
JUNO & JUPITER
YAMILA MIGUEL

1
00:00:10,339 --> 00:00:07,179
[Music]

2
00:00:12,020 --> 00:00:10,349
hello everyone good morning it's really

3
00:00:14,330 --> 00:00:12,030
a pleasure for me to be here today

4
00:00:16,939 --> 00:00:14,340
giving this first lecture so thanks ray

5
00:00:19,790 --> 00:00:16,949
and the organizers for inviting me here

6
00:00:23,120 --> 00:00:19,800
and today I'm going to be talking about

7
00:00:24,950 --> 00:00:23,130
Jupiter mostly its interior and the

8
00:00:28,880 --> 00:00:24,960
things that we learn since we have the

9
00:00:30,769 --> 00:00:28,890
Juno mission out there so since this is

10
00:00:32,389 --> 00:00:30,779
the very first talk and even though I

11
00:00:34,940 --> 00:00:32,399
know everyone here knows a lot about

12
00:00:36,049 --> 00:00:34,950
planets I just want to say why it's

13
00:00:38,420 --> 00:00:36,059

important to study

14
00:00:40,430 --> 00:00:38,430
Dyanne planets well the thing is that

15
00:00:42,889 --> 00:00:40,440
these planets are the first ones to form

16
00:00:45,500 --> 00:00:42,899
in a planetary system and that's why

17
00:00:48,619 --> 00:00:45,510
they have very valuable information in

18
00:00:50,840 --> 00:00:48,629
their interiors and their atmospheres to

19
00:00:54,860 --> 00:00:50,850
understand how these systems form and

20
00:00:57,350 --> 00:00:54,870
how they evolve in the case of our solar

21
00:01:00,410 --> 00:00:57,360
system of course we have four giant

22
00:01:03,560 --> 00:01:00,420
planets mostly I would say Jupiter and

23
00:01:05,000 --> 00:01:03,570
Saturn had a huge influence and the

24
00:01:07,850 --> 00:01:05,010
thing is that we want to know more about

25
00:01:10,490 --> 00:01:07,860
them not only because they were the

26
00:01:12,740 --> 00:01:10,500
first planets to form but also because

27
00:01:15,020 --> 00:01:12,750
they are so big they had a huge

28
00:01:17,870 --> 00:01:15,030
dynamical influence on the smaller

29
00:01:19,700 --> 00:01:17,880
bodies in the system as well so it's

30
00:01:22,280 --> 00:01:19,710
really important for us to understand

31
00:01:24,440 --> 00:01:22,290
the history of our solar system to know

32
00:01:28,490 --> 00:01:24,450
more about how these planets form and

33
00:01:30,740 --> 00:01:28,500
evolved so this is why of course we want

34
00:01:33,319 --> 00:01:30,750
to know more about Jupiter this is the

35
00:01:35,870 --> 00:01:33,329
biggest planet in our system and it had

36
00:01:40,760 --> 00:01:35,880
a huge influence and we want to know

37
00:01:42,859 --> 00:01:40,770
much more about it now Jupiter is as I

38
00:01:45,770 --> 00:01:42,869

said the biggest one is the closest

39
00:01:47,660 --> 00:01:45,780
giant to the earth and there were many

40
00:01:48,499 --> 00:01:47,670
missions that went there we had the

41
00:01:50,660 --> 00:01:48,509
pioneers

42
00:01:52,880 --> 00:01:50,670
the voyagers the Galileo probe that

43
00:01:53,359 --> 00:01:52,890
actually entered into the atmosphere of

44
00:01:55,999 --> 00:01:53,369
Jupiter

45
00:01:58,700 --> 00:01:56,009
we had flybys of other missions by

46
00:02:01,819 --> 00:01:58,710
Cassini the five I new horizons also

47
00:02:04,880 --> 00:02:01,829
pass by we can see Jupiter with the

48
00:02:07,969 --> 00:02:04,890
naked eye and we can also serve it with

49
00:02:10,190 --> 00:02:07,979
very very like small telescopes so there

50
00:02:11,900 --> 00:02:10,200
is a lot of information that we have for

51
00:02:13,890 --> 00:02:11,910
this planet especially if we compare

52
00:02:17,039 --> 00:02:13,900
with exoplanets for example

53
00:02:21,210 --> 00:02:17,049
but still there are very key things

54
00:02:23,369 --> 00:02:21,220
about Jupiter that we don't know and the

55
00:02:25,229 --> 00:02:23,379
ones I'm more interested in than the

56
00:02:29,190 --> 00:02:25,239
ones I will be talking during these

57
00:02:33,509 --> 00:02:29,200
talks it's mostly first of all what is

58
00:02:35,910 --> 00:02:33,519
Jupiter made of and we know is mostly

59
00:02:37,949 --> 00:02:35,920
hydrogen and helium but we don't know

60
00:02:40,259 --> 00:02:37,959
exactly the amount of heavy elements in

61
00:02:42,089 --> 00:02:40,269
the interior of the planet and this is

62
00:02:44,580 --> 00:02:42,099
of course very important if we want to

63
00:02:48,390 --> 00:02:44,590

understand how and where it formed and

64
00:02:51,449 --> 00:02:48,400
how it evolved and also related to these

65
00:02:54,089 --> 00:02:51,459
I want to know how these heavy elements

66
00:02:56,339 --> 00:02:54,099
are distributed in the planet does it

67
00:02:58,229 --> 00:02:56,349
have a core or not which is the

68
00:02:59,670 --> 00:02:58,239
structure where all these heavies

69
00:03:02,220 --> 00:02:59,680
accommodated in the different layers

70
00:03:03,990 --> 00:03:02,230
within the planet which is the relation

71
00:03:06,180 --> 00:03:04,000
between the atmosphere and the interior

72
00:03:08,160 --> 00:03:06,190
are there some things that we can say

73
00:03:10,770 --> 00:03:08,170
when looking at the atmosphere to infer

74
00:03:13,140 --> 00:03:10,780
the interior structure these are all

75
00:03:14,819 --> 00:03:13,150
questions that I want to know and of

76
00:03:17,039 --> 00:03:14,829
course will help us not only to

77
00:03:19,229 --> 00:03:17,049
understand our solar system but in the

78
00:03:21,390 --> 00:03:19,239
future if we think that planet formation

79
00:03:23,490 --> 00:03:21,400
is a general process we might try to

80
00:03:26,849 --> 00:03:23,500
understand exoplanets using these models

81
00:03:27,599 --> 00:03:26,859
as well so that's why I really want to

82
00:03:30,629 --> 00:03:27,609
know these things

83
00:03:32,280 --> 00:03:30,639
and even though let me first give you an

84
00:03:34,949 --> 00:03:32,290
a spoiler I'm not going to give you a

85
00:03:37,199 --> 00:03:34,959
definitive answer on this because it's a

86
00:03:40,670 --> 00:03:37,209
very complex problem but we are learning

87
00:03:44,159 --> 00:03:40,680
many many many things about Jupiter DC

88
00:03:47,059 --> 00:03:44,169

now just to give you an idea of why we

89
00:03:50,069 --> 00:03:47,069
really needed another mission to Jupiter

90
00:03:52,439 --> 00:03:50,079
let me first say what the things that we

91
00:03:55,890 --> 00:03:52,449
knew before Jupiter and Juno arrived to

92
00:03:59,599 --> 00:03:55,900
Jupiter and this is a classical interior

93
00:04:02,640 --> 00:03:59,609
model of Jupiter that we used to to use

94
00:04:05,789 --> 00:04:02,650
there are other alternative models but

95
00:04:09,240 --> 00:04:05,799
many people was using this one where do

96
00:04:11,729 --> 00:04:09,250
Peter had an outer atmosphere mainly

97
00:04:14,189 --> 00:04:11,739
made by molecular hydrogen and helium as

98
00:04:18,240 --> 00:04:14,199
I said it also has heavies but they are

99
00:04:22,110 --> 00:04:18,250
a tiny percentage of the atmosphere then

100
00:04:25,110 --> 00:04:22,120
we have an inner envelope mainly made by

101
00:04:27,040 --> 00:04:25,120
metallic hydrogen if you see hydrogen

102
00:04:29,020 --> 00:04:27,050
has a phase transition it doesn't

103
00:04:31,990 --> 00:04:29,030
we Haven as molecular gas when we had

104
00:04:34,240 --> 00:04:32,000
very high pressure and also helium and

105
00:04:36,100 --> 00:04:34,250
helium is the abundance of helium in

106
00:04:38,439 --> 00:04:36,110
this layer is not the same one as this

107
00:04:41,619 --> 00:04:38,449
one and I'm going to be coming back to

108
00:04:44,529 --> 00:04:41,629
this later during the top I also put

109
00:04:47,680 --> 00:04:44,539
there a core even though has many of you

110
00:04:50,200 --> 00:04:47,690
may be heard there was a thing with the

111
00:04:52,510 --> 00:04:50,210
core of Jupiter that we really didn't

112
00:04:55,390 --> 00:04:52,520
know if to be there halep or because it

113
00:04:57,610 --> 00:04:55,400

was possible to actually feed all the

114
00:05:00,370 --> 00:04:57,620
observational constraints with no

115
00:05:02,290 --> 00:05:00,380
Corrado just be looting all the heavy

116
00:05:04,360 --> 00:05:02,300
elements in the envelope of the funnel

117
00:05:06,850 --> 00:05:04,370
and then we were also able to reproduce

118
00:05:08,740 --> 00:05:06,860
the observables that we had so then this

119
00:05:10,960 --> 00:05:08,750
was a big question because it's

120
00:05:13,300 --> 00:05:10,970
definitely not the same if the planet

121
00:05:16,779 --> 00:05:13,310
has a core or if it doesn't especially

122
00:05:18,820 --> 00:05:16,789
for formation scenarios and we also had

123
00:05:20,980 --> 00:05:18,830
a huge dispersion in the heavy in the

124
00:05:23,740 --> 00:05:20,990
rest of the heavy elements there were

125
00:05:25,959 --> 00:05:23,750
some models where we had very few heavy

126
00:05:27,760 --> 00:05:25,969
elements here and a big score some

127
00:05:30,399 --> 00:05:27,770
others where we have no core everything

128
00:05:31,990 --> 00:05:30,409
was looted there were also some models

129
00:05:33,909 --> 00:05:32,000
that didn't have this classical

130
00:05:34,510 --> 00:05:33,919
structure but where they have like

131
00:05:36,760 --> 00:05:34,520
stairs

132
00:05:39,040 --> 00:05:36,770
I like the model that Jeremy's I can't

133
00:05:41,350 --> 00:05:39,050
introduce a few years ago and then if

134
00:05:42,969 --> 00:05:41,360
you believe that there were many many

135
00:05:45,790 --> 00:05:42,979
more heavy elements that you could put

136
00:05:48,879 --> 00:05:45,800
here so there were huge uncertainties

137
00:05:50,409 --> 00:05:48,889
and just to show you an example this is

138
00:05:53,260 --> 00:05:50,419

a figure of a paper I made a few years

139
00:05:55,600 --> 00:05:53,270
ago where I'm showing here the mass of

140
00:05:58,959 --> 00:05:55,610
heavy elements in the envelope and the

141
00:06:00,279 --> 00:05:58,969
korma and you can see results depending

142
00:06:03,339 --> 00:06:00,289
on the equation of state that we were

143
00:06:05,260 --> 00:06:03,349
using this is a bit outdated there are

144
00:06:07,510 --> 00:06:05,270
new equations of state now that are not

145
00:06:09,399 --> 00:06:07,520
included here so this is just for you to

146
00:06:12,399 --> 00:06:09,409
have an idea of the state of the earth

147
00:06:14,200 --> 00:06:12,409
before Juno arrives to Jupiter so you

148
00:06:17,290 --> 00:06:14,210
can see that there were big differences

149
00:06:19,420 --> 00:06:17,300
for example we have like as either a

150
00:06:22,480 --> 00:06:19,430
very big core and a small amount of

151
00:06:25,360 --> 00:06:22,490
heavy elements in the envelope or even

152
00:06:28,689 --> 00:06:25,370
zero core and the rest of the materials

153
00:06:32,980 --> 00:06:28,699
are included in the envelope itself so

154
00:06:35,620 --> 00:06:32,990
we needed to improve two things first we

155
00:06:37,420 --> 00:06:35,630
needed better methods better numerical

156
00:06:39,850 --> 00:06:37,430
techniques a better model for the

157
00:06:40,930 --> 00:06:39,860
interior of the planet and we also

158
00:06:43,300 --> 00:06:40,940
needed to have

159
00:06:46,090 --> 00:06:43,310
better constraint better observation and

160
00:06:50,770 --> 00:06:46,100
for that reason we needed a new mission

161
00:06:53,110 --> 00:06:50,780
and we thank you know out there so I'm

162
00:06:55,060 --> 00:06:53,120
going to say a few things about the

163
00:06:55,690 --> 00:06:55,070

mission just in case you haven't heard

164
00:06:58,600 --> 00:06:55,700
about it

165
00:07:01,500 --> 00:06:58,610
Juneau is a NASA mission it was launched

166
00:07:04,720 --> 00:07:01,510
in 2011 and it arrived the Jupiter in

167
00:07:07,720 --> 00:07:04,730
2016 so it's been there for three years

168
00:07:10,480 --> 00:07:07,730
now and it's not only doing gravity

169
00:07:12,970 --> 00:07:10,490
science that is what I'm very interested

170
00:07:15,220 --> 00:07:12,980
in but it's also doing other great

171
00:07:18,430 --> 00:07:15,230
science he's measuring and the magnetic

172
00:07:20,350 --> 00:07:18,440
field of Jupiter the aurora and also

173
00:07:22,330 --> 00:07:20,360
doing atmospheric measurements that I

174
00:07:27,850 --> 00:07:22,340
hope we will be hearing more about that

175
00:07:31,570 --> 00:07:27,860
in the next year so it also has a very

176
00:07:34,270 --> 00:07:31,580
nice camera and if you haven't seen so

177
00:07:36,580 --> 00:07:34,280
far pictures of Jupiter I'm putting here

178
00:07:40,210 --> 00:07:36,590
some of them because they are just super

179
00:07:43,510 --> 00:07:40,220
beautiful and I had to show them so this

180
00:07:45,280 --> 00:07:43,520
is a time-lapse that was made by Jean

181
00:07:47,920 --> 00:07:45,290
Duran that is actually a citizen

182
00:07:50,170 --> 00:07:47,930
scientist where you can go to the

183
00:07:52,540 --> 00:07:50,180
website of Juno and download the raw

184
00:07:55,420 --> 00:07:52,550
images play around with and implode them

185
00:07:58,690 --> 00:07:55,430
again and this is an example piece so

186
00:08:00,580 --> 00:07:58,700
this is real Jupiter what Sean did was

187
00:08:03,820 --> 00:08:00,590
to change the beat the colors to change

188
00:08:06,700 --> 00:08:03,830

the contrast and in this way he got like

189
00:08:09,520 --> 00:08:06,710
this very nice definition of different

190
00:08:10,840 --> 00:08:09,530
features but this is real Jupiter before

191
00:08:14,320 --> 00:08:10,850
you ask me is not that the colors are

192
00:08:16,750 --> 00:08:14,330
painted or anything so I think this is

193
00:08:19,300 --> 00:08:16,760
amazing we didn't have pictures of

194
00:08:21,280 --> 00:08:19,310
Jupiter like this once before and that's

195
00:08:22,750 --> 00:08:21,290
why I wanted to show them to you even

196
00:08:24,280 --> 00:08:22,760
though they are not adding to the

197
00:08:26,350 --> 00:08:24,290
science I'm going to be talking about

198
00:08:28,840 --> 00:08:26,360
children's of the talk but I think they

199
00:08:32,440 --> 00:08:28,850
are really beautiful and I have a few

200
00:08:34,360 --> 00:08:32,450
more just one more slide of this here

201
00:08:37,270 --> 00:08:34,370
you can even see the clouds structure

202
00:08:41,200 --> 00:08:37,280
you can see the turbulence that Jupiter

203
00:08:44,890 --> 00:08:41,210
has like this one sphere as well and

204
00:08:46,720 --> 00:08:44,900
these are again just my favorite you can

205
00:08:51,610 --> 00:08:46,730
just go to the website and check all of

206
00:08:53,290 --> 00:08:51,620
them so we also seen some like these all

207
00:08:54,550 --> 00:08:53,300
these patterns we haven't seen those

208
00:08:57,160 --> 00:08:54,560
before

209
00:09:00,670 --> 00:08:57,170
thing is that the spacecrafts cassowary

210
00:09:02,920 --> 00:09:00,680
a 20-car always and in the pre job it's

211
00:09:05,019 --> 00:09:02,930
4,000 kilometers above the clouds of

212
00:09:07,720 --> 00:09:05,029
Jupiter and that's why we have these

213
00:09:10,540 --> 00:09:07,730

very nice images because it's awesome

214
00:09:13,569 --> 00:09:10,550
very close to the planet we also could

215
00:09:17,290 --> 00:09:13,579
see the pole of Jupiter that we've never

216
00:09:19,179 --> 00:09:17,300
seen like this before and well you can

217
00:09:21,009 --> 00:09:19,189
see that the pole is very it looks very

218
00:09:23,980 --> 00:09:21,019
different than the rest of the planet it

219
00:09:25,929 --> 00:09:23,990
has all these cyclones around it also

220
00:09:27,999 --> 00:09:25,939
has this bluish colour that I don't

221
00:09:31,420 --> 00:09:28,009
think we've seen in Jupiter before us at

222
00:09:33,579 --> 00:09:31,430
least I haven't and since I'm showing

223
00:09:36,160 --> 00:09:33,589
pictures of the pole I have this very

224
00:09:38,829 --> 00:09:36,170
last one that is not unbeatable but is

225
00:09:41,290 --> 00:09:38,839
on the infrared and where we can see

226
00:09:43,960 --> 00:09:41,300
here the pole and all the cyclones

227
00:09:45,790 --> 00:09:43,970
around these very very clearly I think

228
00:09:51,340 --> 00:09:45,800
this is one of the best images we have

229
00:09:54,309 --> 00:09:51,350
of the pole of Jupiter ok now let me go

230
00:09:56,499 --> 00:09:54,319
back not to the nice images but also the

231
00:09:59,350 --> 00:09:56,509
data that is actually as good as the

232
00:10:02,110 --> 00:09:59,360
images and the thing is that to do

233
00:10:04,600 --> 00:10:02,120
interior models we usually use two

234
00:10:06,850 --> 00:10:04,610
constraints on the one hand we use the

235
00:10:09,220 --> 00:10:06,860
gravity field of Jupiter this release

236
00:10:11,740 --> 00:10:09,230
what we use to make our interior models

237
00:10:13,600 --> 00:10:11,750
and on the other hand we also use the

238
00:10:15,879 --> 00:10:13,610

information we have for the atmosphere

239
00:10:19,809 --> 00:10:15,889
so I will be saying a few things about

240
00:10:21,939 --> 00:10:19,819
both first on the gravity field we can

241
00:10:24,369 --> 00:10:21,949
write the gravitational potential of 2

242
00:10:26,590 --> 00:10:24,379
Peter in this form where these are the

243
00:10:29,740 --> 00:10:26,600
Legendre polynomials and these are the

244
00:10:32,619 --> 00:10:29,750
gravity harmonics the harmonics that I

245
00:10:36,400 --> 00:10:32,629
wrote down here are very relevant for

246
00:10:38,799 --> 00:10:36,410
two reasons first they give us

247
00:10:40,809 --> 00:10:38,809
information on the density distribution

248
00:10:42,879 --> 00:10:40,819
in the interior of the planet and this

249
00:10:44,860 --> 00:10:42,889
is what we want to know we want to know

250
00:10:47,650 --> 00:10:44,870
how the material is distributed in

251
00:10:50,139 --> 00:10:47,660
interior and second because the

252
00:10:52,239 --> 00:10:50,149
observations are expressed in these

253
00:10:54,850 --> 00:10:52,249
gravity harmonics so then this is what

254
00:10:57,040 --> 00:10:54,860
we get from the observation and that's

255
00:10:58,809 --> 00:10:57,050
why they are very relevant and you will

256
00:10:59,559 --> 00:10:58,819
be hearing about these during the rest

257
00:11:02,530 --> 00:10:59,569
of the talk

258
00:11:05,079 --> 00:11:02,540
so pay attention we have infinite

259
00:11:08,260 --> 00:11:05,089
harmonics we don't have measurement of

260
00:11:10,960 --> 00:11:08,270
all of them so here is a cartoon

261
00:11:12,670 --> 00:11:10,970
also showing the relevance of each of

262
00:11:15,250 --> 00:11:12,680
them to give us information on the

263
00:11:17,470 --> 00:11:15,260

interior of the planet so if here we

264
00:11:19,930 --> 00:11:17,480
have the core and here we have the

265
00:11:24,190 --> 00:11:19,940
atmosphere you can see that the

266
00:11:26,680 --> 00:11:24,200
low-order J's J 2 J 4 up to j6 i would

267
00:11:29,680 --> 00:11:26,690
say give us information on the internal

268
00:11:31,990 --> 00:11:29,690
structure as well as the atmosphere if

269
00:11:34,750 --> 00:11:32,000
we go to higher and higher order J's

270
00:11:36,550 --> 00:11:34,760
then they give us less information on

271
00:11:39,040 --> 00:11:36,560
the interior and more information on the

272
00:11:42,370 --> 00:11:39,050
atmosphere so depending what we want to

273
00:11:44,620 --> 00:11:42,380
study with Jace we use it's not that if

274
00:11:46,329 --> 00:11:44,630
we have measurement of all of them we

275
00:11:48,550 --> 00:11:46,339
will know more about the deep interior

276
00:11:50,290 --> 00:11:48,560
because actually when we have higher and

277
00:11:54,280 --> 00:11:50,300
higher order we know more about this

278
00:11:57,610 --> 00:11:54,290
outer part so this is kind of a summary

279
00:12:00,220 --> 00:11:57,620
of this if we look at the Oh low order

280
00:12:02,470 --> 00:12:00,230
J's we can study better the internal

281
00:12:05,740 --> 00:12:02,480
structure what I will call during these

282
00:12:08,290 --> 00:12:05,750
talks the static components and if we if

283
00:12:10,750 --> 00:12:08,300
we look at high order J then we can

284
00:12:16,660 --> 00:12:10,760
study more the deep atmospheric dynamics

285
00:12:18,790 --> 00:12:16,670
of the channel now we have other J's so

286
00:12:21,880 --> 00:12:18,800
far I've been talking about the even but

287
00:12:24,040 --> 00:12:21,890
we also have the old days and the reason

288
00:12:26,500 --> 00:12:24,050

why we usually don't hear more about

289
00:12:28,840 --> 00:12:26,510
this one is because if the planet is

290
00:12:32,220 --> 00:12:28,850
actually and hemispherical asymmetric

291
00:12:34,300 --> 00:12:32,230
then these ones are 0 for symmetry and

292
00:12:36,940 --> 00:12:34,310
usually the measurements that we have

293
00:12:38,560 --> 00:12:36,950
were not at they didn't have the

294
00:12:40,780 --> 00:12:38,570
sensitivity enough to measure these

295
00:12:43,750 --> 00:12:40,790
things and we didn't have object for any

296
00:12:45,760 --> 00:12:43,760
of the China but now we could measure

297
00:12:48,160 --> 00:12:45,770
them with you know we do have

298
00:12:51,190 --> 00:12:48,170
measurements of the objects and this

299
00:12:55,540 --> 00:12:51,200
implies that the planet is not symmetric

300
00:12:58,060 --> 00:12:55,550
in the in both hemisphere so these days

301
00:13:00,100 --> 00:12:58,070
are actually very important because they

302
00:13:03,550 --> 00:13:00,110
give us direct information of the

303
00:13:06,250 --> 00:13:03,560
atmosphere Jupiter rotates in less than

304
00:13:08,290 --> 00:13:06,260
10 hours so it's a very fast rotator the

305
00:13:10,420 --> 00:13:08,300
interior we would expect that it rotates

306
00:13:13,329 --> 00:13:10,430
as a rigid body and kind of it's well

307
00:13:16,000 --> 00:13:13,339
mixed so then the thing is that if we

308
00:13:17,620 --> 00:13:16,010
have any asymmetry in both hemispheres

309
00:13:19,030 --> 00:13:17,630
they are probably coming from the

310
00:13:23,019 --> 00:13:19,040
atmosphere

311
00:13:25,210 --> 00:13:23,029
and we also made something is not the

312
00:13:26,620 --> 00:13:25,220
nice cartoon I showed before but this is

313
00:13:29,050 --> 00:13:26,630

from a paper that was actually not

314
00:13:31,870 --> 00:13:29,060
published yet so don't post anything

315
00:13:34,269 --> 00:13:31,880
like this so the thing is that here is

316
00:13:36,189 --> 00:13:34,279
the contribution of the old days to the

317
00:13:38,079 --> 00:13:36,199
internal structures similar figures I

318
00:13:42,400 --> 00:13:38,089
showed for the even J's but for the odd

319
00:13:44,889 --> 00:13:42,410
and here what you can see is that if you

320
00:13:49,060 --> 00:13:44,899
look at this number the objects are only

321
00:13:52,180 --> 00:13:49,070
giving us contribution in the outer 8%

322
00:13:53,860 --> 00:13:52,190
of the radio on D so then all the

323
00:13:55,720 --> 00:13:53,870
gravity signal that we are getting from

324
00:13:59,800 --> 00:13:55,730
this one are coming from the outer

325
00:14:02,129 --> 00:13:59,810
atmosphere so they are really a window

326
00:14:04,990 --> 00:14:02,139
to look at deep atmosphere of Jupiter

327
00:14:09,160 --> 00:14:05,000
and I will be again coming back to me

328
00:14:12,490 --> 00:14:09,170
now let me show you what we have before

329
00:14:14,470 --> 00:14:12,500
you know and what we have now so before

330
00:14:16,269 --> 00:14:14,480
you know we have measurements from the

331
00:14:18,730 --> 00:14:16,279
Pioneers the voyagers

332
00:14:20,740 --> 00:14:18,740
the way that we do this is analyzing the

333
00:14:22,660 --> 00:14:20,750
trajectory of the spacecraft around the

334
00:14:25,090 --> 00:14:22,670
planet and the anomalies are due to

335
00:14:26,530 --> 00:14:25,100
anomalies in the gravity field so then

336
00:14:31,030 --> 00:14:26,540
this is the information that we had

337
00:14:34,300 --> 00:14:31,040
before do know now we also have J a we

338
00:14:35,980 --> 00:14:34,310

have J 10 here is very 12 but this is

339
00:14:38,439 --> 00:14:35,990
the uncertainty SOI something we can use

340
00:14:41,280 --> 00:14:38,449
they 12 let's say that we have up to J

341
00:14:44,470 --> 00:14:41,290
10 but we also have as I said

342
00:14:46,840 --> 00:14:44,480
measurement of the odd days so this is

343
00:14:49,150 --> 00:14:46,850
all new that we had in the last three

344
00:14:51,819 --> 00:14:49,160
years and a bit less I would say because

345
00:14:53,680 --> 00:14:51,829
this was published last year actually so

346
00:14:56,860 --> 00:14:53,690
then you can see all these red points

347
00:14:59,860 --> 00:14:56,870
are new information and is much more

348
00:15:01,900 --> 00:14:59,870
than what we had before so this allow us

349
00:15:03,910 --> 00:15:01,910
to study other things that we couldn't

350
00:15:06,509 --> 00:15:03,920
really study before because we just

351
00:15:09,879 --> 00:15:06,519
didn't have the enough information now

352
00:15:13,600 --> 00:15:09,889
we are also having very much better

353
00:15:16,900 --> 00:15:13,610
accuracy so then here I'm showing J 4

354
00:15:18,730 --> 00:15:16,910
and J 6 mostly because this is what was

355
00:15:21,490 --> 00:15:18,740
very important for the interior models

356
00:15:24,250 --> 00:15:21,500
and here what you can see is this point

357
00:15:26,379 --> 00:15:24,260
will be very large share regard that was

358
00:15:29,769 --> 00:15:26,389
everything that we had used in pioneer

359
00:15:31,569 --> 00:15:29,779
and Voyager data now there were as I

360
00:15:32,910 --> 00:15:31,579
said at the beginning other missions

361
00:15:35,129 --> 00:15:32,920
that also want to Jupiter

362
00:15:38,189 --> 00:15:35,139
we had the Galileo probe we had a

363
00:15:42,059 --> 00:15:38,199

Cassini that made a flyby if we add that

364
00:15:45,030 --> 00:15:42,069
information here this is what we get so

365
00:15:47,489 --> 00:15:45,040
you can see that this is very very much

366
00:15:50,280 --> 00:15:47,499
better approximation that what we had

367
00:15:53,400 --> 00:15:50,290
before and of course it helped a lot for

368
00:15:56,220 --> 00:15:53,410
us doing interior models now after only

369
00:16:03,150 --> 00:15:56,230
one orbit of you know like the very

370
00:16:05,220 --> 00:16:03,160
first orbit this is what we got and the

371
00:16:07,409 --> 00:16:05,230
thing is that Juno has a special orbit

372
00:16:09,239 --> 00:16:07,419
that was designed to have better gravity

373
00:16:12,449 --> 00:16:09,249
data and that's why we are getting this

374
00:16:15,569 --> 00:16:12,459
such amazing data and this is the best

375
00:16:19,229 --> 00:16:15,579
that we have now is not that I forgot

376
00:16:21,239 --> 00:16:19,239
the error bars they are inside here is

377
00:16:24,119 --> 00:16:21,249
that good the data that we are getting

378
00:16:26,009 --> 00:16:24,129
and of course this is really amazing

379
00:16:28,949 --> 00:16:26,019
because we are getting to know the

380
00:16:30,539 --> 00:16:28,959
planet much better it also implies some

381
00:16:32,609 --> 00:16:30,549
problems because we actually had to

382
00:16:34,199 --> 00:16:32,619
update and to work a lot in our interior

383
00:16:36,569 --> 00:16:34,209
models to catch up with this amazing

384
00:16:39,629 --> 00:16:36,579
information so we were working a lot

385
00:16:42,059 --> 00:16:39,639
during this year trying to use this

386
00:16:44,280 --> 00:16:42,069
amazing data as it should be and we

387
00:16:49,079 --> 00:16:44,290
still have a lot of things that needs to

388
00:16:51,749 --> 00:16:49,089

be done so now let me move to the other

389
00:16:54,090 --> 00:16:51,759
constraint that we use on the one hand

390
00:16:57,479 --> 00:16:54,100
we use the gravity data on the other

391
00:16:59,939 --> 00:16:57,489
hand we use the atmospheric data and for

392
00:17:03,569 --> 00:16:59,949
these I was just curious and I made this

393
00:17:06,269 --> 00:17:03,579
figure where we have the different main

394
00:17:09,870 --> 00:17:06,279
careers of the different elements for

395
00:17:12,750 --> 00:17:09,880
different temperatures at 0.1 bar okay

396
00:17:14,220 --> 00:17:12,760
so what I wanted to know is is this if I

397
00:17:16,199 --> 00:17:14,230
want to know which is the elemental

398
00:17:19,259 --> 00:17:16,209
abundance of carbon which element should

399
00:17:20,789 --> 00:17:19,269
I look at that's why I maybe figure so

400
00:17:22,889 --> 00:17:20,799
then you can see that depending on the

401
00:17:25,409 --> 00:17:22,899
temperature there are different relevant

402
00:17:27,689 --> 00:17:25,419
elements if we go to the temperatures

403
00:17:30,480 --> 00:17:27,699
that we had into bitter this is like

404
00:17:33,029 --> 00:17:30,490
here so if we want to know the carbon

405
00:17:35,129 --> 00:17:33,039
abundance we see we look at methane if

406
00:17:37,529 --> 00:17:35,139
we want to see the nitrogen we look at

407
00:17:40,470 --> 00:17:37,539
nh3 if we want to see oxygen we look at

408
00:17:44,700 --> 00:17:40,480
water if we want to see sulphur with the

409
00:17:46,700 --> 00:17:44,710
h2s and phosphorous pH 3 this changes a

410
00:17:48,980 --> 00:17:46,710
bit if we go to exoplanet

411
00:17:51,139 --> 00:17:48,990
jeans because if we go to hotter

412
00:17:53,570 --> 00:17:51,149
temperatures some of these are not the

413
00:17:55,940 --> 00:17:53,580

main carriers of the element and for

414
00:17:58,820 --> 00:17:55,950
example for hotel planets instead of

415
00:18:01,519 --> 00:17:58,830
methane we look at Co and also the water

416
00:18:04,430 --> 00:18:01,529
is a bit tricky and this was by the way

417
00:18:07,190 --> 00:18:04,440
I was checking these these are fuzzy

418
00:18:09,159 --> 00:18:07,200
limits and of course this depends on the

419
00:18:11,930 --> 00:18:09,169
main composition this is for solar

420
00:18:13,930 --> 00:18:11,940
composition and also this was for the

421
00:18:16,310 --> 00:18:13,940
second idiom chemistry so there are some

422
00:18:19,190 --> 00:18:16,320
things that might change here but this

423
00:18:30,470 --> 00:18:19,200
give us a broader idea and I'm losing my

424
00:18:32,930 --> 00:18:30,480
thing they are we okay so coming back to

425
00:18:38,149 --> 00:18:32,940
Jupiter this is what we are interested

426
00:18:41,149 --> 00:18:38,159
in and let me move forward and this is

427
00:18:43,190 --> 00:18:41,159
what we have so here I'm showing the

428
00:18:46,190 --> 00:18:43,200
different elements for which we have

429
00:18:48,380 --> 00:18:46,200
abundance is measured and here are the

430
00:18:51,440 --> 00:18:48,390
elemental abundances compared to the

431
00:18:53,810 --> 00:18:51,450
protosun meaning that if the abundance

432
00:18:57,440 --> 00:18:53,820
is one this will be the same one as the

433
00:18:59,779 --> 00:18:57,450
proton this figure was made like this by

434
00:19:02,169 --> 00:18:59,789
actually Susheela TRAI in in a very nice

435
00:19:05,149 --> 00:19:02,179
paper that he polished in 2016 and

436
00:19:07,310 --> 00:19:05,159
because we want to know how enriched are

437
00:19:09,560 --> 00:19:07,320
the atmospheres of the planets in our

438
00:19:11,360 --> 00:19:09,570

solar system compares to the proton

439
00:19:13,730 --> 00:19:11,370
because they form from the same nebula

440
00:19:16,130 --> 00:19:13,740
and we usually assume that they have the

441
00:19:17,899 --> 00:19:16,140
same composition even when we work with

442
00:19:19,430 --> 00:19:17,909
the exoplanets the first assumption is

443
00:19:21,409 --> 00:19:19,440
to say okay they might have solar

444
00:19:23,779 --> 00:19:21,419
composition or the same composition of

445
00:19:25,820 --> 00:19:23,789
say it starts but if we look at the

446
00:19:27,980 --> 00:19:25,830
planet in our solar system we see that

447
00:19:30,560 --> 00:19:27,990
that is not the case they are actually

448
00:19:33,590 --> 00:19:30,570
and reached all of them compared to the

449
00:19:36,889 --> 00:19:33,600
program and there are some other

450
00:19:38,930 --> 00:19:36,899
peculiarities in this figure first you

451
00:19:42,500 --> 00:19:38,940
can see that for Jupiter is the planet

452
00:19:44,419 --> 00:19:42,510
for which we have much more data this is

453
00:19:46,940 --> 00:19:44,429
because we had this Galileo probe that

454
00:19:49,310 --> 00:19:46,950
entered in the atmosphere and made very

455
00:19:51,409 --> 00:19:49,320
nice measurements officially the noble

456
00:19:54,620 --> 00:19:51,419
gases that were measured in situ and we

457
00:19:56,750 --> 00:19:54,630
can not get in any other way so then if

458
00:19:58,840 --> 00:19:56,760
we look at hydrogen and neon

459
00:20:02,299 --> 00:19:58,850
you will see that these two are depleted

460
00:20:04,340 --> 00:20:02,309
compared to the problem and the reason

461
00:20:06,830 --> 00:20:04,350
for that is because there is a phase

462
00:20:08,900 --> 00:20:06,840
transition of helium in the interior of

463
00:20:12,320 --> 00:20:08,910

Jupiter that also happens in nature

464
00:20:14,690 --> 00:20:12,330
Europe pattern and helium the mixes from

465
00:20:17,090 --> 00:20:14,700
there from the hydrogen mixture it kind

466
00:20:19,760 --> 00:20:17,100
of forms droplets that trap the neon and

467
00:20:22,250 --> 00:20:19,770
rain down and then we have a depletion

468
00:20:24,919 --> 00:20:22,260
of helium and neon in the atmosphere in

469
00:20:27,110 --> 00:20:24,929
an overabundance in the interior so this

470
00:20:30,380 --> 00:20:27,120
is really an important constraint for us

471
00:20:33,080 --> 00:20:30,390
doing interior models now if we look at

472
00:20:35,120 --> 00:20:33,090
the other elements for example there is

473
00:20:38,060 --> 00:20:35,130
a peculiarity here and if you look at

474
00:20:40,789 --> 00:20:38,070
oxygen we don't have measurement of

475
00:20:43,730 --> 00:20:40,799
oxygen for any of the giant planets in

476
00:20:46,580 --> 00:20:43,740
the solar system we do have one for

477
00:20:48,289 --> 00:20:46,590
Jupiter I'm sitting here the thing is

478
00:20:50,539 --> 00:20:48,299
that we have this measurement of the

479
00:20:53,960 --> 00:20:50,549
Galileo probe of water that was very low

480
00:20:56,180 --> 00:20:53,970
it was around here and what happened is

481
00:20:58,310 --> 00:20:56,190
that the probe entered in a dry spot and

482
00:21:00,770 --> 00:20:58,320
that's why we can not trust that water

483
00:21:03,289 --> 00:21:00,780
measurements very well and we hope we

484
00:21:06,470 --> 00:21:03,299
need to get that we do know but we don't

485
00:21:08,210 --> 00:21:06,480
have it now and the reason why we don't

486
00:21:10,549 --> 00:21:08,220
have any water measurement is because

487
00:21:12,980 --> 00:21:10,559
all these planets are very cold and the

488
00:21:15,200 --> 00:21:12,990

water is kind of hidden behind clouds of

489
00:21:17,270 --> 00:21:15,210
other elements in the case of Jupiter we

490
00:21:19,909 --> 00:21:17,280
have a lot of ammonia so then we should

491
00:21:22,340 --> 00:21:19,919
pass all that to actually go and see the

492
00:21:24,380 --> 00:21:22,350
water and that's very difficult to do

493
00:21:27,980 --> 00:21:24,390
and we haven't been able to do that so

494
00:21:31,159 --> 00:21:27,990
far now other interesting thing is that

495
00:21:35,210 --> 00:21:31,169
if we look at your another Neptune we

496
00:21:38,360 --> 00:21:35,220
don't know anything about those funds we

497
00:21:40,580 --> 00:21:38,370
just have one dot here and just to put

498
00:21:42,919 --> 00:21:40,590
this in context let me show you what we

499
00:21:45,080 --> 00:21:42,929
do know about exoplanets and I'm sure

500
00:21:48,710 --> 00:21:45,090
that you will you all know more about

501
00:21:50,480 --> 00:21:48,720
this so I have to extend this figure to

502
00:21:54,620 --> 00:21:50,490
add all the water measurements that we

503
00:21:57,770 --> 00:21:54,630
have for exoplanets and here of course

504
00:21:59,810 --> 00:21:57,780
this is not entirely correct because I

505
00:22:01,909 --> 00:21:59,820
divided by the oxygen elements of the

506
00:22:04,010 --> 00:22:01,919
protosun and all of these planets were

507
00:22:06,470 --> 00:22:04,020
forming different stars so they probably

508
00:22:08,529 --> 00:22:06,480
have different metallicity so this was

509
00:22:10,899 --> 00:22:08,539
just to give an idea

510
00:22:14,379 --> 00:22:10,909
of what we have for exoplanets and we

511
00:22:16,599 --> 00:22:14,389
don't have for the solar system so this

512
00:22:18,789 --> 00:22:16,609
is just for context because I know that

513
00:22:22,299 --> 00:22:18,799

there is a lot of exoplanet clouds here

514
00:22:25,089 --> 00:22:22,309
and actually if I want to see this

515
00:22:28,209 --> 00:22:25,099
better here I put the mix in the water

516
00:22:31,419 --> 00:22:28,219
mixing ratio and there are metallicity

517
00:22:32,919 --> 00:22:31,429
of their stars for all the extra planets

518
00:22:36,609 --> 00:22:32,929
for which we have water measurement that

519
00:22:38,919 --> 00:22:36,619
are around 20 and here are the masses of

520
00:22:42,399 --> 00:22:38,929
these planets as a function of in

521
00:22:44,589 --> 00:22:42,409
Jupiter masses so here it will be around

522
00:22:46,389 --> 00:22:44,599
the solar system values right oxygen

523
00:22:50,079 --> 00:22:46,399
turbulence of the protosun and zero

524
00:22:52,779 --> 00:22:50,089
metallicity so we are observing quite

525
00:22:55,019 --> 00:22:52,789
different a big dispersion and we have a

526
00:22:58,749 --> 00:22:55,029
lot of information of these already and

527
00:23:01,659 --> 00:22:58,759
in addition to these four exoplanets we

528
00:23:04,809 --> 00:23:01,669
also have sodium we have potassium we

529
00:23:07,059 --> 00:23:04,819
have the oh we have helium detected so

530
00:23:09,909 --> 00:23:07,069
we are having a lot of information for

531
00:23:11,769 --> 00:23:09,919
this one we do know some exoplanets

532
00:23:14,199 --> 00:23:11,779
better than what we know Uranus and

533
00:23:15,879 --> 00:23:14,209
Neptune so we really should think about

534
00:23:19,539 --> 00:23:15,889
this and try to study those planets

535
00:23:23,889 --> 00:23:19,549
better because they are right here okay

536
00:23:26,859 --> 00:23:23,899
now we use all of these we use our

537
00:23:29,169 --> 00:23:26,869
gravity data we use the radius amount of

538
00:23:31,180 --> 00:23:29,179

the planet the abundance is that we have

539
00:23:34,149 --> 00:23:31,190
in the atmosphere especially Helio

540
00:23:36,039 --> 00:23:34,159
abundance is very relevant and in

541
00:23:38,499 --> 00:23:36,049
addition we have a model that explains

542
00:23:40,659 --> 00:23:38,509
in two year of the time where we assume

543
00:23:43,389 --> 00:23:40,669
hydrostatic equilibrium conservation of

544
00:23:45,099 --> 00:23:43,399
mass energy and the planet we assume

545
00:23:47,079 --> 00:23:45,109
that we have convection inside although

546
00:23:49,239 --> 00:23:47,089
that might also change and I will be

547
00:23:55,569 --> 00:23:49,249
coming back to that again in this thing

548
00:23:58,539 --> 00:23:55,579
is not there okay so of course we don't

549
00:24:00,189 --> 00:23:58,549
do this only one time and the reason for

550
00:24:02,559 --> 00:24:00,199
this is because this is have a generates

551
00:24:04,719 --> 00:24:02,569
problem there are many parameters that

552
00:24:06,999 --> 00:24:04,729
we don't know and that different values

553
00:24:08,889 --> 00:24:07,009
of them might give us a right answer so

554
00:24:10,899 --> 00:24:08,899
we want to know which are all the

555
00:24:13,149 --> 00:24:10,909
possibilities that explain the interior

556
00:24:16,299 --> 00:24:13,159
of Jupiter and for that we made

557
00:24:18,759 --> 00:24:16,309
thousands of models so we start with

558
00:24:21,520 --> 00:24:18,769
some initial parameters some of them we

559
00:24:24,159 --> 00:24:21,530
know some of them we don't know for it

560
00:24:26,440 --> 00:24:24,169
we don't know the mass of the core but

561
00:24:29,169 --> 00:24:26,450
we don't we know the helium elements in

562
00:24:31,419 --> 00:24:29,179
the atmosphere we also have the heavy

563
00:24:33,430 --> 00:24:31,429

elements upon us here and we kind of say

564
00:24:35,350 --> 00:24:33,440
ok we trust that all the other

565
00:24:37,840 --> 00:24:35,360
measurements that we have are more or

566
00:24:39,549 --> 00:24:37,850
less representative or we can wait to

567
00:24:40,590 --> 00:24:39,559
see what the water measurements give us

568
00:24:44,470 --> 00:24:40,600
in the future

569
00:24:46,450 --> 00:24:44,480
we have also that we we know the helium

570
00:24:48,909 --> 00:24:46,460
elements in the deeper interior and so

571
00:24:51,460 --> 00:24:48,919
on so we start with this initial

572
00:24:54,100 --> 00:24:51,470
parameter we calculate which is the

573
00:24:56,560 --> 00:24:54,110
radius and the days of a planet that has

574
00:24:58,930 --> 00:24:56,570
those parameters and then we compared

575
00:25:01,450 --> 00:24:58,940
are these ones the same observations

576
00:25:03,370 --> 00:25:01,460
that we have if they are then we just

577
00:25:05,740 --> 00:25:03,380
keep these as a possible solution for

578
00:25:08,590 --> 00:25:05,750
the interior of Jupiter and we run these

579
00:25:11,230 --> 00:25:08,600
thousands of times and we get about with

580
00:25:15,070 --> 00:25:11,240
all the possible solutions for the

581
00:25:19,270 --> 00:25:15,080
interior of the plant so if we look at

582
00:25:23,380 --> 00:25:19,280
where our models lay then we have here

583
00:25:25,779 --> 00:25:23,390
this is J 4 and this is J 6 and this is

584
00:25:28,299 --> 00:25:25,789
the same figure I showed before where we

585
00:25:30,610 --> 00:25:28,309
have the Galilei the Voyager and Pioneer

586
00:25:32,500 --> 00:25:30,620
point this is the Galileo and Cassini

587
00:25:35,740 --> 00:25:32,510
and here we have dunno with the first

588
00:25:37,899 --> 00:25:35,750

orbit and what this one here I didn't

589
00:25:40,090 --> 00:25:37,909
show it before but this is when we take

590
00:25:42,130 --> 00:25:40,100
into account new horizons data but

591
00:25:44,620 --> 00:25:42,140
apparently there was a problem with the

592
00:25:46,149 --> 00:25:44,630
systemic noise in the innovator they

593
00:25:48,100 --> 00:25:46,159
hadn't that's why this point is so far

594
00:25:54,010 --> 00:25:48,110
out so I took it out from the other

595
00:25:56,980 --> 00:25:54,020
figure now our models are all different

596
00:26:00,340 --> 00:25:56,990
here all these blue represents where all

597
00:26:02,230 --> 00:26:00,350
our models lay and we are not the only

598
00:26:04,270 --> 00:26:02,240
ones doing these calculations so I

599
00:26:06,130 --> 00:26:04,280
included here results by Borkar

600
00:26:08,289 --> 00:26:06,140
milliliter and will hovered and these

601
00:26:10,750 --> 00:26:08,299
are calculations made by many metalman

602
00:26:12,580 --> 00:26:10,760
and these are just greasing calculations

603
00:26:15,310 --> 00:26:12,590
there were previous calculations made as

604
00:26:17,799 --> 00:26:15,320
well on these so you can see that there

605
00:26:20,649 --> 00:26:17,809
is a huge dispersion in the values that

606
00:26:23,140 --> 00:26:20,659
we are getting and Jupiter does not look

607
00:26:25,210 --> 00:26:23,150
the same he fits around here or if it's

608
00:26:26,919 --> 00:26:25,220
around here and we want to know which is

609
00:26:29,470 --> 00:26:26,929
the difference because we already want

610
00:26:31,210 --> 00:26:29,480
these models so then we were studying

611
00:26:33,460 --> 00:26:31,220
which is the main difference between all

612
00:26:34,430 --> 00:26:33,470
of these and we found that they are

613
00:26:36,799 --> 00:26:34,440

mainly

614
00:26:39,619 --> 00:26:36,809
two parameters that really determine the

615
00:26:43,220 --> 00:26:39,629
internal structure one is the equation

616
00:26:46,070 --> 00:26:43,230
of state and of hydrogen mostly and

617
00:26:47,990 --> 00:26:46,080
believe it or not we still don't know

618
00:26:51,200 --> 00:26:48,000
very well the equation of state of

619
00:26:54,580 --> 00:26:51,210
hydrogen at least not for the conditions

620
00:26:57,320 --> 00:26:54,590
in planet in giant planet interiors so

621
00:26:59,029 --> 00:26:57,330
fortunately there is a lot of people

622
00:27:00,680 --> 00:26:59,039
working on this now there is a new

623
00:27:03,230 --> 00:27:00,690
equation of state published this year

624
00:27:05,659 --> 00:27:03,240
that kind of agrees much more with the

625
00:27:07,700 --> 00:27:05,669
previous ones than others but there are

626
00:27:10,639 --> 00:27:07,710
still some uncertainties on this problem

627
00:27:12,200 --> 00:27:10,649
and I'm really happy that there is

628
00:27:13,850 --> 00:27:12,210
people working on this because this is a

629
00:27:17,930 --> 00:27:13,860
very important thing that we need to

630
00:27:20,060 --> 00:27:17,940
solve the other important parameter is

631
00:27:23,840 --> 00:27:20,070
the distribution of heavy elements in

632
00:27:25,850 --> 00:27:23,850
the interior so then in this figure I'm

633
00:27:29,149 --> 00:27:25,860
showing exactly the same thing as before

634
00:27:32,389 --> 00:27:29,159
but now our models instead of being with

635
00:27:35,840 --> 00:27:32,399
that blue area are all this point here

636
00:27:38,419 --> 00:27:35,850
and the difference the gradient means

637
00:27:40,610 --> 00:27:38,429
the difference in heavy elements in the

638
00:27:43,669 --> 00:27:40,620

atmosphere and the deep interior of the

639
00:27:46,399 --> 00:27:43,679
planet so then what we see here is that

640
00:27:48,200 --> 00:27:46,409
this difference is zero when the planet

641
00:27:49,940 --> 00:27:48,210
is completely homogeneous when there is

642
00:27:51,740 --> 00:27:49,950
no difference between the heavy elements

643
00:27:55,580 --> 00:27:51,750
in the atmosphere and any parameter and

644
00:27:58,639 --> 00:27:55,590
when that happens we are around here so

645
00:28:01,700 --> 00:27:58,649
you see that Jupiter is definitely not

646
00:28:04,369 --> 00:28:01,710
homogeneous these values here can not

647
00:28:07,430 --> 00:28:04,379
explain the data that we are getting so

648
00:28:09,200 --> 00:28:07,440
we need to have a kind of more heavy

649
00:28:11,299 --> 00:28:09,210
element towards the interior of the

650
00:28:13,430 --> 00:28:11,309
planet and this is actually a very

651
00:28:15,799 --> 00:28:13,440
important result because it's telling us

652
00:28:18,590 --> 00:28:15,809
that the planet is not homogeneous we

653
00:28:20,389 --> 00:28:18,600
need to have something down there so it

654
00:28:24,710 --> 00:28:20,399
kind of proves out the no course

655
00:28:26,899 --> 00:28:24,720
scenario that we had before so then we

656
00:28:30,440 --> 00:28:26,909
included and you introduced a new model

657
00:28:33,049 --> 00:28:30,450
for Jupiter that is similar to the one I

658
00:28:35,419 --> 00:28:33,059
showed you before in the sense that we

659
00:28:38,090 --> 00:28:35,429
have the atmosphere mainly made of

660
00:28:40,399 --> 00:28:38,100
molecular hydrogen and helium the deeper

661
00:28:43,249 --> 00:28:40,409
interior of metallic hydrogen and

662
00:28:45,230 --> 00:28:43,259
enriched in helium but I included here

663
00:28:47,880 --> 00:28:45,240

another layer that we call the youth

664
00:28:50,670 --> 00:28:47,890
core that actually is

665
00:28:53,010 --> 00:28:50,680
layer that is highly enriched where the

666
00:28:56,370 --> 00:28:53,020
heavy elements mixed with a hydrogen and

667
00:28:59,310 --> 00:28:56,380
helium envelope and here we have the

668
00:29:01,260 --> 00:28:59,320
core itself so of course this is one

669
00:29:02,940 --> 00:29:01,270
model there are other authoritative

670
00:29:04,650 --> 00:29:02,950
models and if you are interested I

671
00:29:06,530 --> 00:29:04,660
invite you to look for example the paper

672
00:29:08,940 --> 00:29:06,540
by Debrecen chevrier published this year

673
00:29:11,130 --> 00:29:08,950
but this is one possibility that

674
00:29:14,220 --> 00:29:11,140
actually explains the result that we are

675
00:29:15,570 --> 00:29:14,230
finding with Juno right now and we like

676
00:29:17,580 --> 00:29:15,580
this much more than the previous one

677
00:29:19,470 --> 00:29:17,590
also because there are some formation

678
00:29:21,900 --> 00:29:19,480
models that said that the planet can

679
00:29:27,720 --> 00:29:21,910
actually have at the youth core from the

680
00:29:31,020 --> 00:29:27,730
formation point of view okay now let me

681
00:29:34,380 --> 00:29:31,030
move to the second and final part of my

682
00:29:37,260 --> 00:29:34,390
talk that is talking about another issue

683
00:29:39,270 --> 00:29:37,270
but that is also related to understand

684
00:29:42,300 --> 00:29:39,280
the interior of the planet and is the

685
00:29:45,420 --> 00:29:42,310
rotation of Jupiter in particular the

686
00:29:47,430 --> 00:29:45,430
differential rotation of Jupiter so when

687
00:29:50,550 --> 00:29:47,440
we observe the planet and we've been

688
00:29:53,340 --> 00:29:50,560

doing these things long time ago we can

689
00:29:55,380 --> 00:29:53,350
see that we have these zonal winds that

690
00:29:57,600 --> 00:29:55,390
Jupiter has in one like that some of

691
00:29:59,460 --> 00:29:57,610
them go in one direction some go in the

692
00:30:02,670 --> 00:29:59,470
other one they have different velocities

693
00:30:05,550 --> 00:30:02,680
and we've been observing that in years

694
00:30:09,300 --> 00:30:05,560
the thing is that what we don't know is

695
00:30:12,270 --> 00:30:09,310
how deep these winds extend into the

696
00:30:14,880 --> 00:30:12,280
planet and the reason why this is

697
00:30:17,610 --> 00:30:14,890
important is because all the models that

698
00:30:20,150 --> 00:30:17,620
I show to you so far are assuming that

699
00:30:23,310 --> 00:30:20,160
the planet rotates as a rigid body and

700
00:30:25,590 --> 00:30:23,320
if that is not the case if these winds

701
00:30:28,500 --> 00:30:25,600
extend very deep into the atmosphere

702
00:30:30,180 --> 00:30:28,510
into the planet then we have to take

703
00:30:31,950 --> 00:30:30,190
this into account in our interior

704
00:30:35,910 --> 00:30:31,960
calculations otherwise we might be

705
00:30:38,610 --> 00:30:35,920
taking wrong as wrong results so we

706
00:30:41,700 --> 00:30:38,620
wanted to know more about this and what

707
00:30:44,580 --> 00:30:41,710
we did first was to quantify how big is

708
00:30:47,340 --> 00:30:44,590
this so then again this is the same

709
00:30:49,530 --> 00:30:47,350
figure I showed before J 4 J 6 our

710
00:30:52,260 --> 00:30:49,540
models and the Doudna data and here

711
00:30:56,160 --> 00:30:52,270
enjoying the last calculation that we

712
00:30:58,320 --> 00:30:56,170
have and the thing is this all these

713
00:31:00,410 --> 00:30:58,330

models as I said are calculated assuming

714
00:31:03,410 --> 00:31:00,420
a rigid body

715
00:31:06,470 --> 00:31:03,420
happen so if you be the rotate in these

716
00:31:10,580 --> 00:31:06,480
as a rigid body the only good solution

717
00:31:12,350 --> 00:31:10,590
are the ones exactly here now we know

718
00:31:14,660 --> 00:31:12,360
that the planet does not rotate as a

719
00:31:16,970 --> 00:31:14,670
rigid body so then if we include these

720
00:31:19,820 --> 00:31:16,980
differential rotations there might be

721
00:31:21,770 --> 00:31:19,830
other models around here here that also

722
00:31:24,920 --> 00:31:21,780
explain the data when we take these into

723
00:31:27,500 --> 00:31:24,930
account so then we did an exploration of

724
00:31:29,510 --> 00:31:27,510
the extreme we said okay let's assume

725
00:31:30,320 --> 00:31:29,520
that this winds extend all the way to

726
00:31:33,050 --> 00:31:30,330
the core

727
00:31:35,360 --> 00:31:33,060
then which models which ones of all of

728
00:31:38,300 --> 00:31:35,370
these actually explain the data if we

729
00:31:40,190 --> 00:31:38,310
take that into account and we found that

730
00:31:43,580 --> 00:31:40,200
all of those ones here can actually

731
00:31:46,250 --> 00:31:43,590
explain the data in this case so you see

732
00:31:49,160 --> 00:31:46,260
that this again represents a huge error

733
00:31:51,200 --> 00:31:49,170
bar for us because these models here can

734
00:31:53,900 --> 00:31:51,210
also explain this point in these models

735
00:31:58,670 --> 00:31:53,910
here as well so we need it definitely to

736
00:32:00,350 --> 00:31:58,680
quantify this better now do you remember

737
00:32:04,630 --> 00:32:00,360
this figure that I showed at the very

738
00:32:07,910 --> 00:32:04,640

beginning yes no you're a fear waking up

739
00:32:10,610 --> 00:32:07,920
so we have the even harmonics and the

740
00:32:12,350 --> 00:32:10,620
old harmonics and if you remember I was

741
00:32:14,870 --> 00:32:12,360
telling you that the high order

742
00:32:16,970 --> 00:32:14,880
harmonics are the ones that we look at

743
00:32:20,060 --> 00:32:16,980
if we are seeing the deep atmospheric

744
00:32:22,820 --> 00:32:20,070
dynamics and I also mentioned that the

745
00:32:25,340 --> 00:32:22,830
old gravity harmonics are only giving us

746
00:32:28,520 --> 00:32:25,350
information on the on the outer part on

747
00:32:31,010 --> 00:32:28,530
the atmosphere of the planet and as I

748
00:32:33,530 --> 00:32:31,020
also said we even have information of

749
00:32:36,980 --> 00:32:33,540
these ones or this one before you know

750
00:32:38,480 --> 00:32:36,990
we only have it now so then now we can

751
00:32:40,610 --> 00:32:38,490
use this information to actually

752
00:32:42,530 --> 00:32:40,620
understand and constrain this

753
00:32:45,680 --> 00:32:42,540
differential rotation in the interior of

754
00:32:48,890 --> 00:32:45,690
the planet and that is what we did so we

755
00:32:51,170 --> 00:32:48,900
did that with two different methods we

756
00:32:54,050 --> 00:32:51,180
use on the one hand this information

757
00:32:56,510 --> 00:32:54,060
with the even gravity harmonics and on

758
00:32:58,520 --> 00:32:56,520
the other hand we use the old gravity

759
00:33:01,970 --> 00:32:58,530
harmonics and we check if we were

760
00:33:03,940 --> 00:33:01,980
finding similar results so let me first

761
00:33:06,740 --> 00:33:03,950
show you what we did with the even J's

762
00:33:10,130 --> 00:33:06,750
this is the first figure the same one

763
00:33:13,310 --> 00:33:10,140

I've been showing so far J 4 J 6 all

764
00:33:14,360 --> 00:33:13,320
these points are our interior models for

765
00:33:18,049 --> 00:33:14,370
now ignore

766
00:33:20,299 --> 00:33:18,059
these squares here and that yellow tiny

767
00:33:23,990 --> 00:33:20,309
yellow point is the Doudna point that

768
00:33:26,540 --> 00:33:24,000
actually is zoom in there no surprises

769
00:33:28,670 --> 00:33:26,550
here now let me show you what happened

770
00:33:34,520 --> 00:33:28,680
when we actually do the same thing for

771
00:33:37,730 --> 00:33:34,530
higher order J this is for j6 j 6 and j

772
00:33:40,910 --> 00:33:37,740
8 and again here are all our interior

773
00:33:43,760 --> 00:33:40,920
models that is the juno data you can see

774
00:33:45,770 --> 00:33:43,770
the zoom in here our interior models and

775
00:33:48,530 --> 00:33:45,780
the Doudna later just don't look at the

776
00:33:51,910 --> 00:33:48,540
squares and now i want you to tell me is

777
00:33:55,640 --> 00:33:51,920
there any model that explains the data

778
00:33:58,580 --> 00:33:55,650
not even one of all the models are down

779
00:34:00,230 --> 00:33:58,590
here the data is up here we tried many

780
00:34:02,120 --> 00:34:00,240
different things we try with other

781
00:34:04,130 --> 00:34:02,130
models there are also calculations like

782
00:34:06,200 --> 00:34:04,140
worker militar here which i different

783
00:34:07,580 --> 00:34:06,210
equations of the state we try all the

784
00:34:09,379 --> 00:34:07,590
different things that we could think of

785
00:34:11,810 --> 00:34:09,389
and there was no way of explaining the

786
00:34:13,580 --> 00:34:11,820
data and of course the reason for this

787
00:34:15,830 --> 00:34:13,590
is because we are looking at high order

788
00:34:18,139 --> 00:34:15,840

chase and differential rotation starts

789
00:34:20,659 --> 00:34:18,149
to be important and we have to take that

790
00:34:23,240 --> 00:34:20,669
into account and the same thing happens

791
00:34:26,060 --> 00:34:23,250
if you go to even higher JS we are here

792
00:34:28,070 --> 00:34:26,070
I'm showing day eight and a ten and here

793
00:34:29,810 --> 00:34:28,080
are our models and now the arrow bars

794
00:34:31,970 --> 00:34:29,820
are a bit larger and it looks like we

795
00:34:35,510 --> 00:34:31,980
actually can't explain them but it's

796
00:34:38,240 --> 00:34:35,520
like bossy so then the thing is that we

797
00:34:40,610 --> 00:34:38,250
said okay which is the depth of these

798
00:34:44,180 --> 00:34:40,620
wings that will actually allow us to

799
00:34:47,510 --> 00:34:44,190
explain these and our exploration showed

800
00:34:50,060 --> 00:34:47,520
that if we have winds as we've at three

801
00:34:53,119 --> 00:34:50,070
thousand kilometers then we are actually

802
00:34:56,480 --> 00:34:53,129
able to explain all the J's with our

803
00:34:59,270 --> 00:34:56,490
calculation so then this is really great

804
00:35:01,130 --> 00:34:59,280
we could put some constraints on the

805
00:35:04,220 --> 00:35:01,140
differential rotation of Jupiter for the

806
00:35:07,970 --> 00:35:04,230
first time and now let me show you what

807
00:35:10,700 --> 00:35:07,980
we found with the odd J's and this is a

808
00:35:12,590 --> 00:35:10,710
much more trustworthy method I have to

809
00:35:14,960 --> 00:35:12,600
say because the objects directly are

810
00:35:17,630 --> 00:35:14,970
related to the atmospheric dynamics they

811
00:35:20,930 --> 00:35:17,640
have no influence on the interior has no

812
00:35:22,610 --> 00:35:20,940
influence on these and this figure is a

813
00:35:24,500 --> 00:35:22,620

nice figure calculate is actually by

814
00:35:26,840 --> 00:35:24,510
your high copy and all of these are heap

815
00:35:28,130 --> 00:35:26,850
models where he was done in the

816
00:35:31,220 --> 00:35:28,140
circulation of the

817
00:35:33,620 --> 00:35:31,230
swing and then he calculated which would

818
00:35:37,010 --> 00:35:33,630
be the value of the difference or J

819
00:35:39,500 --> 00:35:37,020
depending on the depth of this wind so

820
00:35:42,290 --> 00:35:39,510
if these winds are very shallow if they

821
00:35:44,930 --> 00:35:42,300
don't go very deep into the planet then

822
00:35:47,300 --> 00:35:44,940
there is a very little math involved in

823
00:35:49,430 --> 00:35:47,310
the wind and then the gravity signal is

824
00:35:50,330 --> 00:35:49,440
going to be small so therefore we will

825
00:35:53,510 --> 00:35:50,340
be around here

826
00:35:56,990 --> 00:35:53,520
now if the winds go deeper into the

827
00:35:59,450 --> 00:35:57,000
planet and there then there is more mass

828
00:36:01,820 --> 00:35:59,460
involving the wind there is a larger

829
00:36:04,400 --> 00:36:01,830
gravity signal and that's why we have a

830
00:36:07,130 --> 00:36:04,410
larger values here so he made this

831
00:36:09,950 --> 00:36:07,140
figure theoretically and now we can over

832
00:36:13,850 --> 00:36:09,960
put here the measurements that we have

833
00:36:15,710 --> 00:36:13,860
and what you can see is that all the

834
00:36:17,990 --> 00:36:15,720
measurements overlap with the

835
00:36:20,990 --> 00:36:18,000
theoretical calculations at more or less

836
00:36:25,220 --> 00:36:21,000
the same place and that is also between

837
00:36:28,550 --> 00:36:25,230
1,000 and 3,000 kilometers so then with

838
00:36:31,160 --> 00:36:28,560

two independent path calculations we

839
00:36:33,740 --> 00:36:31,170
reach the same result that the winds

840
00:36:37,370 --> 00:36:33,750
that we observe in Jupiter extend up to

841
00:36:39,980 --> 00:36:37,380
three thousand kilometers and this this

842
00:36:42,530 --> 00:36:39,990
number am I not telling you much this is

843
00:36:45,710 --> 00:36:42,540
around four percent of the radius of the

844
00:36:49,370 --> 00:36:45,720
planet and it involves between three and

845
00:36:52,660 --> 00:36:49,380
four earth masses of materials going

846
00:36:55,310 --> 00:36:52,670
around in this wind and that's why it

847
00:36:57,470 --> 00:36:55,320
depends on the on the point of view from

848
00:37:00,350 --> 00:36:57,480
the interior point of view the rest of

849
00:37:03,200 --> 00:37:00,360
the planet is a rigid body so 96% of the

850
00:37:05,150 --> 00:37:03,210
radius is rigid body it's fine it's not

851
00:37:07,910 --> 00:37:05,160
a terrible approximation the one we were

852
00:37:10,390 --> 00:37:07,920
making now if we look at this from the

853
00:37:14,420 --> 00:37:10,400
perspective of the atmospheric dynamics

854
00:37:16,940 --> 00:37:14,430
this is a lot this is four percent of

855
00:37:19,340 --> 00:37:16,950
the radius it's around three Earth

856
00:37:22,730 --> 00:37:19,350
masses of material moving around in

857
00:37:25,160 --> 00:37:22,740
those wing so it really is it's

858
00:37:27,500 --> 00:37:25,170
something I think and we can constrain

859
00:37:29,690 --> 00:37:27,510
this as I said for the first time we

860
00:37:31,670 --> 00:37:29,700
also did a similar analysis for Saturn

861
00:37:33,830 --> 00:37:31,680
I'm not going to show it here because I

862
00:37:35,390 --> 00:37:33,840
want it to focus on Jupiter and the

863
00:37:37,849 --> 00:37:35,400

Dunamis on but if you are interested we

864
00:37:41,479 --> 00:37:37,859
can talk about that later

865
00:37:44,660 --> 00:37:41,489
so one last thing that I want to say is

866
00:37:47,150 --> 00:37:44,670
okay why this happen and we are trying

867
00:37:50,209 --> 00:37:47,160
to understand what is actually stopping

868
00:37:51,650 --> 00:37:50,219
this flow and now there are different

869
00:37:54,949 --> 00:37:51,660
things that we have to take into account

870
00:37:56,719 --> 00:37:54,959
and a nice thing of these periods of the

871
00:37:58,579 --> 00:37:56,729
Juno mission is that now we have to

872
00:37:59,930 --> 00:37:58,589
start talking with the other teams and

873
00:38:02,900 --> 00:37:59,940
trying to put all the puzzle pieces

874
00:38:04,969 --> 00:38:02,910
together one of the big puzzle pieces

875
00:38:06,709 --> 00:38:04,979
that we have to combine definitely with

876
00:38:09,259 --> 00:38:06,719
this interior model is the magnetic

877
00:38:11,239 --> 00:38:09,269
field that we actually have very good

878
00:38:13,549 --> 00:38:11,249
measurements of the magnetic field of

879
00:38:16,999 --> 00:38:13,559
Jupiter that we didn't have before and

880
00:38:19,729 --> 00:38:17,009
that might be playing a big role here so

881
00:38:22,609 --> 00:38:19,739
what I'm showing here is again the best

882
00:38:25,459 --> 00:38:22,619
of these winds and this is this black

883
00:38:26,900 --> 00:38:25,469
one is the profile the wind profile that

884
00:38:28,370 --> 00:38:26,910
actually was used in the previous

885
00:38:30,410 --> 00:38:28,380
calculations because that's another

886
00:38:33,410 --> 00:38:30,420
question right we are measuring the

887
00:38:35,329 --> 00:38:33,420
winds very up in the atmosphere how is

888
00:38:37,999 --> 00:38:35,339

the form the shape of these winds when

889
00:38:41,059 --> 00:38:38,009
we go deeper so in this case we were

890
00:38:43,339 --> 00:38:41,069
assuming an exponential decay that you

891
00:38:45,859 --> 00:38:43,349
can see it here and this blue our new

892
00:38:47,839 --> 00:38:45,869
canoe estimations calculated by current

893
00:38:49,910 --> 00:38:47,849
or where she has she's having this

894
00:38:52,459 --> 00:38:49,920
magnetic field into account and we are

895
00:38:54,769 --> 00:38:52,469
trying to improve this and what you can

896
00:38:57,259 --> 00:38:54,779
see here in the dashed line is the

897
00:38:59,870 --> 00:38:57,269
electrical conductivity in the interior

898
00:39:03,469 --> 00:38:59,880
of Jupiter made by models mostly by

899
00:39:05,410 --> 00:39:03,479
Kalka so what you can see is that the

900
00:39:08,269 --> 00:39:05,420
electrical conductivity increases

901
00:39:10,819 --> 00:39:08,279
suddenly when we have when our winds

902
00:39:13,219 --> 00:39:10,829
stop so we think that actually there is

903
00:39:15,529 --> 00:39:13,229
a magnetic drag playing a role there and

904
00:39:18,229 --> 00:39:15,539
stopping the flow and that's why then we

905
00:39:21,519 --> 00:39:18,239
have a rigid body rotation but we are

906
00:39:25,609 --> 00:39:21,529
just trying to understand this right now

907
00:39:28,549 --> 00:39:25,619
okay so I was much faster than I

908
00:39:30,949 --> 00:39:28,559
expected actually I just want to show

909
00:39:33,650 --> 00:39:30,959
this nice animation just to give you a

910
00:39:35,809 --> 00:39:33,660
more visual idea of these effects and

911
00:39:37,969 --> 00:39:35,819
this is from a press release that NASA

912
00:39:40,699 --> 00:39:37,979
made for the result of our papers and

913
00:39:43,549 --> 00:39:40,709

you can see here the flow the zonal

914
00:39:46,459 --> 00:39:43,559
winds that I was talking about and that

915
00:39:49,009 --> 00:39:46,469
they extend up to around four percent of

916
00:39:50,450 --> 00:39:49,019
the radius of the planet and in the

917
00:39:52,790 --> 00:39:50,460
deeper part the plan

918
00:39:55,550 --> 00:39:52,800
that rotates as a rigid body so I think

919
00:39:58,040 --> 00:39:55,560
this is a nice way of visualizing this

920
00:40:02,300 --> 00:39:58,050
problem and that's why I wanted to show

921
00:40:06,079 --> 00:40:02,310
it to you now let me just go to the

922
00:40:08,960 --> 00:40:06,089
take-home messages of this talk and the

923
00:40:12,320 --> 00:40:08,970
thing first of all is that we had much

924
00:40:14,750 --> 00:40:12,330
larger great improvement in the gravity

925
00:40:16,550 --> 00:40:14,760
data that we have with Juno and I think

926
00:40:18,410 --> 00:40:16,560
this is really the best we don't have

927
00:40:20,690 --> 00:40:18,420
this kind of data for the other giant

928
00:40:22,579 --> 00:40:20,700
planet we do have very good data for

929
00:40:24,710 --> 00:40:22,589
Saturn for certain we also have some

930
00:40:27,859 --> 00:40:24,720
extra information that seems from

931
00:40:30,980 --> 00:40:27,869
seismology but we don't have such a good

932
00:40:33,410 --> 00:40:30,990
gravity data for the other one and this

933
00:40:37,970 --> 00:40:33,420
is really due to this special orbit that

934
00:40:39,980 --> 00:40:37,980
Juno you know how we also could learn a

935
00:40:42,410 --> 00:40:39,990
bit more about the internal structure

936
00:40:44,450 --> 00:40:42,420
even though I cannot tell you yet which

937
00:40:46,370 --> 00:40:44,460
is the mass of the core and I know you

938
00:40:47,720 --> 00:40:46,380

all want to know because every time I

939
00:40:49,160 --> 00:40:47,730
give this talk the people is very well

940
00:40:51,589 --> 00:40:49,170
but you didn't tell us the amount of the

941
00:40:54,349 --> 00:40:51,599
core and the thing is that that is a

942
00:40:55,970 --> 00:40:54,359
very complex problem and now that we

943
00:40:58,760 --> 00:40:55,980
have this dilute core we are adding

944
00:41:00,980 --> 00:40:58,770
extra layers of complication let's say

945
00:41:03,500 --> 00:41:00,990
that we didn't have before because now

946
00:41:05,900 --> 00:41:03,510
we have other questions like how steep

947
00:41:08,720 --> 00:41:05,910
is the gradient of the composition there

948
00:41:10,730 --> 00:41:08,730
how that may affect the way that we are

949
00:41:12,310 --> 00:41:10,740
transporting energy and therefore the

950
00:41:14,780 --> 00:41:12,320
amount of heavy elements that we can put

951
00:41:17,510 --> 00:41:14,790
which is actually the amount of heavy

952
00:41:20,210 --> 00:41:17,520
there and how they increase in this

953
00:41:22,250 --> 00:41:20,220
dilute core so there are like many many

954
00:41:25,160 --> 00:41:22,260
new questions that we need to solve and

955
00:41:27,950 --> 00:41:25,170
discuss what we actually call up or if

956
00:41:30,349 --> 00:41:27,960
it's only the tiny part that has 100

957
00:41:33,050 --> 00:41:30,359
percent heavy elements or is this fancy

958
00:41:35,180 --> 00:41:33,060
the new score also counts at a core from

959
00:41:37,010 --> 00:41:35,190
the formation point of view so we need

960
00:41:39,109 --> 00:41:37,020
to have some discussions to actually

961
00:41:41,480 --> 00:41:39,119
understand this habit more and of course

962
00:41:44,450 --> 00:41:41,490
study this better before we can give a

963
00:41:46,070 --> 00:41:44,460

definitive answer but something that we

964
00:41:48,859 --> 00:41:46,080
can say is that we need to have

965
00:41:51,079 --> 00:41:48,869
something down there there is definitely

966
00:41:55,030 --> 00:41:51,089
a need for a larger amount of heavies

967
00:41:58,670 --> 00:41:55,040
deep down to explain the observation

968
00:42:00,980 --> 00:41:58,680
there are we could also constrain the

969
00:42:02,760 --> 00:42:00,990
differential rotations in the planet and

970
00:42:05,370 --> 00:42:02,770
these goes approximately up to

971
00:42:07,080 --> 00:42:05,380
3000 kilometers and of course this is

972
00:42:08,910 --> 00:42:07,090
also something that we have to put in

973
00:42:11,190 --> 00:42:08,920
the interior model because even though

974
00:42:13,680 --> 00:42:11,200
the rigid body is not such a bad

975
00:42:15,270 --> 00:42:13,690
approximation we still need to have this

976
00:42:17,160 --> 00:42:15,280
into account if we want to get more

977
00:42:19,920 --> 00:42:17,170
accurate results and especially because

978
00:42:23,550 --> 00:42:19,930
now we know how did they go so we need

979
00:42:25,770 --> 00:42:23,560
to take this into account and finally

980
00:42:26,820 --> 00:42:25,780
but not least I haven't done all of

981
00:42:29,460 --> 00:42:26,830
these by myself

982
00:42:32,250 --> 00:42:29,470
there is a very nice interior working

983
00:42:34,290 --> 00:42:32,260
group in dunno and all of them are here

984
00:42:36,420 --> 00:42:34,300
and now from this year we also have

985
00:42:39,000 --> 00:42:36,430
Jonathan for Denis and Nadine etymon

986
00:42:41,700 --> 00:42:39,010
joining us so they will be here in the

987
00:42:44,160 --> 00:42:41,710
next talk and here we have the whole

988
00:42:45,840 --> 00:42:44,170

juno team where you can see on the side

989
00:42:48,660 --> 00:42:45,850
the engineers and decide all the

990
00:42:51,030 --> 00:42:48,670
scientists that actually made this very

991
00:43:13,560 --> 00:42:51,040
nice mission possible and thank you for

992
00:43:18,850 --> 00:43:15,670
yes okay

993
00:43:20,950 --> 00:43:18,860
amazing yes mean I yeah I mean I you're

994
00:43:23,380 --> 00:43:20,960
you're leading the way I hope everybody

995
00:43:26,410 --> 00:43:23,390
will be five minutes early on the top

996
00:43:28,420 --> 00:43:26,420
like you so we do have a lot of time for

997
00:43:31,990 --> 00:43:28,430
questions but you know wanting to make

998
00:43:46,900 --> 00:43:43,120
any questions so for the magnetic drag

999
00:43:49,390 --> 00:43:46,910
you you this 3000 or some routine 1,000

1000
00:43:50,590 --> 00:43:49,400
to 3,000 kilometers deep part on Jupiter

1001
00:43:52,060 --> 00:43:50,600
what's the pressure and temperature

1002
00:43:55,030 --> 00:43:52,070
there I'm trying to reconcile this with

1003
00:43:57,190 --> 00:43:55,040
with like hot Jupiters and um and my

1004
00:43:59,980 --> 00:43:57,200
gonna track their Oh temperatures I

1005
00:44:06,310 --> 00:43:59,990
don't remember the pressure is 0.1 mega

1006
00:44:07,720 --> 00:44:06,320
bars so it's a lot the temperature I

1007
00:44:10,230 --> 00:44:07,730
don't remember I can I can check and

1008
00:44:13,180 --> 00:44:10,240
give you those number later

1009
00:44:15,790 --> 00:44:13,190
yeah I remember well the temperature is

1010
00:44:31,140 --> 00:44:15,800
very beeping the Cora 20,000 K but in

1011
00:44:36,190 --> 00:44:34,630
yeah would it be true to say or not that

1012
00:44:39,100 --> 00:44:36,200
the Juno results would be consistent

1013
00:44:41,550 --> 00:44:39,110

with having deep equatorial Jets say

1014
00:44:44,790 --> 00:44:41,560
from minus 20 to plus 20 with shallower

1015
00:44:47,470 --> 00:44:44,800
extra-tropical and high latitude Jets

1016
00:44:49,570 --> 00:44:47,480
what do you mean like deep a bit the

1017
00:44:52,350 --> 00:44:49,580
Jets that we observe suppose the Jets

1018
00:44:54,520 --> 00:44:52,360
yeah Jesse you observed perhaps with

1019
00:45:00,040 --> 00:44:54,530
tops they're only deep in the equatorial

1020
00:45:02,770 --> 00:45:00,050
regions ah okay yes I see so right now

1021
00:45:04,990 --> 00:45:02,780
we may like a global analysis of these

1022
00:45:07,810 --> 00:45:05,000
but you are right that we now have to go

1023
00:45:09,460 --> 00:45:07,820
to specific parts of the planet also we

1024
00:45:11,450 --> 00:45:09,470
are interested in the red red spot for

1025
00:45:13,790 --> 00:45:11,460
example to see how deep it goes

1026
00:45:15,589 --> 00:45:13,800
we haven't done that yet like specific

1027
00:45:27,740 --> 00:45:15,599
parts is something that we need to do

1028
00:45:32,059 --> 00:45:27,750
yeah thank you

1029
00:45:36,170 --> 00:45:32,069
from the outside it's all gravity but

1030
00:45:38,770 --> 00:45:36,180
you presented the model fitting to the

1031
00:45:44,540 --> 00:45:38,780
odd and even harmonics is quote-unquote

1032
00:45:46,880 --> 00:45:44,550
independent how within the team did that

1033
00:45:49,130 --> 00:45:46,890
sort of arise did did somebody say uh

1034
00:45:56,870 --> 00:45:49,140
you know I'll do the odd ones you do the

1035
00:46:00,559 --> 00:45:56,880
even one how did that how does the

1036
00:46:01,940 --> 00:46:00,569
process work so we are around between

1037
00:46:04,370 --> 00:46:01,950
twenty and thirty I would say I don't

1038
00:46:06,770 --> 00:46:04,380

know exactly the number but half the

1039
00:46:08,359 --> 00:46:06,780
team is doing the analysis of the

1040
00:46:10,609 --> 00:46:08,369
observations themselves and the other

1041
00:46:13,400 --> 00:46:10,619
half we are doing the interior models

1042
00:46:15,109 --> 00:46:13,410
within the interior models so far we had

1043
00:46:17,390 --> 00:46:15,119
two independent teams now as I said

1044
00:46:19,339 --> 00:46:17,400
Jonathan Nadine and also joining but it

1045
00:46:22,039 --> 00:46:19,349
was a three son and me on the one side

1046
00:46:24,280 --> 00:46:22,049
and I brought her military hover than

1047
00:46:27,140 --> 00:46:24,290
their team so we were doing independent

1048
00:46:29,539 --> 00:46:27,150
interior models and trying to discuss

1049
00:46:31,700 --> 00:46:29,549
and get her consensus between us and

1050
00:46:33,859 --> 00:46:31,710
with the observations it was more or

1051
00:46:36,410 --> 00:46:33,869
less the same there were two teams there

1052
00:46:38,930 --> 00:46:36,420
was a JPL team leads by wheels voltner

1053
00:46:41,480 --> 00:46:38,940
and there was people from Italy fees by

1054
00:46:43,910 --> 00:46:41,490
Luciana gist and they were both doing

1055
00:46:46,640 --> 00:46:43,920
independent calculations and then trying

1056
00:46:48,799 --> 00:46:46,650
to discuss I heard endless discussions

1057
00:46:50,839 --> 00:46:48,809
about their the error bars and you can

1058
00:46:54,170 --> 00:46:50,849
see that they're tiny but they really

1059
00:46:57,740 --> 00:46:54,180
wanted to have the consensus on that so

1060
00:47:00,650 --> 00:46:57,750
there was a submission of the various

1061
00:47:02,450 --> 00:47:00,660
publications coordinated or yes yes yes

1062
00:47:03,440 --> 00:47:02,460
we definitely discussed everything and

1063
00:47:13,370 --> 00:47:03,450

coordinate everything

1064
00:47:15,260 --> 00:47:13,380
yeah thanks yeah so I was right I was

1065
00:47:18,020 --> 00:47:15,270
interested in the in the data point you

1066
00:47:19,010 --> 00:47:18,030
put up for the carbon in Uranus and I

1067
00:47:22,280 --> 00:47:19,020
presume that's from spectroscopic

1068
00:47:23,770 --> 00:47:22,290
measurements of the of the outer part of

1069
00:47:25,280 --> 00:47:23,780
the Atmos Road do we have any

1070
00:47:28,160 --> 00:47:25,290
constraints from

1071
00:47:32,390 --> 00:47:28,170
the bulk density of Uranus on how that

1072
00:47:33,740 --> 00:47:32,400
carbon abundance relates to the bulk I'm

1073
00:47:35,390 --> 00:47:33,750
wondering there's always this question

1074
00:47:37,910 --> 00:47:35,400
of had the outer atmosphere that you can

1075
00:47:40,670 --> 00:47:37,920
see relates to bulk up the interior

1076
00:47:43,490 --> 00:47:40,680
composition because for the exoplanets

1077
00:47:45,470 --> 00:47:43,500
we will have bulk density and we'll have

1078
00:47:48,440 --> 00:47:45,480
outer atmosphere and putting those

1079
00:47:52,400 --> 00:47:48,450
pieces together is is always a tough

1080
00:47:54,410 --> 00:47:52,410
thing yeah I definitely agree I'm also

1081
00:47:56,330 --> 00:47:54,420
doing exoplanets so that's why I'm also

1082
00:47:58,310 --> 00:47:56,340
interested in this problem the thing we

1083
00:48:01,370 --> 00:47:58,320
do Renison neptune is that we also have

1084
00:48:04,160 --> 00:48:01,380
very very poor information on the

1085
00:48:06,530 --> 00:48:04,170
gravity as well only the Voyager 2 went

1086
00:48:09,710 --> 00:48:06,540
to those planets and then we have like a

1087
00:48:13,160 --> 00:48:09,720
only one point with huge error bars we

1088
00:48:16,700 --> 00:48:13,170

don't even have j6 we just have J 2 and

1089
00:48:18,500 --> 00:48:16,710
J 4 so then we have very these gravity

1090
00:48:20,600 --> 00:48:18,510
Zeta doesn't allow us to make such

1091
00:48:23,150 --> 00:48:20,610
detail models as we are doing here and

1092
00:48:25,880 --> 00:48:23,160
find a relation on the on the heavy

1093
00:48:28,190 --> 00:48:25,890
elements so I don't think we do have an

1094
00:48:30,290 --> 00:48:28,200
answer or at least I don't really know

1095
00:48:33,200 --> 00:48:30,300
an answer for that I haven't been doing

1096
00:48:35,000 --> 00:48:33,210
a lot of interior models on that so but

1097
00:48:36,710 --> 00:48:35,010
that is definitely something important

1098
00:48:38,330 --> 00:48:36,720
to look at and that's also why I'm

1099
00:48:40,280 --> 00:48:38,340
saying that we need to observe them more

1100
00:48:43,340 --> 00:48:40,290
because they are here they might give a

1101
00:49:05,630 --> 00:48:43,350
clue of how exoplanets work and we don't

1102
00:49:09,200 --> 00:49:05,640
know a lot about them wait for 10

1103
00:49:12,070 --> 00:49:09,210
seconds there we go

1104
00:49:13,790 --> 00:49:12,080
yeah could you comment on the

1105
00:49:16,070 --> 00:49:13,800
possibilities for constraining the

1106
00:49:17,180 --> 00:49:16,080
temporal evolution of the core dilution

1107
00:49:18,920 --> 00:49:17,190
because it seems like you could have

1108
00:49:22,010 --> 00:49:18,930
thank you by a member scenarios you have

1109
00:49:23,690 --> 00:49:22,020
a core forming and then stuff diffusing

1110
00:49:25,880 --> 00:49:23,700
out or you might have a later delivery

1111
00:49:29,090 --> 00:49:25,890
of heavies which then puts it in place

1112
00:49:31,250 --> 00:49:29,100
and it's not really significantly

1113
00:49:32,600 --> 00:49:31,260

evolving subsequently from formation so

1114
00:49:35,480 --> 00:49:32,610
and clearly that there's big

1115
00:49:37,400 --> 00:49:35,490
implications in terms of constraining

1116
00:49:38,420 --> 00:49:37,410
formation scenarios between the series

1117
00:49:41,210 --> 00:49:38,430
you want yeah

1118
00:49:43,280 --> 00:49:41,220
some prospects for concern yeah sure so

1119
00:49:45,890 --> 00:49:43,290
there are very nice model by Ilana

1120
00:49:48,530 --> 00:49:45,900
Masson actually doing evolution models

1121
00:49:52,220 --> 00:49:48,540
of Jupiter considering compositional

1122
00:49:54,589 --> 00:49:52,230
gradients and their results show that

1123
00:49:56,390 --> 00:49:54,599
actually it's possible to have so she

1124
00:49:58,339 --> 00:49:56,400
picked she starts the planet with

1125
00:50:00,200 --> 00:49:58,349
compositional gradients and she looks at

1126
00:50:02,089 --> 00:50:00,210
how these evolve and if it's possible to

1127
00:50:04,760 --> 00:50:02,099
maintain that from formation to what we

1128
00:50:06,920 --> 00:50:04,770
observed today and she found that indeed

1129
00:50:09,559 --> 00:50:06,930
it's possible to just maintain the

1130
00:50:12,380 --> 00:50:09,569
solute core from the formation point of

1131
00:50:14,900 --> 00:50:12,390
view so there might be two possibilities

1132
00:50:17,329 --> 00:50:14,910
one is that when we were forming the

1133
00:50:20,000 --> 00:50:17,339
planet and we were accreting gas and

1134
00:50:22,970 --> 00:50:20,010
solids at the same time then this kind

1135
00:50:25,339 --> 00:50:22,980
of dissolves and enriched like this part

1136
00:50:28,609 --> 00:50:25,349
around the core itself something like

1137
00:50:30,829 --> 00:50:28,619
that but if this is again being a study

1138
00:50:32,270 --> 00:50:30,839

I think that there are a few papers that

1139
00:50:34,700 --> 00:50:32,280
are dealing with this as far as I know

1140
00:50:37,220 --> 00:50:34,710
the other possibility is that this was

1141
00:50:40,309 --> 00:50:37,230
this happened later on and it's not a

1142
00:50:42,559 --> 00:50:40,319
dilute core but an eroded core so then

1143
00:50:44,809 --> 00:50:42,569
you had your core forming and that was

1144
00:50:47,089 --> 00:50:44,819
the erosion during the evolution could

1145
00:50:49,490 --> 00:50:47,099
mix the heavy elements there that's the

1146
00:50:51,680 --> 00:50:49,500
other possibility but I know that

1147
00:50:53,539 --> 00:50:51,690
ravit held with Tristan we're analyzing

1148
00:50:56,630 --> 00:50:53,549
that and apparently it's a very

1149
00:50:59,150 --> 00:50:56,640
inefficient process so they erosion it

1150
00:51:02,329 --> 00:50:59,160
might be the other scenario might be a

1151
00:51:26,990 --> 00:51:02,339
bit more favorable but we again need to

1152
00:51:28,549 --> 00:51:27,000
study all of these more great talk I had

1153
00:51:30,109 --> 00:51:28,559
a follow-up comment related to the

1154
00:51:33,079 --> 00:51:30,119
question that I guess that was Jeff

1155
00:51:35,660 --> 00:51:33,089
Alice hey I'm about the you know the

1156
00:51:38,059 --> 00:51:35,670
relative sort of chakra toriel versus

1157
00:51:40,640 --> 00:51:38,069
high up with toriel the the the dominant

1158
00:51:42,109 --> 00:51:40,650
sort of a sim and sort of the lack of

1159
00:51:43,819 --> 00:51:42,119
symmetry around the equator and the

1160
00:51:45,859 --> 00:51:43,829
cloud table zonal winds is that huge

1161
00:51:47,900 --> 00:51:45,869
zonal jetta sort of 23 degrees latitude

1162
00:51:50,059 --> 00:51:47,910
which lacks the counterpart of the other

1163
00:51:51,500 --> 00:51:50,069

hemisphere and of course outside the

1164
00:51:53,960 --> 00:51:51,510
equatorial jet

1165
00:51:56,450 --> 00:51:53,970
then and so that would sort of suggest

1166
00:51:58,340 --> 00:51:56,460
that the odd harmonics are actually

1167
00:51:59,300 --> 00:51:58,350
sensing you know when one sort of quotes

1168
00:52:01,850 --> 00:51:59,310
the number three thousand kilometers

1169
00:52:04,160 --> 00:52:01,860
it's not just inside the equatorial jet

1170
00:52:06,710 --> 00:52:04,170
and Yohai actually did an analysis where

1171
00:52:09,350 --> 00:52:06,720
he looked at the latitude variation of

1172
00:52:11,240 --> 00:52:09,360
this parameter age and that analysis

1173
00:52:12,800 --> 00:52:11,250
showed that a low latitudes the

1174
00:52:14,870 --> 00:52:12,810
thickness is somewhat larger than a high

1175
00:52:16,760 --> 00:52:14,880
latitudes but I specifically asked him

1176
00:52:20,080 --> 00:52:16,770
to exact question the US whether it's

1177
00:52:22,610 --> 00:52:20,090
possible to have all of the the sort of

1178
00:52:24,650 --> 00:52:22,620
deep you know the signature of the

1179
00:52:26,240 --> 00:52:24,660
harmonics inside just an equatorial jet

1180
00:52:27,770 --> 00:52:26,250
that cuts across the planet and have the

1181
00:52:29,900 --> 00:52:27,780
highlighted two Jets all died out of a

1182
00:52:31,250 --> 00:52:29,910
very shallow depth and the answer is no

1183
00:52:32,630 --> 00:52:31,260
as far as I understand they're enough

1184
00:52:33,080 --> 00:52:32,640
that would agree with you what you think

1185
00:52:35,720 --> 00:52:33,090
of it

1186
00:52:49,070 --> 00:52:35,730
yeah yeah thank you yeah thanks for the

1187
00:52:53,380 --> 00:52:49,080
comment thank you you know this is an

1188
00:53:02,810 --> 00:53:00,830

you never know but always constraining

1189
00:53:04,760 --> 00:53:02,820
the circulation of the deep interior or

1190
00:53:06,980 --> 00:53:04,770
is it just going to be entirely too

1191
00:53:11,510 --> 00:53:06,990
shallow for the problems that have been

1192
00:53:13,130 --> 00:53:11,520
interesting you 100 bar but that's

1193
00:53:14,860 --> 00:53:13,140
probably you're talking about a hundred

1194
00:53:17,780 --> 00:53:14,870
thousand bar that seems a little far off

1195
00:53:21,890 --> 00:53:17,790
yeah so you you gave the question in the

1196
00:53:23,570 --> 00:53:21,900
answer yes so yes with the microwave we

1197
00:53:25,910 --> 00:53:23,580
are seeing a hundred bars this is much

1198
00:53:28,670 --> 00:53:25,920
much much deeper but still with the

1199
00:53:30,890 --> 00:53:28,680
microwave radiometer we we we hope to

1200
00:53:33,260 --> 00:53:30,900
have the water abundance at some point

1201
00:53:36,290 --> 00:53:33,270
and that will definitely help up here

1202
00:53:38,210 --> 00:53:36,300
because the big quest of course that if

1203
00:53:40,940 --> 00:53:38,220
this planet formed beyond the snow line

1204
00:53:42,470 --> 00:53:40,950
the ices the water is going to be what

1205
00:53:44,480 --> 00:53:42,480
represents the heavy element in the

1206
00:53:46,940 --> 00:53:44,490
interior so we want to know they water

1207
00:53:50,840 --> 00:53:46,950
upon us and we don't have that yet so

1208
00:53:56,880 --> 00:53:50,850
yeah so you will help a lot but not on

1209
00:54:04,940 --> 00:54:00,769
and there's one more question anybody