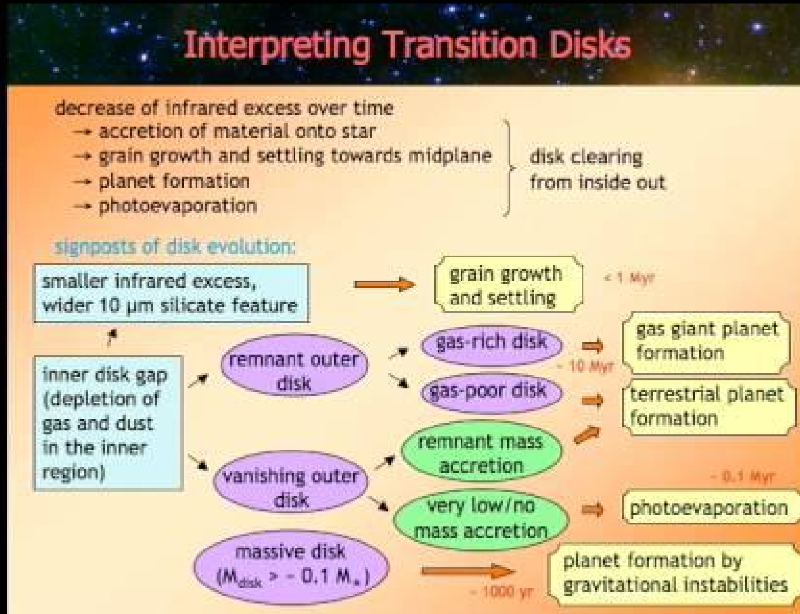
Interpreting Transition Disks
decrease of infrared excess over time
→ accretion of material onto star
→ grain growth and settling towards midplane
→ planet formation
→ photoevaporation
disk clearing from inside out
signposts of disk evolution:
smaller infrared excess, wider 10 μm silicate feature
grain growth and settling
< 1 Myr
inner disk gap (depletion of gas and dust in the inner region)
remnant outer disk
gas-rich disk
gas-poor disk
~ 10 Myr
gas giant planet formation
terrestrial planet formation
vanishing outer disk
remnant mass accretion
very low/no mass accretion
~ 0.1 Myr
photoevaporation
massive disk (M_{disk} > ~ 0.1 M_*)
~ 1000 yr
planet formation by gravitational instabilities

1
00:00:04,789 --> 00:00:03,190
good afternoon to everyone on the east

2
00:00:06,550 --> 00:00:04,799
coast and good morning to those of you

3
00:00:08,470 --> 00:00:06,560
in hawaii who have

4
00:00:10,470 --> 00:00:08,480
woken up at this early hour to join us

5
00:00:12,870 --> 00:00:10,480
some of you are probably calling in from

6
00:00:17,029 --> 00:00:12,880
uh from home we appreciate you coming

7
00:00:19,029 --> 00:00:17,039
along and i'm uh presenting from the new

8
00:00:22,230 --> 00:00:19,039
home with nai you may see some boxes

9
00:00:23,990 --> 00:00:22,240
behind us it's because we're we're uh

10
00:00:25,590 --> 00:00:24,000
we're getting up and running and marco's

11
00:00:27,429 --> 00:00:25,600
done a great job of

12
00:00:29,910 --> 00:00:27,439
moving all the technical connections

13
00:00:31,990 --> 00:00:29,920

over to this new site and

14
00:00:33,670 --> 00:00:32,000
looks like looks like it's working keep

15
00:00:35,830 --> 00:00:33,680
our fingers crossed

16
00:00:38,069 --> 00:00:35,840
so welcome to the first far seminar in a

17
00:00:39,990 --> 00:00:38,079
while i'm very glad that we have 12

18
00:00:41,030 --> 00:00:40,000
flights connecting today

19
00:00:44,630 --> 00:00:41,040
and

20
00:00:45,670 --> 00:00:44,640
this is a kickoff of

21
00:00:48,150 --> 00:00:45,680
kind of

22
00:00:50,549 --> 00:00:48,160
re-building the student and postdoctoral

23
00:00:52,310 --> 00:00:50,559
community and we'll be doing some other

24
00:00:53,670 --> 00:00:52,320
activities along with the far seminars

25
00:00:54,709 --> 00:00:53,680
which you'll get some emails from me

26
00:00:57,029 --> 00:00:54,719
about

27
00:00:59,189 --> 00:00:57,039
and i'm going to turn it over to carl

28
00:01:01,830 --> 00:00:59,199
pilcher who will be doing the

29
00:01:03,029 --> 00:01:01,840
introductions for today's far seminar

30
00:01:05,350 --> 00:01:03,039
carl

31
00:01:06,950 --> 00:01:05,360
well hello everybody as uh estelle said

32
00:01:09,350 --> 00:01:06,960
good morning good afternoon depending

33
00:01:12,469 --> 00:01:09,360
upon where you are or good really really

34
00:01:14,390 --> 00:01:12,479
early morning for hawaii

35
00:01:16,149 --> 00:01:14,400
when i became director of the nai about

36
00:01:18,390 --> 00:01:16,159
a year ago one of my first questions is

37
00:01:20,230 --> 00:01:18,400
why did we ever stop the far seminar

38
00:01:22,870 --> 00:01:20,240

because it always struck me that this

39
00:01:24,870 --> 00:01:22,880
was really a great thing to do i'm

40
00:01:27,429 --> 00:01:24,880
really really glad that we're doing it

41
00:01:29,270 --> 00:01:27,439
again i want to thank estelle for

42
00:01:31,429 --> 00:01:29,280
helping us get organized but i want to

43
00:01:33,749 --> 00:01:31,439
look at everybody who's

44
00:01:37,670 --> 00:01:33,759
participating today and pointed all of

45
00:01:41,350 --> 00:01:37,680
you and say i really would like you all

46
00:01:43,190 --> 00:01:41,360
to take ownership of this and to really

47
00:01:45,830 --> 00:01:43,200
do the organization identify the

48
00:01:48,230 --> 00:01:45,840
speakers and keep this all going and

49
00:01:49,749 --> 00:01:48,240
provide the energy for this i think that

50
00:01:52,950 --> 00:01:49,759
one of the great strengths of the

51
00:01:54,389 --> 00:01:52,960
institute and of astrobiology in general

52
00:01:56,469 --> 00:01:54,399
are the young researchers that are

53
00:01:58,389 --> 00:01:56,479
attracted into the field and so

54
00:02:00,230 --> 00:01:58,399
graduate students and postdocs i think

55
00:02:02,230 --> 00:02:00,240
are the real strengths of astrobiology

56
00:02:03,830 --> 00:02:02,240
and i would just ask you to apply some

57
00:02:06,069 --> 00:02:03,840
of your energy to this and let's keep

58
00:02:08,389 --> 00:02:06,079
this going to make it a really active

59
00:02:10,949 --> 00:02:08,399
vital seminar series

60
00:02:14,150 --> 00:02:10,959
so i really really appreciate elise and

61
00:02:16,949 --> 00:02:14,160
evgenya volunteering to lead this off so

62
00:02:19,830 --> 00:02:16,959
we will hear uh first from elise furlin

63
00:02:21,510 --> 00:02:19,840

who got her phd at cornell university

64
00:02:23,110 --> 00:02:21,520
we're going to be hearing from her about

65
00:02:25,589 --> 00:02:23,120
first steps of planet formation and

66
00:02:28,869 --> 00:02:25,599
protoplanetary discs and then we'll hear

67
00:02:30,949 --> 00:02:28,879
from agnes shkalnik on the on off nature

68
00:02:34,150 --> 00:02:30,959
of star planet interactions a probe of

69
00:02:35,430 --> 00:02:34,160
magnetized exoplanets and elise take it

70
00:02:37,110 --> 00:02:35,440
away

71
00:02:39,110 --> 00:02:37,120
okay thank you

72
00:02:40,470 --> 00:02:39,120
so uh my talk today is you introduced to

73
00:02:42,229 --> 00:02:40,480
me about the first steps of land

74
00:02:44,070 --> 00:02:42,239
information

75
00:02:45,589 --> 00:02:44,080
and this first slide has a

76
00:02:47,990 --> 00:02:45,599
pretty background it's a spitzer image

77
00:02:51,350 --> 00:02:48,000
of the orion star forming region which

78
00:02:53,670 --> 00:02:51,360
forms massive stars

79
00:02:55,589 --> 00:02:53,680
so here's a brief outline of my talk

80
00:02:58,869 --> 00:02:55,599
i'll first give a brief overview of star

81
00:03:01,589 --> 00:02:58,879
formation this structure this clearing

82
00:03:03,190 --> 00:03:01,599
then i will show you disk evolution at a

83
00:03:06,070 --> 00:03:03,200
really early age of one to two million

84
00:03:08,149 --> 00:03:06,080
years in the total star forming region

85
00:03:09,509 --> 00:03:08,159
grain growth and settling transition

86
00:03:11,430 --> 00:03:09,519
discs

87
00:03:13,910 --> 00:03:11,440
gap formation and then give you my

88
00:03:15,509 --> 00:03:13,920

conclusions

89
00:03:18,149 --> 00:03:15,519
so this is an introduction star

90
00:03:20,869 --> 00:03:18,159
formation what are the main steps so the

91
00:03:23,509 --> 00:03:20,879
earliest stage is the class zero stage

92
00:03:25,750 --> 00:03:23,519
up here where a young star is surrounded

93
00:03:28,229 --> 00:03:25,760
by a massive envelope of dust and gas

94
00:03:29,670 --> 00:03:28,239
that's in falling onto the central

95
00:03:31,670 --> 00:03:29,680
forming star

96
00:03:33,589 --> 00:03:31,680
and if you look at the spectral energy

97
00:03:35,910 --> 00:03:33,599
distribution that's a plot of land of

98
00:03:37,750 --> 00:03:35,920
lambda so flam is a flux density versus

99
00:03:38,949 --> 00:03:37,760
wavelength

100
00:03:40,869 --> 00:03:38,959
it usually peaks at very long

101
00:03:42,309 --> 00:03:40,879
wavelengths by infrareds a millimeter

102
00:03:44,789 --> 00:03:42,319
and it's shorter wavelength you'll

103
00:03:46,309 --> 00:03:44,799
usually see almost nothing or very faint

104
00:03:47,990 --> 00:03:46,319
and like you can see here images taken

105
00:03:50,149 --> 00:03:48,000
from the ground and the optical to the

106
00:03:51,910 --> 00:03:50,159
dark spot because it's so extinct well

107
00:03:54,630 --> 00:03:51,920
if you go to the mid-infrared like iraq

108
00:03:57,509 --> 00:03:54,640
spitzer images iraq and mips there's a

109
00:04:01,110 --> 00:03:59,270
the next stage is the class 1 stage

110
00:04:02,390 --> 00:04:01,120
after this brief class zero stage where

111
00:04:04,710 --> 00:04:02,400
the object is still surrounded by a

112
00:04:07,110 --> 00:04:04,720
large envelope that's falling in

113
00:04:08,949 --> 00:04:07,120

and it starts becoming more visible

114
00:04:11,350 --> 00:04:08,959
detectable with infrared wavelengths and

115
00:04:12,309 --> 00:04:11,360
also near infrared

116
00:04:14,869 --> 00:04:12,319
and

117
00:04:16,870 --> 00:04:14,879
the envelope material falls onto the

118
00:04:18,789 --> 00:04:16,880
central object that's surrounded by a

119
00:04:19,670 --> 00:04:18,799
disk and then secreted by this star in

120
00:04:21,670 --> 00:04:19,680
the middle

121
00:04:23,510 --> 00:04:21,680
and after about a hundred thousand years

122
00:04:26,070 --> 00:04:23,520
this stage is over when we have a class

123
00:04:27,350 --> 00:04:26,080
two object also known as t tori star and

124
00:04:28,469 --> 00:04:27,360
uh there the envelope is mostly

125
00:04:30,629 --> 00:04:28,479
dispersed

126
00:04:32,870 --> 00:04:30,639
and um the object is surrounded by a

127
00:04:35,350 --> 00:04:32,880
protoplanetary a circumstellar disk and

128
00:04:37,350 --> 00:04:35,360
this is the stage where we think planets

129
00:04:38,790 --> 00:04:37,360
form out of this disk that's called the

130
00:04:40,469 --> 00:04:38,800
protoplanetary

131
00:04:42,469 --> 00:04:40,479
disk that's accreting onto the central

132
00:04:45,430 --> 00:04:42,479
star and over time millions of years

133
00:04:46,870 --> 00:04:45,440
this get dissipated as well and then um

134
00:04:49,030 --> 00:04:46,880
we are left over eventually with the

135
00:04:51,590 --> 00:04:49,040
self-tree stage where the object is not

136
00:04:54,469 --> 00:04:51,600
surrounded by any material anymore and

137
00:04:56,870 --> 00:04:54,479
it's sorely contracting and once

138
00:04:59,830 --> 00:04:56,880

not in the core we talk about a messy

139
00:05:03,189 --> 00:05:01,909
so as i mentioned earlier planet form in

140
00:05:05,670 --> 00:05:03,199
this protoplanet this ground may

141
00:05:07,189 --> 00:05:05,680
sequence stars and the two sort of main

142
00:05:09,270 --> 00:05:07,199
i wouldn't miss even conflicting but two

143
00:05:10,390 --> 00:05:09,280
scenarios one is the core accretion here

144
00:05:11,830 --> 00:05:10,400
on the left and one is the

145
00:05:14,070 --> 00:05:11,840
discrimination instabilities on the

146
00:05:15,909 --> 00:05:14,080
right and the core equations is this

147
00:05:18,230 --> 00:05:15,919
typical scenario where you think grains

148
00:05:19,830 --> 00:05:18,240
stick collide grow and form larger

149
00:05:21,670 --> 00:05:19,840
particles the larger particles settle

150
00:05:24,469 --> 00:05:21,680
down to the disk midplane where it's

151
00:05:26,150 --> 00:05:24,479
denser cooler and they start

152
00:05:28,070 --> 00:05:26,160
colliding more and coagulating and

153
00:05:29,990 --> 00:05:28,080
forming larger larger bodies

154
00:05:31,430 --> 00:05:30,000
finally we form these protoplanets they

155
00:05:33,430 --> 00:05:31,440
have a diameter about a thousand

156
00:05:35,510 --> 00:05:33,440
kilometers and once they're big enough

157
00:05:37,430 --> 00:05:35,520
they can start creating gaps and sweep

158
00:05:39,510 --> 00:05:37,440
up the gas

159
00:05:41,830 --> 00:05:39,520
in the surroundings and that's how we

160
00:05:43,590 --> 00:05:41,840
think giant planets form in this core

161
00:05:45,430 --> 00:05:43,600
accretion scenario well this

162
00:05:47,670 --> 00:05:45,440
gravitational abilities

163
00:05:49,990 --> 00:05:47,680

well it requires massive disks usually

164
00:05:52,390 --> 00:05:50,000
about a tenth of the mass of the star so

165
00:05:54,550 --> 00:05:52,400
here you can see it's about

166
00:05:55,670 --> 00:05:54,560
about a tenth of a solar mass for solar

167
00:05:58,230 --> 00:05:55,680
mass star

168
00:06:00,550 --> 00:05:58,240
and when a disk is massive enough we can

169
00:06:02,550 --> 00:06:00,560
have formation of fragments and that can

170
00:06:04,309 --> 00:06:02,560
form giant plants on a very rapid time

171
00:06:06,390 --> 00:06:04,319
scale so about less than a thousand

172
00:06:08,150 --> 00:06:06,400
years maybe a few hundred years

173
00:06:10,070 --> 00:06:08,160
and there's also this relatively new

174
00:06:11,670 --> 00:06:10,080
hybrid scenario where we still have a

175
00:06:13,749 --> 00:06:11,680
massive disk forming gravitational

176
00:06:15,189 --> 00:06:13,759
stabilities but then we can have core

177
00:06:17,029 --> 00:06:15,199
creation going on

178
00:06:19,430 --> 00:06:17,039
by concentrating particles in these

179
00:06:21,029 --> 00:06:19,440
higher density regions so it's a

180
00:06:22,629 --> 00:06:21,039
gravitational stability but at the same

181
00:06:25,990 --> 00:06:22,639
time core creation going on in grain

182
00:06:29,270 --> 00:06:27,590
we talk about protoplanetary disk and

183
00:06:32,230 --> 00:06:29,280
disk structure

184
00:06:35,909 --> 00:06:32,240
um one thing again here is this icd plot

185
00:06:37,350 --> 00:06:35,919
new fnu versus lambda and uh one thing

186
00:06:39,670 --> 00:06:37,360
to keep in mind that later on i show you

187
00:06:41,590 --> 00:06:39,680
mid-infrared spectra in the wavelengths

188
00:06:43,670 --> 00:06:41,600

range from

189
00:06:46,070 --> 00:06:43,680
about uh four to thirty microns or point

190
00:06:47,749 --> 00:06:46,080
one to ten uh samples the inner disk

191
00:06:50,790 --> 00:06:47,759
and what we are sampling in the mid

192
00:06:53,749 --> 00:06:50,800
infrared is just the upper disk layer

193
00:06:55,189 --> 00:06:53,759
here so it's usually just this uh heated

194
00:06:57,830 --> 00:06:55,199
upper layer that's can be seen also here

195
00:07:00,150 --> 00:06:57,840
on the right top side up here um where's

196
00:07:02,550 --> 00:07:00,160
this hot surface layer that's heated by

197
00:07:04,469 --> 00:07:02,560
the star and emits this optically thin

198
00:07:06,469 --> 00:07:04,479
emission that we can see here this is a

199
00:07:08,550 --> 00:07:06,479
silicate emission feature 10 micron and

200
00:07:10,550 --> 00:07:08,560
20 micron and we also sample this kind

201
00:07:12,390 --> 00:07:10,560
of upper layer of the so called mid

202
00:07:13,909 --> 00:07:12,400
plane of the optically thick part so we

203
00:07:15,589 --> 00:07:13,919
just sample sort of the upper layers

204
00:07:17,110 --> 00:07:15,599
here in this

205
00:07:18,629 --> 00:07:17,120
in the middle of red and what i will not

206
00:07:20,390 --> 00:07:18,639
go into this talk like to see down here

207
00:07:22,150 --> 00:07:20,400
says gas structure that would be a

208
00:07:23,830 --> 00:07:22,160
totally different topic or in a way they

209
00:07:26,870 --> 00:07:23,840
are related but here

210
00:07:28,950 --> 00:07:26,880
concentrate on the dust structure

211
00:07:30,950 --> 00:07:28,960
so as far as this evolution goes we know

212
00:07:33,589 --> 00:07:30,960
from observations both from the ground

213
00:07:35,909 --> 00:07:33,599

so jh khaled's ground-based measurements

214
00:07:37,510 --> 00:07:35,919
infrared from about one to three micron

215
00:07:40,950 --> 00:07:37,520
and then this iraq mix that's from the

216
00:07:43,749 --> 00:07:40,960
spitzer space telescope 3 to 8 micron 24

217
00:07:46,550 --> 00:07:43,759
micron that this fraction decreases with

218
00:07:49,029 --> 00:07:46,560
age so at about like 1 million years or

219
00:07:51,110 --> 00:07:49,039
less we have about 80 90 disc fraction

220
00:07:53,270 --> 00:07:51,120
and then it really goes down with age

221
00:07:55,270 --> 00:07:53,280
kind of rapidly 5 million years just a

222
00:07:58,790 --> 00:07:55,280
few maybe 10 20

223
00:08:00,550 --> 00:07:58,800
and then if you go to older and older

224
00:08:03,189 --> 00:08:00,560
systems about 10 million years there's

225
00:08:04,950 --> 00:08:03,199
basically no more disk left so this

226
00:08:06,390 --> 00:08:04,960
survived for about 10 million years is a

227
00:08:09,749 --> 00:08:06,400
kind of a larger dispersion so that's

228
00:08:11,909 --> 00:08:09,759
the time we have to form planets

229
00:08:13,510 --> 00:08:11,919
and when looking at the median sed media

230
00:08:15,110 --> 00:08:13,520
stack for energy distribution such as

231
00:08:17,270 --> 00:08:15,120
taking a start from region that has a

232
00:08:20,150 --> 00:08:17,280
lot of young stars taking the median of

233
00:08:22,629 --> 00:08:20,160
those and uh normalizing them at some

234
00:08:24,309 --> 00:08:22,639
wavelength uh we can see here on this

235
00:08:26,950 --> 00:08:24,319
dash line here one million years old you

236
00:08:28,550 --> 00:08:26,960
have an axis of 8 micron 24 microns and

237
00:08:30,869 --> 00:08:28,560
then when we go over to a region for

238
00:08:33,190 --> 00:08:30,879

example at 4 million years the decrease

239
00:08:35,430 --> 00:08:33,200
is kind of sharp at 8 micron and

240
00:08:37,269 --> 00:08:35,440
at 8 million years the decrease is much

241
00:08:39,269 --> 00:08:37,279
more pronounced at shorter wavelengths

242
00:08:41,029 --> 00:08:39,279
than it's a longer wavelength so that

243
00:08:43,430 --> 00:08:41,039
points towards evolution of the disk

244
00:08:45,430 --> 00:08:43,440
from inside out so whatever happens in

245
00:08:48,150 --> 00:08:45,440
the disk and dissipated

246
00:08:50,150 --> 00:08:48,160
it evolves or the processes are faster

247
00:08:52,550 --> 00:08:50,160
and into this and then eventually to

248
00:08:57,509 --> 00:08:54,790
what causes this this clearing

249
00:08:59,590 --> 00:08:57,519
well one standard there is four main

250
00:09:00,550 --> 00:08:59,600
processes and those are combination of

251
00:09:01,750 --> 00:09:00,560
those so don't say that they're

252
00:09:04,070 --> 00:09:01,760
exclusive but these are the main

253
00:09:06,150 --> 00:09:04,080
processes we have in mind accretion

254
00:09:07,829 --> 00:09:06,160
under the star grain growth and settling

255
00:09:09,829 --> 00:09:07,839
plant formation and photo evaporation i

256
00:09:11,110 --> 00:09:09,839
will briefly talk about those four here

257
00:09:13,590 --> 00:09:11,120
so you have in mind what are the

258
00:09:15,750 --> 00:09:13,600
processes that cause this clearing

259
00:09:17,750 --> 00:09:15,760
and uh accretion well material gets

260
00:09:20,070 --> 00:09:17,760
secreted onto the star on those

261
00:09:21,910 --> 00:09:20,080
magnetospheric accretion columns and

262
00:09:23,750 --> 00:09:21,920
over time it just decreases there's a

263
00:09:25,750 --> 00:09:23,760

large scanner we see like this mass

264
00:09:27,910 --> 00:09:25,760
accretion rate versus age there's a

265
00:09:29,590 --> 00:09:27,920
large scatter at each individual age but

266
00:09:31,430 --> 00:09:29,600
overall in time at least when we go to

267
00:09:32,790 --> 00:09:31,440
10 million years and older it's really

268
00:09:34,389 --> 00:09:32,800
decreased

269
00:09:35,829 --> 00:09:34,399
there's less and less material available

270
00:09:37,990 --> 00:09:35,839
to be

271
00:09:39,509 --> 00:09:38,000
done with brain growth and settling well

272
00:09:41,269 --> 00:09:39,519
like i mentioned earlier too that with

273
00:09:42,870 --> 00:09:41,279
this core equation scenario we think

274
00:09:44,949 --> 00:09:42,880
that rain starts sticking growing

275
00:09:47,750 --> 00:09:44,959
forming larger bodies and then settle

276
00:09:50,630 --> 00:09:47,760
down to the disc midplane and the disc

277
00:09:53,269 --> 00:09:50,640
the the grain growth in this is thought

278
00:09:55,110 --> 00:09:53,279
to be faster in the inner disc and also

279
00:09:56,870 --> 00:09:55,120
faster for larger grains larger grains

280
00:09:59,430 --> 00:09:56,880
of course they're heavier they settle

281
00:10:00,710 --> 00:09:59,440
faster and then um it's also fascinating

282
00:10:02,550 --> 00:10:00,720
this will have higher densities and

283
00:10:04,710 --> 00:10:02,560
higher orbital speed so i think it's

284
00:10:06,070 --> 00:10:04,720
more sticking and growing happening

285
00:10:08,470 --> 00:10:06,080
and what happens here with again this

286
00:10:10,710 --> 00:10:08,480
lcd lambda flanders

287
00:10:12,790 --> 00:10:10,720
versus lambda plot um

288
00:10:15,269 --> 00:10:12,800

with simulations over time starting the

289
00:10:17,190 --> 00:10:15,279
simulation we have this excess 10 micron

290
00:10:19,910 --> 00:10:17,200
and the excess medium thread and then

291
00:10:22,069 --> 00:10:19,920
over time it just decreases and comes

292
00:10:24,389 --> 00:10:22,079
more and lower just because the grain

293
00:10:26,150 --> 00:10:24,399
grows start the grains grow and saddle

294
00:10:28,630 --> 00:10:26,160
and this becomes less and less flared

295
00:10:30,470 --> 00:10:28,640
like in this view here so it is this

296
00:10:33,110 --> 00:10:30,480
less flare and then emits less in the

297
00:10:34,470 --> 00:10:33,120
mid-infrared

298
00:10:36,870 --> 00:10:34,480
and the plan information of this

299
00:10:39,990 --> 00:10:36,880
scenarios correction discrimination's

300
00:10:41,910 --> 00:10:40,000
abilities and once a major larger planet

301
00:10:44,230 --> 00:10:41,920
forms it's just clearing out a gap in

302
00:10:46,949 --> 00:10:44,240
the disk and what happens is that the

303
00:10:49,190 --> 00:10:46,959
disk inside of that gap is being

304
00:10:51,030 --> 00:10:49,200
accreted onto the star so we create an

305
00:10:53,269 --> 00:10:51,040
inner disc hole so if you see a disc

306
00:10:55,750 --> 00:10:53,279
with a large in a disc hole i think well

307
00:10:57,350 --> 00:10:55,760
maybe a planet formed in there and uh

308
00:10:58,550 --> 00:10:57,360
caused there for the inner discs to be

309
00:11:00,710 --> 00:10:58,560
accreted and sort of prevents the

310
00:11:01,990 --> 00:11:00,720
material from outside to come in and get

311
00:11:03,430 --> 00:11:02,000
accredited

312
00:11:04,790 --> 00:11:03,440
at least does that set a particular

313
00:11:08,230 --> 00:11:04,800

scale

314
00:11:09,829 --> 00:11:08,240
yes the snow lines you can't have two

315
00:11:11,350 --> 00:11:09,839
smaller numbers

316
00:11:13,509 --> 00:11:11,360
because if you're going to form plants

317
00:11:16,310 --> 00:11:13,519
quickly they have to at least the disc

318
00:11:18,069 --> 00:11:16,320
has to extend down to a few of you

319
00:11:19,509 --> 00:11:18,079
so if you had a whole lot of half a

320
00:11:22,310 --> 00:11:19,519
negative

321
00:11:23,990 --> 00:11:22,320
that's probably not easily explained by

322
00:11:26,310 --> 00:11:24,000
except for the gravitational stability

323
00:11:29,350 --> 00:11:26,320
for example if the conditions are right

324
00:11:31,990 --> 00:11:30,550
yeah because yeah you need higher

325
00:11:34,470 --> 00:11:32,000
density but yeah

326
00:11:36,870 --> 00:11:34,480
at lower window speeds but it's it's

327
00:11:40,310 --> 00:11:36,880
tumor q parameter it says when a disk is

328
00:11:41,910 --> 00:11:40,320
unstable and yeah yeah

329
00:11:43,190 --> 00:11:41,920
but i knew that prior migration at the

330
00:11:45,430 --> 00:11:43,200
same time so the whole picture's a

331
00:11:46,230 --> 00:11:45,440
little bit muddied by that too

332
00:11:48,069 --> 00:11:46,240
so

333
00:11:50,069 --> 00:11:48,079
it's not as easy to explain usually like

334
00:11:52,310 --> 00:11:50,079
we try to figure out things but they're

335
00:11:54,150 --> 00:11:52,320
obviously complications too

336
00:11:55,990 --> 00:11:54,160
and again i said this cold might be a

337
00:11:57,430 --> 00:11:56,000
planet but any sort of a natural way to

338
00:11:59,430 --> 00:11:57,440

produce an innovative call and that sort

339
00:12:01,110 --> 00:11:59,440
of operation and that's just because a

340
00:12:03,670 --> 00:12:01,120
young star is known to meet uv and

341
00:12:05,269 --> 00:12:03,680
x-rays and they start heating the upper

342
00:12:07,750 --> 00:12:05,279
layer of the disc

343
00:12:10,389 --> 00:12:07,760
and a little biograph down here and

344
00:12:12,069 --> 00:12:10,399
what happens is that the uv photons and

345
00:12:14,470 --> 00:12:12,079
probably extras are mostly uv photons

346
00:12:16,629 --> 00:12:14,480
ionize the gas so the gas is a hot

347
00:12:18,150 --> 00:12:16,639
temperature has a high thermal speed and

348
00:12:20,310 --> 00:12:18,160
if at a certain radius that thermal

349
00:12:22,550 --> 00:12:20,320
speed is higher than the escape velocity

350
00:12:24,550 --> 00:12:22,560
at that distance the gas is blown away

351
00:12:25,829 --> 00:12:24,560
this is evaporative flow let's start at

352
00:12:28,069 --> 00:12:25,839
a certain radius so this is sort of a

353
00:12:30,870 --> 00:12:28,079
simulation with sigma that's the surface

354
00:12:32,470 --> 00:12:30,880
density versus radius and at the start

355
00:12:34,550 --> 00:12:32,480
it's okay it's usually decreasing with

356
00:12:35,350 --> 00:12:34,560
radius and then when the simulation is

357
00:12:37,590 --> 00:12:35,360
run

358
00:12:39,430 --> 00:12:37,600
once this photo evaporation sets in the

359
00:12:41,110 --> 00:12:39,440
disc is cleared out in the inner part

360
00:12:42,790 --> 00:12:41,120
much quicker than the other part because

361
00:12:45,590 --> 00:12:42,800
starting at this radius here current

362
00:12:47,670 --> 00:12:45,600
simulation one eu the

363
00:12:49,269 --> 00:12:47,680

dust and gas is blown away and then the

364
00:12:50,949 --> 00:12:49,279
inner disk accretes and then eventually

365
00:12:53,670 --> 00:12:50,959
the outer disk is very quickly eroded

366
00:12:57,590 --> 00:12:53,680
too so that causes quick disappearance

367
00:13:01,430 --> 00:12:59,670
so what do we observe now

368
00:13:03,750 --> 00:13:01,440
so focus mainly on tauros that's a star

369
00:13:05,829 --> 00:13:03,760
forming region that's about 140 parsecs

370
00:13:08,150 --> 00:13:05,839
away it's nearby about one to two

371
00:13:10,389 --> 00:13:08,160
million years old has no extinction

372
00:13:12,310 --> 00:13:10,399
which is good so we can really see a lot

373
00:13:15,110 --> 00:13:12,320
of the young stars they're not obscured

374
00:13:16,550 --> 00:13:15,120
by dust and it has uh it's more isolated

375
00:13:18,550 --> 00:13:16,560
star formations are not really in a lot

376
00:13:20,550 --> 00:13:18,560
of big clumps and it forms low mass

377
00:13:22,550 --> 00:13:20,560
stars so less than about um two solar

378
00:13:24,150 --> 00:13:22,560
masses and this is just sort of a sample

379
00:13:25,750 --> 00:13:24,160
it's kind of hard to see but you're not

380
00:13:27,430 --> 00:13:25,760
supposed to look at all the detailed

381
00:13:29,829 --> 00:13:27,440
names it's just to show you sample of

382
00:13:31,990 --> 00:13:29,839
irs spectra this is spitzer rs an

383
00:13:35,110 --> 00:13:32,000
instrument that takes spectra from 5 to

384
00:13:37,190 --> 00:13:35,120
36 micron down here after touring stars

385
00:13:39,430 --> 00:13:37,200
we observe tutorial stars in taurus and

386
00:13:41,670 --> 00:13:39,440
it's just a large diversity of spectra

387
00:13:43,829 --> 00:13:41,680
and some of them have this very strong

388
00:13:45,829 --> 00:13:43,839

well 10 micron and 20 micro silicate

389
00:13:48,230 --> 00:13:45,839
emission feature and then overall we can

390
00:13:50,150 --> 00:13:48,240
see how does the scd change from five

391
00:13:52,550 --> 00:13:50,160
micron to the longest wavelength about

392
00:13:53,750 --> 00:13:52,560
40 micron and this is quite a diversity

393
00:13:55,910 --> 00:13:53,760
of objects

394
00:13:57,750 --> 00:13:55,920
which i will explain why

395
00:14:00,069 --> 00:13:57,760
so one thing we started looking into is

396
00:14:01,269 --> 00:14:00,079
dust growth in those disks and like i

397
00:14:02,949 --> 00:14:01,279
mentioned there is a tenant twenty

398
00:14:04,870 --> 00:14:02,959
micron feature they kind of tell us

399
00:14:06,870 --> 00:14:04,880
something about grain growth the sizes

400
00:14:08,710 --> 00:14:06,880
of grains when we have this is just the

401
00:14:11,430 --> 00:14:08,720
model grains or

402
00:14:13,509 --> 00:14:11,440
astronomical silicates and uh when we

403
00:14:16,069 --> 00:14:13,519
look at small sizes point one one micron

404
00:14:19,430 --> 00:14:16,079
we see a nice peak strong peakly shaped

405
00:14:21,829 --> 00:14:19,440
feature at 10 micron and 20 micron but

406
00:14:23,430 --> 00:14:21,839
then when the grains grow like 2.5 for 6

407
00:14:25,110 --> 00:14:23,440
micron you see that this feature gets

408
00:14:27,269 --> 00:14:25,120
sort of washed out they become much less

409
00:14:28,470 --> 00:14:27,279
pronounced and much wider up than a 6

410
00:14:32,230 --> 00:14:28,480
micron

411
00:14:33,990 --> 00:14:32,240
totally washed out we don't see any more

412
00:14:36,629 --> 00:14:34,000
emission feature

413
00:14:39,750 --> 00:14:36,639

and what we did is to fit about 70

414
00:14:42,470 --> 00:14:39,760
tutorial star spectra uh with um

415
00:14:44,949 --> 00:14:42,480
actually opacities derived from the lab

416
00:14:46,790 --> 00:14:44,959
and what we found is that um in the

417
00:14:49,350 --> 00:14:46,800
inner disc which is about a few tenths

418
00:14:51,509 --> 00:14:49,360
of a year relatively warm the typical

419
00:14:53,269 --> 00:14:51,519
mass fraction of large grains is about

420
00:14:55,189 --> 00:14:53,279
fifty percent when we talk about large

421
00:14:57,509 --> 00:14:55,199
grains here it's about five microns so

422
00:14:59,030 --> 00:14:57,519
so about fifty percent um

423
00:15:00,310 --> 00:14:59,040
and here is this number versus

424
00:15:02,389 --> 00:15:00,320
formulated

425
00:15:05,350 --> 00:15:02,399
warm large grain mass fraction but it's

426
00:15:06,470 --> 00:15:05,360
40 50 60 percent well in the outer disk

427
00:15:08,629 --> 00:15:06,480
and that's characterized by cooler

428
00:15:11,350 --> 00:15:08,639
temperatures of fuel the mass fraction

429
00:15:13,350 --> 00:15:11,360
is actually much smaller so about like

430
00:15:14,629 --> 00:15:13,360
most discs have only about a 10

431
00:15:17,189 --> 00:15:14,639
mass fraction of

432
00:15:19,269 --> 00:15:17,199
cold large grains and there are a few

433
00:15:20,470 --> 00:15:19,279
objects that have a 100

434
00:15:22,470 --> 00:15:20,480
of um

435
00:15:25,110 --> 00:15:22,480
cold large grains there so it's a large

436
00:15:26,629 --> 00:15:25,120
variety between systems so

437
00:15:28,470 --> 00:15:26,639
it's not that we can say that it's a

438
00:15:30,389 --> 00:15:28,480

really uh continuous evolution towards

439
00:15:32,230 --> 00:15:30,399
large grains but already indicating in

440
00:15:34,710 --> 00:15:32,240
the inner disc where we think processes

441
00:15:36,550 --> 00:15:34,720
occur faster the grains apparently are

442
00:15:39,750 --> 00:15:36,560
growing can i tell the difference

443
00:15:42,870 --> 00:15:39,760
between refractory grains and

444
00:15:44,870 --> 00:15:42,880
uh yeah because these are all because

445
00:15:46,629 --> 00:15:44,880
isis have also characteristic features

446
00:15:48,389 --> 00:15:46,639
but some grains might have some ice

447
00:15:49,350 --> 00:15:48,399
coating on them yes because that would

448
00:15:51,670 --> 00:15:49,360
be something that would be interesting

449
00:15:54,470 --> 00:15:51,680
to see that there's like five to five a

450
00:15:55,509 --> 00:15:54,480
year you'd expect a big difference

451
00:15:59,350 --> 00:15:55,519
yeah

452
00:16:00,150 --> 00:15:59,360
the same five micron amorphous

453
00:16:02,230 --> 00:16:00,160
uh

454
00:16:03,269 --> 00:16:02,240
five mark five micropores are more per

455
00:16:06,230 --> 00:16:03,279
square

456
00:16:08,150 --> 00:16:06,240
but you can't tell whether those are

457
00:16:10,150 --> 00:16:08,160
hand or do not have knives

458
00:16:11,509 --> 00:16:10,160
no but with this fit we already get good

459
00:16:12,870 --> 00:16:11,519
fits just having that component if

460
00:16:14,790 --> 00:16:12,880
there's an extra ice component maybe it

461
00:16:16,310 --> 00:16:14,800
might improve the fit a little bit but

462
00:16:18,230 --> 00:16:16,320
already with this five micron grain you

463
00:16:19,670 --> 00:16:18,240

can set our larger grains

464
00:16:20,949 --> 00:16:19,680
but you kind of yeah we cannot exclude

465
00:16:23,110 --> 00:16:20,959
there might be some other components in

466
00:16:24,310 --> 00:16:23,120
those fits but i'm supposedly minor

467
00:16:27,110 --> 00:16:24,320
because we really get good fits just

468
00:16:28,790 --> 00:16:27,120
with those five hybrid grains

469
00:16:30,790 --> 00:16:28,800
and again we sample the disk the higher

470
00:16:33,430 --> 00:16:30,800
layers anyway too so the ices are more

471
00:16:35,350 --> 00:16:33,440
in the inner plane

472
00:16:37,350 --> 00:16:35,360
and the next thing we looked at is like

473
00:16:39,110 --> 00:16:37,360
uh dust settling because as mentioned

474
00:16:40,389 --> 00:16:39,120
earlier dust growth is supposedly

475
00:16:42,389 --> 00:16:40,399
accompanied by

476
00:16:45,670 --> 00:16:42,399
settling and these are just a few model

477
00:16:47,829 --> 00:16:45,680
plots that are kind of visible here um

478
00:16:49,990 --> 00:16:47,839
so different models of accretion disks

479
00:16:51,749 --> 00:16:50,000
and uh this epsilon parameter here is

480
00:16:54,629 --> 00:16:51,759
like the purple line is kind of

481
00:16:56,550 --> 00:16:54,639
correlated blue line and yellow line and

482
00:16:59,030 --> 00:16:56,560
red line there's a different settling in

483
00:17:02,550 --> 00:16:59,040
the upper disk layer so for example this

484
00:17:04,230 --> 00:17:02,560
epsilon 0.1 means it's a 10 depletion of

485
00:17:05,669 --> 00:17:04,240
small grains in the upper disk

486
00:17:08,069 --> 00:17:05,679
atmosphere due to

487
00:17:10,309 --> 00:17:08,079
grains growth and settling

488
00:17:13,110 --> 00:17:10,319

and again here this the immediate

489
00:17:16,150 --> 00:17:13,120
axis decreases sharply with saddling

490
00:17:18,069 --> 00:17:16,160
and what we did then is to take all 85

491
00:17:20,870 --> 00:17:18,079
class 2 objects to torrey stars in

492
00:17:22,549 --> 00:17:20,880
taurus and compute the spectral indices

493
00:17:25,429 --> 00:17:22,559
again islam that lambda versus lambda

494
00:17:28,470 --> 00:17:25,439
blood looking at a slope between 6 and

495
00:17:30,070 --> 00:17:28,480
13 micron and then between 13 and 25

496
00:17:31,990 --> 00:17:30,080
micron which is supposedly

497
00:17:33,510 --> 00:17:32,000
characteristic of the continuum of the

498
00:17:35,590 --> 00:17:33,520
optically thick part so not this

499
00:17:37,750 --> 00:17:35,600
optically thin layer but more the

500
00:17:40,150 --> 00:17:37,760
optically thick layer is just underneath

501
00:17:41,029 --> 00:17:40,160
the disc atmosphere

502
00:17:43,029 --> 00:17:41,039
so more

503
00:17:45,669 --> 00:17:43,039
level of how much has the disc settled

504
00:17:46,950 --> 00:17:45,679
so if it's more flat than flare

505
00:17:49,909 --> 00:17:46,960
and this

506
00:17:51,830 --> 00:17:49,919
13 to 25 micron versus the 6 to 13 macro

507
00:17:53,669 --> 00:17:51,840
spectral index are just a slope those

508
00:17:56,390 --> 00:17:53,679
open diamonds are the data points and

509
00:17:57,990 --> 00:17:56,400
those color dots here are the models so

510
00:18:00,310 --> 00:17:58,000
models with different inclination angles

511
00:18:03,669 --> 00:18:00,320
so down here you can see that key is a

512
00:18:06,549 --> 00:18:03,679
different inclination from 75 to 11

513
00:18:08,630 --> 00:18:06,559

degrees and this size of those dots

514
00:18:10,310 --> 00:18:08,640
represent different depletion factors of

515
00:18:11,190 --> 00:18:10,320
dust in the upper layer so the large

516
00:18:14,390 --> 00:18:11,200
dots

517
00:18:16,310 --> 00:18:14,400
is 0.001 is a point one percent

518
00:18:17,830 --> 00:18:16,320
depletion or a factor of a thousand

519
00:18:20,310 --> 00:18:17,840
deviations

520
00:18:21,830 --> 00:18:20,320
so a thousand times less small screens

521
00:18:24,710 --> 00:18:21,840
in the upper layer than

522
00:18:26,150 --> 00:18:24,720
the standard mixture that we assume

523
00:18:27,669 --> 00:18:26,160
and it's not a perfect match but most

524
00:18:29,430 --> 00:18:27,679
data points definitely agree more with

525
00:18:31,430 --> 00:18:29,440
the larger dots and not with the small

526
00:18:33,110 --> 00:18:31,440
ones that are kind of up here so that's

527
00:18:34,950 --> 00:18:33,120
already an indication that in taurus at

528
00:18:37,669 --> 00:18:34,960
one to two million years

529
00:18:39,350 --> 00:18:37,679
we have the saddling of kind of factors

530
00:18:41,669 --> 00:18:39,360
a hundred to a thousand in the upper

531
00:18:43,510 --> 00:18:41,679
layers so indication it is dust settling

532
00:18:46,070 --> 00:18:43,520
going on in those

533
00:18:48,070 --> 00:18:46,080
lists and most likely grain growth and

534
00:18:51,590 --> 00:18:48,080
combining that with the previous result

535
00:18:53,190 --> 00:18:51,600
to then correlate the warmly warm large

536
00:18:55,510 --> 00:18:53,200
grain mass fraction

537
00:18:57,270 --> 00:18:55,520
with this spectral index system from 13

538
00:18:58,710 --> 00:18:57,280

to 31 microns in a longer wavelength

539
00:19:00,549 --> 00:18:58,720
spectral index it's a little bit of a

540
00:19:01,669 --> 00:19:00,559
scatter plot and

541
00:19:03,110 --> 00:19:01,679
if you just compute the correlation

542
00:19:05,990 --> 00:19:03,120
coefficient it's sort of a very very

543
00:19:07,430 --> 00:19:06,000
weak correlation that you have a trend

544
00:19:10,230 --> 00:19:07,440
of greater

545
00:19:12,630 --> 00:19:10,240
warm large grain mass fraction with more

546
00:19:14,310 --> 00:19:12,640
settling or negative spectral index so

547
00:19:15,990 --> 00:19:14,320
it shows this kind of correlated the

548
00:19:18,070 --> 00:19:16,000
dust settling and the dust growth as

549
00:19:20,390 --> 00:19:18,080
expected too but it's already it is one

550
00:19:22,390 --> 00:19:20,400
to two million years but this large

551
00:19:24,230 --> 00:19:22,400
dispersion definitely has to be taken

552
00:19:26,070 --> 00:19:24,240
into account and that definitely shows

553
00:19:27,990 --> 00:19:26,080
that systematically like a continuous

554
00:19:29,590 --> 00:19:28,000
dust processing which just does growth

555
00:19:32,390 --> 00:19:29,600
settling and that's it there might be

556
00:19:34,549 --> 00:19:32,400
some radial mixing some turbulence this

557
00:19:36,390 --> 00:19:34,559
was magneto rotational instabilities

558
00:19:37,990 --> 00:19:36,400
taking place and maybe even planet

559
00:19:40,310 --> 00:19:38,000
forming larger bodies it might totally

560
00:19:41,909 --> 00:19:40,320
sweep up the inner region and then it

561
00:19:43,750 --> 00:19:41,919
gets probably replenished with smaller

562
00:19:45,350 --> 00:19:43,760
brains so there might be a lot of

563
00:19:47,029 --> 00:19:45,360

process going on so they're very dynamic

564
00:19:51,750 --> 00:19:47,039
systems so it's not just a linear

565
00:19:53,510 --> 00:19:51,760
evolution from small mix to large grains

566
00:19:55,830 --> 00:19:53,520
and going back to the index two spectral

567
00:19:58,870 --> 00:19:55,840
index plots so the long wavelength 13 to

568
00:20:01,110 --> 00:19:58,880
25 micron versus that six to 13 micron

569
00:20:02,789 --> 00:20:01,120
index um it's kind of a larger scale

570
00:20:05,029 --> 00:20:02,799
here and there's certain outliers up

571
00:20:07,190 --> 00:20:05,039
there that i would like to point out to

572
00:20:09,029 --> 00:20:07,200
that have a 6 to 13 microns so the

573
00:20:11,190 --> 00:20:09,039
shorter wavelength index roughly

574
00:20:12,310 --> 00:20:11,200
comparable to the bulk of t tourist

575
00:20:15,270 --> 00:20:12,320
stars here

576
00:20:17,270 --> 00:20:15,280
but they're 13 to 25 micron index so the

577
00:20:19,350 --> 00:20:17,280
longer wavelength side is much steeper

578
00:20:21,029 --> 00:20:19,360
so they have this kind of steep rise and

579
00:20:23,190 --> 00:20:21,039
hope you can see that too that between

580
00:20:26,549 --> 00:20:23,200
so basically around 13 to 25 micron

581
00:20:28,070 --> 00:20:26,559
longer wavelength this is deep rise

582
00:20:30,390 --> 00:20:28,080
and what we call these objects are

583
00:20:32,870 --> 00:20:30,400
transition disks that have cleared out

584
00:20:34,310 --> 00:20:32,880
inner disks so in this plot

585
00:20:36,549 --> 00:20:34,320
this dash land represents the

586
00:20:38,070 --> 00:20:36,559
photosphere and then those curves here

587
00:20:40,630 --> 00:20:38,080
are the different uh

588
00:20:42,710 --> 00:20:40,640

rest spectra and especially kokuta four

589
00:20:45,750 --> 00:20:42,720
dm tau have basically photospheric

590
00:20:47,510 --> 00:20:45,760
emission at the shortest wavelength and

591
00:20:50,149 --> 00:20:47,520
then they really take off at the longer

592
00:20:51,830 --> 00:20:50,159
wavelength which shows us most likely

593
00:20:53,110 --> 00:20:51,840
that we have an inner disc hole and

594
00:20:55,190 --> 00:20:53,120
there's still an outer disc that's

595
00:20:56,789 --> 00:20:55,200
remaining and some kind of individual

596
00:20:58,870 --> 00:20:56,799
differences yes you can already see jim

597
00:21:00,630 --> 00:20:58,880
ryje has some kind of axis above the

598
00:21:02,470 --> 00:21:00,640
photosphere the shortest wavelength so

599
00:21:05,590 --> 00:21:02,480
it has some material most likely in a

600
00:21:07,430 --> 00:21:05,600
disk while kokuta iv and dientau de fly

601
00:21:09,669 --> 00:21:07,440
almost perfectly on the photosphere so

602
00:21:11,510 --> 00:21:09,679
it's really cleared out in our disk

603
00:21:13,270 --> 00:21:11,520
and one of them is a creating like dm

604
00:21:14,310 --> 00:21:13,280
one isn't so there's some differences

605
00:21:17,270 --> 00:21:14,320
there too

606
00:21:20,149 --> 00:21:17,280
point out later so this is a schematic

607
00:21:22,149 --> 00:21:20,159
here um that means the science center of

608
00:21:24,070 --> 00:21:22,159
how we interpret again these transition

609
00:21:26,070 --> 00:21:24,080
disks so when we have a star with no

610
00:21:28,230 --> 00:21:26,080
disk in a logarithmic plot brightness

611
00:21:30,390 --> 00:21:28,240
versus wavelength or no if no versus

612
00:21:32,310 --> 00:21:30,400
wavelength sort of a straight line rally

613
00:21:34,870 --> 00:21:32,320

jeans tail then when we have a star with

614
00:21:37,029 --> 00:21:34,880
a full disc it has this emission the

615
00:21:39,430 --> 00:21:37,039
macro emission tiny macro emission and

616
00:21:41,669 --> 00:21:39,440
just a lot of access in the infrared

617
00:21:43,350 --> 00:21:41,679
while if you have these transition discs

618
00:21:44,390 --> 00:21:43,360
uh they have this photospheric emission

619
00:21:46,230 --> 00:21:44,400
shorter wavelength just because there's

620
00:21:49,190 --> 00:21:46,240
no material there's a hole in there and

621
00:21:51,190 --> 00:21:49,200
then access it along its wavelengths

622
00:21:54,149 --> 00:21:51,200
and what we did is compute models for

623
00:21:55,590 --> 00:21:54,159
these objects who could afford gmri dm

624
00:21:57,590 --> 00:21:55,600
time but now there are a couple others

625
00:21:59,430 --> 00:21:57,600
that have been modeled in detail

626
00:22:01,029 --> 00:21:59,440
and there's some differences like uh

627
00:22:03,510 --> 00:22:01,039
goku therefore doesn't have a creation

628
00:22:05,830 --> 00:22:03,520
going on when dm tau and gmrij they do

629
00:22:08,470 --> 00:22:05,840
have gas accretion onto the star so even

630
00:22:11,350 --> 00:22:08,480
though dm tao like you see up here

631
00:22:13,990 --> 00:22:11,360
has photospheric emissions apparently no

632
00:22:16,310 --> 00:22:14,000
dust grains in the inner disc

633
00:22:18,390 --> 00:22:16,320
there is likely some gas still streaming

634
00:22:20,870 --> 00:22:18,400
in and accreting onto the star

635
00:22:22,789 --> 00:22:20,880
and kuguta 4 has a negligible outer disk

636
00:22:25,510 --> 00:22:22,799
so probably it's just a very tiny ring

637
00:22:27,510 --> 00:22:25,520
of material but both dmta and gmri they

638
00:22:29,750 --> 00:22:27,520

do have other disks

639
00:22:31,669 --> 00:22:29,760
certainly give us clues about what

640
00:22:33,590 --> 00:22:31,679
caused these inner disc holes what is

641
00:22:36,070 --> 00:22:33,600
happening in those disks

642
00:22:37,909 --> 00:22:36,080
and it is a little flow chart

643
00:22:41,350 --> 00:22:37,919
oopsies on top there well

644
00:22:43,190 --> 00:22:41,360
this little flowchart to um

645
00:22:45,110 --> 00:22:43,200
show what can we

646
00:22:46,789 --> 00:22:45,120
what clues can be used to interpret

647
00:22:48,870 --> 00:22:46,799
those transition disks

648
00:22:50,870 --> 00:22:48,880
and one thing is if we see a smaller

649
00:22:51,830 --> 00:22:50,880
infrared access and a wider 10 micron

650
00:22:53,190 --> 00:22:51,840
feature

651
00:22:55,510 --> 00:22:53,200
then that's definitely for sure

652
00:22:57,430 --> 00:22:55,520
indication for grain growth and settling

653
00:22:59,590 --> 00:22:57,440
and models and both observations they

654
00:23:01,190 --> 00:22:59,600
tell us that happens in a time scale of

655
00:23:03,190 --> 00:23:01,200
less than a million years so that's

656
00:23:04,870 --> 00:23:03,200
expected and we observe that and that's

657
00:23:07,350 --> 00:23:04,880
a definite cool

658
00:23:10,630 --> 00:23:07,360
then if we see it in this gap with

659
00:23:12,149 --> 00:23:10,640
depletion of dust and gas in your disk

660
00:23:13,669 --> 00:23:12,159
if at the same time we have a ram and

661
00:23:16,070 --> 00:23:13,679
outer disk

662
00:23:18,149 --> 00:23:16,080
then we can form planets and just down

663
00:23:20,070 --> 00:23:18,159

to this castle a lot of gas left over we

664
00:23:22,710 --> 00:23:20,080
can form a gas giant if there's not much

665
00:23:24,789 --> 00:23:22,720
gas then just from terrestrial planets

666
00:23:27,430 --> 00:23:24,799
and um if you think about core accretion

667
00:23:28,950 --> 00:23:27,440
it probably takes 10 20 30 million years

668
00:23:30,230 --> 00:23:28,960
but as long as there's an outer disk

669
00:23:32,470 --> 00:23:30,240
there

670
00:23:34,230 --> 00:23:32,480
we have hope for plant formation but

671
00:23:35,909 --> 00:23:34,240
it's just a vanishing outer disk so very

672
00:23:38,630 --> 00:23:35,919
little like in coconut kokuto worst case

673
00:23:40,549 --> 00:23:38,640
we have almost no outer disk left over

674
00:23:42,630 --> 00:23:40,559
if there's still mass equation left over

675
00:23:44,470 --> 00:23:42,640
so we have accretion from in the inner

676
00:23:47,510 --> 00:23:44,480
this cold probably gas

677
00:23:49,510 --> 00:23:47,520
um we could still have planets for me

678
00:23:50,870 --> 00:23:49,520
but yeah so there's some material out

679
00:23:53,029 --> 00:23:50,880
there that

680
00:23:54,230 --> 00:23:53,039
come from planets but most likely maybe

681
00:23:56,149 --> 00:23:54,240
only terrestrial because it's not that

682
00:23:57,350 --> 00:23:56,159
much material out there but if at the

683
00:23:59,909 --> 00:23:57,360
same time we have very low mass

684
00:24:01,830 --> 00:23:59,919
secretion then one interpretation is

685
00:24:04,310 --> 00:24:01,840
photo evaporation so these are not

686
00:24:06,470 --> 00:24:04,320
really exclusive formation scenarios

687
00:24:08,390 --> 00:24:06,480
it's just so more or less what to keep

688
00:24:10,070 --> 00:24:08,400

in mind that photo evaporation really

689
00:24:12,070 --> 00:24:10,080
requires you to have a

690
00:24:13,669 --> 00:24:12,080
very small outer disk and also very low

691
00:24:15,110 --> 00:24:13,679
mass secretion just so that the disk can

692
00:24:17,510 --> 00:24:15,120
be blown away otherwise if you have mass

693
00:24:19,830 --> 00:24:17,520
accretion then the photo evaporated flow

694
00:24:21,350 --> 00:24:19,840
will have an influence on the disk

695
00:24:23,590 --> 00:24:21,360
and finally no matter what you see in

696
00:24:24,230 --> 00:24:23,600
terms of the micro feature or in terms

697
00:24:25,750 --> 00:24:24,240
of

698
00:24:28,950 --> 00:24:25,760
um

699
00:24:30,710 --> 00:24:28,960
in terms of uh depletion of thinner disk

700
00:24:32,549 --> 00:24:30,720
uh the if you have a massive outer disc

701
00:24:35,909 --> 00:24:32,559
then we come from planets

702
00:24:37,269 --> 00:24:35,919
by gravitational stabilities

703
00:24:39,110 --> 00:24:37,279
and yeah in the last few minutes of my

704
00:24:42,070 --> 00:24:39,120
talk i will show you some very new

705
00:24:44,070 --> 00:24:42,080
results on the um also again to identify

706
00:24:46,230 --> 00:24:44,080
the disc evolution in protoplanetary

707
00:24:47,669 --> 00:24:46,240
disk and one is to look at the degree of

708
00:24:51,350 --> 00:24:47,679
dust settling so again the spectral

709
00:24:53,110 --> 00:24:51,360
index between 13 and 31 micron and the

710
00:24:54,870 --> 00:24:53,120
equivalent width of the 10 micron

711
00:24:57,510 --> 00:24:54,880
feature up here so that's basically the

712
00:24:59,669 --> 00:24:57,520
spectral index on the y-axis and on the

713
00:25:01,830 --> 00:24:59,679

x-axis is the strength of this 10 micron

714
00:25:03,669 --> 00:25:01,840
feature here and just in this box just

715
00:25:06,230 --> 00:25:03,679
results from models where is a certain

716
00:25:07,909 --> 00:25:06,240
spread in one direction due to up here

717
00:25:09,750 --> 00:25:07,919
we find more flare discs down here we

718
00:25:12,310 --> 00:25:09,760
find more cell disk and this other

719
00:25:14,310 --> 00:25:12,320
spread is due to different stellar

720
00:25:16,310 --> 00:25:14,320
parameters like or this parameter

721
00:25:18,950 --> 00:25:16,320
creation inclination angle

722
00:25:20,310 --> 00:25:18,960
and what we did is then to look at what

723
00:25:22,310 --> 00:25:20,320
you have just one to two million years

724
00:25:24,070 --> 00:25:22,320
like a fukus taurus comedian of and of

725
00:25:25,830 --> 00:25:24,080
you who's off core the slightly

726
00:25:27,430 --> 00:25:25,840
different ages and just to have again

727
00:25:29,029 --> 00:25:27,440
this plot of this factory next versus

728
00:25:30,789 --> 00:25:29,039
equivalent with

729
00:25:32,630 --> 00:25:30,799
and where for example taurus we have a

730
00:25:35,110 --> 00:25:32,640
lot of objects in this box which is

731
00:25:36,470 --> 00:25:35,120
expected for full protoplanetary disks

732
00:25:38,789 --> 00:25:36,480
there are some outliers on the right

733
00:25:40,549 --> 00:25:38,799
hand side chameleon there even more and

734
00:25:42,789 --> 00:25:40,559
if you use off core even though you have

735
00:25:44,230 --> 00:25:42,799
like very small number statistics a lot

736
00:25:47,110 --> 00:25:44,240
of objects

737
00:25:49,510 --> 00:25:47,120
out here and um what what are these

738
00:25:52,230 --> 00:25:49,520

objects they have spectral indices 13 to

739
00:25:54,549 --> 00:25:52,240
20 31 micron that are roughly the same

740
00:25:56,310 --> 00:25:54,559
as typical full accretion disks but they

741
00:25:57,830 --> 00:25:56,320
have this micro feature that is really

742
00:25:59,269 --> 00:25:57,840
really strong

743
00:26:01,350 --> 00:25:59,279
and when we interpret that i did this

744
00:26:03,430 --> 00:26:01,360
little sketch this is sort of a disc

745
00:26:05,110 --> 00:26:03,440
around the star and if we have a full

746
00:26:07,350 --> 00:26:05,120
disc so never mind it's kind of ringing

747
00:26:09,029 --> 00:26:07,360
here it's for example like this digital

748
00:26:11,110 --> 00:26:09,039
where we just have the micro feature and

749
00:26:13,990 --> 00:26:11,120
a certain slope of the icd

750
00:26:15,750 --> 00:26:14,000
well if we start forming a gap with some

751
00:26:18,470 --> 00:26:15,760
optically thin material

752
00:26:21,110 --> 00:26:18,480
then the macro feature is expected to be

753
00:26:22,549 --> 00:26:21,120
stronger than just a normal full disc

754
00:26:24,710 --> 00:26:22,559
just because we have this extra optical

755
00:26:27,269 --> 00:26:24,720
symmetry that emits especially a tan and

756
00:26:28,950 --> 00:26:27,279
then a 20 micron so that's how we start

757
00:26:30,950 --> 00:26:28,960
interpreting these

758
00:26:35,430 --> 00:26:30,960
outliers in those diagrams there might

759
00:26:39,909 --> 00:26:37,830
so so i'll probably give you quickly my

760
00:26:41,430 --> 00:26:39,919
conclusions so first of all we know that

761
00:26:43,590 --> 00:26:41,440
this dissipation is about 10 million

762
00:26:45,830 --> 00:26:43,600
years it goes from the inside out

763
00:26:48,230 --> 00:26:45,840

relatively fast grain growth and

764
00:26:50,230 --> 00:26:48,240
settling is observed at

765
00:26:51,750 --> 00:26:50,240
about 1 million years old in at an age

766
00:26:53,669 --> 00:26:51,760
of 1 million years in a tourist

767
00:26:55,190 --> 00:26:53,679
suffering region transition days seem to

768
00:26:57,269 --> 00:26:55,200
be very interesting to understand all

769
00:26:58,549 --> 00:26:57,279
this process of disk clearing from grain

770
00:27:00,710 --> 00:26:58,559
growth photo evaporation planet

771
00:27:02,070 --> 00:27:00,720
formation and these last clouds i showed

772
00:27:04,149 --> 00:27:02,080
you with the medium fret spectral index

773
00:27:05,430 --> 00:27:04,159
versus the equivalent width of the micro

774
00:27:07,269 --> 00:27:05,440
features of the strength of the micro

775
00:27:09,430 --> 00:27:07,279
feature might indicate the opening of

776
00:27:11,750 --> 00:27:09,440
gaps in some of those objects

777
00:27:13,029 --> 00:27:11,760
and at this age of one million years

778
00:27:15,110 --> 00:27:13,039
when we're talking about first steps of

779
00:27:16,549 --> 00:27:15,120
planet formation well when we see grain

780
00:27:19,110 --> 00:27:16,559
growth and settling that could really be

781
00:27:20,549 --> 00:27:19,120
the early steps of core accretion again

782
00:27:21,909 --> 00:27:20,559
it might not be a linear process but at

783
00:27:23,269 --> 00:27:21,919
least we start having those larger

784
00:27:25,750 --> 00:27:23,279
grains that are required for the

785
00:27:28,230 --> 00:27:25,760
coercion process and if we see in our

786
00:27:30,070 --> 00:27:28,240
gaps and holes like we fully cleared out

787
00:27:32,310 --> 00:27:30,080
regions it might really point that

788
00:27:33,990 --> 00:27:32,320

planets formed already by gravitational

789
00:27:39,269 --> 00:27:34,000
instabilities

790
00:27:43,350 --> 00:27:41,269
thank you elise and we just have a few

791
00:27:45,669 --> 00:27:43,360
minutes for questions i'd like to ask

792
00:27:48,470 --> 00:27:45,679
everyone to raise your hand in webex if

793
00:27:52,870 --> 00:27:48,480
you have a question so we can uh make it

794
00:27:54,149 --> 00:27:52,880
go smoothly and uh let's see

795
00:27:56,789 --> 00:27:54,159
yeah i think were there some questions

796
00:27:59,510 --> 00:27:57,750
and

797
00:28:01,990 --> 00:27:59,520
any questions i'll just open it up to

798
00:28:04,310 --> 00:28:02,000
the floor at least can we can we do it

799
00:28:08,470 --> 00:28:04,320
verbally from here

800
00:28:13,669 --> 00:28:11,269
at least can you tell us why um you have

801
00:28:16,549 --> 00:28:13,679
there are some stars with

802
00:28:18,549 --> 00:28:16,559
rapid rates of gas secretion that

803
00:28:20,470 --> 00:28:18,559
seem to have very little dust associated

804
00:28:22,070 --> 00:28:20,480
with the gas and other stars with

805
00:28:24,149 --> 00:28:22,080
comparable amounts of gas secretion

806
00:28:26,389 --> 00:28:24,159
where there seems to be

807
00:28:29,110 --> 00:28:26,399
lots of dust the full complement of warm

808
00:28:31,110 --> 00:28:29,120
dust why why is there this seemingly

809
00:28:33,830 --> 00:28:31,120
dramatic difference between rapidly

810
00:28:35,510 --> 00:28:33,840
feeding stars with and without dust

811
00:28:37,029 --> 00:28:35,520
could be a fact of grain growth because

812
00:28:39,750 --> 00:28:37,039
once the grains are really large they

813
00:28:43,430 --> 00:28:39,760

sort of decoupled from the gas

814
00:28:47,430 --> 00:28:45,990
so that anymore be one thing

815
00:28:48,870 --> 00:28:47,440
but um

816
00:28:50,710 --> 00:28:48,880
yeah usually with the foot of vibration

817
00:28:52,549 --> 00:28:50,720
for example that when grades are really

818
00:28:55,430 --> 00:28:52,559
small they get blown out with the gas at

819
00:28:57,110 --> 00:28:55,440
the same time but once um the grains

820
00:28:59,669 --> 00:28:57,120
have grown then it just affects the gas

821
00:29:01,110 --> 00:28:59,679
and the dust remains behind

822
00:29:02,950 --> 00:29:01,120
so yeah

823
00:29:04,549 --> 00:29:02,960
then also the story about binaries and

824
00:29:07,110 --> 00:29:04,559
so on who knows that that might be

825
00:29:12,310 --> 00:29:07,120
applied thanks to

826
00:29:12,320 --> 00:29:19,350
any other questions from many sites

827
00:29:23,350 --> 00:29:21,590
thank you elise and i'm going to turn

828
00:29:26,149 --> 00:29:23,360
the floor back over to carl who will

829
00:29:28,389 --> 00:29:26,159
introduce our next presenter okay i also

830
00:29:30,549 --> 00:29:28,399
realized i did a bad job of introducing

831
00:29:32,070 --> 00:29:30,559
the presenter who just spoke i didn't

832
00:29:34,310 --> 00:29:32,080
mention where she was from and she was

833
00:29:36,149 --> 00:29:34,320
speaking to us from ucla of course as a

834
00:29:38,149 --> 00:29:36,159
member of the ucla team

835
00:29:39,990 --> 00:29:38,159
and our next speaker is of daniel

836
00:29:42,389 --> 00:29:40,000
shkolnik who is speaking to us from the

837
00:29:44,549 --> 00:29:42,399
moon room at the university of hawaii i

838
00:29:46,870 --> 00:29:44,559

remember that room well

839
00:29:48,389 --> 00:29:46,880
and as i mentioned she's going to be

840
00:29:50,230 --> 00:29:48,399
talking to us

841
00:29:52,149 --> 00:29:50,240
about the on off nature of star planet

842
00:29:58,149 --> 00:29:52,159
interactions a probe of magnetized

843
00:29:58,159 --> 00:30:09,430
i think your mic is muted

844
00:30:19,029 --> 00:30:12,630
you may be muted on your end can you

845
00:30:23,350 --> 00:30:20,630
hello i didn't touch it since you and i

846
00:30:25,269 --> 00:30:23,360
last spoke we hear you now so it worked

847
00:30:28,070 --> 00:30:25,279
itself out

848
00:30:29,909 --> 00:30:28,080
mocking technology go ahead thanks

849
00:30:31,510 --> 00:30:29,919
i'm amazed that this is actually working

850
00:30:33,190 --> 00:30:31,520
for all of us sitting here they're

851
00:30:34,710 --> 00:30:33,200
talking so

852
00:30:36,870 --> 00:30:34,720
i'm sitting here on a pile of rabbits

853
00:30:40,149 --> 00:30:36,880
feet and all sorts of you know poorly

854
00:30:41,669 --> 00:30:40,159
clovers with my fingers crossed

855
00:30:43,110 --> 00:30:41,679
um all right well thank you so much for

856
00:30:44,870 --> 00:30:43,120
the invitation i'm going to talk about

857
00:30:46,549 --> 00:30:44,880
work that i've been doing with my

858
00:30:49,029 --> 00:30:46,559
collaborators gordon walker david

859
00:30:51,350 --> 00:30:49,039
bollander fingal gu and martin kerster

860
00:30:54,230 --> 00:30:51,360
for the last five years or so

861
00:30:57,430 --> 00:30:54,240
and we'll be talking about the later

862
00:30:58,950 --> 00:30:57,440
stages of kind of the end stage of what

863
00:31:01,269 --> 00:30:58,960

elise was talking about the actual

864
00:31:03,190 --> 00:31:01,279
planets i'll talk about the planets that

865
00:31:05,029 --> 00:31:03,200
have been detected and what kind of

866
00:31:07,909 --> 00:31:05,039
follow-up research we can be done that

867
00:31:10,549 --> 00:31:07,919
can be done with them

868
00:31:13,190 --> 00:31:10,559
so in brief for those of you who don't

869
00:31:14,710 --> 00:31:13,200
follow you know the news the emails that

870
00:31:16,830 --> 00:31:14,720
we get every week or so about the new

871
00:31:19,510 --> 00:31:16,840
planets that are discovered now there's

872
00:31:22,230 --> 00:31:19,520
217 planets as of last night i didn't

873
00:31:24,789 --> 00:31:22,240
check this morning um but this is a

874
00:31:26,549 --> 00:31:24,799
simple plot of them where on the y-axis

875
00:31:28,549 --> 00:31:26,559
it's just the names of the stars so

876
00:31:31,029 --> 00:31:28,559
there's so many they're hard to read and

877
00:31:32,789 --> 00:31:31,039
on the x-axis is the orbital um

878
00:31:34,070 --> 00:31:32,799
semi-major axis

879
00:31:35,990 --> 00:31:34,080
and so the stars that i'm going to be

880
00:31:37,350 --> 00:31:36,000
talking about are called hot jupiters

881
00:31:39,750 --> 00:31:37,360
and it's these in

882
00:31:40,950 --> 00:31:39,760
inward inside planets that orbit very

883
00:31:43,750 --> 00:31:40,960
tightly

884
00:31:45,990 --> 00:31:43,760
here's a zoomed in shot of them

885
00:31:48,230 --> 00:31:46,000
and so their general characteristics are

886
00:31:50,070 --> 00:31:48,240
that they're about a jupiter mass

887
00:31:51,990 --> 00:31:50,080
and that their distance from the star is

888
00:31:53,909 --> 00:31:52,000

less than 0.1 a u where an a u is the

889
00:31:56,070 --> 00:31:53,919
distance between the star between the

890
00:31:58,389 --> 00:31:56,080
sun and the earth and their orbital

891
00:31:59,909 --> 00:31:58,399
periods are very short less than 10 days

892
00:32:01,509 --> 00:31:59,919
and the stars in particular that i'll be

893
00:32:03,830 --> 00:32:01,519
talking about are actually less than

894
00:32:06,230 --> 00:32:03,840
seven days orbital periods so people

895
00:32:08,549 --> 00:32:06,240
have called them roasters close and

896
00:32:10,630 --> 00:32:08,559
giant planets hot jupiters all kind of

897
00:32:12,389 --> 00:32:10,640
be tossing those around

898
00:32:13,190 --> 00:32:12,399
um but needless to say they're very very

899
00:32:15,669 --> 00:32:13,200
hot

900
00:32:17,909 --> 00:32:15,679
and uh also our only real options for

901
00:32:21,029 --> 00:32:17,919
doing a lot of follow-up science for on

902
00:32:23,350 --> 00:32:21,039
extrasolar planets right now

903
00:32:24,630 --> 00:32:23,360
and here's just an image to scale just

904
00:32:27,350 --> 00:32:24,640
to give you an idea of how different

905
00:32:29,509 --> 00:32:27,360
this is from jupiter and the sun

906
00:32:31,590 --> 00:32:29,519
this is hd179949

907
00:32:34,070 --> 00:32:31,600
a star that i'll be spending most of my

908
00:32:36,230 --> 00:32:34,080
time talking about and it has a massive

909
00:32:38,310 --> 00:32:36,240
planet at about one jupiter mass

910
00:32:41,669 --> 00:32:38,320
orbiting at three days and a distance of

911
00:32:43,350 --> 00:32:41,679
0.05 a yu now put that in context

912
00:32:46,070 --> 00:32:43,360
relative to the star that's only seven

913
00:32:47,830 --> 00:32:46,080

stellar radii away it's very very close

914
00:32:51,990 --> 00:32:47,840
and compare that with jupiter which is

915
00:32:57,669 --> 00:32:53,750
and so current observations of hot

916
00:32:59,590 --> 00:32:57,679
jupiters are really amazing and i think

917
00:33:01,190 --> 00:32:59,600
it's fascinating what we can learn about

918
00:33:03,190 --> 00:33:01,200
hot jupiters

919
00:33:04,070 --> 00:33:03,200
in the last five years

920
00:33:05,430 --> 00:33:04,080
um

921
00:33:07,830 --> 00:33:05,440
so for instance i'll just run through

922
00:33:09,750 --> 00:33:07,840
these quickly in a transiting system

923
00:33:12,149 --> 00:33:09,760
where the planet is actually eclipsing

924
00:33:14,549 --> 00:33:12,159
the star as in this cartoon or this uh

925
00:33:16,149 --> 00:33:14,559
artistic impression here you can see the

926
00:33:17,990 --> 00:33:16,159
absorption through the planet's

927
00:33:21,029 --> 00:33:18,000
atmosphere and so this has been detected

928
00:33:22,789 --> 00:33:21,039
the sodium lyman alpha this hydrogen

929
00:33:24,870 --> 00:33:22,799
oxygen and carbon absorption has been

930
00:33:25,710 --> 00:33:24,880
detected in the atmosphere of the planet

931
00:33:27,830 --> 00:33:25,720
around

932
00:33:29,509 --> 00:33:27,840
hd209458 but you've probably heard

933
00:33:30,549 --> 00:33:29,519
something about

934
00:33:32,470 --> 00:33:30,559
and so there's you know that

935
00:33:35,430 --> 00:33:32,480
interpretations about huge mass loss and

936
00:33:38,549 --> 00:33:35,440
runaway evaporation because we detect so

937
00:33:40,710 --> 00:33:38,559
much more of this than we would expect

938
00:33:41,990 --> 00:33:40,720

given the size of the atmosphere of the

939
00:33:43,669 --> 00:33:42,000
planet

940
00:33:45,669 --> 00:33:43,679
another interesting thing is the thermal

941
00:33:47,269 --> 00:33:45,679
emission that has been studied on

942
00:33:48,789 --> 00:33:47,279
several planets

943
00:33:50,630 --> 00:33:48,799
using the spitzer space telescope and

944
00:33:54,230 --> 00:33:50,640
this is actually measuring temperatures

945
00:33:55,990 --> 00:33:54,240
on the day night side of the planets

946
00:33:58,950 --> 00:33:56,000
and getting a weather really a kind of a

947
00:34:00,870 --> 00:33:58,960
weather map of these hot jupiters

948
00:34:01,830 --> 00:34:00,880
a very recent detection by tinnetti

949
00:34:03,909 --> 00:34:01,840
adele

950
00:34:05,269 --> 00:34:03,919
has actually shown also with spitzer

951
00:34:06,990 --> 00:34:05,279
that there's water in the atmosphere

952
00:34:10,629 --> 00:34:07,000
around the planet

953
00:34:12,470 --> 00:34:10,639
hd189733 also a transiting planet

954
00:34:14,869 --> 00:34:12,480
so one thing about these three

955
00:34:16,710 --> 00:34:14,879
top ones is that all of these are done

956
00:34:19,270 --> 00:34:16,720
with space telescopes i mean you really

957
00:34:21,190 --> 00:34:19,280
need the high sensitivity you need the

958
00:34:22,470 --> 00:34:21,200
top of the end instruments to be doing

959
00:34:24,550 --> 00:34:22,480
all that

960
00:34:26,069 --> 00:34:24,560
and for most of them the work has to be

961
00:34:27,669 --> 00:34:26,079
done with a transiting planet which is

962
00:34:28,790 --> 00:34:27,679
not always the case there's only about

963
00:34:31,030 --> 00:34:28,800

20

964
00:34:33,990 --> 00:34:31,040
27 actually transiting planets right now

965
00:34:35,190 --> 00:34:34,000
known out of the 217

966
00:34:36,790 --> 00:34:35,200
what i'm going to be talking about is

967
00:34:37,990 --> 00:34:36,800
star planet interactions and this is

968
00:34:40,950 --> 00:34:38,000
something that

969
00:34:42,310 --> 00:34:40,960
we've been doing from the ground using

970
00:34:43,349 --> 00:34:42,320
excellent instruments and

971
00:34:45,190 --> 00:34:43,359
top-of-the-line instruments but

972
00:34:48,629 --> 00:34:45,200
ground-based instruments

973
00:34:52,389 --> 00:34:50,389
and so the take-home message i'll give

974
00:34:54,869 --> 00:34:52,399
you right now about star planet

975
00:34:56,550 --> 00:34:54,879
interactions is that we've detected them

976
00:34:58,390 --> 00:34:56,560
we've detected an actual magnetic

977
00:35:01,430 --> 00:34:58,400
interaction between a close and giant

978
00:35:03,990 --> 00:35:01,440
planet and its star and that is our

979
00:35:05,750 --> 00:35:04,000
first indirect evidence of planetary

980
00:35:06,950 --> 00:35:05,760
magnetic fields outside of our solar

981
00:35:08,390 --> 00:35:06,960
system

982
00:35:10,790 --> 00:35:08,400
we've been monitoring for long enough

983
00:35:11,750 --> 00:35:10,800
for five years um where we can actually

984
00:35:13,510 --> 00:35:11,760
see

985
00:35:15,750 --> 00:35:13,520
it happen and then disappear and then

986
00:35:19,430 --> 00:35:15,760
happen again so i call this the on off

987
00:35:20,470 --> 00:35:19,440
nature of spy star planet it's it's uh

988
00:35:21,670 --> 00:35:20,480

it's going to be all the rage star

989
00:35:23,510 --> 00:35:21,680
planet interaction so that's what i'm

990
00:35:25,190 --> 00:35:23,520
going to be calling it spy

991
00:35:27,190 --> 00:35:25,200
due to stellar magnetic fields and

992
00:35:29,910 --> 00:35:27,200
lastly what we want to be doing with

993
00:35:31,670 --> 00:35:29,920
this is detecting the magnetic fields is

994
00:35:33,270 --> 00:35:31,680
one thing but also figuring out how we

995
00:35:34,870 --> 00:35:33,280
can measure the magnetic field itself

996
00:35:36,550 --> 00:35:34,880
because right now we don't know we can't

997
00:35:38,550 --> 00:35:36,560
tell you if it's the same as jupiter

998
00:35:40,390 --> 00:35:38,560
which is 4.3 gauss or the same as the

999
00:35:42,550 --> 00:35:40,400
earth's magnetic field we just don't

1000
00:35:45,430 --> 00:35:42,560
know but we want to develop a potential

1001
00:35:46,870 --> 00:35:45,440
probe of these

1002
00:35:48,310 --> 00:35:46,880
so naturally what are the

1003
00:35:49,910 --> 00:35:48,320
astrobiological implications for

1004
00:35:51,510 --> 00:35:49,920
magnetic fields well

1005
00:35:53,510 --> 00:35:51,520
for those of you who do any do the

1006
00:35:55,109 --> 00:35:53,520
planetary science in our solar system

1007
00:35:58,310 --> 00:35:55,119
understand very well probably better

1008
00:35:59,670 --> 00:35:58,320
than i do about what magnetic fields do

1009
00:36:01,430 --> 00:35:59,680
especially for the earth and how they

1010
00:36:02,870 --> 00:36:01,440
protect our atmosphere so

1011
00:36:04,390 --> 00:36:02,880
from

1012
00:36:06,150 --> 00:36:04,400
detecting and understanding magnetic

1013
00:36:08,150 --> 00:36:06,160

fields on extrasolar planets we can then

1014
00:36:09,589 --> 00:36:08,160
get magnetic field geometries for

1015
00:36:11,430 --> 00:36:09,599
instance

1016
00:36:13,030 --> 00:36:11,440
the planetary structure we have definite

1017
00:36:15,750 --> 00:36:13,040
implications for the internal structure

1018
00:36:17,589 --> 00:36:15,760
of the planet itself

1019
00:36:18,870 --> 00:36:17,599
we also can set constraints on the

1020
00:36:22,630 --> 00:36:18,880
environment for the planetary

1021
00:36:24,790 --> 00:36:22,640
atmospheres because as you know the um

1022
00:36:28,150 --> 00:36:24,800
the magnetic field of the earth protects

1023
00:36:30,550 --> 00:36:28,160
us from high-energy cosmic radiation um

1024
00:36:32,150 --> 00:36:30,560
high-energy particles from the sun

1025
00:36:34,069 --> 00:36:32,160
and we need that in order for our

1026
00:36:36,390 --> 00:36:34,079
atmosphere to exist

1027
00:36:38,710 --> 00:36:36,400
also mass loss if there were no

1028
00:36:40,790 --> 00:36:38,720
magnetic field we would have some sort

1029
00:36:43,589 --> 00:36:40,800
of streaming or photo evaporation of our

1030
00:36:45,270 --> 00:36:43,599
atmosphere and there's a an issue of

1031
00:36:46,630 --> 00:36:45,280
orbital decay especially for these hot

1032
00:36:48,710 --> 00:36:46,640
jupiters

1033
00:36:50,870 --> 00:36:48,720
because as i'll show you

1034
00:36:52,550 --> 00:36:50,880
the energy that is lost is has to come

1035
00:36:54,550 --> 00:36:52,560
from somewhere and it's

1036
00:36:57,030 --> 00:36:54,560
modeled to come from the orbital energy

1037
00:36:59,190 --> 00:36:57,040
between the of the planet so there's

1038
00:37:00,790 --> 00:36:59,200

some implications for orbital decay and

1039
00:37:04,950 --> 00:37:00,800
possibly migration and that sort of

1040
00:37:08,950 --> 00:37:07,750
my next slide is not going

1041
00:37:11,190 --> 00:37:08,960
there we go

1042
00:37:13,510 --> 00:37:11,200
so this um we didn't come up with this

1043
00:37:15,670 --> 00:37:13,520
idea in a vacuum it was actually first

1044
00:37:18,710 --> 00:37:15,680
published by manfred kunst and steve

1045
00:37:21,750 --> 00:37:18,720
starr and musialic in 2000 just in time

1046
00:37:23,349 --> 00:37:21,760
for me when i was looking for graduates

1047
00:37:25,109 --> 00:37:23,359
theses tourcon

1048
00:37:27,510 --> 00:37:25,119
and so it worked well

1049
00:37:30,069 --> 00:37:27,520
and so they published this idea of

1050
00:37:32,390 --> 00:37:30,079
maybe the start the hot jupiters have a

1051
00:37:34,390 --> 00:37:32,400
tidal perhaps or a magnetic interaction

1052
00:37:36,150 --> 00:37:34,400
with a star that would induce some sort

1053
00:37:37,990 --> 00:37:36,160
of observable heating of the outer

1054
00:37:39,430 --> 00:37:38,000
atmosphere of the star

1055
00:37:41,670 --> 00:37:39,440
all right so if it was a tidal

1056
00:37:42,710 --> 00:37:41,680
interaction then you would expect

1057
00:37:44,550 --> 00:37:42,720
that the

1058
00:37:45,750 --> 00:37:44,560
period of the interaction

1059
00:37:47,990 --> 00:37:45,760
is

1060
00:37:49,750 --> 00:37:48,000
half that of the orbital period

1061
00:37:52,069 --> 00:37:49,760
so you'd see whatever effect happened

1062
00:37:53,430 --> 00:37:52,079
twice as the planet goes around the star

1063
00:37:55,670 --> 00:37:53,440

and this effect drops off as the

1064
00:37:57,750 --> 00:37:55,680
semi-major axis to the one-third to the

1065
00:37:59,829 --> 00:37:57,760
minus three

1066
00:38:01,910 --> 00:37:59,839
um and if it was a magnetic interaction

1067
00:38:04,790 --> 00:38:01,920
you would just see it once you'd see it

1068
00:38:06,230 --> 00:38:04,800
as a planet orbits around the star and

1069
00:38:07,670 --> 00:38:06,240
so would have the same the interaction

1070
00:38:09,270 --> 00:38:07,680
period would be the same as the orbital

1071
00:38:11,190 --> 00:38:09,280
period and again it drops as one over

1072
00:38:12,950 --> 00:38:11,200
eight to the minus two which is why of

1073
00:38:14,790 --> 00:38:12,960
course hot jupiters are our best bet is

1074
00:38:18,950 --> 00:38:14,800
detecting the sort of thing because it

1075
00:38:20,790 --> 00:38:18,960
drops off quickly with semi-major axis

1076
00:38:22,470 --> 00:38:20,800
and you would have the concentration of

1077
00:38:25,430 --> 00:38:22,480
the heating at what i call what's called

1078
00:38:28,550 --> 00:38:25,440
the subplanetary point and that is the

1079
00:38:30,310 --> 00:38:28,560
phase where the planet um and the star

1080
00:38:31,349 --> 00:38:30,320
are aligned with the observer with us on

1081
00:38:33,270 --> 00:38:31,359
earth

1082
00:38:34,630 --> 00:38:33,280
so if it was transiting it would be at

1083
00:38:36,630 --> 00:38:34,640
the point of transit if it's not

1084
00:38:37,589 --> 00:38:36,640
transiting it would still it would just

1085
00:38:39,109 --> 00:38:37,599
be

1086
00:38:41,430 --> 00:38:39,119
you know as if they were lined up and

1087
00:38:43,829 --> 00:38:41,440
here's an image an actual reconstruction

1088
00:38:45,910 --> 00:38:43,839

of a binary star system that exhibits

1089
00:38:47,829 --> 00:38:45,920
this exact same behavior and of course

1090
00:38:49,349 --> 00:38:47,839
it's enhanced because we have two stars

1091
00:38:51,190 --> 00:38:49,359
with two strong magnetic fields

1092
00:38:54,390 --> 00:38:51,200
interacting but it is an observable

1093
00:38:56,710 --> 00:38:54,400
effect this is an example of er vol

1094
00:38:58,310 --> 00:38:56,720
and you can see that hot spot as it

1095
00:39:00,230 --> 00:38:58,320
rotates in and out of view so the

1096
00:39:06,310 --> 00:39:00,240
hotspot is always there the question is

1097
00:39:10,230 --> 00:39:07,750
and so

1098
00:39:12,150 --> 00:39:10,240
when you think about an interaction from

1099
00:39:13,990 --> 00:39:12,160
the x outside so it's not the star

1100
00:39:16,069 --> 00:39:14,000
itself producing it something external

1101
00:39:18,870 --> 00:39:16,079
to it you would expect the interaction

1102
00:39:21,589 --> 00:39:18,880
to be greater in the corona which is

1103
00:39:24,150 --> 00:39:21,599
closer in proximity to the planet itself

1104
00:39:25,510 --> 00:39:24,160
and in the outer layers which um

1105
00:39:26,870 --> 00:39:25,520
which

1106
00:39:28,390 --> 00:39:26,880
you may not have known but there is a

1107
00:39:30,470 --> 00:39:28,400
temperature inversion that happens above

1108
00:39:32,470 --> 00:39:30,480
the photosphere so the sun's photosphere

1109
00:39:34,230 --> 00:39:32,480
let's say it's about 6000 kelvin and it

1110
00:39:36,069 --> 00:39:34,240
actually becomes hotter as you move

1111
00:39:37,589 --> 00:39:36,079
further further up in the atmosphere the

1112
00:39:39,349 --> 00:39:37,599
chromosphere is about 10 000 and the

1113
00:39:41,430 --> 00:39:39,359

corona is quite hot and several million

1114
00:39:43,589 --> 00:39:41,440
degrees now ideally we would love to

1115
00:39:45,430 --> 00:39:43,599
look at this um

1116
00:39:46,390 --> 00:39:45,440
look at this effect in the corona but

1117
00:39:48,150 --> 00:39:46,400
you need

1118
00:39:49,510 --> 00:39:48,160
space telescope time which is very hard

1119
00:39:51,670 --> 00:39:49,520
to get um

1120
00:39:53,270 --> 00:39:51,680
and um especially for the duration the

1121
00:39:56,550 --> 00:39:53,280
kind of monitoring programs that we want

1122
00:39:58,950 --> 00:39:56,560
to do it's hard to do um from space

1123
00:40:00,790 --> 00:39:58,960
so we devised a program that we can do

1124
00:40:04,470 --> 00:40:00,800
look at chromospheric activity

1125
00:40:08,069 --> 00:40:06,150
and so here's an example here's the sun

1126
00:40:10,470 --> 00:40:08,079
and broadband this is the full visible

1127
00:40:13,030 --> 00:40:10,480
spectrum of yeah well the visible

1128
00:40:15,030 --> 00:40:13,040
spectrum and you can see how if you look

1129
00:40:17,030 --> 00:40:15,040
now in calcium 2

1130
00:40:20,790 --> 00:40:17,040
you're now looking into the chromosphere

1131
00:40:23,270 --> 00:40:20,800
further up calcium 2 is ionized calcium

1132
00:40:24,950 --> 00:40:23,280
that is emitted at

1133
00:40:27,670 --> 00:40:24,960
at about 10 000 kelvin so a little

1134
00:40:29,030 --> 00:40:27,680
higher up and you can see the hot spots

1135
00:40:30,069 --> 00:40:29,040
it's a little brighter where there's

1136
00:40:32,710 --> 00:40:30,079
activity where there's strong

1137
00:40:34,550 --> 00:40:32,720
concentrations of magnetic activity and

1138
00:40:35,990 --> 00:40:34,560

we sort of call them magnetic storms but

1139
00:40:37,670 --> 00:40:36,000
you you know you get the idea that

1140
00:40:39,109 --> 00:40:37,680
there's just more activity going on

1141
00:40:40,630 --> 00:40:39,119
which means there's more emission in the

1142
00:40:43,270 --> 00:40:40,640
calcium too and that is going to be our

1143
00:40:45,349 --> 00:40:43,280
primary indicator of stellar activity

1144
00:40:49,910 --> 00:40:45,359
looking for this excess heating

1145
00:40:53,670 --> 00:40:52,310
and where do we do this well mostly um

1146
00:40:56,630 --> 00:40:53,680
most of the work i'm going to be showing

1147
00:40:59,589 --> 00:40:56,640
you is was done at the 3.6 meter canada

1148
00:41:00,630 --> 00:40:59,599
france hawaii telescope here in hawaii

1149
00:41:03,349 --> 00:41:00,640
um

1150
00:41:04,950 --> 00:41:03,359
it is a collaboration by those three

1151
00:41:06,870 --> 00:41:04,960
agencies

1152
00:41:09,670 --> 00:41:06,880
and worked out quite well

1153
00:41:11,190 --> 00:41:09,680
for me because being canadian we got we

1154
00:41:12,230 --> 00:41:11,200
have 42 percent of the time there so i

1155
00:41:14,390 --> 00:41:12,240
could do my

1156
00:41:16,150 --> 00:41:14,400
do get a lot of research

1157
00:41:18,309 --> 00:41:16,160
done there and so for those of you who

1158
00:41:20,069 --> 00:41:18,319
have never been there it's about

1159
00:41:21,190 --> 00:41:20,079
five stories high you can see the little

1160
00:41:23,430 --> 00:41:21,200
people

1161
00:41:24,550 --> 00:41:23,440
up front so it's quite a big structure

1162
00:41:26,230 --> 00:41:24,560
and if you're ever in hawaii i

1163
00:41:27,589 --> 00:41:26,240

definitely recommend visiting mauna kea

1164
00:41:30,710 --> 00:41:27,599
and checking out all the infrastructure

1165
00:41:32,390 --> 00:41:30,720
that astronomy has afforded us

1166
00:41:34,710 --> 00:41:32,400
but what it has there aside from the

1167
00:41:35,829 --> 00:41:34,720
telescope itself is an instrument

1168
00:41:38,470 --> 00:41:35,839
that collects

1169
00:41:42,309 --> 00:41:38,480
the complete optical spectrum

1170
00:41:44,390 --> 00:41:42,319
of a star and this is a epo version of a

1171
00:41:45,910 --> 00:41:44,400
stellar spectrum

1172
00:41:49,349 --> 00:41:45,920
this just happens to be of the sun but

1173
00:41:51,589 --> 00:41:49,359
each of those lines are absorption lines

1174
00:41:53,510 --> 00:41:51,599
in this in the atmosphere of the sun

1175
00:41:55,990 --> 00:41:53,520
and so if you cut across one of those

1176
00:41:57,190 --> 00:41:56,000
lines you get the spectrum

1177
00:42:01,349 --> 00:41:57,200
that we're interested in this is a

1178
00:42:03,510 --> 00:42:01,359
spectrum of a star called hd189733

1179
00:42:04,870 --> 00:42:03,520
and even though all these lines that i

1180
00:42:06,790 --> 00:42:04,880
point out here are very interesting

1181
00:42:08,150 --> 00:42:06,800
chromospheric lines they actually probe

1182
00:42:10,470 --> 00:42:08,160
various heights in the stellar

1183
00:42:13,349 --> 00:42:10,480
atmosphere i'm going to only focus on

1184
00:42:18,309 --> 00:42:13,359
for simplicity the calcium 2k line it's

1185
00:42:21,190 --> 00:42:19,510
angstroms

1186
00:42:23,589 --> 00:42:21,200
and so you can see how in this little

1187
00:42:25,349 --> 00:42:23,599
red box the strong peak shows that this

1188
00:42:26,390 --> 00:42:25,359

particular star has a lot of magnetic

1189
00:42:28,790 --> 00:42:26,400
activity

1190
00:42:30,950 --> 00:42:28,800
and has a lot of energy being emitted in

1191
00:42:33,190 --> 00:42:30,960
just this line and i'm going to zoom in

1192
00:42:34,870 --> 00:42:33,200
on this box for another star that you'll

1193
00:42:36,390 --> 00:42:34,880
see does not have the same this is a

1194
00:42:37,670 --> 00:42:36,400
much weaker

1195
00:42:39,190 --> 00:42:37,680
um

1196
00:42:40,230 --> 00:42:39,200
this star has a much weaker magnetic

1197
00:42:43,190 --> 00:42:40,240
field

1198
00:42:45,190 --> 00:42:43,200
in general but still it has some calcium

1199
00:42:47,190 --> 00:42:45,200
two emission and you can see this is

1200
00:42:49,030 --> 00:42:47,200
over this is a plot that's overlay

1201
00:42:50,870 --> 00:42:49,040
overlaying nine different knights of the

1202
00:42:52,630 --> 00:42:50,880
same star you can see in these other

1203
00:42:54,710 --> 00:42:52,640
photospheric absorption lines that

1204
00:42:56,950 --> 00:42:54,720
there's no activity whereas right in the

1205
00:42:58,550 --> 00:42:56,960
chromosphere you see there's some wobble

1206
00:42:59,829 --> 00:42:58,560
it's kind of hard to see i'll show you a

1207
00:43:01,670 --> 00:42:59,839
better plot

1208
00:43:02,950 --> 00:43:01,680
next but what i want to emphasize is

1209
00:43:05,910 --> 00:43:02,960
that we're looking at something very

1210
00:43:08,150 --> 00:43:05,920
small but clearly detectable okay so

1211
00:43:10,069 --> 00:43:08,160
there's actually increased energy being

1212
00:43:12,069 --> 00:43:10,079
emitted in calcium two in the

1213
00:43:14,309 --> 00:43:12,079

chromosphere of the star and it varies

1214
00:43:16,630 --> 00:43:14,319
from night to night

1215
00:43:19,910 --> 00:43:16,640
um here's more spectra of the same star

1216
00:43:22,150 --> 00:43:19,920
taken in different times the first um

1217
00:43:24,870 --> 00:43:22,160
i guess the left hand side is taken from

1218
00:43:27,589 --> 00:43:24,880
september 2005 where the top is just the

1219
00:43:29,829 --> 00:43:27,599
overlaying chromospheric

1220
00:43:32,550 --> 00:43:29,839
emission the calcium two absorption

1221
00:43:34,870 --> 00:43:32,560
and the second panel is show you the

1222
00:43:37,190 --> 00:43:34,880
residuals so it's just taking the

1223
00:43:39,349 --> 00:43:37,200
difference from the mean

1224
00:43:41,270 --> 00:43:39,359
and the bottom is what we call the mad

1225
00:43:43,349 --> 00:43:41,280
plot the mean absolute deviation it's

1226
00:43:45,670 --> 00:43:43,359
just a kind of form of saying

1227
00:43:47,430 --> 00:43:45,680
how much activity is really going on in

1228
00:43:50,309 --> 00:43:47,440
this star so you'll see that in if you

1229
00:43:53,430 --> 00:43:50,319
compare september 2005 to the right

1230
00:43:56,390 --> 00:43:53,440
panel 2006 there's a lot more activity

1231
00:43:58,309 --> 00:43:56,400
going on in 2005 than in 2006 however in

1232
00:43:59,990 --> 00:43:58,319
2006 there's still a significant amount

1233
00:44:01,990 --> 00:44:00,000
it's small but there's still significant

1234
00:44:04,309 --> 00:44:02,000
amount of variation variability going on

1235
00:44:05,670 --> 00:44:04,319
from night to night and um and when i

1236
00:44:07,430 --> 00:44:05,680
say from night to night we usually

1237
00:44:09,430 --> 00:44:07,440
typically observe for about five or six

1238
00:44:11,270 --> 00:44:09,440

nights

1239
00:44:14,069 --> 00:44:11,280
hopefully at least three or four will be

1240
00:44:15,990 --> 00:44:14,079
clear and

1241
00:44:17,589 --> 00:44:16,000
and so it's just really from you know

1242
00:44:20,870 --> 00:44:17,599
monday to tuesday to wednesday there's a

1243
00:44:22,710 --> 00:44:20,880
real measurable change

1244
00:44:24,630 --> 00:44:22,720
and if you measure the integrated flux

1245
00:44:26,710 --> 00:44:24,640
of these residuals

1246
00:44:29,670 --> 00:44:26,720
um you get this kind of plot where the

1247
00:44:31,190 --> 00:44:29,680
y-axis is just the amount of energy the

1248
00:44:33,109 --> 00:44:31,200
residual energy

1249
00:44:35,109 --> 00:44:33,119
um in the calcium 2

1250
00:44:37,109 --> 00:44:35,119
emission and the x-axis is the

1251
00:44:38,870 --> 00:44:37,119
rotational phase and remember that phase

1252
00:44:42,150 --> 00:44:38,880
equals zero is the subplanetary point

1253
00:44:43,910 --> 00:44:42,160
where the planet is um in front

1254
00:44:46,390 --> 00:44:43,920
with it where the planet is in front of

1255
00:44:48,230 --> 00:44:46,400
the star relative to us

1256
00:44:50,069 --> 00:44:48,240
so what you see here is that

1257
00:44:52,710 --> 00:44:50,079
over three different observing runs we

1258
00:44:54,790 --> 00:44:52,720
see a very nice correlation with a spot

1259
00:44:56,870 --> 00:44:54,800
model the black line is a spot model as

1260
00:44:58,950 --> 00:44:56,880
if there was a spot on the actual star

1261
00:45:00,470 --> 00:44:58,960
that comes into view and then out of

1262
00:45:04,069 --> 00:45:00,480
view and then interview as the planet

1263
00:45:08,710 --> 00:45:06,790

and what's what was a surprise was that

1264
00:45:09,670 --> 00:45:08,720
that the peak of it doesn't actually

1265
00:45:14,150 --> 00:45:09,680
happen

1266
00:45:16,870 --> 00:45:14,160
bit sooner there's actually a phase lead

1267
00:45:19,270 --> 00:45:16,880
and that leads us to wonder what's going

1268
00:45:20,710 --> 00:45:19,280
on what kind of magnetic structure must

1269
00:45:21,910 --> 00:45:20,720
there be in order for there to be a

1270
00:45:23,750 --> 00:45:21,920
phase lead

1271
00:45:25,829 --> 00:45:23,760
you might intuitively guess well it must

1272
00:45:28,230 --> 00:45:25,839
be a maybe there should be a phase lag

1273
00:45:29,990 --> 00:45:28,240
some sort of time delay but really it's

1274
00:45:31,030 --> 00:45:30,000
a phase lead so this is giving us some

1275
00:45:32,390 --> 00:45:31,040
other

1276
00:45:34,230 --> 00:45:32,400
indication

1277
00:45:36,790 --> 00:45:34,240
what's happening so here's my little

1278
00:45:38,630 --> 00:45:36,800
cartoon of the star in chromospheric

1279
00:45:41,109 --> 00:45:38,640
light emitted and there's the planet and

1280
00:45:42,470 --> 00:45:41,119
so you can see how

1281
00:45:45,190 --> 00:45:42,480
oh

1282
00:45:48,870 --> 00:45:46,950
you can see how the stars

1283
00:45:50,550 --> 00:45:48,880
how the star spots track the planet in

1284
00:45:52,390 --> 00:45:50,560
its orbit not with the rotation of the

1285
00:45:55,030 --> 00:45:52,400
star the rotation of the star is much

1286
00:45:56,630 --> 00:45:55,040
longer um at this point before we knew

1287
00:45:58,630 --> 00:45:56,640
the rotation i'll get to that in a

1288
00:46:00,230 --> 00:45:58,640

minute but all indirect evidence showed

1289
00:46:02,390 --> 00:46:00,240
that the rotation of the star was longer

1290
00:46:04,230 --> 00:46:02,400
than nine days and there wasn't a way to

1291
00:46:06,150 --> 00:46:04,240
phase these plots with more than with

1292
00:46:07,990 --> 00:46:06,160
within well enough with a nine day

1293
00:46:10,069 --> 00:46:08,000
period so it's not just

1294
00:46:14,150 --> 00:46:10,079
that the rotation of the star is moving

1295
00:46:17,829 --> 00:46:16,390
now if you measure the energy output of

1296
00:46:20,630 --> 00:46:17,839
this kind of

1297
00:46:23,190 --> 00:46:20,640
uh of the spot it's about 10 to the 27

1298
00:46:25,510 --> 00:46:23,200
ergs per second which happens to be very

1299
00:46:27,510 --> 00:46:25,520
close to the typical solar flare energy

1300
00:46:31,430 --> 00:46:27,520
so we're talking about some some sort of

1301
00:46:33,430 --> 00:46:31,440
magnetic activity on the star

1302
00:46:35,510 --> 00:46:33,440
and um

1303
00:46:37,030 --> 00:46:35,520
given that we've come back several years

1304
00:46:40,069 --> 00:46:37,040
the fact that it's lasted for several

1305
00:46:42,550 --> 00:46:40,079
years is amazing because a normal star

1306
00:46:44,390 --> 00:46:42,560
spot really only lasts for one or two

1307
00:46:45,750 --> 00:46:44,400
solar or stellar rotations so that's

1308
00:46:47,910 --> 00:46:45,760
just a few months

1309
00:46:50,790 --> 00:46:47,920
um it also appears to be magnetic

1310
00:46:53,030 --> 00:46:50,800
because there's one hump in the plot not

1311
00:46:54,710 --> 00:46:53,040
two if it was tidal you might see some

1312
00:46:55,910 --> 00:46:54,720
sort of activity happening twice per

1313
00:46:57,910 --> 00:46:55,920

orbit

1314
00:46:59,829 --> 00:46:57,920
and the fact that there's a phase lead

1315
00:47:01,750 --> 00:46:59,839
indicate some sort of magnetic um

1316
00:47:03,670 --> 00:47:01,760
geometry like a parker spiral for

1317
00:47:04,870 --> 00:47:03,680
instance where you where the

1318
00:47:06,550 --> 00:47:04,880
for instance on the sun there's some

1319
00:47:09,030 --> 00:47:06,560
magnetic field lines that are spiraled

1320
00:47:11,030 --> 00:47:09,040
with its rotation and so you would have

1321
00:47:12,950 --> 00:47:11,040
you have some sort of energy being

1322
00:47:15,670 --> 00:47:12,960
dumped ahead of where the planet

1323
00:47:17,510 --> 00:47:15,680
actually is relative to us

1324
00:47:20,630 --> 00:47:17,520
now since we first published that work

1325
00:47:22,630 --> 00:47:20,640
in 2003 and 2005

1326
00:47:24,950 --> 00:47:22,640
there has been other evidence of star

1327
00:47:27,829 --> 00:47:24,960
planet interactions um here's just a few

1328
00:47:29,589 --> 00:47:27,839
of them most as a space telescope

1329
00:47:31,750 --> 00:47:29,599
that does very high precision photometry

1330
00:47:34,309 --> 00:47:31,760
of stars with hot jupiters and they've

1331
00:47:36,470 --> 00:47:34,319
seen photo photospheric spots on the

1332
00:47:38,150 --> 00:47:36,480
star that vary with the planets orbit

1333
00:47:41,349 --> 00:47:38,160
and not with a stellar rotation which is

1334
00:47:45,190 --> 00:47:41,359
what traditionally we would expect um

1335
00:47:47,829 --> 00:47:45,200
saradal had also used um an x-ray

1336
00:47:49,270 --> 00:47:47,839
telescope chandra to look for phased

1337
00:47:50,950 --> 00:47:49,280
x-ray emission

1338
00:47:53,430 --> 00:47:50,960

and so they have claimed that they see

1339
00:47:56,069 --> 00:47:53,440
that and that the phasing works with

1340
00:47:58,309 --> 00:47:56,079
hours without calcium two emission

1341
00:48:00,390 --> 00:47:58,319
um and lastly was this um this cache

1342
00:48:02,390 --> 00:48:00,400
japanese work

1343
00:48:03,510 --> 00:48:02,400
did a statistical study of x-ray

1344
00:48:04,470 --> 00:48:03,520
emission

1345
00:48:06,550 --> 00:48:04,480
of

1346
00:48:08,390 --> 00:48:06,560
stars with hot jupiters and stars with

1347
00:48:10,870 --> 00:48:08,400
planets that are further out and what

1348
00:48:13,430 --> 00:48:10,880
they show is that there's a three

1349
00:48:15,829 --> 00:48:13,440
there's that statistically at least

1350
00:48:17,270 --> 00:48:15,839
three times as much x-ray emission from

1351
00:48:21,270 --> 00:48:17,280
stars

1352
00:48:23,430 --> 00:48:21,280
that don't so this also indicates that

1353
00:48:26,230 --> 00:48:23,440
there must be some sort of

1354
00:48:32,069 --> 00:48:26,240
increased stellar activity going on

1355
00:48:36,870 --> 00:48:33,990
so what's really going on i mean the

1356
00:48:39,190 --> 00:48:36,880
models are there's been about i'd say

1357
00:48:40,790 --> 00:48:39,200
almost a dozen papers trying to explain

1358
00:48:42,390 --> 00:48:40,800
this theoretically

1359
00:48:43,750 --> 00:48:42,400
and there seems to be some convergence

1360
00:48:46,870 --> 00:48:43,760
going on but still we definitely need

1361
00:48:48,950 --> 00:48:46,880
more data to give the modelers um

1362
00:48:51,349 --> 00:48:48,960
something to keep working with but i'll

1363
00:48:54,309 --> 00:48:51,359

just go through two of the earlier ones

1364
00:48:56,150 --> 00:48:54,319
one was by ipodal where they

1365
00:48:57,349 --> 00:48:56,160
modeled this magnetic reconnection type

1366
00:48:59,829 --> 00:48:57,359
of event

1367
00:49:01,589 --> 00:48:59,839
using the jupiter io

1368
00:49:04,230 --> 00:49:01,599
taurus model where there's these

1369
00:49:07,990 --> 00:49:04,240
footprints on jupiter that's induced by

1370
00:49:09,910 --> 00:49:08,000
io's motion around around jupiter

1371
00:49:11,430 --> 00:49:09,920
and it develops this current loop and so

1372
00:49:13,589 --> 00:49:11,440
on and so you get these hot spots in

1373
00:49:15,670 --> 00:49:13,599
high and low latitudes and so it but

1374
00:49:17,990 --> 00:49:15,680
i'll measure

1375
00:49:20,309 --> 00:49:18,000
model it this way and they theoretically

1376
00:49:22,150 --> 00:49:20,319
get the same 10 to the 27 ergs per

1377
00:49:25,510 --> 00:49:22,160
second that we got observationally so

1378
00:49:29,589 --> 00:49:27,910
and then sabine prusadel for her phd

1379
00:49:31,670 --> 00:49:29,599
thesis started working on this

1380
00:49:33,910 --> 00:49:31,680
communication scenario

1381
00:49:36,710 --> 00:49:33,920
and i'll try and work through that step

1382
00:49:39,589 --> 00:49:36,720
by step so if this were a star rotating

1383
00:49:41,270 --> 00:49:39,599
here is a spiraled magnetic

1384
00:49:43,270 --> 00:49:41,280
field line and there's the planet if

1385
00:49:45,430 --> 00:49:43,280
this were the solar system such that the

1386
00:49:47,910 --> 00:49:45,440
distance between the planet and the star

1387
00:49:50,790 --> 00:49:47,920
was now about 5 a.u

1388
00:49:52,390 --> 00:49:50,800

the stellar wind at 5 a.u

1389
00:49:54,230 --> 00:49:52,400
is much

1390
00:49:55,910 --> 00:49:54,240
faster than the alphein wave velocity

1391
00:49:57,349 --> 00:49:55,920
which means that any kind of

1392
00:49:59,190 --> 00:49:57,359
information you can consider or

1393
00:50:01,190 --> 00:49:59,200
disturbance of the magnetic field at

1394
00:50:03,829 --> 00:50:01,200
that distance would be carried away by

1395
00:50:06,390 --> 00:50:03,839
the stellar wind as opposed to if it was

1396
00:50:08,309 --> 00:50:06,400
in a hot jupiter system the and now the

1397
00:50:11,030 --> 00:50:08,319
distance between the star and the planet

1398
00:50:13,109 --> 00:50:11,040
this distance here is now .05 a u

1399
00:50:15,750 --> 00:50:13,119
instead of five au you are within the

1400
00:50:18,630 --> 00:50:15,760
alphein radius which is defined as a

1401
00:50:20,150 --> 00:50:18,640
location in space where the velocity of

1402
00:50:22,710 --> 00:50:20,160
the stellar wind and the velocity of the

1403
00:50:25,510 --> 00:50:22,720
alphane waves are equal now if you are

1404
00:50:26,390 --> 00:50:25,520
within this alpha and radius then

1405
00:50:28,710 --> 00:50:26,400
you can

1406
00:50:30,710 --> 00:50:28,720
actually transmit information back onto

1407
00:50:33,109 --> 00:50:30,720
the star energy back onto the star along

1408
00:50:34,950 --> 00:50:33,119
magnetic field lines and the sto and the

1409
00:50:37,030 --> 00:50:34,960
stellar wind is just too slow to take it

1410
00:50:40,390 --> 00:50:37,040
away and she calls this the magnetic

1411
00:50:42,630 --> 00:50:40,400
communication scenario

1412
00:50:44,710 --> 00:50:42,640
she's also able to interestingly enough

1413
00:50:47,190 --> 00:50:44,720

reproduce the

1414
00:50:49,910 --> 00:50:47,200
phase difference that we observe so the

1415
00:50:51,510 --> 00:50:49,920
phase being that the maximum activity

1416
00:50:54,630 --> 00:50:51,520
happens at

1417
00:50:57,990 --> 00:50:54,640
at uh 0.83 in phase so it leads the

1418
00:50:59,910 --> 00:50:58,000
planet by 0 by about 60 degrees

1419
00:51:03,109 --> 00:50:59,920
and she does this by using this weber

1420
00:51:04,950 --> 00:51:03,119
davis stellar wind model where

1421
00:51:07,270 --> 00:51:04,960
now this phase

1422
00:51:08,309 --> 00:51:07,280
the phase offset let's say from the

1423
00:51:10,870 --> 00:51:08,319
phase equals zero which is the

1424
00:51:12,710 --> 00:51:10,880
subplanetary point um is a function of

1425
00:51:14,710 --> 00:51:12,720
the stellar rotation speed as you would

1426
00:51:16,710 --> 00:51:14,720
expect and also the orbital semi-major

1427
00:51:19,190 --> 00:51:16,720
axis so once you are outside of a

1428
00:51:21,109 --> 00:51:19,200
certain region outside the alpha radius

1429
00:51:23,829 --> 00:51:21,119
you cannot get the information or the

1430
00:51:26,150 --> 00:51:23,839
energy back onto the star and but if you

1431
00:51:28,069 --> 00:51:26,160
are within it then the further you are

1432
00:51:32,150 --> 00:51:28,079
away the larger this phase offset would

1433
00:51:35,430 --> 00:51:33,910
all right so then we go back to the so

1434
00:51:37,430 --> 00:51:35,440
back to the telescope after all this

1435
00:51:40,950 --> 00:51:37,440
activity's been going on in the modeling

1436
00:51:43,910 --> 00:51:40,960
and our effect seems to have disappeared

1437
00:51:45,109 --> 00:51:43,920
which is a bit nerve-wracking however

1438
00:51:48,549 --> 00:51:45,119

there is some

1439
00:51:51,589 --> 00:51:48,559
significant variability just on a

1440
00:51:53,109 --> 00:51:51,599
smaller scale

1441
00:51:55,430 --> 00:51:53,119
and that was we first saw that in

1442
00:51:57,270 --> 00:51:55,440
september 2003

1443
00:51:59,190 --> 00:51:57,280
we also saw that in epsilon n which is

1444
00:52:00,390 --> 00:51:59,200
another hot jupiter system

1445
00:52:03,109 --> 00:52:00,400
um

1446
00:52:06,150 --> 00:52:03,119
where the orbital period is now

1447
00:52:07,910 --> 00:52:06,160
i think it's 4.6 days and this here we

1448
00:52:09,349 --> 00:52:07,920
saw it happen for a few years and it was

1449
00:52:11,910 --> 00:52:09,359
actually in the first year we didn't see

1450
00:52:13,190 --> 00:52:11,920
very much going on

1451
00:52:14,950 --> 00:52:13,200
so

1452
00:52:16,470 --> 00:52:14,960
but then we went back of course we've

1453
00:52:18,549 --> 00:52:16,480
been monitoring the system for a few

1454
00:52:21,829 --> 00:52:18,559
years we went back in 2005

1455
00:52:24,390 --> 00:52:21,839
and for hd179949

1456
00:52:26,710 --> 00:52:24,400
again we saw the same amplitude at

1457
00:52:29,589 --> 00:52:26,720
almost nearly the exact same phase of

1458
00:52:31,750 --> 00:52:29,599
activity going on

1459
00:52:34,069 --> 00:52:31,760
but in 2006 i'll just back up for a

1460
00:52:35,190 --> 00:52:34,079
second in 2006 we saw the same thing i

1461
00:52:37,349 --> 00:52:35,200
don't have them plotted here but it's

1462
00:52:39,670 --> 00:52:37,359
kind of a lower a lower amplitude

1463
00:52:41,349 --> 00:52:39,680

variability

1464
00:52:44,309 --> 00:52:41,359
and so then if we plot them up with a

1465
00:52:45,750 --> 00:52:44,319
seven day period now remember we um we

1466
00:52:47,510 --> 00:52:45,760
still don't know the rotation period of

1467
00:52:48,870 --> 00:52:47,520
the star that is surprisingly difficult

1468
00:52:50,150 --> 00:52:48,880
to measure i know it seems like such a

1469
00:52:51,589 --> 00:52:50,160
basic thing

1470
00:52:53,430 --> 00:52:51,599
you know how can we not know how these

1471
00:52:55,109 --> 00:52:53,440
stars rotate but it's it's really a more

1472
00:52:57,109 --> 00:52:55,119
complicated measurement than we would

1473
00:52:58,630 --> 00:52:57,119
expect than one would expect

1474
00:53:00,150 --> 00:52:58,640
um so we didn't know what the rotation

1475
00:53:04,710 --> 00:53:00,160
period was but here we have from two

1476
00:53:07,670 --> 00:53:04,720
different epochs from both 2003 and 2006

1477
00:53:10,790 --> 00:53:07,680
we can fit them relatively well with a

1478
00:53:12,630 --> 00:53:10,800
seven day rotation period so

1479
00:53:14,470 --> 00:53:12,640
i think this is the first

1480
00:53:15,589 --> 00:53:14,480
direct measurement of the rotation of

1481
00:53:17,589 --> 00:53:15,599
the star

1482
00:53:20,150 --> 00:53:17,599
um they're offset by phase because

1483
00:53:22,230 --> 00:53:20,160
there's no reason to believe that

1484
00:53:23,670 --> 00:53:22,240
they're the same spot let's just say so

1485
00:53:25,190 --> 00:53:23,680
i just have a relative phase here it's

1486
00:53:27,510 --> 00:53:25,200
not an absolute phase

1487
00:53:29,750 --> 00:53:27,520
but anyway so what we see now is that

1488
00:53:32,150 --> 00:53:29,760

star planet interactions seems to have

1489
00:53:34,390 --> 00:53:32,160
this on-again off-again

1490
00:53:36,549 --> 00:53:34,400
characteristic

1491
00:53:38,870 --> 00:53:36,559
and lo and behold theorists came through

1492
00:53:41,589 --> 00:53:38,880
for us and kramer and star put out a

1493
00:53:44,069 --> 00:53:41,599
paper in 2007

1494
00:53:47,750 --> 00:53:44,079
um that explains this and does a very

1495
00:53:51,829 --> 00:53:49,109
and so what they've done here you have

1496
00:53:53,430 --> 00:53:51,839
at the top you have they take the actual

1497
00:53:54,710 --> 00:53:53,440
solar magnetic

1498
00:53:57,430 --> 00:53:54,720
field

1499
00:53:59,750 --> 00:53:57,440
structure at its various stages in the

1500
00:54:01,990 --> 00:53:59,760
11-year stellar activity cycle solar

1501
00:54:04,390 --> 00:54:02,000
activity cycle they do the modeling of

1502
00:54:07,750 --> 00:54:04,400
the this magnetic interaction with a

1503
00:54:11,430 --> 00:54:07,760
closen planet and what they show is that

1504
00:54:13,990 --> 00:54:11,440
um the amplitude um and whether or not

1505
00:54:15,670 --> 00:54:14,000
the spy start plant interaction emission

1506
00:54:16,790 --> 00:54:15,680
excess emission of calcium two is even

1507
00:54:17,589 --> 00:54:16,800
visible

1508
00:54:19,589 --> 00:54:17,599
um

1509
00:54:22,549 --> 00:54:19,599
has to do with the magnetic structure of

1510
00:54:23,990 --> 00:54:22,559
the star and so this is a whole other

1511
00:54:25,670 --> 00:54:24,000
you know piece of the puzzle that we

1512
00:54:27,349 --> 00:54:25,680
really need to model is we need to

1513
00:54:30,309 --> 00:54:27,359

understand the magnetic field structure

1514
00:54:32,589 --> 00:54:30,319
and we've then taken that um taken this

1515
00:54:35,030 --> 00:54:32,599
into an observational test using

1516
00:54:36,069 --> 00:54:35,040
spectropolarimetry and zeeman doppler

1517
00:54:37,510 --> 00:54:36,079
imaging

1518
00:54:39,670 --> 00:54:37,520
a technique that we're going to that we

1519
00:54:41,910 --> 00:54:39,680
are using now um in order to map the

1520
00:54:43,990 --> 00:54:41,920
magnetic fields of the stars at the same

1521
00:54:46,069 --> 00:54:44,000
time as measuring these stellar activity

1522
00:54:49,109 --> 00:54:46,079
indicators and so as you can see over

1523
00:54:51,270 --> 00:54:49,119
here you know in five consecutive orbits

1524
00:54:53,589 --> 00:54:51,280
you know we hear the green line is kind

1525
00:54:55,270 --> 00:54:53,599
of hard to see but in the green line

1526
00:54:57,109 --> 00:54:55,280
um is the stellar rotation the

1527
00:54:58,950 --> 00:54:57,119
modulation of the calcium emission just

1528
00:55:01,750 --> 00:54:58,960
by cell rotation and the black line is

1529
00:55:03,589 --> 00:55:01,760
the rotation plus any star uh planet

1530
00:55:05,670 --> 00:55:03,599
induced you can see that even from orbit

1531
00:55:06,870 --> 00:55:05,680
to orbit it varies so it's always hovers

1532
00:55:09,349 --> 00:55:06,880
around

1533
00:55:11,990 --> 00:55:09,359
phase zero which is the one two three

1534
00:55:13,589 --> 00:55:12,000
four marks but even from orbit orbit it

1535
00:55:14,630 --> 00:55:13,599
could disappear and especially from

1536
00:55:16,230 --> 00:55:14,640
season

1537
00:55:18,630 --> 00:55:16,240
and how it varies when the stellar

1538
00:55:21,109 --> 00:55:18,640

magnetic field structure

1539
00:55:22,790 --> 00:55:21,119
varies in itself

1540
00:55:24,630 --> 00:55:22,800
and so lastly if we look at the

1541
00:55:26,150 --> 00:55:24,640
collection of the 13 stars that we saw

1542
00:55:27,510 --> 00:55:26,160
together

1543
00:55:29,750 --> 00:55:27,520
um the 13 stars that we've been

1544
00:55:32,470 --> 00:55:29,760
monitoring for a few years we see this

1545
00:55:34,549 --> 00:55:32,480
very interesting correlation now i'll

1546
00:55:37,510 --> 00:55:34,559
quickly explain what it is on the white

1547
00:55:39,109 --> 00:55:37,520
on the y-axis we have mad well the mean

1548
00:55:41,190 --> 00:55:39,119
absolute deviations just the integrated

1549
00:55:42,950 --> 00:55:41,200
flux of this activity so it's just

1550
00:55:45,109 --> 00:55:42,960
saying how active is this star on a

1551
00:55:48,789 --> 00:55:45,119
short-term time scale

1552
00:55:50,470 --> 00:55:48,799
and on the y-axis i have plotted the

1553
00:55:53,030 --> 00:55:50,480
mass of the planet divided by the

1554
00:55:54,549 --> 00:55:53,040
rotation period which is a value

1555
00:55:56,549 --> 00:55:54,559
proportional to the planet's magnetic

1556
00:55:57,750 --> 00:55:56,559
moment and what's amazing is that even

1557
00:55:59,670 --> 00:55:57,760
though we only have four points there

1558
00:56:02,309 --> 00:55:59,680
seems to be this great correlation that

1559
00:56:03,829 --> 00:56:02,319
says that the stellar activity appears

1560
00:56:05,829 --> 00:56:03,839
to correlate with the magnetic moment of

1561
00:56:07,430 --> 00:56:05,839
the planet and this is going to one day

1562
00:56:10,309 --> 00:56:07,440
if we actually if we can really

1563
00:56:12,309 --> 00:56:10,319

understand this plot in detail um

1564
00:56:14,470 --> 00:56:12,319
allow us to measure the magnetic fields

1565
00:56:17,510 --> 00:56:14,480
of these extrasolar planets by observing

1566
00:56:19,430 --> 00:56:17,520
their host star and talboo here you see

1567
00:56:21,109 --> 00:56:19,440
it off to the side is sort of the

1568
00:56:25,109 --> 00:56:21,119
exception that proves the

1569
00:56:27,030 --> 00:56:25,119
that is because talboo the planet and

1570
00:56:28,710 --> 00:56:27,040
the star are tidally locked meaning that

1571
00:56:30,390 --> 00:56:28,720
the stellar rotation period and the

1572
00:56:32,230 --> 00:56:30,400
planetary period

1573
00:56:34,870 --> 00:56:32,240
are the same and which means that

1574
00:56:36,470 --> 00:56:34,880
there's no relative velocity there's no

1575
00:56:38,870 --> 00:56:36,480
there's no planets sweeping through

1576
00:56:41,910 --> 00:56:38,880
magnetic fields so you have this kind of

1577
00:56:43,349 --> 00:56:41,920
this depressed um level of activity than

1578
00:56:45,190 --> 00:56:43,359
you would expect given the mass of the

1579
00:56:47,190 --> 00:56:45,200
planet

1580
00:56:48,390 --> 00:56:47,200
and so in summary

1581
00:56:50,549 --> 00:56:48,400
um

1582
00:56:52,549 --> 00:56:50,559
we have detected a magnetic interaction

1583
00:56:54,549 --> 00:56:52,559
between a planet and it's hot between a

1584
00:56:56,309 --> 00:56:54,559
star and it's hot jupiter

1585
00:56:57,589 --> 00:56:56,319
monitoring for all these years has shown

1586
00:56:59,750 --> 00:56:57,599
that there's definitely an on and off

1587
00:57:01,510 --> 00:56:59,760
nature that appears to correlate with

1588
00:57:02,789 --> 00:57:01,520

the stellar magnetic

1589
00:57:07,670 --> 00:57:02,799
activity

1590
00:57:09,589 --> 00:57:07,680
um the correlation between stellar

1591
00:57:11,910 --> 00:57:09,599
activity and planetary magnetic moment

1592
00:57:13,190 --> 00:57:11,920
is really what's going to give us our

1593
00:57:23,430 --> 00:57:13,200
first

1594
00:57:28,150 --> 00:57:24,710
great thank you

1595
00:57:30,789 --> 00:57:28,160
okay and again if any of the sites have

1596
00:57:32,789 --> 00:57:30,799
questions please raise your hand in

1597
00:57:34,230 --> 00:57:32,799
webex but because i don't see anybody

1598
00:57:37,030 --> 00:57:34,240
i'm just going to open up the floor and

1599
00:57:38,710 --> 00:57:37,040
see yeah one question yeah

1600
00:57:42,549 --> 00:57:38,720
okay can i ask you to repeat their

1601
00:57:45,829 --> 00:57:44,950
i can't hear it is that me

1602
00:57:49,030 --> 00:57:45,839
yep

1603
00:57:50,710 --> 00:57:49,040
okay uh great talk uh i have a question

1604
00:57:53,190 --> 00:57:50,720
about this

1605
00:57:57,670 --> 00:57:53,200
inaction basically if it's uh the

1606
00:58:00,309 --> 00:57:57,680
communication model that's working then

1607
00:58:01,430 --> 00:58:00,319
does the planet have to have a magnetic

1608
00:58:03,589 --> 00:58:01,440
field

1609
00:58:06,789 --> 00:58:03,599
in order to be able to feedback

1610
00:58:08,390 --> 00:58:06,799
information to the star what about the

1611
00:58:12,230 --> 00:58:08,400
ionosphere

1612
00:58:15,190 --> 00:58:12,240
of the planet such as winners uh type of

1613
00:58:17,190 --> 00:58:15,200

interaction with that be able to act as

1614
00:58:19,349 --> 00:58:17,200
an obstacle and feed the information

1615
00:58:20,789 --> 00:58:19,359
back to the start

1616
00:58:23,349 --> 00:58:20,799
that's a great question because peru

1617
00:58:25,589 --> 00:58:23,359
said i'll say that they um

1618
00:58:27,109 --> 00:58:25,599
they don't need a magnetic field in

1619
00:58:30,950 --> 00:58:27,119
order to have this interaction the

1620
00:58:32,630 --> 00:58:30,960
question then why goo pingal gu and ip

1621
00:58:35,109 --> 00:58:32,640
and um

1622
00:58:37,589 --> 00:58:35,119
maureen jardine who has a recent paper

1623
00:58:39,589 --> 00:58:37,599
2006 paper they need to invoke a

1624
00:58:42,150 --> 00:58:39,599
magnetic field to get the energies that

1625
00:58:44,470 --> 00:58:42,160
we see so then it becomes

1626
00:58:46,630 --> 00:58:44,480
a matter of what is the energy budget

1627
00:58:49,190 --> 00:58:46,640
and how do you how do you determine that

1628
00:58:51,109 --> 00:58:49,200
so when i showed at the beginning

1629
00:58:52,950 --> 00:58:51,119
the various part components that we're

1630
00:58:55,109 --> 00:58:52,960
interested in the stellar spectrum

1631
00:58:57,190 --> 00:58:55,119
trying to sample the various heights is

1632
00:59:00,309 --> 00:58:57,200
in order to do to really do

1633
00:59:02,710 --> 00:59:00,319
a measurement of the energy budget

1634
00:59:04,549 --> 00:59:02,720
for this so it's not just 10 to the 27

1635
00:59:06,870 --> 00:59:04,559
ergs per second there's more going on

1636
00:59:08,309 --> 00:59:06,880
it's only 10 to the 27 ergs per second

1637
00:59:10,069 --> 00:59:08,319
in calcium

1638
00:59:12,150 --> 00:59:10,079

but there's obviously much more going on

1639
00:59:14,230 --> 00:59:12,160
i mean there's the x-ray detections and

1640
00:59:15,990 --> 00:59:14,240
so you're right

1641
00:59:18,470 --> 00:59:16,000
prue says you don't need it to have that

1642
00:59:20,390 --> 00:59:18,480
kind in that communication scenario but

1643
00:59:21,750 --> 00:59:20,400
she can't work out um

1644
00:59:23,910 --> 00:59:21,760
but it doesn't work out with the energy

1645
00:59:26,230 --> 00:59:23,920
you just need more

1646
00:59:27,589 --> 00:59:26,240
heated more than what we've seen so

1647
00:59:29,750 --> 00:59:27,599
that then invokes it has to be a

1648
00:59:31,270 --> 00:59:29,760
relatively strong magnetic field so

1649
00:59:33,030 --> 00:59:31,280
right now the magnetic field strength

1650
00:59:34,630 --> 00:59:33,040
that people are

1651
00:59:37,430 --> 00:59:34,640
plugging into the models is jupiter's

1652
00:59:38,470 --> 00:59:37,440
4.3 gals for the la for lack of anything

1653
00:59:40,069 --> 00:59:38,480
better

1654
00:59:41,670 --> 00:59:40,079
um

1655
00:59:43,910 --> 00:59:41,680
and it's still

1656
00:59:45,589 --> 00:59:43,920
still a bit low like in the sense that i

1657
00:59:47,990 --> 00:59:45,599
but again we don't have the full all the

1658
00:59:50,069 --> 00:59:48,000
numbers yet but it seems like you need a

1659
00:59:51,670 --> 00:59:50,079
relatively strong magnetic field on the

1660
00:59:53,349 --> 00:59:51,680
planet in order to get those kinds of

1661
00:59:56,549 --> 00:59:53,359
energies to begin with

1662
01:00:00,309 --> 00:59:57,910
great thank you

1663
01:00:01,910 --> 01:00:00,319

okay we have time for one more question

1664
01:00:07,750 --> 01:00:01,920
if there's any signs out there with the

1665
01:00:13,430 --> 01:00:10,390
ucla i noticed you were doing some fine

1666
01:00:16,390 --> 01:00:14,950
okay great

1667
01:00:18,549 --> 01:00:16,400
well thank you all for attending and i'm

1668
01:00:20,630 --> 01:00:18,559
gonna turn it over to carl for some

1669
01:00:23,510 --> 01:00:20,640
closing remarks okay well thank you very

1670
01:00:25,270 --> 01:00:23,520
much elise and evgenya uh for two

1671
01:00:27,109 --> 01:00:25,280
interesting talks i just wanted to

1672
01:00:30,309 --> 01:00:27,119
encourage graduate students to

1673
01:00:32,710 --> 01:00:30,319
participate in this series as well

1674
01:00:34,309 --> 01:00:32,720
evgenya and elise are both postdocs and

1675
01:00:35,910 --> 01:00:34,319
both postdocs and graduate students are

1676
01:00:37,430 --> 01:00:35,920
welcome but i want the grad students in

1677
01:00:40,069 --> 01:00:37,440
particular

1678
01:00:42,309 --> 01:00:40,079
to feel welcome to participate and any

1679
01:00:45,349 --> 01:00:42,319
graduate student who was at the recent

1680
01:00:48,470 --> 01:00:45,359
ab grad con in puerto rico and gave a

1681
01:00:51,750 --> 01:00:48,480
talk there i would urge you to plan to

1682
01:00:54,630 --> 01:00:51,760
give that talk here in one of these far

1683
01:00:56,870 --> 01:00:54,640
seminars so thank you all for attending

1684
01:00:58,470 --> 01:00:56,880
and we'll see the next time