330  
01:15:26,469 --> 01:15:36,609  
at some point when they grow enough in

1331  
01:15:33,698 --> 01:15:38,529  
solids they start to be to decouple from

1332  
01:15:36,609 --> 01:15:42,158  
the gas because they are too big to

1333  
01:15:38,529 --> 01:15:45,698  
follow entirely the gas when they start

1334  
01:15:42,158 --> 01:15:47,289  
to do that they start to interact with

1335  
01:15:45,698 --> 01:15:49,029  
the gas in a different way okay they

1336  
01:15:47,289 --> 01:15:51,670  
start to go at their own velocity em

1337  
01:15:49,029 --> 01:15:53,649  
feel the gas drag okay that's that this

1338  
01:15:51,670 --> 01:15:56,050  
is the reason of the gas drag that then

1339  
01:15:53,649 --> 01:15:58,960  
they feel sucked in really sucked in

1340

01:15:56,050 --> 01:16:02,619  
through the disc okay onto the star so

1341  
01:15:58,960 --> 01:16:04,840  
it is indeed a man so different sizes of

1342  
01:16:02,618 --> 01:16:07,149  
the earth particles have do have

1343  
01:16:04,840 --> 01:16:09,969  
different different velocities because

1344  
01:16:07,149 --> 01:16:12,488  
they they interact in a different way

1345  
01:16:09,969 --> 01:16:17,279  
with the environment okay also the shape

1346  
01:16:12,488 --> 01:16:29,169  
matters to some extent the composition

1347  
01:16:17,279 --> 01:16:32,050  
not and I don't think the shape also so

1348  
01:16:29,170 --> 01:16:34,210  
in this kind of studies use that from

1349  
01:16:32,050 --> 01:16:36,989  
assuming the simplest conditions and you

1350  
01:16:34,210 --> 01:16:39,579  
assume dust grains that are spheres just

1351  
01:16:36,988 --> 01:16:44,079  
compact spheres with some composition

1352  
01:16:39,579 --> 01:16:46,238  
against a mass if they grow by speaking

1353  
01:16:44,079 --> 01:16:48,130  
of small particles is very happy they

1354  
01:16:46,238 --> 01:16:49,319

are not spheres for they are fluffier

1355

01:16:48,130 --> 01:16:52,340

okay so

1356

01:16:49,319 --> 01:16:54,869

love experiments we see that when we

1357

01:16:52,340 --> 01:16:57,449

lower self when when we stick together

1358

01:16:54,869 --> 01:17:00,090

these dis particles they are not never

1359

01:16:57,449 --> 01:17:03,479

his fear but they are fluffier and then

1360

01:17:00,090 --> 01:17:06,529

again that would affect their lost yes

1361

01:17:03,479 --> 01:17:10,609

people could not an account for a

1362

01:17:06,529 --> 01:17:10,609

particle trap Orchestra

1363

01:17:17,970 --> 01:17:24,090

maybe in some in something III would

1364

01:17:20,920 --> 01:17:27,539

have to think in more details about that

1365

01:17:24,090 --> 01:17:31,720

sounds like a rolling back up on the

1366

01:17:27,539 --> 01:17:35,109

classic classically you would expect

1367

01:17:31,720 --> 01:17:37,180

that when you reach a certain size maybe

1368

01:17:35,109 --> 01:17:38,710

even assuming the simplified sphere okay



1369  
01:17:37,180 --> 01:17:40,360  
but when you reach a certain size you

1370  
01:17:38,710 --> 01:17:44,829  
start to the capital from the gas and

1371  
01:17:40,359 --> 01:17:48,279  
keep this gas track if the shady the

1372  
01:17:44,829 --> 01:17:49,988  
shape fluffier or less fluffy can matter

1373  
01:17:48,279 --> 01:17:54,969  
on this death-trap

1374  
01:17:49,988 --> 01:17:57,729  
I don't know in this detail I'd like

1375  
01:17:54,970 --> 01:18:00,340  
to thank doctor been solid for his time

1376  
01:17:57,729 --> 01:18:01,779  
tonight very excellent questions your

1377  
01:18:00,340 --> 01:18:04,360  
really deep thank you sir

1378  
01:18:01,779 --> 01:18:06,789  
I forgot to mention at the beginning

1379  
01:18:04,359 --> 01:18:11,139  
there is no observatory tonight we have

1380  
01:18:06,789 --> 01:18:14,430  
clouds rain but a lot of stuff to think

1381  
01:18:11,140 --> 01:18:14,430  
about this idea going from