Molecules in YSO Disks

- Inner Disks: water, organics, & other molecules
- *Sub-mm & mm*: CN, HCN, H_2CO (e.g., Dutrey et al 1997, A&A, 317, L55; Thi et al 2004, A&A, 425, 955; Kastner et al 2008, A&A, 492, 469; Öberg et al 2010, ApJ, 720, 480)
- *Infrared*, before *Spitzer*-IRS: Carr et al (1993, ApJ, 411, L37); Najita et al (1996, ApJ, 462, 919); Carr et al (2004, ApJ, 603, 213)
- Carr & Najita (2008, Sci, 319, 1504): H_2O, OH, HCN, C_2H_2, CO_2 *Spitzer* **R=600** AA Tau spectrum
- Pascucci et al (2009, ApJ, 696, 143) and Teske et al (2011, ApJ, 734, 27): studies of HCN, C_2H_2 with **R ~ 90** *Spitzer*-IRS **low-resolution** spectra

1
00:00:11,110 --> 00:00:08,950
my name is ben sargen i'm actually i'm

2
00:00:13,430 --> 00:00:11,120
from rochester institute of technology

3
00:00:17,269 --> 00:00:13,440
so other side of the state

4
00:00:19,029 --> 00:00:17,279
um so i'm a postdoc and i'm an

5
00:00:22,470 --> 00:00:19,039
observational astronomer

6
00:00:24,150 --> 00:00:22,480
and i'll be talking about studies of uh

7
00:00:26,150 --> 00:00:24,160
infrared spectral studies of

8
00:00:28,310 --> 00:00:26,160
pre-planetary disks

9
00:00:30,390 --> 00:00:28,320
um

10
00:00:31,750 --> 00:00:30,400
so first a bit of background

11
00:00:33,670 --> 00:00:31,760
um so

12
00:00:37,430 --> 00:00:33,680
when stars form

13
00:00:40,310 --> 00:00:37,440

uh they form from giant molecular clouds

14
00:00:43,190 --> 00:00:40,320
and so if if you get a cloud that's a

15
00:00:44,950 --> 00:00:43,200
little over dense it begins contracting

16
00:00:46,790 --> 00:00:44,960
under its own gravity

17
00:00:49,430 --> 00:00:46,800
and if there's any

18
00:00:50,389 --> 00:00:49,440
angular momentum there's any spin to the

19
00:00:54,869 --> 00:00:50,399
cloud

20
00:00:56,790 --> 00:00:54,879
will collapse to form the star

21
00:01:00,229 --> 00:00:56,800
what's left over that doesn't make it to

22
00:01:02,549 --> 00:01:00,239
the star forms a disk of gas and dust

23
00:01:04,469 --> 00:01:02,559
and so it collapses and becomes a

24
00:01:06,710 --> 00:01:04,479
protoplanetary disk

25
00:01:08,950 --> 00:01:06,720
and so eventually all of the cloud

26
00:01:10,950 --> 00:01:08,960
reigns on to the disk and then after a

27
00:01:13,350 --> 00:01:10,960
few million years

28
00:01:16,390 --> 00:01:13,360
our observations are finding the discs

29
00:01:18,390 --> 00:01:16,400
seem to dissipate and this is the stage

30
00:01:19,749 --> 00:01:18,400
where planets and all the other solid

31
00:01:22,149 --> 00:01:19,759
bodies of

32
00:01:24,149 --> 00:01:22,159
planetary systems form

33
00:01:26,870 --> 00:01:24,159
so i'm studying this intermediate stage

34
00:01:29,429 --> 00:01:26,880
where you still have the the massive

35
00:01:31,749 --> 00:01:29,439
disc of gas and dust

36
00:01:34,069 --> 00:01:31,759
and i'm using infrared spectroscopy to

37
00:01:36,870 --> 00:01:34,079
study the gaseous component

38
00:01:38,870 --> 00:01:36,880

so in the past maybe 20 or so years

39
00:01:42,069 --> 00:01:38,880
there's been a number of studies

40
00:01:43,510 --> 00:01:42,079
um at the sub millimeter and millimeter

41
00:01:46,149 --> 00:01:43,520
wavelengths

42
00:01:48,789 --> 00:01:46,159
studying the the molecules in the discs

43
00:01:50,950 --> 00:01:48,799
and they found such things as cn and

44
00:01:53,670 --> 00:01:50,960
hcn and formaldehyde

45
00:01:55,830 --> 00:01:53,680
and there are ongoing studies surveys of

46
00:01:57,910 --> 00:01:55,840
these protoplanetary disks

47
00:01:59,670 --> 00:01:57,920
looking for these molecules

48
00:02:02,149 --> 00:01:59,680
also in the same time

49
00:02:04,950 --> 00:02:02,159
there have been infrared studies

50
00:02:06,870 --> 00:02:04,960
of the same disks looking at various

51
00:02:09,190 --> 00:02:06,880
molecules

52
00:02:11,750 --> 00:02:09,200
so maybe in the the 90s beginning in the

53
00:02:13,670 --> 00:02:11,760
90s there were these um studies looking

54
00:02:17,350 --> 00:02:13,680
for things like uh

55
00:02:18,949 --> 00:02:17,360
carbon monoxide and water and so forth

56
00:02:20,790 --> 00:02:18,959
however it was the

57
00:02:22,630 --> 00:02:20,800
launch of the spitzer space telescope

58
00:02:23,510 --> 00:02:22,640
about a little over 10 years ago that

59
00:02:24,710 --> 00:02:23,520
allowed

60
00:02:29,350 --> 00:02:24,720
um

61
00:02:31,910 --> 00:02:29,360
protoplanetary disks

62
00:02:32,869 --> 00:02:31,920
and then a few years into the mission we

63
00:02:35,030 --> 00:02:32,879

started

64
00:02:37,430 --> 00:02:35,040
there were a number of papers here's the

65
00:02:39,750 --> 00:02:37,440
first one that began reporting a number

66
00:02:42,309 --> 00:02:39,760
of uh various molecules from the

67
00:02:44,790 --> 00:02:42,319
slightly higher resolution setting

68
00:02:47,670 --> 00:02:44,800
of the infrared spectrograph on spitzer

69
00:02:52,150 --> 00:02:47,680
finding things like water and oh

70
00:02:54,150 --> 00:02:52,160
hcn c8 c2h2 and carbon dioxide

71
00:02:56,630 --> 00:02:54,160
so this this resolution that's

72
00:02:58,150 --> 00:02:56,640
wavelength divided by the

73
00:03:00,710 --> 00:02:58,160
spectral uh

74
00:03:02,309 --> 00:03:00,720
resolution element so it's the smallest

75
00:03:03,430 --> 00:03:02,319
wavelength detail you can see on the

76
00:03:06,229 --> 00:03:03,440
spectrum

77
00:03:08,470 --> 00:03:06,239
so this isn't all that great 600 but

78
00:03:09,910 --> 00:03:08,480
that's that's the best we can do

79
00:03:12,630 --> 00:03:09,920
so people were studying things with the

80
00:03:14,710 --> 00:03:12,640
higher resolution setting there's also a

81
00:03:16,550 --> 00:03:14,720
lower resolution setting

82
00:03:18,710 --> 00:03:16,560
r of 90.

83
00:03:20,390 --> 00:03:18,720
so it's very difficult to study gases

84
00:03:24,070 --> 00:03:20,400
with such low resolution but you can

85
00:03:25,990 --> 00:03:24,080
still find lines from such gases as hcn

86
00:03:27,430 --> 00:03:26,000
and c2h2

87
00:03:29,910 --> 00:03:27,440
this study

88
00:03:31,589 --> 00:03:29,920

this talk focuses on the stuff you can

89
00:03:34,149 --> 00:03:31,599
see at short wavelengths with this low

90
00:03:35,750 --> 00:03:34,159
resolution setting there are many more

91
00:03:37,589 --> 00:03:35,760
spectra of the

92
00:03:39,990 --> 00:03:37,599
many more spectrum the low resolution

93
00:03:41,990 --> 00:03:40,000
mode than high resolution because it

94
00:03:44,390 --> 00:03:42,000
takes either a brighter source or a

95
00:03:46,470 --> 00:03:44,400
longer observation time to get a good

96
00:03:50,309 --> 00:03:46,480
spectrum at the higher resolution so we

97
00:03:51,830 --> 00:03:50,319
have many more low resolution spectra

98
00:03:54,229 --> 00:03:51,840
so here are

99
00:03:56,149 --> 00:03:54,239
sample spectra from

100
00:03:59,509 --> 00:03:56,159
from a titari star

101
00:04:02,869 --> 00:03:59,519
i call it rw riga a so this is a a star

102
00:04:06,149 --> 00:04:02,879
with a protoplanetary disk around it the

103
00:04:09,589 --> 00:04:06,159
spectrum in blue is a of an fu orionis

104
00:04:12,630 --> 00:04:09,599
star called v1057 cygni

105
00:04:14,149 --> 00:04:12,640
furiona star is a slightly earlier stage

106
00:04:16,550 --> 00:04:14,159
when there's much more material in the

107
00:04:19,189 --> 00:04:16,560
disc so that the disc is an accretion

108
00:04:23,350 --> 00:04:19,199
disc it's material that's

109
00:04:25,990 --> 00:04:23,360
being accreted towards the star

110
00:04:27,430 --> 00:04:26,000
and for effiorionis stars

111
00:04:29,350 --> 00:04:27,440
it's thought that the disc is much more

112
00:04:31,909 --> 00:04:29,360
massive there's much more accretion

113
00:04:33,270 --> 00:04:31,919

going on and so the heating for for

114
00:04:35,430 --> 00:04:33,280
those discs

115
00:04:37,189 --> 00:04:35,440
they're heated more from within than

116
00:04:38,310 --> 00:04:37,199
without and so you get absorption

117
00:04:42,150 --> 00:04:38,320
features

118
00:04:45,430 --> 00:04:42,160
and so i start so my my study focuses on

119
00:04:48,870 --> 00:04:45,440
these t tauri discs but i'll start with

120
00:04:51,110 --> 00:04:48,880
the every your own fu orionis disc

121
00:04:52,950 --> 00:04:51,120
so all of the spectral structure that

122
00:04:55,350 --> 00:04:52,960
you're seeing in this spectrum

123
00:04:57,189 --> 00:04:55,360
comes from water vapor at one

124
00:04:59,350 --> 00:04:57,199
temperature

125
00:05:01,350 --> 00:04:59,360
that's a 800 kelvin

126
00:05:04,230 --> 00:05:01,360
model that i'm using that's the orange

127
00:05:06,390 --> 00:05:04,240
that fits the spectrum the i'm using

128
00:05:09,430 --> 00:05:06,400
also some continuum but you get all of

129
00:05:11,990 --> 00:05:09,440
the structure with just a simple model

130
00:05:15,029 --> 00:05:12,000
so you see this sort of feature here at

131
00:05:17,510 --> 00:05:15,039
6.6 microns and some sort of ripples

132
00:05:19,430 --> 00:05:17,520
here at shorter wavelengths

133
00:05:21,990 --> 00:05:19,440
so this is kind of telling for what's

134
00:05:24,230 --> 00:05:22,000
going on in the titari disks

135
00:05:26,150 --> 00:05:24,240
they are systems that have less

136
00:05:27,430 --> 00:05:26,160
accretion they're heated more from

137
00:05:29,830 --> 00:05:27,440
without

138
00:05:32,310 --> 00:05:29,840

more by the star

139
00:05:34,790 --> 00:05:32,320
the radiation from the star so you get

140
00:05:36,950 --> 00:05:34,800
emission from those systems and here you

141
00:05:40,870 --> 00:05:36,960
have the same feature but it's a mirror

142
00:05:42,950 --> 00:05:40,880
image so yet so it's emission here

143
00:05:45,189 --> 00:05:42,960
so if i just had emission

144
00:05:46,870 --> 00:05:45,199
from water vapor in the spectrum

145
00:05:49,270 --> 00:05:46,880
everything else would be the same and

146
00:05:51,270 --> 00:05:49,280
here i would have the dashed line but

147
00:05:52,870 --> 00:05:51,280
that doesn't fit the data

148
00:05:54,230 --> 00:05:52,880
so it appears there's some sort of

149
00:05:56,550 --> 00:05:54,240
component

150
00:05:59,189 --> 00:05:56,560
there's something absorbing at those

151
00:06:02,390 --> 00:05:59,199
wavelengths and in this model i've used

152
00:06:07,510 --> 00:06:02,400
formaldehyde and i get a decent fit to

153
00:06:11,830 --> 00:06:10,150
so if i had very high resolution like

154
00:06:13,430 --> 00:06:11,840
perhaps i could get from a ground-based

155
00:06:15,510 --> 00:06:13,440
telescope

156
00:06:17,510 --> 00:06:15,520
this is what i would see if all i had

157
00:06:20,070 --> 00:06:17,520
were just water vapor

158
00:06:22,070 --> 00:06:20,080
over the five to seven and a half micron

159
00:06:24,550 --> 00:06:22,080
wavelength part of the spectrum

160
00:06:25,510 --> 00:06:24,560
so you can see that this 6.3 microns

161
00:06:27,430 --> 00:06:25,520
which was

162
00:06:29,270 --> 00:06:27,440
sort of a minimum here

163
00:06:31,590 --> 00:06:29,280

it's not really absorption but it's just

164
00:06:32,950 --> 00:06:31,600
a lack of emission you're seeing down

165
00:06:35,510 --> 00:06:32,960
close to the continuum of those

166
00:06:37,189 --> 00:06:35,520
wavelengths at other wavelengths the

167
00:06:38,469 --> 00:06:37,199
shorter wavelengths you see sort of a

168
00:06:41,029 --> 00:06:38,479
cluster of

169
00:06:43,110 --> 00:06:41,039
lines that get a bit more densely packed

170
00:06:46,070 --> 00:06:43,120
and stronger

171
00:06:48,550 --> 00:06:46,080
around 5.7 microns or so

172
00:06:50,870 --> 00:06:48,560
what looked like a 6.6 micron feature is

173
00:06:54,230 --> 00:06:50,880
just a whole bunch of strong lines

174
00:06:56,390 --> 00:06:54,240
close to 6.6 microns

175
00:06:59,029 --> 00:06:56,400
but we don't have high resolution we

176
00:07:00,950 --> 00:06:59,039
just have the low resolution

177
00:07:03,270 --> 00:07:00,960
so a bit about perhaps

178
00:07:05,589 --> 00:07:03,280
what might not be going on

179
00:07:07,670 --> 00:07:05,599
so there are spectra of tetori stars

180
00:07:09,670 --> 00:07:07,680
that are completely boring over these

181
00:07:11,589 --> 00:07:09,680
wavelengths they're more or less just

182
00:07:13,430 --> 00:07:11,599
sort of continuum

183
00:07:14,390 --> 00:07:13,440
nothing much going on

184
00:07:17,909 --> 00:07:14,400
and those

185
00:07:18,870 --> 00:07:17,919
spectra so um that would suggest that

186
00:07:21,990 --> 00:07:18,880
perhaps

187
00:07:23,110 --> 00:07:22,000
it's not an artifact that's responsible

188
00:07:24,790 --> 00:07:23,120

although

189
00:07:26,469 --> 00:07:24,800
you can't rule it out but you know the

190
00:07:29,189 --> 00:07:26,479
fact that you don't see the features and

191
00:07:30,790 --> 00:07:29,199
all of these stars suggest it might not

192
00:07:33,990 --> 00:07:30,800
be an artifact

193
00:07:36,550 --> 00:07:34,000
another thing that it probably is not is

194
00:07:39,430 --> 00:07:36,560
uh features from the stellar spectrum

195
00:07:40,950 --> 00:07:39,440
this the spectrum of the star itself

196
00:07:43,589 --> 00:07:40,960
typically the emission over these

197
00:07:44,629 --> 00:07:43,599
wavelengths is like five to thirty 30

198
00:07:46,550 --> 00:07:44,639
times

199
00:07:47,430 --> 00:07:46,560
that of the star

200
00:07:49,749 --> 00:07:47,440
so

201
00:07:51,830 --> 00:07:49,759
whatever spectral structure you'll see

202
00:07:53,589 --> 00:07:51,840
over these wavelengths should be drowned

203
00:07:55,350 --> 00:07:53,599
out by a lot of

204
00:07:57,990 --> 00:07:55,360
emission from the the protoplanetary

205
00:08:00,150 --> 00:07:58,000
disk what's what structure you do see is

206
00:08:03,189 --> 00:08:00,160
probably water at least in the later

207
00:08:04,469 --> 00:08:03,199
type cooler stars

208
00:08:07,189 --> 00:08:04,479
perhaps

209
00:08:09,749 --> 00:08:07,199
some solid materials have features over

210
00:08:12,950 --> 00:08:09,759
these wavelengths these are

211
00:08:15,830 --> 00:08:12,960
opacity curves of phyllosilicates so

212
00:08:17,830 --> 00:08:15,840
those are silicate dust grains

213
00:08:19,990 --> 00:08:17,840

and and such that the crystalline

214
00:08:21,189 --> 00:08:20,000
structure

215
00:08:23,270 --> 00:08:21,199
is that the

216
00:08:26,150 --> 00:08:23,280
you get the silicon

217
00:08:27,830 --> 00:08:26,160
sio4 tetrahedron that arrange themselves

218
00:08:29,589 --> 00:08:27,840
in sheets and in between the sheets you

219
00:08:30,869 --> 00:08:29,599
have various molecules

220
00:08:33,269 --> 00:08:30,879
and so you can get some spectral

221
00:08:35,110 --> 00:08:33,279
structure over these wavelengths

222
00:08:37,190 --> 00:08:35,120
but it doesn't seem to match up to the

223
00:08:39,509 --> 00:08:37,200
stuff we see in our spectra

224
00:08:42,070 --> 00:08:39,519
so probably not phylosilicates

225
00:08:45,269 --> 00:08:42,080
it could also be ices ices have features

226
00:08:47,990 --> 00:08:45,279
over these wavelengths here are ice

227
00:08:49,509 --> 00:08:48,000
opacity profiles for formaldehyde formic

228
00:08:51,190 --> 00:08:49,519
acid and water

229
00:08:52,949 --> 00:08:51,200
and although they have features that are

230
00:08:55,350 --> 00:08:52,959
close they're not

231
00:08:56,790 --> 00:08:55,360
exactly a good match

232
00:08:58,870 --> 00:08:56,800
and there are various there have been

233
00:08:59,910 --> 00:08:58,880
various studies over the past 20 plus

234
00:09:01,829 --> 00:08:59,920
years

235
00:09:03,350 --> 00:09:01,839
over

236
00:09:07,430 --> 00:09:03,360
of ices

237
00:09:09,750 --> 00:09:07,440
you might see in

238
00:09:11,590 --> 00:09:09,760

around dust grains and big molecular

239
00:09:14,150 --> 00:09:11,600
clouds and again

240
00:09:16,230 --> 00:09:14,160
not a good match to our spectra

241
00:09:18,230 --> 00:09:16,240
what does seem to be a good match

242
00:09:19,350 --> 00:09:18,240
um so there are there seem to be

243
00:09:20,949 --> 00:09:19,360
different

244
00:09:24,870 --> 00:09:20,959
types of spectra they're the ones that

245
00:09:26,550 --> 00:09:24,880
have the 6.6 micron

246
00:09:29,670 --> 00:09:26,560
peak with the shoulder at shorter

247
00:09:31,350 --> 00:09:29,680
wavelengths sort of a minimum at 6.3 and

248
00:09:33,190 --> 00:09:31,360
then

249
00:09:34,470 --> 00:09:33,200
a sort of a

250
00:09:36,790 --> 00:09:34,480
sort of a

251
00:09:39,269 --> 00:09:36,800
upward rise to shorter wavelengths

252
00:09:42,070 --> 00:09:39,279
um so the water vapor and emission like

253
00:09:44,710 --> 00:09:42,080
with the the spectrum a few slides ago

254
00:09:46,710 --> 00:09:44,720
seems to fit overall fairly well and

255
00:09:48,550 --> 00:09:46,720
then i need to include absorption from

256
00:09:51,030 --> 00:09:48,560
something and

257
00:09:53,350 --> 00:09:51,040
for these at least formaldehyde

258
00:09:56,070 --> 00:09:53,360
seems to be a good fit

259
00:09:58,550 --> 00:09:56,080
for others water vapor and emission but

260
00:10:01,829 --> 00:09:58,560
uh something different in this case

261
00:10:04,550 --> 00:10:01,839
formic acid and absorption this uh

262
00:10:05,750 --> 00:10:04,560
spectrum df tau seems especially well

263
00:10:08,389 --> 00:10:05,760

fit with the

264
00:10:10,070 --> 00:10:08,399
formaldehyde formic acid

265
00:10:12,550 --> 00:10:10,080
there are other stars that don't have

266
00:10:14,949 --> 00:10:12,560
much or they have perhaps no water

267
00:10:16,230 --> 00:10:14,959
emission discernible this one has

268
00:10:17,509 --> 00:10:16,240
perhaps a little

269
00:10:19,590 --> 00:10:17,519
but they have these

270
00:10:22,150 --> 00:10:19,600
stronger absorption bands at the shorter

271
00:10:25,430 --> 00:10:22,160
wavelengths in this case that are better

272
00:10:27,750 --> 00:10:25,440
fit by formaldehyde

273
00:10:29,430 --> 00:10:27,760
and then others with a narrower feature

274
00:10:31,829 --> 00:10:29,440
like bf towel

275
00:10:35,990 --> 00:10:31,839
that again seem to be fit better by

276
00:10:37,430 --> 00:10:36,000
formic acid but but very little water

277
00:10:40,230 --> 00:10:37,440
so i'm not going to go through the whole

278
00:10:43,190 --> 00:10:40,240
table but these are models that i've

279
00:10:45,430 --> 00:10:43,200
generated to to match the spectra

280
00:10:46,470 --> 00:10:45,440
so the main features are that the

281
00:10:48,949 --> 00:10:46,480
emitting

282
00:10:50,710 --> 00:10:48,959
areas that i need for the water vapor

283
00:10:53,430 --> 00:10:50,720
component are

284
00:10:55,269 --> 00:10:53,440
on the order of a few astronomical units

285
00:10:58,150 --> 00:10:55,279
one astronomical unit is the average

286
00:11:00,150 --> 00:10:58,160
earth sun distance okay

287
00:11:02,630 --> 00:11:00,160
so if uaeu the typical water

288
00:11:04,069 --> 00:11:02,640

temperatures are 600 to 1200 kelvin

289
00:11:06,790 --> 00:11:04,079
which are fairly consistent with

290
00:11:09,910 --> 00:11:06,800
previous studies the formaldehyde seems

291
00:11:14,230 --> 00:11:09,920
to be fairly cool relatively speaking so

292
00:11:16,230 --> 00:11:14,240
50 to 500 kelvin and the formic acid

293
00:11:19,910 --> 00:11:16,240
it's not well constrained but also

294
00:11:22,150 --> 00:11:19,920
another a few hundred kelvin or so

295
00:11:25,030 --> 00:11:22,160
um i'm running short on time so i'll

296
00:11:27,269 --> 00:11:25,040
just summarize the disc so

297
00:11:28,870 --> 00:11:27,279
the idea is that

298
00:11:30,550 --> 00:11:28,880
if you looked at a protoplanetary disc

299
00:11:31,910 --> 00:11:30,560
edge on you're looking at cooler stuff

300
00:11:34,230 --> 00:11:31,920
in front of warmer stuff and you might

301
00:11:34,949 --> 00:11:34,240
expect absorption features

302
00:11:37,269 --> 00:11:34,959
but

303
00:11:39,670 --> 00:11:37,279
the few discs that have

304
00:11:43,910 --> 00:11:39,680
inclination estimates it doesn't seem

305
00:11:49,190 --> 00:11:46,389
one thing one sanity check

306
00:11:51,590 --> 00:11:49,200
is to compare the strength of the 6.6

307
00:11:54,389 --> 00:11:51,600
micron feature versus

308
00:11:56,150 --> 00:11:54,399
strengths of water vapor lines at 17

309
00:11:59,030 --> 00:11:56,160
microns from the higher resolution

310
00:12:01,110 --> 00:11:59,040
spectra where you have a better grasp on

311
00:12:03,750 --> 00:12:01,120
you can even better constrain the water

312
00:12:06,230 --> 00:12:03,760
properties and so the the two strengths

313
00:12:08,550 --> 00:12:06,240

seem to correlate so it kind of makes

314
00:12:10,790 --> 00:12:08,560
sense the stronger the water vapor one

315
00:12:13,030 --> 00:12:10,800
wavelength the stronger it is at the

316
00:12:13,910 --> 00:12:13,040
other wavelength

317
00:12:18,310 --> 00:12:13,920
for

318
00:12:19,829 --> 00:12:18,320
observed at a number of other

319
00:12:21,910 --> 00:12:19,839
wavelengths

320
00:12:25,670 --> 00:12:21,920
formaldehyde has been observed for one

321
00:12:27,269 --> 00:12:25,680
protostar at 3.6 microns in absorption

322
00:12:29,590 --> 00:12:27,279
so that would be

323
00:12:32,150 --> 00:12:29,600
a good wavelength to try to confirm the

324
00:12:35,910 --> 00:12:32,160
formaldehyde

325
00:12:38,069 --> 00:12:35,920
spectra the formic acid

326
00:12:39,269 --> 00:12:38,079
has bands at 9 and fifteen and a half

327
00:12:41,670 --> 00:12:39,279
microns

328
00:12:45,350 --> 00:12:41,680
the latter is only accessible from

329
00:12:47,030 --> 00:12:45,360
uh space-based observatories

330
00:12:49,430 --> 00:12:47,040
excuse me while the

331
00:12:51,350 --> 00:12:49,440
nine micron band is probably the best

332
00:12:55,430 --> 00:12:51,360
one as it's well suited for ground-based

333
00:13:05,509 --> 00:12:57,670
and i'll leave my conclusion slide thank

334
00:13:10,389 --> 00:13:06,870
questions

335
00:13:14,310 --> 00:13:12,069
and we have to give you a microphone if

336
00:13:15,990 --> 00:13:14,320
you can ask a question by the way

337
00:13:19,190 --> 00:13:16,000
so is there something that precludes

338
00:13:20,949 --> 00:13:19,200

both formaldehyde and formic acid in

339
00:13:22,790 --> 00:13:20,959
combination because they seem to overlap

340
00:13:24,550 --> 00:13:22,800
in that spectral region

341
00:13:35,190 --> 00:13:24,560
yeah there's nothing that precludes them

342
00:13:39,509 --> 00:13:36,790
uh do you have any thoughts as to what's

343
00:13:41,350 --> 00:13:39,519
going on as to why you see very cold

344
00:13:44,069 --> 00:13:41,360
formaldehyde but fairly hot water in the

345
00:13:48,710 --> 00:13:46,230
um so yeah the

346
00:13:50,150 --> 00:13:48,720
so this this uh was written up recently

347
00:13:51,430 --> 00:13:50,160
in a paper and that was a question the

348
00:13:54,069 --> 00:13:51,440
referee asked

349
00:13:56,550 --> 00:13:54,079
um so yeah perhaps um

350
00:13:58,470 --> 00:13:56,560
the water can survive but

351
00:14:00,310 --> 00:13:58,480
we could we can see water vapor and

352
00:14:03,750 --> 00:14:00,320
spectra of uh

353
00:14:04,870 --> 00:14:03,760
the coolest stars so 3000 kelvin stars

354
00:14:07,750 --> 00:14:04,880
cooler

355
00:14:09,430 --> 00:14:07,760
so it's a hearty molecule but the

356
00:14:12,230 --> 00:14:09,440
formaldehyde is

357
00:14:14,470 --> 00:14:12,240
uh apparently it dissociates

358
00:14:15,670 --> 00:14:14,480
at higher temperatures so perhaps it

359
00:14:19,509 --> 00:14:15,680
just

360
00:14:24,550 --> 00:14:22,790
co and molecular hydrogen

361
00:14:25,829 --> 00:14:24,560
that be it could be an explanation for

362
00:14:28,829 --> 00:14:25,839
why it's only

363
00:14:30,710 --> 00:14:28,839

cold you only see cold

364
00:14:32,150 --> 00:14:30,720
formaldehyde all right we gotta move on