2017 Astrobiology Graduate Conference

Charlottesville, VA

1
00:00:11,900 --> 00:00:10,970
I am Ryan Loomis and I'm at the

2
00:00:13,430 --> 00:00:11,910
harvard-smithsonian Center for

3
00:00:15,829 --> 00:00:13,440
Astrophysics and I'm going to be talking

4
00:00:17,420 --> 00:00:15,839
today about uncovering dust substructure

5
00:00:19,400 --> 00:00:17,430
and chemical complexity and

6
00:00:22,689 --> 00:00:19,410
protoplanetary discs so thank you sunny

7
00:00:25,340 --> 00:00:22,699
for the the introduction there so

8
00:00:27,349 --> 00:00:25,350
basically what I want to talk about

9
00:00:29,150 --> 00:00:27,359
today is with protoplanetary discs

10
00:00:31,429 --> 00:00:29,160
there's there's two main things that are

11
00:00:33,290 --> 00:00:31,439
relevant for astrobiology the first is

12
00:00:35,299 --> 00:00:33,300
that as Sonny mentioned protoplanetary

13
00:00:38,000 --> 00:00:35,309

discs are kind of the middle stage in

14
00:00:39,709 --> 00:00:38,010
between when you start off from a cloud

15
00:00:42,049 --> 00:00:39,719
and then it starts to collapse down and

16
00:00:43,220 --> 00:00:42,059
form a star protoplanetary discs forms

17
00:00:45,020 --> 00:00:43,230
from the angular momentum of the

18
00:00:46,580 --> 00:00:45,030
material around the star and that's

19
00:00:48,170 --> 00:00:46,590
going to include all the material that

20
00:00:50,690 --> 00:00:48,180
eventually becomes planets comets

21
00:00:52,549 --> 00:00:50,700
everything in the solar system so

22
00:00:54,439 --> 00:00:52,559
anything that you care about in terms of

23
00:00:56,810 --> 00:00:54,449
exoplanets etc is coming from a

24
00:00:57,799 --> 00:00:56,820
protoplanetary disk so that's the first

25
00:00:59,270 --> 00:00:57,809
thing that I'm going to talk about is

26
00:01:00,560 --> 00:00:59,280
basically what the dust substructure

27
00:01:02,510 --> 00:01:00,570
looks like and what that tells us about

28
00:01:04,549 --> 00:01:02,520
plant information the other thing that I

29
00:01:06,289 --> 00:01:04,559
want to talk about is how the planetary

30
00:01:08,480 --> 00:01:06,299
initial conditions and that includes all

31
00:01:11,000 --> 00:01:08,490
the chemical conditions are set by the

32
00:01:13,399 --> 00:01:11,010
conditions in the protoplanetary disk so

33
00:01:16,460 --> 00:01:13,409
all the chemistry all the the chemicals

34
00:01:18,590 --> 00:01:16,470
that end up onto comets that end up into

35
00:01:20,330 --> 00:01:18,600
exoplanet atmospheres etc they're coming

36
00:01:23,060 --> 00:01:20,340
from the disk so the question is really

37
00:01:24,380 --> 00:01:23,070
one of inheritance if you have chemicals

38
00:01:24,890 --> 00:01:24,390

in the diffuse clouds and the dense

39
00:01:27,740 --> 00:01:24,900
clouds

40
00:01:29,899 --> 00:01:27,750
how do those get transmitted through the

41
00:01:32,300 --> 00:01:29,909
disk and into comets and eventually

42
00:01:35,240 --> 00:01:32,310
delivered to planets because we know

43
00:01:38,929 --> 00:01:35,250
that there are things like amino acids

44
00:01:41,510 --> 00:01:38,939
or other more complex species on comets

45
00:01:42,920 --> 00:01:41,520
and we also see complex molecules in the

46
00:01:44,240 --> 00:01:42,930
fused clouds but the question is really

47
00:01:47,240 --> 00:01:44,250
what does that look like in the

48
00:01:49,010 --> 00:01:47,250
intermediate stages and what what's

49
00:01:50,330 --> 00:01:49,020
going on here and what actually gets

50
00:01:52,249 --> 00:01:50,340
incorporated into comets what does that

51
00:01:54,350 --> 00:01:52,259
look like maybe an other exoplanet solar

52
00:01:56,719 --> 00:01:54,360
exoplanet solar systems that we haven't

53
00:01:58,010 --> 00:01:56,729
had a chance to look at yet and the

54
00:01:59,420 --> 00:01:58,020
instrument that I'm going to be talking

55
00:02:01,399 --> 00:01:59,430
about that we're using for most of these

56
00:02:04,190 --> 00:02:01,409
studies is almost so Alma is the atacama

57
00:02:06,679 --> 00:02:04,200
large submillimetre right eye and it's

58
00:02:08,119 --> 00:02:06,689
down in Chile it's in the Atacama Desert

59
00:02:10,790 --> 00:02:08,129
of Chile up in the northern mountains

60
00:02:13,910 --> 00:02:10,800
there it's very high up because we want

61
00:02:15,440 --> 00:02:13,920
low water vapor to allow us to look

62
00:02:18,080 --> 00:02:15,450
using radio frequencies so

63
00:02:20,450 --> 00:02:18,090

millimeter/submillimeter frequencies to

64
00:02:22,490 --> 00:02:20,460
look at these discs that allows us to do

65
00:02:24,770 --> 00:02:22,500
two things one is by looking in the

66
00:02:26,330 --> 00:02:24,780
millimeter we're probing dust grains

67
00:02:28,400 --> 00:02:26,340
that are approximately a millimeter in

68
00:02:29,720 --> 00:02:28,410
size so these are little tiny dust

69
00:02:31,490 --> 00:02:29,730
grains that are floating around that are

70
00:02:34,160 --> 00:02:31,500
eventually going to Co s coalesce and

71
00:02:36,410 --> 00:02:34,170
form planets the other thing that we can

72
00:02:38,060 --> 00:02:36,420
do is that molecules emit in the

73
00:02:40,460 --> 00:02:38,070
millimeter and centimeter frequencies

74
00:02:42,200 --> 00:02:40,470
using a rotational spectroscopy so we

75
00:02:43,640 --> 00:02:42,210
can use a rotational spectroscopy to

76
00:02:45,650 --> 00:02:43,650
look for these molecules and see their

77
00:02:48,380 --> 00:02:45,660
signatures and fingerprint them so that

78
00:02:51,410 --> 00:02:48,390
we know what's present in these discs so

79
00:02:52,880 --> 00:02:51,420
as Sonny mentioned Alma is completely

80
00:02:54,890 --> 00:02:52,890
revolutionising our understanding of

81
00:02:56,840 --> 00:02:54,900
protoplanetary discs so this is a really

82
00:02:58,970 --> 00:02:56,850
simple cartoon of what such a disc would

83
00:03:00,290 --> 00:02:58,980
look like this is like an edge on view

84
00:03:01,730 --> 00:03:00,300
and this is a top-down view that's this

85
00:03:04,070 --> 00:03:01,740
is what we used to think was going on

86
00:03:06,950 --> 00:03:04,080
because these were observations from say

87
00:03:09,500 --> 00:03:06,960
the sub as small sorry

88
00:03:11,420 --> 00:03:09,510

it's a millimeter array in Hawaii the

89
00:03:14,660 --> 00:03:11,430
SMA which is kind of like a precursor to

90
00:03:16,160 --> 00:03:14,670
Alma so these were originally the images

91
00:03:17,290 --> 00:03:16,170
of what we thought was going on we

92
00:03:20,450 --> 00:03:17,300
thought that these disks were quite

93
00:03:22,820 --> 00:03:20,460
basically full completely filled in with

94
00:03:24,010 --> 00:03:22,830
dust and then a flared kind of gas disc

95
00:03:27,200 --> 00:03:24,020
around it

96
00:03:28,820 --> 00:03:27,210
however Alma you can see that the beam

97
00:03:30,920 --> 00:03:28,830
size here has this is like our

98
00:03:33,560 --> 00:03:30,930
resolution element has gone from this

99
00:03:35,390 --> 00:03:33,570
large beam to this absolutely tiny beam

100
00:03:38,330 --> 00:03:35,400
Alma has completely blown this out of

101
00:03:40,610 --> 00:03:38,340
the water so now we can see that we're

102
00:03:42,650 --> 00:03:40,620
originally we had no idea that there

103
00:03:44,870 --> 00:03:42,660
were all those rings now we can see all

104
00:03:47,450 --> 00:03:44,880
of these nested rings in both disks like

105
00:03:48,800 --> 00:03:47,460
HL tau and TW Hydra and we know that

106
00:03:50,840 --> 00:03:48,810
there's all this substructure in the

107
00:03:52,550 --> 00:03:50,850
disk so I'm going to talk about a new

108
00:03:54,080 --> 00:03:52,560
disk in which we've seen some of the

109
00:03:55,480 --> 00:03:54,090
substructure and what we might take away

110
00:03:57,770 --> 00:03:55,490
from that in terms of what's causing

111
00:03:59,360 --> 00:03:57,780
these gaps so there's going to be a talk

112
00:04:00,770 --> 00:03:59,370
later talking about how magnetic fields

113
00:04:02,690 --> 00:04:00,780

might play into that and there's a lot

114
00:04:04,190 --> 00:04:02,700
of possibilities as to what's going on

115
00:04:05,630 --> 00:04:04,200
with this but one thing that's been

116
00:04:07,430 --> 00:04:05,640
proposed and it was thought about for a

117
00:04:09,740 --> 00:04:07,440
long time before we actually observed it

118
00:04:12,050 --> 00:04:09,750
with Alma is that planets as they go

119
00:04:13,850 --> 00:04:12,060
around they're going to basically shift

120
00:04:15,710 --> 00:04:13,860
the dust around kind of like blow it out

121
00:04:17,150 --> 00:04:15,720
of the way and suck it in where they

122
00:04:18,500 --> 00:04:17,160
have gravitational pull on it and

123
00:04:21,050 --> 00:04:18,510
they're going to cause pressure traps

124
00:04:24,380 --> 00:04:21,060
that basically carve out these gaps and

125
00:04:26,240 --> 00:04:24,390
rings in the disk so I'm going to talk

126
00:04:27,180 --> 00:04:26,250
about this object a itaú which is a

127
00:04:28,830 --> 00:04:27,190
pretty unique

128
00:04:31,710 --> 00:04:28,840
that's been studied for a long time

129
00:04:33,240 --> 00:04:31,720
since the early 90s and one of the

130
00:04:35,820 --> 00:04:33,250
things that we look at when we look at

131
00:04:38,130 --> 00:04:35,830
stars is we're trying to understand not

132
00:04:39,540 --> 00:04:38,140
only what the properties of the star are

133
00:04:40,710 --> 00:04:39,550
but what are those properties look like

134
00:04:43,830 --> 00:04:40,720
as a function of time

135
00:04:45,450 --> 00:04:43,840
so what we do is we measure the the

136
00:04:47,460 --> 00:04:45,460
brightness of the star as a function of

137
00:04:48,900 --> 00:04:47,470
time and that tells us something about

138
00:04:50,820 --> 00:04:48,910

what's going on so this is used for the

139
00:04:52,800 --> 00:04:50,830
transit method of detecting exoplanets

140
00:04:54,420 --> 00:04:52,810
but it's also used to find a bunch of

141
00:04:57,900 --> 00:04:54,430
other features about what's going on

142
00:05:00,390 --> 00:04:57,910
with the star its magnetic field etc and

143
00:05:01,740 --> 00:05:00,400
so people were monitoring a tile back in

144
00:05:04,200 --> 00:05:01,750
the 90s and they notice that it had this

145
00:05:05,820 --> 00:05:04,210
weird short-term variability and they've

146
00:05:08,670 --> 00:05:05,830
also noticed more recently that it has a

147
00:05:09,750 --> 00:05:08,680
weird long-term dimming trend so I'm

148
00:05:12,030 --> 00:05:09,760
going to talk a little bit more about

149
00:05:14,040 --> 00:05:12,040
those later but right now the the kind

150
00:05:15,720 --> 00:05:14,050
of takeaway to start with is that people

151
00:05:18,480 --> 00:05:15,730
thought the short-term variability was

152
00:05:20,250 --> 00:05:18,490
caused by a highly inclined disc so that

153
00:05:21,830 --> 00:05:20,260
means that it's geometry when you're

154
00:05:24,510 --> 00:05:21,840
looking at it is that it's quite edge on

155
00:05:26,550 --> 00:05:24,520
and that it had this little warp in the

156
00:05:28,530 --> 00:05:26,560
center and that were piz basically

157
00:05:31,410 --> 00:05:28,540
blocking out the light that's coming

158
00:05:33,330 --> 00:05:31,420
that's that you're looking at from the

159
00:05:34,770 --> 00:05:33,340
center of the star there and that goes

160
00:05:36,300 --> 00:05:34,780
as a function of time as it rotates

161
00:05:39,240 --> 00:05:36,310
around and that's causing these little

162
00:05:40,980 --> 00:05:39,250
dips so for right now the takeaway is

163
00:05:44,070 --> 00:05:40,990

that a a tail was thought to be really

164
00:05:46,260 --> 00:05:44,080
edged on but when we started looking at

165
00:05:48,420 --> 00:05:46,270
with Alma it's clearly not edged on it's

166
00:05:50,400 --> 00:05:48,430
a inclined at about like 60 degrees so

167
00:05:53,460 --> 00:05:50,410
that's much more like this rather than

168
00:05:57,000 --> 00:05:53,470
edge-on and it's got weird features so

169
00:05:58,740 --> 00:05:57,010
just like HL tau and T do Hydra it's got

170
00:06:01,680 --> 00:05:58,750
things like this weird little flux

171
00:06:03,840 --> 00:06:01,690
bridge it's got rings here so there's

172
00:06:05,220 --> 00:06:03,850
one ring there another ring bear the

173
00:06:06,270 --> 00:06:05,230
third one's a little hard to see but you

174
00:06:08,670 --> 00:06:06,280
can see it better when I put some

175
00:06:10,260 --> 00:06:08,680
contours on it and so now you can see

176
00:06:12,090 --> 00:06:10,270
that there's there's all these rings in

177
00:06:13,710 --> 00:06:12,100
the disk which are just like HL tau and

178
00:06:15,870 --> 00:06:13,720
tau Hydra where we think that these

179
00:06:18,750 --> 00:06:15,880
might be caused by planets carving out

180
00:06:20,370 --> 00:06:18,760
those those gaps um the other thing that

181
00:06:21,750 --> 00:06:20,380
you might notice is with these contours

182
00:06:24,360 --> 00:06:21,760
you can see that it's kind of twisted in

183
00:06:26,010 --> 00:06:24,370
the center it's got that slight twist to

184
00:06:28,770 --> 00:06:26,020
it I'll come back to that as to a

185
00:06:32,820 --> 00:06:28,780
feature that we think might be involved

186
00:06:34,740 --> 00:06:32,830
with a feature with exoplanets so we

187
00:06:36,210 --> 00:06:34,750
took this data and we tried to reproduce

188
00:06:37,290 --> 00:06:36,220

it with some simple models the first

189
00:06:39,570 --> 00:06:37,300
thing we tried is basically just a

190
00:06:41,100 --> 00:06:39,580
series of concentric rings and that

191
00:06:42,780 --> 00:06:41,110
reproduces the observations really

192
00:06:44,760 --> 00:06:42,790
well the observations are in black here

193
00:06:48,000 --> 00:06:44,770
with the red dashed lines being our

194
00:06:50,940 --> 00:06:48,010
model so it fits it quite well but

195
00:06:52,890 --> 00:06:50,950
there's systemic residuals left over and

196
00:06:54,570 --> 00:06:52,900
those residuals are negative on either

197
00:06:56,880 --> 00:06:54,580
side here and positive on either side

198
00:07:00,920 --> 00:06:56,890
there and so that kind of checkerboard

199
00:07:03,210 --> 00:07:00,930
pattern we think might be caused by a

200
00:07:05,820 --> 00:07:03,220
warp in the disk and I'll get to that in

201
00:07:09,570 --> 00:07:05,830
just a second but for right now we know

202
00:07:11,010 --> 00:07:09,580
that by using this simple model we can

203
00:07:14,190 --> 00:07:11,020
show that there are rings in the disk

204
00:07:16,230 --> 00:07:14,200
and like I was talking about before

205
00:07:18,830 --> 00:07:16,240
there's rings in all these other discs

206
00:07:22,080 --> 00:07:18,840
and almost starting to show that I

207
00:07:24,840 --> 00:07:22,090
there's a whole class of objects at the

208
00:07:26,220 --> 00:07:24,850
substructure disks and all these

209
00:07:30,420 --> 00:07:26,230
substructure disks are showing evidence

210
00:07:32,760 --> 00:07:30,430
for EXO planet formation directly now

211
00:07:35,940 --> 00:07:32,770
going back to that slight twist in the

212
00:07:38,130 --> 00:07:35,950
center what we think might be going on

213
00:07:39,450 --> 00:07:38,140

here is if I kind of put up a schematic

214
00:07:41,970 --> 00:07:39,460
of what we think the system looks like

215
00:07:43,410 --> 00:07:41,980
so there's three rings there's the star

216
00:07:45,900 --> 00:07:43,420
in the center the stars align at about

217
00:07:48,360 --> 00:07:45,910
60 degrees and the Rings are at 60 if

218
00:07:50,550 --> 00:07:48,370
you guys degrees there and we're looking

219
00:07:52,190 --> 00:07:50,560
at it like this so that's what we think

220
00:07:56,660 --> 00:07:52,200
you know schematically it looks like

221
00:07:59,190 --> 00:07:56,670
however we know that because we see that

222
00:08:00,870 --> 00:07:59,200
variability that I mentioned earlier we

223
00:08:03,600 --> 00:08:00,880
know that the inner disk has to be close

224
00:08:06,540 --> 00:08:03,610
to edge on and the other thing that we

225
00:08:08,250 --> 00:08:06,550
know is that there are polar outflows

226
00:08:09,270 --> 00:08:08,260
that come out of the the Jets here I

227
00:08:11,130 --> 00:08:09,280
don't have an image over here but

228
00:08:13,350 --> 00:08:11,140
they're jets that come out and we know

229
00:08:15,870 --> 00:08:13,360
that those are anti aligned with the

230
00:08:17,430 --> 00:08:15,880
disk so rather than being whether the

231
00:08:19,050 --> 00:08:17,440
axis of the star being like this the

232
00:08:21,180 --> 00:08:19,060
axis of the star is actually aligned

233
00:08:23,280 --> 00:08:21,190
this way so this means that the inner

234
00:08:26,910 --> 00:08:23,290
disk and the outer disk are actually

235
00:08:28,980 --> 00:08:26,920
misaligned furthermore it might be

236
00:08:30,360 --> 00:08:28,990
possible that you're getting material

237
00:08:33,270 --> 00:08:30,370
that's streaming across from this

238
00:08:35,610 --> 00:08:33,280

innermost ring here and streaming across

239
00:08:38,760 --> 00:08:35,620
the gap into the star so that might be

240
00:08:43,170 --> 00:08:38,770
associated with that inner flux bridge

241
00:08:45,300 --> 00:08:43,180
as that those radial flows are moving

242
00:08:47,310 --> 00:08:45,310
around the disk then that might be

243
00:08:49,710 --> 00:08:47,320
causing this this flux bridge here now

244
00:08:51,780 --> 00:08:49,720
that's interesting because there are two

245
00:08:54,780 --> 00:08:51,790
features that this might explain so

246
00:08:56,310 --> 00:08:54,790
first of all we know that these stars

247
00:08:58,020 --> 00:08:56,320
signatures of accretion so that's

248
00:08:59,820 --> 00:08:58,030
basically where material is coming on to

249
00:09:02,550 --> 00:08:59,830
the star and feeding the star as it's

250
00:09:03,960 --> 00:09:02,560
being formed that's that's well observed

251
00:09:06,120 --> 00:09:03,970
that a lot of these stars that are in

252
00:09:09,210 --> 00:09:06,130
the disk stage still show signatures of

253
00:09:11,280 --> 00:09:09,220
accretion but if you have these gaps in

254
00:09:14,220 --> 00:09:11,290
the disk material needs to be crossing

255
00:09:16,050 --> 00:09:14,230
those gaps in order to get on to the

256
00:09:18,240 --> 00:09:16,060
star and that's a problem because the

257
00:09:21,120 --> 00:09:18,250
way that these these gaps work is there

258
00:09:23,340 --> 00:09:21,130
pressure traps so you basically got a

259
00:09:24,780 --> 00:09:23,350
gap of pressure and then everything's

260
00:09:26,520 --> 00:09:24,790
kind of pushed up on one side here and

261
00:09:28,230 --> 00:09:26,530
pushed up on the other side so to get

262
00:09:30,420 --> 00:09:28,240
material across that it requires a lot

263
00:09:32,220 --> 00:09:30,430

of energy or an instability in the disk

264
00:09:33,570 --> 00:09:32,230
and that's what we think is going on is

265
00:09:36,060 --> 00:09:33,580
that there's an instability in that

266
00:09:38,400 --> 00:09:36,070
region in between the innermost ring and

267
00:09:40,200 --> 00:09:38,410
the inner disk there must be some sort

268
00:09:42,240 --> 00:09:40,210
of instability here and that instability

269
00:09:44,040 --> 00:09:42,250
can actually be caused by planets so

270
00:09:45,870 --> 00:09:44,050
planets both carve out the gaps but they

271
00:09:47,730 --> 00:09:45,880
can also cause slight instabilities that

272
00:09:50,040 --> 00:09:47,740
allow material to stream across and

273
00:09:51,840 --> 00:09:50,050
solve the problem so this is indirect

274
00:09:54,990 --> 00:09:51,850
evidence for plant information directly

275
00:10:00,540 --> 00:09:55,000
in this disc the other thing that this

276
00:10:02,460 --> 00:10:00,550
is quite interesting for is that this

277
00:10:05,640 --> 00:10:02,470
material that's coming across as it

278
00:10:07,140 --> 00:10:05,650
comes across there it's going to go

279
00:10:09,540 --> 00:10:07,150
across the line of sight that we're

280
00:10:11,250 --> 00:10:09,550
observing so as it comes across the line

281
00:10:13,800 --> 00:10:11,260
of sight it may block out some of that

282
00:10:15,300 --> 00:10:13,810
Starlight this is thick dust so imagine

283
00:10:17,040 --> 00:10:15,310
like looking through a cloud of dust

284
00:10:18,600 --> 00:10:17,050
it's going to block out quite a bit of

285
00:10:21,750 --> 00:10:18,610
light and that might be what's causing

286
00:10:23,550 --> 00:10:21,760
this long-term dimming trend the other

287
00:10:26,520 --> 00:10:23,560
thing that's kind of interesting about

288
00:10:29,760 --> 00:10:26,530

this is okay so you see this this set up

289
00:10:31,860 --> 00:10:29,770
where we've got the disc that's aligned

290
00:10:33,720 --> 00:10:31,870
this way and that's fine because it

291
00:10:35,880 --> 00:10:33,730
doesn't really matter what alignment the

292
00:10:38,220 --> 00:10:35,890
system has relative to us because it can

293
00:10:39,510 --> 00:10:38,230
be you know all 360 degrees it doesn't

294
00:10:41,490 --> 00:10:39,520
matter for the purposes of planet

295
00:10:43,290 --> 00:10:41,500
formation what is interesting though is

296
00:10:45,660 --> 00:10:43,300
that the inner disc and the outer discs

297
00:10:46,890 --> 00:10:45,670
are misaligned and that plays a big role

298
00:10:49,320 --> 00:10:46,900
in planet formation

299
00:10:52,710 --> 00:10:49,330
one of the main observations from the

300
00:10:55,110 --> 00:10:52,720
Kepler project is that they're seeing

301
00:10:57,540 --> 00:10:55,120
one thousands of planets but - they're

302
00:10:59,550 --> 00:10:57,550
seeing that these planets I don't

303
00:11:01,830 --> 00:10:59,560
necessarily always mesh up with radial

304
00:11:03,470 --> 00:11:01,840
velocity measurements so radial velocity

305
00:11:05,970 --> 00:11:03,480
measurements are where rather than

306
00:11:08,290 --> 00:11:05,980
watching the the transit signatures as a

307
00:11:10,570 --> 00:11:08,300
planet goes across in front of the star

308
00:11:12,250 --> 00:11:10,580
you might see signatures of the wobble

309
00:11:14,590 --> 00:11:12,260
of the stars of Planet tugs on it

310
00:11:16,330 --> 00:11:14,600
so from radial velocity signatures we

311
00:11:18,640 --> 00:11:16,340
sometimes see evidence of large outer

312
00:11:21,460 --> 00:11:18,650
planets that are misaligned with the

313
00:11:23,080 --> 00:11:21,470

planets closer in towards the star so if

314
00:11:25,570 --> 00:11:23,090
you want to compare this to say our

315
00:11:27,460 --> 00:11:25,580
solar system the size here is you know

316
00:11:29,290 --> 00:11:27,470
not scale but the size here would be

317
00:11:31,420 --> 00:11:29,300
that this would be our stunt our Sun and

318
00:11:32,860 --> 00:11:31,430
then all of the interests reapply odds

319
00:11:34,870 --> 00:11:32,870
would be inside of this inner disk it's

320
00:11:37,030 --> 00:11:34,880
it's quite small only a few au in size

321
00:11:38,770 --> 00:11:37,040
and then maybe Jupiter will be about

322
00:11:39,970 --> 00:11:38,780
here Saturn will be out here and the

323
00:11:41,140 --> 00:11:39,980
Oort cloud will be out here in the

324
00:11:44,470 --> 00:11:41,150
Kuiper belt New York cloud would be out

325
00:11:47,560 --> 00:11:44,480
here so this means that basically you

326
00:11:49,150 --> 00:11:47,570
could easily have a giant outer planet

327
00:11:51,130 --> 00:11:49,160
here that's misaligned with the

328
00:11:52,780 --> 00:11:51,140
terrestrial planets and our solar system

329
00:11:53,950 --> 00:11:52,790
they're all aligned but Kepler seeing

330
00:11:56,350 --> 00:11:53,960
that there are a lot of systems where

331
00:11:57,850 --> 00:11:56,360
these are misaligned so directly having

332
00:11:59,500 --> 00:11:57,860
evidence for this sort of misaligned

333
00:12:00,970 --> 00:11:59,510
system kind of fills in some of our

334
00:12:03,330 --> 00:12:00,980
missing pieces as to how would those

335
00:12:05,230 --> 00:12:03,340
systems in Kepler actually be formed and

336
00:12:08,350 --> 00:12:05,240
we're going to be able to test this

337
00:12:10,120 --> 00:12:08,360
directly with new observations in the

338
00:12:12,340 --> 00:12:10,130

future where we're actually able to go

339
00:12:14,470 --> 00:12:12,350
even higher resolution more comparable

340
00:12:16,150 --> 00:12:14,480
to those hl2 observations and we should

341
00:12:18,610 --> 00:12:16,160
be able to see whether this is actually

342
00:12:20,680 --> 00:12:18,620
going on or not the other thing that I

343
00:12:22,480 --> 00:12:20,690
want to just briefly touch on is I

344
00:12:25,060 --> 00:12:22,490
mentioned that not only are we looking

345
00:12:26,200 --> 00:12:25,070
at the planet formation in the discs but

346
00:12:27,970 --> 00:12:26,210
we're also trying to figure out the

347
00:12:29,500 --> 00:12:27,980
chemistry that's going into these

348
00:12:32,320 --> 00:12:29,510
planets into these comets that are

349
00:12:33,880 --> 00:12:32,330
forming and for all of the you know

350
00:12:35,530 --> 00:12:33,890
chemists and biologists in the audience

351
00:12:37,300 --> 00:12:35,540
these aren't complex molecules for you

352
00:12:40,600 --> 00:12:37,310
guys but for our purposes they are

353
00:12:42,760 --> 00:12:40,610
because a stellar radiation interstellar

354
00:12:43,360 --> 00:12:42,770
radiation it'll blast apart molecules no

355
00:12:46,690 --> 00:12:43,370
problem

356
00:12:48,730 --> 00:12:46,700
so I most of the molecules that we see

357
00:12:49,930 --> 00:12:48,740
in space are quite small compared to

358
00:12:53,110 --> 00:12:49,940
what you guys are used to working with

359
00:12:54,880 --> 00:12:53,120
and for our purposes methyl methyl and

360
00:12:56,470 --> 00:12:54,890
methyl cyanide are kind of the the first

361
00:12:58,720 --> 00:12:56,480
building blocks for being able to form

362
00:13:00,340 --> 00:12:58,730
more complex species so it's really

363
00:13:02,080 --> 00:13:00,350

important to be able to trace these and

364
00:13:06,190 --> 00:13:02,090
see how do they get incorporated into

365
00:13:08,260 --> 00:13:06,200
comets and very recently we put out two

366
00:13:10,000 --> 00:13:08,270
papers that showed for the first time at

367
00:13:11,770 --> 00:13:10,010
a detection of both methanol and our

368
00:13:13,960 --> 00:13:11,780
detection of methyl cyanide now the

369
00:13:15,730 --> 00:13:13,970
problem here is so these contours are

370
00:13:18,070 --> 00:13:15,740
only one and a half sigma contours so

371
00:13:20,260 --> 00:13:18,080
these are quite weak detection zhh and

372
00:13:21,910 --> 00:13:20,270
the problem is that basically as you go

373
00:13:24,129 --> 00:13:21,920
up in complexity with MA

374
00:13:26,199 --> 00:13:24,139
heels in in space you get fewer and

375
00:13:27,759 --> 00:13:26,209
fewer of them which makes sense but that

376
00:13:29,319 --> 00:13:27,769
means that as you go to more complex

377
00:13:30,579 --> 00:13:29,329
species they're going to get weaker and

378
00:13:32,470 --> 00:13:30,589
weaker and we're not going to be able to

379
00:13:35,110 --> 00:13:32,480
see their their signatures as strongly

380
00:13:36,610 --> 00:13:35,120
so to be able to investigate complex

381
00:13:38,230 --> 00:13:36,620
chemistry and protoplanetary discs is

382
00:13:40,509 --> 00:13:38,240
going to require us to probe much much

383
00:13:43,000 --> 00:13:40,519
deeper use up more telescope time which

384
00:13:45,069 --> 00:13:43,010
is expensive etc so something that I've

385
00:13:46,870 --> 00:13:45,079
been working on is a new method to pull

386
00:13:48,430 --> 00:13:46,880
out these signals with higher

387
00:13:50,079 --> 00:13:48,440
signal-to-noise so if you're familiar

388
00:13:51,699 --> 00:13:50,089

with radar one of the things that they

389
00:13:53,079 --> 00:13:51,709
use is something called match filtering

390
00:13:54,550 --> 00:13:53,089
where basically if you know what your

391
00:13:56,019 --> 00:13:54,560
signal looks like you can convolve it

392
00:13:59,560 --> 00:13:56,029
through the data and get out and improve

393
00:14:01,840 --> 00:13:59,570
the spectrum so we've used this for our

394
00:14:03,340 --> 00:14:01,850
data so these were the observations of

395
00:14:04,870 --> 00:14:03,350
the methanol that I showed so these were

396
00:14:07,000 --> 00:14:04,880
the individual lines there they're very

397
00:14:08,769 --> 00:14:07,010
very weakly detected less than 3 Sigma

398
00:14:11,199 --> 00:14:08,779
for each of these and it's just barely

399
00:14:12,670 --> 00:14:11,209
detected in the stack spectrum but when

400
00:14:14,319 --> 00:14:12,680
we applied the match filter to it

401
00:14:16,720 --> 00:14:14,329
we get strong detections of each of the

402
00:14:20,500 --> 00:14:16,730
individual lines and it's over seven

403
00:14:22,180 --> 00:14:20,510
segment detection of the stack lines so

404
00:14:23,800 --> 00:14:22,190
that was roughly a 45 percent

405
00:14:25,360 --> 00:14:23,810
signal-to-noise boost which sounds like

406
00:14:27,340 --> 00:14:25,370
maybe a little bit but it's not too much

407
00:14:29,230 --> 00:14:27,350
but that actually translates to a factor

408
00:14:30,970 --> 00:14:29,240
of over two and observing time so we

409
00:14:32,740 --> 00:14:30,980
actually save a lot of telescope time by

410
00:14:33,939 --> 00:14:32,750
by using this method and I'm pretty

411
00:14:35,380 --> 00:14:33,949
excited we're going to be able to apply

412
00:14:36,880 --> 00:14:35,390
this to a couple other studies in the

413
00:14:39,130 --> 00:14:36,890

future and one thing that we're really

414
00:14:41,710 --> 00:14:39,140
hoping to do is apply it to spectral

415
00:14:43,420 --> 00:14:41,720
lines surveys where we can start to look

416
00:14:45,160 --> 00:14:43,430
for all sorts of different lines of

417
00:14:46,990 --> 00:14:45,170
complex species and look for ones that

418
00:14:48,819 --> 00:14:47,000
we might not have thought would be there

419
00:14:50,560 --> 00:14:48,829
in the first place already from one of

420
00:14:53,050 --> 00:14:50,570
these surveys we have five new molecular

421
00:14:56,350 --> 00:14:53,060
detection x' in that survey so just as a

422
00:14:58,240 --> 00:14:56,360
takeaways from this I using Alma

423
00:15:00,939 --> 00:14:58,250
we're basically probing two aspects of

424
00:15:02,800 --> 00:15:00,949
planet formation and comet formation one

425
00:15:04,750 --> 00:15:02,810
is we're actually probing directly what

426
00:15:06,040 --> 00:15:04,760
structure the disk looks like we saw

427
00:15:07,630 --> 00:15:06,050
that for a a Tau that it's a

428
00:15:10,090 --> 00:15:07,640
substructure disk that has those rings

429
00:15:12,040 --> 00:15:10,100
and gaps with direct evidence for planet

430
00:15:14,139 --> 00:15:12,050
formation and it's got this warp the

431
00:15:16,809 --> 00:15:14,149
warp might explain misaligned exoplanet

432
00:15:18,790 --> 00:15:16,819
systems and we're also starting to use

433
00:15:21,819 --> 00:15:18,800
Alma to find complex molecules and disks

434
00:15:24,759 --> 00:15:21,829
which proves that they're abundant

435
00:15:27,129 --> 00:15:24,769
during the processes of planet and kamek

436
00:15:29,500 --> 00:15:27,139
formation and so that means that they

437
00:15:32,259 --> 00:15:29,510
might be delivered from those comets on

438
00:15:33,639 --> 00:15:32,269

two planets in the future and then

439
00:15:35,710 --> 00:15:33,649
they're usable for all of you guys in

440
00:15:49,990 --> 00:15:35,720
all the other studies that you're doing

441
00:15:52,660 --> 00:15:50,000
so that's it questions I was just

442
00:15:54,340 --> 00:15:52,670
wondering do many hypotheses about how

443
00:15:55,150 --> 00:15:54,350
you actually get those warps how you get

444
00:15:57,370 --> 00:15:55,160
the misaligned

445
00:15:59,800 --> 00:15:57,380
discs yeah there's a couple different

446
00:16:01,810 --> 00:15:59,810
things that might be going on I ate

447
00:16:03,790 --> 00:16:01,820
house a little bit weird in this respect

448
00:16:06,060 --> 00:16:03,800
actually because it's quite easy to form

449
00:16:08,290 --> 00:16:06,070
those warps if you have a binary star

450
00:16:09,940 --> 00:16:08,300
and that's been theorized before that

451
00:16:12,820 --> 00:16:09,950
binary stars can basically cause torques

452
00:16:14,050 --> 00:16:12,830
that would allow that to happen it's a

453
00:16:16,750 --> 00:16:14,060
little bit harder to do that with a

454
00:16:18,610 --> 00:16:16,760
single star system like a Tau but

455
00:16:20,620 --> 00:16:18,620
there's a couple different mechanisms

456
00:16:21,940 --> 00:16:20,630
that that might be able to work and

457
00:16:24,400 --> 00:16:21,950
there's a few groups that are trying to

458
00:16:25,810 --> 00:16:24,410
do theory on that right now so maybe in

459
00:16:27,340 --> 00:16:25,820
about half a year we should have an

460
00:16:30,610 --> 00:16:27,350
answer for that but there are groups

461
00:16:32,920 --> 00:16:30,620
that are working on that Thanks okay

462
00:16:34,210 --> 00:16:32,930
this is a total hypothetical I'm not

463
00:16:36,070 --> 00:16:34,220

sure if you even know the answer right

464
00:16:37,930 --> 00:16:36,080
off the top of your head but um so

465
00:16:40,300 --> 00:16:37,940
obviously within this line disk you're

466
00:16:41,800 --> 00:16:40,310
gonna have a change in the way that the

467
00:16:43,030 --> 00:16:41,810
star light is able to illuminate the

468
00:16:45,100 --> 00:16:43,040
rest of the disk mm-hmm

469
00:16:47,350 --> 00:16:45,110
how do you expect that would affect like

470
00:16:48,760 --> 00:16:47,360
what chemical species can form in the

471
00:16:50,680 --> 00:16:48,770
parts of the disc that are misaligned

472
00:16:54,430 --> 00:16:50,690
with that yet index Center that's a

473
00:16:57,190 --> 00:16:54,440
great question actually um so for one

474
00:16:59,050 --> 00:16:57,200
thing on the the misaligned inner disc

475
00:17:00,940 --> 00:16:59,060
is going to process and so that's going

476
00:17:03,580 --> 00:17:00,950
to process on timescales of maybe like

477
00:17:06,640 --> 00:17:03,590
decades or so so it's not going to have

478
00:17:08,439 --> 00:17:06,650
a huge impact on say if a comet is

479
00:17:10,300 --> 00:17:08,449
forming at this distance versus that

480
00:17:12,819 --> 00:17:10,310
distance it's not going to totally

481
00:17:14,410 --> 00:17:12,829
change the cometary composition what can

482
00:17:15,790 --> 00:17:14,420
happen though is that shadowing will

483
00:17:16,990 --> 00:17:15,800
cause temperature differences in the

484
00:17:19,480 --> 00:17:17,000
disk which can't affect the chemistry

485
00:17:21,880 --> 00:17:19,490
dramatically and that also gives me a

486
00:17:24,490 --> 00:17:21,890
chance to talk about a new result that

487
00:17:25,569 --> 00:17:24,500
that our group has where we're looking

488
00:17:28,240 --> 00:17:25,579

at something slightly different with

489
00:17:30,930 --> 00:17:28,250
flares so a lot of these stars flare

490
00:17:33,460 --> 00:17:30,940
quite frequently in the x-ray and flares

491
00:17:34,660 --> 00:17:33,470
which also can be affected by shadowing

492
00:17:37,870 --> 00:17:34,670
and things like that can dramatically

493
00:17:39,670 --> 00:17:37,880
change the the chemical composition of

494
00:17:41,350 --> 00:17:39,680
the disc because those flares can

495
00:17:43,870 --> 00:17:41,360
radiate things and completely change

496
00:17:46,510 --> 00:17:43,880
them and that might also affect things

497
00:17:48,550 --> 00:17:46,520
like say amino acid stability on comets

498
00:17:49,420 --> 00:17:48,560
right because these flares can vary

499
00:17:51,010 --> 00:17:49,430
dramatically

500
00:17:56,680 --> 00:17:51,020
affect the chemistry and there and

501
00:17:58,870 --> 00:17:56,690
destroy more complex species so just you

502
00:18:01,270 --> 00:17:58,880
mentioned that you can study rotation of

503
00:18:05,170 --> 00:18:01,280
molecules with these radio telescopes

504
00:18:08,110 --> 00:18:05,180
right so is that due to redshift if yes

505
00:18:11,680 --> 00:18:08,120
can you study vibrational transitions

506
00:18:14,470 --> 00:18:11,690
electronic and if yes what's the reason

507
00:18:17,350 --> 00:18:14,480
to use other techniques to basically

508
00:18:19,870 --> 00:18:17,360
detect molecules yes radio telescopes

509
00:18:22,740 --> 00:18:19,880
are cheaper yes so um there's a couple

510
00:18:25,480 --> 00:18:22,750
different things there so first we use

511
00:18:27,940 --> 00:18:25,490
radio telescopes they are a lot cheaper

512
00:18:29,560 --> 00:18:27,950
in some respects because you can use

513
00:18:30,520 --> 00:18:29,570

radio telescopes on the ground because

514
00:18:33,550 --> 00:18:30,530
they're not as affected by the

515
00:18:36,850 --> 00:18:33,560
atmosphere infrared telescopes and other

516
00:18:39,790 --> 00:18:36,860
things need to be pushed up into the in

517
00:18:41,460 --> 00:18:39,800
orbit or in space so that's why JWST is

518
00:18:43,800 --> 00:18:41,470
going to be launched into space

519
00:18:46,600 --> 00:18:43,810
rotational spectroscopy can only probe

520
00:18:47,980 --> 00:18:46,610
molecules that are in the gas phase so

521
00:18:50,110 --> 00:18:47,990
that's great for being able to probe

522
00:18:51,790 --> 00:18:50,120
things in kind of the the gas portion of

523
00:18:53,380 --> 00:18:51,800
the disk what that doesn't what that

524
00:18:56,020 --> 00:18:53,390
means is that we aren't able to probe

525
00:19:00,400 --> 00:18:56,030
species that are on grain surfaces so in

526
00:19:02,650 --> 00:19:00,410
the very the kind of middle layer of the

527
00:19:04,000 --> 00:19:02,660
disk these molecules are freezing out

528
00:19:07,060 --> 00:19:04,010
onto grain surfaces and they're going to

529
00:19:08,710 --> 00:19:07,070
be incorporated I into the on from those

530
00:19:10,120 --> 00:19:08,720
grains into comments things like that so

531
00:19:12,070 --> 00:19:10,130
the planet formation zone is actually

532
00:19:13,480 --> 00:19:12,080
mostly frozen out on two-brains and we

533
00:19:15,430 --> 00:19:13,490
can't probe that with rotational

534
00:19:16,990 --> 00:19:15,440
spectroscopy what you might be able to

535
00:19:18,640 --> 00:19:17,000
use you could use vibrational

536
00:19:19,540 --> 00:19:18,650
spectroscopy to probe that but the

537
00:19:21,580 --> 00:19:19,550
problem is that you need to have a

538
00:19:24,010 --> 00:19:21,590

backlit source in order to do that

539
00:19:27,430 --> 00:19:24,020
efficiently so you need to have a way to

540
00:19:29,080 --> 00:19:27,440
illuminate those those icy grains from

541
00:19:31,570 --> 00:19:29,090
behind and the only way to do that is a

542
00:19:33,810 --> 00:19:31,580
very edge on disk and if you have an

543
00:19:37,420 --> 00:19:33,820
extremely edge on disk it may be like

544
00:19:39,310 --> 00:19:37,430
you know 87 degrees inclination or

545
00:19:41,920 --> 00:19:39,320
something it's a very narrow range then

546
00:19:43,690 --> 00:19:41,930
you could use JWST to to investigate

547
00:19:45,760 --> 00:19:43,700
those eye screens but it's going to

548
00:19:46,690 --> 00:19:45,770
require a very narrow set of parameters

549
00:19:48,130 --> 00:19:46,700
and that's actually one of the reasons

550
00:19:49,300 --> 00:19:48,140
that we originally looked at a a tile

551
00:19:51,100 --> 00:19:49,310
because we knew that it was supposed to

552
00:19:52,780 --> 00:19:51,110
be a John and we were hoping to find a

553
00:19:54,640 --> 00:19:52,790
system that might be able to then be

554
00:19:56,140 --> 00:19:54,650
used for data OST there's a couple other

555
00:20:00,610 --> 00:19:56,150
target systems that might be able to be

556
00:20:01,560 --> 00:20:00,620
used for that I have a question so what

557
00:20:02,910 --> 00:20:01,570
keeps the dust

558
00:20:05,550 --> 00:20:02,920
dreamers from like getting smeared out

559
00:20:07,590 --> 00:20:05,560
like why why is it rotating rigidly yeah

560
00:20:09,480 --> 00:20:07,600
that's a great question um it doesn't

561
00:20:13,830 --> 00:20:09,490
rotate rigidly that was just because I'm

562
00:20:15,300 --> 00:20:13,840
bad at PowerPoint uh and I don't do

563
00:20:17,910 --> 00:20:15,310

hydrodynamic simulations so I don't have

564
00:20:19,680 --> 00:20:17,920
anything pretty to show but in reality

565
00:20:21,570 --> 00:20:19,690
it's more of like a vortex type thing

566
00:20:23,070 --> 00:20:21,580
like I said it's an instability so you

567
00:20:25,650 --> 00:20:23,080
would get all sorts of swirling

568
00:20:28,110 --> 00:20:25,660
streamers but those streamers might be

569
00:20:30,480 --> 00:20:28,120
coherent on timescales of maybe 10 to 20

570
00:20:31,740 --> 00:20:30,490
years so enough to rotate around and

571
00:20:37,710 --> 00:20:31,750
basically cause the features that we're

572
00:20:38,970 --> 00:20:37,720
seeing so yeah so that yeah so actually

573
00:20:40,770 --> 00:20:38,980
that's that's one thing that we're

574
00:20:42,750 --> 00:20:40,780
starting to see is actually so it looks

575
00:20:44,100 --> 00:20:42,760
like that long term dimming it's

576
00:20:46,320 --> 00:20:44,110
starting to come out of that right now

577
00:20:48,420 --> 00:20:46,330
and if that is happening then it would

578
00:20:50,130 --> 00:20:48,430
basically show that it's it's a one

579
00:20:52,800 --> 00:20:50,140
feature that's moving across the face of

580
00:20:54,000 --> 00:20:52,810
the disk and also with all my

581
00:20:55,260 --> 00:20:54,010
observations with the high-resolution

582
00:20:57,150 --> 00:20:55,270
observations we'll be able to make a

583
00:20:58,800 --> 00:20:57,160
prediction then as to when it would come

584
00:21:00,090 --> 00:20:58,810
back around so we're hoping to be able

585
00:21:02,570 --> 00:21:00,100
to make an actual testable prediction