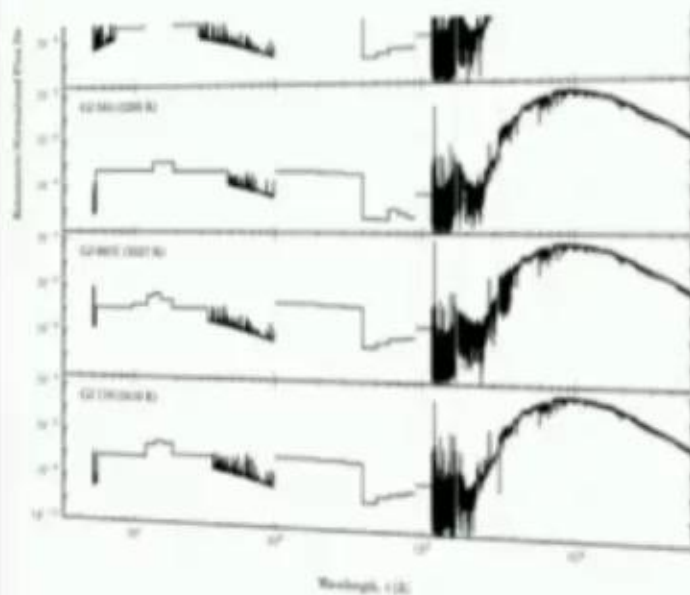
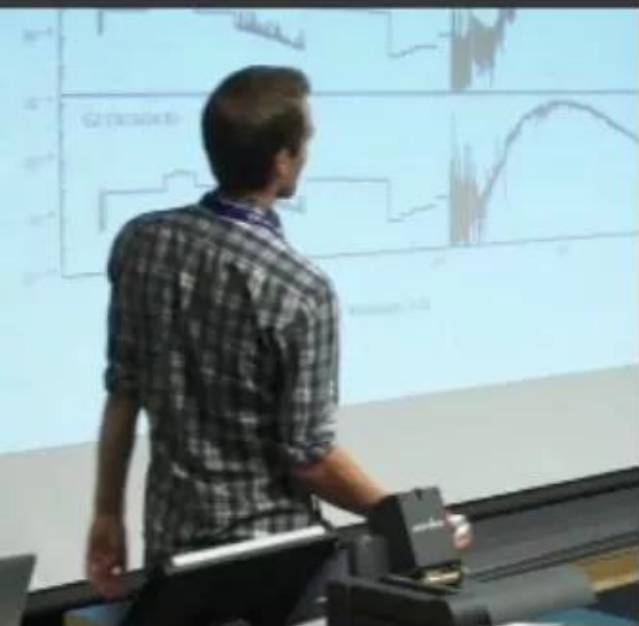


MUSCLES Data Product

Plug-n-play spectra for the photochemical modelers out there!



<https://archive.stsci.edu/prepds/muscles/>
Or search "muscles spectral catalog"



1
00:00:09,110 --> 00:00:08,089
I did a little switcheroo on the title

2
00:00:10,580 --> 00:00:09,120
and you guys sorry i thought i was going

3
00:00:12,589 --> 00:00:10,590
to be in the Astra chemistry session so

4
00:00:15,350 --> 00:00:12,599
i modified it a little bit to make it a

5
00:00:17,840 --> 00:00:15,360
little bit more relevant to that but we

6
00:00:20,269 --> 00:00:17,850
just got a boatload of data from Hubble

7
00:00:22,939 --> 00:00:20,279
Space Telescope on low mass stars that

8
00:00:26,359 --> 00:00:22,949
host planets and I'm going to give you a

9
00:00:31,009 --> 00:00:26,369
little tour of the what we see in those

10
00:00:32,630 --> 00:00:31,019
data ok so first here's how we're going

11
00:00:34,760 --> 00:00:32,640
to do it and I tell you about what

12
00:00:38,090 --> 00:00:34,770
muscles is and you know why we undertook

13
00:00:39,410 --> 00:00:38,100

this survey and then a quick a little

14

00:00:40,700 --> 00:00:39,420

bit about spectra and then we'll get

15

00:00:43,040 --> 00:00:40,710

into the what I think is the most

16

00:00:46,340 --> 00:00:43,050

interesting which is players that we see

17

00:00:47,869 --> 00:00:46,350

in these data and then I will brief

18

00:00:50,380 --> 00:00:47,879

overview what some of the possible

19

00:00:53,330 --> 00:00:50,390

implications of those flares are for

20

00:00:55,790 --> 00:00:53,340

exoplanet atmospheres all right so

21

00:00:58,490 --> 00:00:55,800

starting with muscles all right just

22

00:00:59,869 --> 00:00:58,500

like most acronyms in science

23

00:01:01,369 --> 00:00:59,879

engineering it's pretty contrived and

24

00:01:03,260 --> 00:01:01,379

goes measurements of the ultraviolet

25

00:01:05,000 --> 00:01:03,270

spectral characteristics of low-mass XO

26

00:01:06,380 --> 00:01:05,010

planetary systems so first let me

27

00:01:08,690 --> 00:01:06,390

shorten that a little bit so I can fit

28

00:01:11,450 --> 00:01:08,700

it on the top of the slide and then

29

00:01:13,460 --> 00:01:11,460

let's unpack the two important parts of

30

00:01:14,990 --> 00:01:13,470

this first of all why the ultraviolet

31

00:01:16,760 --> 00:01:15,000

spectral characteristics as opposed to

32

00:01:19,010 --> 00:01:16,770

other parts of the electromagnetic

33

00:01:21,050 --> 00:01:19,020

spectrum and then why low-mass

34

00:01:24,649 --> 00:01:21,060

exoplanetary systems so I'm going to go

35

00:01:26,390 --> 00:01:24,659

in reverse order since its near lunch I

36

00:01:30,260 --> 00:01:26,400

will go ahead and give you this little

37

00:01:31,640 --> 00:01:30,270

introduction to spectral types of stars

38

00:01:36,950 --> 00:01:31,650

even though this is briefly discussed

39

00:01:39,980 --> 00:01:36,960

earlier of course astronomers referred

40

00:01:41,300 --> 00:01:39,990

or classify stars using this lettering

41

00:01:42,740 --> 00:01:41,310

system which doesn't really make that

42

00:01:44,800 --> 00:01:42,750

much sense because it's not ordered by

43

00:01:49,969 --> 00:01:44,810

the alphabet but it has historical

44

00:01:52,340 --> 00:01:49,979

reasons for that and basically these

45

00:01:54,830 --> 00:01:52,350

stars on the left are as you can see the

46

00:01:56,030 --> 00:01:54,840

image k stars are cooler there redder

47

00:01:59,179 --> 00:01:56,040

which means they're cooler they're

48

00:02:01,639 --> 00:01:59,189

smaller the less luminous and as you

49

00:02:03,950 --> 00:02:01,649

know you go to spectral types of a piano

50

00:02:05,480 --> 00:02:03,960

they get bigger and hotter the sons of g

51
00:02:07,190 --> 00:02:05,490
star and the low-mass stars and i'm

52
00:02:10,040 --> 00:02:07,200
talking about our ending k stars and

53
00:02:11,510 --> 00:02:10,050
i'll probably eventually mess up and say

54
00:02:12,790 --> 00:02:11,520
endorse even though i don't want to do

55
00:02:15,190 --> 00:02:12,800
that to you guys because it makes it

56
00:02:16,450 --> 00:02:15,200
like these stars are irregular or

57
00:02:18,970 --> 00:02:16,460
something that they are not a normal

58
00:02:20,710 --> 00:02:18,980
size but it just means that they aren't

59
00:02:23,980 --> 00:02:20,720
they haven't become Giants yet so if I

60
00:02:26,380 --> 00:02:23,990
say m dwarf I mean a regular in star all

61
00:02:27,820 --> 00:02:26,390
right so the reason we care about these

62
00:02:29,290 --> 00:02:27,830
M stars is because basically there's a

63
00:02:33,190 --> 00:02:29,300

lot of them and you all probably seen

64

00:02:36,360 --> 00:02:33,200

this sketch from XKCD and all of the

65

00:02:39,190 --> 00:02:36,370

gray dots on this represent

66

00:02:40,900 --> 00:02:39,200

statistically at least planetary systems

67

00:02:44,320 --> 00:02:40,910

within 60 light-years of Earth that

68

00:02:46,510 --> 00:02:44,330

should be and should have stars that are

69

00:02:49,480 --> 00:02:46,520

smaller than the Sun essentially and the

70

00:02:51,120 --> 00:02:49,490

red points are sun-like stars and the

71

00:02:54,070 --> 00:02:51,130

gray points make up about ninety percent

72

00:02:55,630 --> 00:02:54,080

so by sheer numbers alone we should care

73

00:02:58,300 --> 00:02:55,640

about low mass stars when we think about

74

00:02:59,770 --> 00:02:58,310

planets okay so now you know about the

75

00:03:02,980 --> 00:02:59,780

low-mass part of that title what about

76

00:03:06,730 --> 00:03:02,990

the UV well here is a stellar spectrum I

77

00:03:09,820 --> 00:03:06,740

have modified the scale a little bit so

78

00:03:12,400 --> 00:03:09,830

the black body part of the spectrum is

79

00:03:13,330 --> 00:03:12,410

actually fits on the diagram but we're

80

00:03:15,820 --> 00:03:13,340

actually not gonna talk about the black

81

00:03:18,640 --> 00:03:15,830

body at all instead we're curious about

82

00:03:20,710 --> 00:03:18,650

the UV because photons in the UV have

83

00:03:25,720 --> 00:03:20,720

about the right amount of energy to

84

00:03:29,410 --> 00:03:25,730

split atoms off of molecules oh so for

85

00:03:31,360 --> 00:03:29,420

example you can associate oxygen and we

86

00:03:34,449 --> 00:03:31,370

were also curious about slightly shorter

87

00:03:35,920 --> 00:03:34,459

wavelengths the x-ray and extreme

88

00:03:40,110 --> 00:03:35,930

ultraviolet because these have enough

89

00:03:42,790 --> 00:03:40,120

energy to eject an electron from an atom

90

00:03:43,870 --> 00:03:42,800

and this actually has a big role plays a

91

00:03:46,030 --> 00:03:43,880

big role in heating the upper atmosphere

92

00:03:50,110 --> 00:03:46,040

of planets so that's the ultraviolet

93

00:03:52,210 --> 00:03:50,120

part of this ok so before I go any

94

00:03:54,220 --> 00:03:52,220

further let me just plug our main

95

00:03:56,650 --> 00:03:54,230

spectral data products go fast we

96

00:03:59,050 --> 00:03:56,660

managed to squeeze 30 I mean we managed

97

00:04:02,530 --> 00:03:59,060

to write three very important

98

00:04:04,060 --> 00:04:02,540

informative favors about how we reduce

99

00:04:05,979 --> 00:04:04,070

these data and everything that went into

100

00:04:08,949 --> 00:04:05,989

getting spectra that go all the way from

101
00:04:10,210 --> 00:04:08,959
the x-ray to the infrared and actually

102
00:04:12,280 --> 00:04:10,220
there is a ton that goes into it so the

103
00:04:13,930 --> 00:04:12,290
three papers were necessary and for you

104
00:04:16,180 --> 00:04:13,940
photochemical modelers out there anybody

105
00:04:17,560 --> 00:04:16,190
else who's interested you can find these

106
00:04:19,449 --> 00:04:17,570
spectra by going to that link or

107
00:04:21,640 --> 00:04:19,459
searching muscules spectral catalog which

108
00:04:23,350 --> 00:04:21,650
has the additional benefit of giving you

109
00:04:24,420 --> 00:04:23,360
some interesting google image search

110
00:04:27,659 --> 00:04:24,430
results

111
00:04:30,870 --> 00:04:27,669
oh ok so now let's go on to some more

112
00:04:33,450 --> 00:04:30,880
results basically I just up one side of

113
00:04:34,980 --> 00:04:33,460

this and then we'll get two flares the

114

00:04:37,080 --> 00:04:34,990

main result is that these stars are

115

00:04:38,400 --> 00:04:37,090

actually all kind of similar at least in

116

00:04:41,159 --> 00:04:38,410

astronomy terms which means you know

117

00:04:43,110 --> 00:04:41,169

order of magnitude as far as how much

118

00:04:44,749 --> 00:04:43,120

what fraction of light they emit in

119

00:04:47,999 --> 00:04:44,759

their photo chemically active

120

00:04:49,950 --> 00:04:48,009

ultraviolet part of the spectrum same is

121

00:04:51,540 --> 00:04:49,960

true for the extreme UV but they all are

122

00:04:53,129 --> 00:04:51,550

somewhat elevated relative to the Sun

123

00:04:54,570 --> 00:04:53,139

the cool thing about this is it means

124

00:04:56,930 --> 00:04:54,580

that once the Hubble Space Telescope

125

00:05:01,379 --> 00:04:56,940

dies and we can't get ultraviolet on

126
00:05:03,089 --> 00:05:01,389
servations anymore you if you want to do

127
00:05:06,810 --> 00:05:03,099
photochemical modeling you can sort of

128
00:05:08,040 --> 00:05:06,820
just pick a good median star in here and

129
00:05:09,839 --> 00:05:08,050
you'll at least know it to within an

130
00:05:13,770 --> 00:05:09,849
order of magnitude you're kind of on

131
00:05:15,120 --> 00:05:13,780
money all right so the cool thing about

132
00:05:17,520 --> 00:05:15,130
these observations is we can look at

133
00:05:21,779 --> 00:05:17,530
them both spectrally but also Tim poorly

134
00:05:24,689 --> 00:05:21,789
we can split them up in time and so for

135
00:05:28,620 --> 00:05:24,699
this next part I talk I am just focusing

136
00:05:29,909 --> 00:05:28,630
on the UV purely and these are the only

137
00:05:32,070 --> 00:05:29,919
observations for which we have several

138
00:05:34,680 --> 00:05:32,080

hours of data and for which we can

139

00:05:36,750 --> 00:05:34,690

actually buy things up in time so when

140

00:05:40,020 --> 00:05:36,760

you start cutting that up in time what

141

00:05:42,420 --> 00:05:40,030

you see is that all right let's get this

142

00:05:45,379 --> 00:05:42,430

real fast not super necessary you see

143

00:05:48,360 --> 00:05:45,389

that the ultraviolet emission which is

144

00:05:54,689 --> 00:05:48,370

mostly manifested in a few very narrow

145

00:05:57,120 --> 00:05:54,699

emission lines it often flares it took

146

00:06:00,480 --> 00:05:57,130

quite an extreme extent so for example a

147

00:06:01,980 --> 00:06:00,490

mission from this one mission line went

148

00:06:03,810 --> 00:06:01,990

to a hundred times of its quiescent

149

00:06:06,060 --> 00:06:03,820

level during this flare and we saw this

150

00:06:08,670 --> 00:06:06,070

on five out of seven of the M stars that

151
00:06:11,210 --> 00:06:08,680
were in the survey so it's common even

152
00:06:14,370 --> 00:06:11,220
though these M stars are basically

153
00:06:16,290 --> 00:06:14,380
normal or typical I guess you would say

154
00:06:19,529 --> 00:06:16,300
they don't stand out from stellar

155
00:06:21,300 --> 00:06:19,539
populations in any particular way oh so

156
00:06:23,129 --> 00:06:21,310
flares are a big deal in these stars

157
00:06:24,210 --> 00:06:23,139
they're happening frequently enough that

158
00:06:29,100 --> 00:06:24,220
even with three and a half hours of

159
00:06:31,020 --> 00:06:29,110
observations you can you can see one so

160
00:06:33,690 --> 00:06:31,030
then I can look at these Flyers

161
00:06:35,550 --> 00:06:33,700
statistically make a cumulative

162
00:06:38,250 --> 00:06:35,560
distribution plots like this where you

163
00:06:39,900 --> 00:06:38,260

have how frequently the players occur

164

00:06:42,380 --> 00:06:39,910

if they have an energy less than or

165

00:06:44,820 --> 00:06:42,390

equal to the value on the x axis and

166

00:06:46,230 --> 00:06:44,830

this is similar to like creator

167

00:06:48,200 --> 00:06:46,240

accounting diagrams or I think something

168

00:06:52,110 --> 00:06:48,210

in biology would be a like a lifetime

169

00:06:54,960 --> 00:06:52,120

plot so the stars in our muscle sample

170

00:06:57,390 --> 00:06:54,970

fall right here sort of in between the

171

00:07:00,630 --> 00:06:57,400

Sun down here on the bottom and some

172

00:07:02,160 --> 00:07:00,640

stars that have had have been the

173

00:07:04,080 --> 00:07:02,170

subject of a lot of observations because

174

00:07:09,180 --> 00:07:04,090

they flare a lot so we knew that they

175

00:07:12,300 --> 00:07:09,190

were pretty interesting so again boy I

176
00:07:14,490 --> 00:07:12,310
was significant and last night I decided

177
00:07:17,010 --> 00:07:14,500
I would integrate this and see just how

178
00:07:19,740 --> 00:07:17,020
much energy a planet might receive from

179
00:07:22,110 --> 00:07:19,750
these UV flares and the answer was a

180
00:07:24,900 --> 00:07:22,120
little surprising it was enough to

181
00:07:27,270 --> 00:07:24,910
obliterate quite a few Earth's which you

182
00:07:28,710 --> 00:07:27,280
know I guess NASA should have consulted

183
00:07:30,210 --> 00:07:28,720
me before they said Kepler up there and

184
00:07:31,440 --> 00:07:30,220
waste all that money I could have told

185
00:07:35,340 --> 00:07:31,450
him that then we're going to find

186
00:07:37,140 --> 00:07:35,350
anything but uh but I think the real

187
00:07:39,210 --> 00:07:37,150
problem here is that I don't know what's

188
00:07:43,020 --> 00:07:39,220

a good upper limit for the integration

189

00:07:44,430 --> 00:07:43,030

and what I used was you know what's the

190

00:07:46,800 --> 00:07:44,440

highest energy where you get one flare

191

00:07:49,260 --> 00:07:46,810

in the life of the universe and I

192

00:07:51,000 --> 00:07:49,270

imagine that the real upper limit is

193

00:07:54,420 --> 00:07:51,010

much lower but that's something I'm

194

00:07:56,370 --> 00:07:54,430

going to be exploring in the future okay

195

00:07:58,320 --> 00:07:56,380

so what do these players mean four

196

00:08:00,600 --> 00:07:58,330

atmospheres well here I'm just going

197

00:08:04,050 --> 00:08:00,610

into the literature to give you all some

198

00:08:06,210 --> 00:08:04,060

perspective there was a group that

199

00:08:07,860 --> 00:08:06,220

published a paper in astro bio in 2010

200

00:08:09,480 --> 00:08:07,870

where they exposed an earth atmosphere

201
00:08:12,150 --> 00:08:09,490
to the largest player that's ever been

202
00:08:14,750 --> 00:08:12,160
observed on an in star and if they

203
00:08:18,510 --> 00:08:14,760
incorporate just the UV light they get

204
00:08:21,870 --> 00:08:18,520
somewhat modest depletions of ozone

205
00:08:23,580 --> 00:08:21,880
factory for you for ozone and a few

206
00:08:26,190 --> 00:08:23,590
orders of magnitude for or one order of

207
00:08:27,480 --> 00:08:26,200
magnitude for water but there's not much

208
00:08:29,850 --> 00:08:27,490
water up at the levels where they saw

209
00:08:34,350 --> 00:08:29,860
that so here you're looking at basically

210
00:08:36,860 --> 00:08:34,360
amount versus altitude but then they

211
00:08:41,850 --> 00:08:36,870
decided they would incorporate particles

212
00:08:43,260 --> 00:08:41,860
which as you might know for the Sun

213
00:08:45,270 --> 00:08:43,270

often players are associated with

214

00:08:47,640 --> 00:08:45,280

ejections of particles which do things

215

00:08:49,080 --> 00:08:47,650

like mess with our power grids and when

216

00:08:51,430 --> 00:08:49,090

they did that they got pretty

217

00:08:55,460 --> 00:08:51,440

substantial depletions of ozone

218

00:08:57,850 --> 00:08:55,470

it like you know almost goes away in the

219

00:09:00,019 --> 00:08:57,860

upper atmosphere the result is a

220

00:09:02,680 --> 00:09:00,029

reduction of the ozone column do I think

221

00:09:04,670 --> 00:09:02,690

about Timbers in its original value and

222

00:09:05,840 --> 00:09:04,680

so that's pretty significant it might

223

00:09:07,460 --> 00:09:05,850

sound like that might be damaging for

224

00:09:09,050 --> 00:09:07,470

life but Tim person that Bo zone is

225

00:09:10,910 --> 00:09:09,060

still okay and then there was this

226

00:09:12,740 --> 00:09:10,920

really interesting paper recently by the

227

00:09:15,019 --> 00:09:12,750

air patient group where they suggested

228

00:09:17,650 --> 00:09:15,029

that if you expose the earlier at the

229

00:09:19,880 --> 00:09:17,660

atmosphere to players like these then

230

00:09:22,940 --> 00:09:19,890

you might actually produce some

231

00:09:24,920 --> 00:09:22,950

biologically relevant molecules and in

232

00:09:26,060 --> 00:09:24,930

fact these are also greenhouse gases so

233

00:09:30,500 --> 00:09:26,070

they could help solve the faint young

234

00:09:33,800 --> 00:09:30,510

Sun paradox so basically flares are

235

00:09:36,079 --> 00:09:33,810

important but there's one caveat one

236

00:09:37,970 --> 00:09:36,089

important thing that this brings to mind

237

00:09:39,940 --> 00:09:37,980

I hope you all can read this in the back

238

00:09:42,110 --> 00:09:39,950

but a question that we need to answer is

239

00:09:43,550 --> 00:09:42,120

just how many particles are actually

240

00:09:45,110 --> 00:09:43,560

coming out of these indoor flares if

241

00:09:47,329 --> 00:09:45,120

import players are so frequent and

242

00:09:49,519 --> 00:09:47,339

strong and they we have pretty good

243

00:09:50,900 --> 00:09:49,529

reason to believe that it might be

244

00:09:53,200 --> 00:09:50,910

different than the Sun we might not just

245

00:09:55,430 --> 00:09:53,210

be able to scale the Sun in this case

246

00:09:57,560 --> 00:09:55,440

but until we have measurements we don't

247

00:10:00,680 --> 00:09:57,570

really know and so far we don't have any

248

00:10:09,050 --> 00:10:00,690

measurements so with that I'll leave the

249

00:10:10,660 --> 00:10:09,060

conclusions and take any questions I'm

250

00:10:14,420 --> 00:10:10,670

gonna ask the first question this time

251

00:10:15,950 --> 00:10:14,430

so you said that you got a five out of

252

00:10:17,210 --> 00:10:15,960

seven of these had these flares while

253

00:10:18,980 --> 00:10:17,220

you're observing it over three and a

254

00:10:20,690 --> 00:10:18,990

half hours yeah can you back out an

255

00:10:23,900 --> 00:10:20,700

expected actual frequency of the flares

256

00:10:25,400 --> 00:10:23,910

how often on average Oh Clara I mean is

257

00:10:28,310 --> 00:10:25,410

it is it once every three and a half

258

00:10:30,890 --> 00:10:28,320

hours is it uh yeah it's about that's

259

00:10:32,540 --> 00:10:30,900

well yeah if you divided by the seven

260

00:10:35,150 --> 00:10:32,550

stars you get about one every three and

261

00:10:37,100 --> 00:10:35,160

a half hours so and these are players

262

00:10:39,530 --> 00:10:37,110

that so the one I showed you of course I

263

00:10:42,050 --> 00:10:39,540

showed you the best one that was 100

264

00:10:44,390 --> 00:10:42,060

times you know at an elevation of 100

265

00:10:47,269 --> 00:10:44,400

times the quiescent level but the other

266

00:10:56,449 --> 00:10:47,279

ones are about 10 times minimum so

267

00:11:03,359 --> 00:11:00,569

so I'm great talk are these flares that

268

00:11:04,710 --> 00:11:03,369

are coming out directional and if so

269

00:11:07,589 --> 00:11:04,720

what's the probability that they would

270

00:11:08,789 --> 00:11:07,599

actually be hitting the planet yeah this

271

00:11:14,369 --> 00:11:08,799

is something I haven't explored fully

272

00:11:15,839 --> 00:11:14,379

either and I am sure that the of course

273

00:11:18,119 --> 00:11:15,849

you have to be at least on the right

274

00:11:19,379 --> 00:11:18,129

hemisphere of the star the players are

275

00:11:22,979 --> 00:11:19,389

so short that the star is not going to

276

00:11:24,659 --> 00:11:22,989

rotate into the view of the planet dirt

277

00:11:26,729 --> 00:11:24,669

over the course of a player for at least

278

00:11:31,019 --> 00:11:26,739

the players that we saw so direction

279

00:11:34,559 --> 00:11:31,029

matters and but I don't have any good

280

00:11:43,670 --> 00:11:34,569

answer for like how how directed it

281

00:11:51,720 --> 00:11:49,680

so you you said that to measure the

282

00:11:55,440 --> 00:11:51,730

particle flux you can't just scale down

283

00:11:57,420 --> 00:11:55,450

the Sun so is there any plan to study m

284

00:11:59,639 --> 00:11:57,430

dwarfs in the near future to like try

285

00:12:02,009 --> 00:11:59,649

and back out what their particle flux is

286

00:12:03,449 --> 00:12:02,019

compared to like what we do with our son

287

00:12:06,480 --> 00:12:03,459

and then comparing it to other sun-like

288

00:12:09,449 --> 00:12:06,490

stars yeah the most intriguing plan that

289

00:12:10,560 --> 00:12:09,459

I've heard is I know and hopefully I

290

00:12:12,090 --> 00:12:10,570

won't murder this because I don't know

291

00:12:13,740 --> 00:12:12,100

much about this particular type of

292

00:12:15,210 --> 00:12:13,750

observing but I know there's a group

293

00:12:16,740 --> 00:12:15,220

that it's empty to get radio

294

00:12:18,360 --> 00:12:16,750

observations where you could see a

295

00:12:20,579 --> 00:12:18,370

mission from the particles as they

296

00:12:23,610 --> 00:12:20,589

spiral out on the magnetic field lines

297

00:12:25,710 --> 00:12:23,620

from the star and that would be an

298

00:12:27,900 --> 00:12:25,720

awesome basically direct measurement of