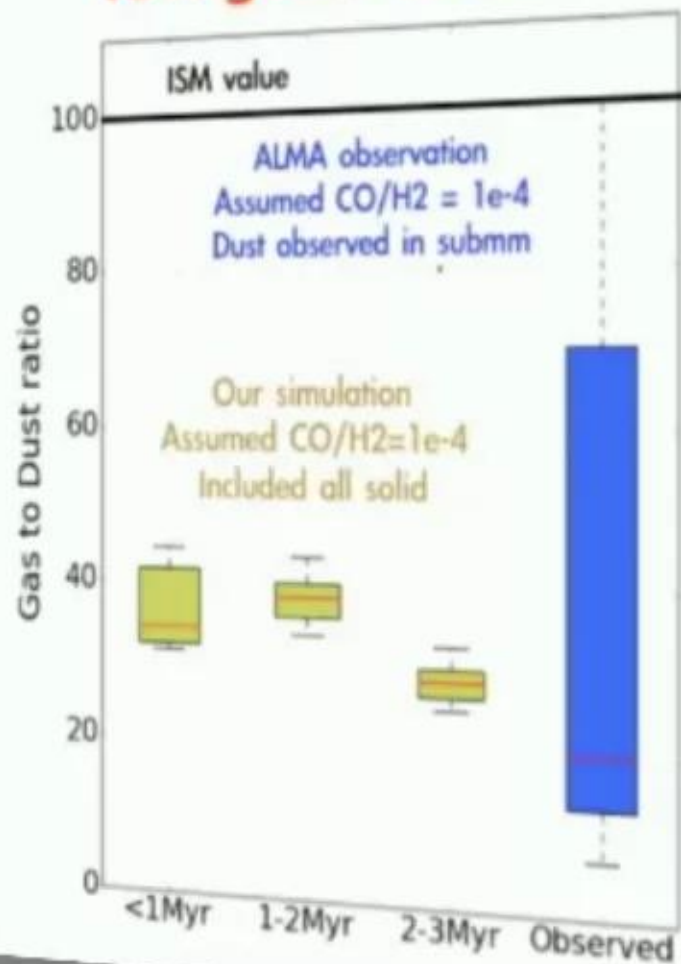


CO depletion can explain apparent low gas / dust ratios



Observed data from a recent ALMA survey of Lupus disks, Ansdell et al. (2016)

1
00:00:11,089 --> 00:00:08,629
thanks Brett and Brendan for awesome

2
00:00:13,070 --> 00:00:11,099
talks on chemistry now let's take a step

3
00:00:16,369 --> 00:00:13,080
back and look at some physical

4
00:00:18,710 --> 00:00:16,379
properties turns out we don't know some

5
00:00:21,890 --> 00:00:18,720
really fundamental properties say how

6
00:00:25,700 --> 00:00:21,900
massive food aplenty distal are even up

7
00:00:28,790 --> 00:00:25,710
to order magnitude level traditionally

8
00:00:30,679 --> 00:00:28,800
this mass has been measured from dust

9
00:00:32,870 --> 00:00:30,689
emissions in submillimeter and

10
00:00:35,389 --> 00:00:32,880
millimeter so basically we're seeing

11
00:00:38,299 --> 00:00:35,399
continuum emission from dust particles

12
00:00:40,430 --> 00:00:38,309
the problem is the spar do squirrel in

13
00:00:42,530 --> 00:00:40,440

polokwane two discs into rocks and

14

00:00:45,380 --> 00:00:42,540

boulders and plant test knows whence

15

00:00:48,440 --> 00:00:45,390

they grow bigger into cited bigger in

16

00:00:50,119 --> 00:00:48,450

size they're no longer emissive in the

17

00:00:52,760 --> 00:00:50,129

wavelength of that we're observing

18

00:00:54,950 --> 00:00:52,770

therefore we're missing a lot of mass if

19

00:00:59,180 --> 00:00:54,960

you only measure mass in submillimeter a

20

00:01:02,599 --> 00:00:59,190

mission so turns out ninety-nine percent

21

00:01:04,520 --> 00:01:02,609

of the disc mass is in h₂ gas to ask the

22

00:01:07,219 --> 00:01:04,530

question what about we measure the

23

00:01:10,490 --> 00:01:07,229

dispatch directly from the gas emission

24

00:01:13,039 --> 00:01:10,500

the problem is h₂ doesn't have a lecture

25

00:01:16,219 --> 00:01:13,049

dipole moment so it doesn't meet in

26
00:01:18,980 --> 00:01:16,229
typical in today's environment so this

27
00:01:22,130 --> 00:01:18,990
has been done once with HD emission by

28
00:01:25,840 --> 00:01:22,140
her show super Canelo's they measure the

29
00:01:29,390 --> 00:01:25,850
HD emission level oops right here and

30
00:01:33,649 --> 00:01:29,400
then the estimated this mask to be

31
00:01:36,440 --> 00:01:33,659
roughly 2005 solar mass and that's more

32
00:01:39,350 --> 00:01:36,450
massive than Allah estimates made in

33
00:01:41,840 --> 00:01:39,360
dust emission so her show is no longer

34
00:01:43,940 --> 00:01:41,850
with us and this lie is actually fairly

35
00:01:46,719 --> 00:01:43,950
sensitive to temperature so does not

36
00:01:50,719 --> 00:01:46,729
necessarily good probe for this mess and

37
00:01:54,200 --> 00:01:50,729
luckily we have Alma so traditionally

38
00:01:56,480 --> 00:01:54,210

people have been measuring mass of

39

00:01:59,870 --> 00:01:56,490

molecular clouds in co that's just

40

00:02:02,209 --> 00:01:59,880

because co is the last and the second

41

00:02:04,969 --> 00:02:02,219

most abundant molecule in molecular cows

42

00:02:08,089 --> 00:02:04,979

so that's the first thing people look at

43

00:02:09,469 --> 00:02:08,099

when they first got all my very first

44

00:02:10,740 --> 00:02:09,479

became able to detect molecular

45

00:02:13,920 --> 00:02:10,750

emissions in those days

46

00:02:16,290 --> 00:02:13,930

and even though typical I'm commonly

47

00:02:19,350 --> 00:02:16,300

observed CEO lines from regular co-op

48

00:02:23,670 --> 00:02:19,360

Lee sick we can still observe where as a

49

00:02:25,920 --> 00:02:23,680

cop locks se13 COC 1800's c-17 oh and

50

00:02:27,720 --> 00:02:25,930

they could be ugly thin to trace the

51
00:02:31,250 --> 00:02:27,730
Disney play and therefore the entire

52
00:02:34,890 --> 00:02:31,260
mess budget however to translate our

53
00:02:37,590 --> 00:02:34,900
observation of omission to the actual

54
00:02:40,440 --> 00:02:37,600
dis mess mostly in h2 is a very

55
00:02:42,840 --> 00:02:40,450
non-trivial process so first of all the

56
00:02:46,310 --> 00:02:42,850
different fractionation processes that

57
00:02:50,220 --> 00:02:46,320
could change a ver Co to Co ratio and

58
00:02:52,350 --> 00:02:50,230
still chemistry can also deviate the co

59
00:02:56,040 --> 00:02:52,360
2 h 2 ratio away from the molecular

60
00:02:58,290 --> 00:02:56,050
cloud value so this temperature and

61
00:03:00,390 --> 00:02:58,300
density structures they determine the

62
00:03:03,120 --> 00:03:00,400
chemical processes and they also do the

63
00:03:06,120 --> 00:03:03,130

ab decide the excitation processes that

64

00:03:08,670 --> 00:03:06,130

eventually lead to the emission lines so

65

00:03:11,400 --> 00:03:08,680

our approach is to model the

66

00:03:14,900 --> 00:03:11,410

thermochemistry of an evolving poll

67

00:03:17,280 --> 00:03:14,910

century disks so we first look at the

68

00:03:19,590 --> 00:03:17,290

thermodynamical structure we follow the

69

00:03:21,270 --> 00:03:19,600

evolution of a t-tauri disk for 3

70

00:03:25,229 --> 00:03:21,280

million years that's roughly the

71

00:03:29,009 --> 00:03:25,239

lifetime of Apollo villages around the

72

00:03:31,289 --> 00:03:29,019

solar type star and then we look at

73

00:03:34,110 --> 00:03:31,299

kinetic chemistry motto so the model was

74

00:03:37,560 --> 00:03:34,120

built upon that you miss database we

75

00:03:39,900 --> 00:03:37,570

have more than 1,300 reactions including

76

00:03:42,090 --> 00:03:39,910

gas phase reactions graceful

77

00:03:45,360 --> 00:03:42,100

distractions and different photochemical

78

00:03:50,850 --> 00:03:45,370

reactions to count for fractionation

79

00:03:55,080 --> 00:03:50,860

processes so this is what we found so

80

00:03:56,640 --> 00:03:55,090

now we're seeing a cut of the polyp ng

81

00:04:00,150 --> 00:03:56,650

disk so we're only seeing the cross

82

00:04:03,600 --> 00:04:00,160

section and then the quantity plot here

83

00:04:05,640 --> 00:04:03,610

is the number density of the species

84

00:04:07,410 --> 00:04:05,650

divided by the total proton number

85

00:04:10,710 --> 00:04:07,420

density is overseeing the dependence

86

00:04:12,810 --> 00:04:10,720

here a minus 4.2 the right color here is

87

00:04:15,720 --> 00:04:12,820

the info dependence of red means a lot

88

00:04:18,960 --> 00:04:15,730

and blue means the sternness beaches is

89

00:04:21,810 --> 00:04:18,970

depleted so we're having a lower carbon

90

00:04:25,910 --> 00:04:21,820

dioxide ice and turns out that in here

91

00:04:31,050 --> 00:04:25,920

from the cloud phase chemistry model

92

00:04:33,390 --> 00:04:31,060

however co is depleted beyond 28 you

93

00:04:35,820 --> 00:04:33,400

from the central star and turns out the

94

00:04:38,040 --> 00:04:35,830

disk is hot enough for co₂ stay in the

95

00:04:40,890 --> 00:04:38,050

gas phase the whole time so does not do

96

00:04:43,020 --> 00:04:40,900

to freeze out we ask the question what

97

00:04:45,660 --> 00:04:43,030

happens so if you look at one particular

98

00:04:48,450 --> 00:04:45,670

point in this case 68 you on the

99

00:04:50,130 --> 00:04:48,460

midplane the black line here is showing

100

00:04:53,250 --> 00:04:50,140

the time evolution of the abundance of

101
00:04:57,060 --> 00:04:53,260
co it drops a million-year timescale

102
00:05:00,090 --> 00:04:57,070
same for many things and is that the

103
00:05:03,120 --> 00:05:00,100
vendors of organic molecules increase

104
00:05:05,400 --> 00:05:03,130
and they pretty much plateaued after 2

105
00:05:08,190 --> 00:05:05,410
million years of evolution if it

106
00:05:11,520 --> 00:05:08,200
averages over the entire disk it turns

107
00:05:13,650 --> 00:05:11,530
out more than forty five percent in some

108
00:05:16,470 --> 00:05:13,660
models around forty five percent of

109
00:05:18,570 --> 00:05:16,480
available carbon is stored in organic

110
00:05:23,910 --> 00:05:18,580
Isis by the end of the teacher in

111
00:05:26,940 --> 00:05:23,920
evolution so we asked the cross my heart

112
00:05:30,600 --> 00:05:26,950
robust or is Elias so we tested a result

113
00:05:33,030 --> 00:05:30,610

against of different models so we have I

114

00:05:35,940 --> 00:05:33,040

see this is a different chemical network

115

00:05:38,460 --> 00:05:35,950

different input evidences and different

116

00:05:42,000 --> 00:05:38,470

dust properties so the takeaway of this

117

00:05:44,550 --> 00:05:42,010

is um we have a lot of carbon dioxide

118

00:05:48,110 --> 00:05:44,560

ice in all cases around thirty five

119

00:05:51,420 --> 00:05:48,120

percent and a lower organics roughly

120

00:05:53,820 --> 00:05:51,430

Irish forty percent of available carbon

121

00:05:56,310 --> 00:05:53,830

and the CEO at Venice is only around

122

00:05:59,220 --> 00:05:56,320

fifteen percent so unless in molecular

123

00:06:04,850 --> 00:05:59,230

cloud we think co may not be the most

124

00:06:07,440 --> 00:06:04,860

abundant molecule out there alright so

125

00:06:10,470 --> 00:06:07,450

with starting this project trying to

126

00:06:14,060 --> 00:06:10,480

find out what can I use as the probe for

127

00:06:18,870 --> 00:06:14,070

the dismay plan and it turns out seeds

128

00:06:21,690 --> 00:06:18,880

18yo sorry c7000 becomes ugly spin after

129

00:06:24,510 --> 00:06:21,700

ten ato from the central star and for

130

00:06:27,860 --> 00:06:24,520

c18 know the numbers around 15 a you

131

00:06:31,830 --> 00:06:27,870

basically that means yes we can observe

132

00:06:33,999 --> 00:06:31,840

c70 or CAT know and use those lines as a

133

00:06:36,489 --> 00:06:34,009

direct probe of the dismay

134

00:06:40,269 --> 00:06:36,499

and use the adult slides to measure this

135

00:06:42,159 --> 00:06:40,279

mess however because the chemical

136

00:06:44,859 --> 00:06:42,169

evolution happens on a million year time

137

00:06:47,230 --> 00:06:44,869

scale so turns out the obviously the

138

00:06:50,439 --> 00:06:47,240

opacity changes quite dramatically as it

139

00:06:55,359 --> 00:06:50,449

disables so the now we're looking at up

140

00:06:58,209 --> 00:06:55,369

to depths of MCO 120 line as a function

141

00:07:02,589 --> 00:06:58,219

of radius so we start with a brief lat

142

00:07:05,139 --> 00:07:02,599

pulls out and then a dependence drops at

143

00:07:08,950 --> 00:07:05,149

around fifteen twenty eight us it dis

144

00:07:12,579 --> 00:07:08,960

evolves and interesting this has been

145

00:07:15,999 --> 00:07:12,589

seen recently in the observation of teva

146

00:07:19,089 --> 00:07:16,009

hydrate so now we're again looking at

147

00:07:22,689 --> 00:07:19,099

the column density of cos the function

148

00:07:24,820 --> 00:07:22,699

of radius the line is flat if we're only

149

00:07:27,790 --> 00:07:24,830

looking at decimation but we're seeing a

150

00:07:30,480 --> 00:07:27,800

huge drop at about twenty a you just as

151

00:07:33,760 --> 00:07:30,490

what we predicted here in the bottom

152

00:07:35,799 --> 00:07:33,770

alright if we take a step back and look

153

00:07:38,170 --> 00:07:35,809

at some global properties turns out

154

00:07:41,860 --> 00:07:38,180

people are seeing really small gas to

155

00:07:44,409 --> 00:07:41,870

dust ratios Impala plenty disks just for

156

00:07:48,129 --> 00:07:44,419

reference the canonical intersil of

157

00:07:51,129 --> 00:07:48,139

value is 100 in disks people have been

158

00:07:55,059 --> 00:07:51,139

observing a whole range of values all

159

00:07:57,820 --> 00:07:55,069

the way from 10 to 70 so the blue box

160

00:08:00,939 --> 00:07:57,830

here is observed data and the yellow

161

00:08:02,769 --> 00:08:00,949

boxes here are our model predictions if

162

00:08:07,019 --> 00:08:02,779

people interpret the observation

163

00:08:12,179 --> 00:08:07,029

assuming a constant CO₂ / H₂ ratio

164

00:08:14,769 --> 00:08:12,189

alright so back to the question of the

165

00:08:17,259 --> 00:08:14,779

global dis mass so are we actually

166

00:08:20,529 --> 00:08:17,269

seeing the gas depletion globally were

167

00:08:22,959 --> 00:08:20,539

just CO depletion so does it mean we're

168

00:08:27,759 --> 00:08:22,969

under estimating the gas mask just

169

00:08:30,820 --> 00:08:27,769

because your is depleted so in order to

170

00:08:34,719 --> 00:08:30,830

do that we model the line emission based

171

00:08:38,230 --> 00:08:34,729

our chemistry model and then luckily the

172

00:08:40,870 --> 00:08:38,240

CO depletion does have chemical

173

00:08:42,990 --> 00:08:40,880

signature is macula line profiles so now

174

00:08:46,500 --> 00:08:43,000

we're looking at C₇₀ no

175

00:08:49,920 --> 00:08:46,510

a three to two rotational inversion for

176

00:08:53,520 --> 00:08:49,930

the end of evolution and the top panel

177

00:08:55,680 --> 00:08:53,530

we're seeing the actual spectra and then

178

00:08:58,340 --> 00:08:55,690

the lower wise normalized land profiles

179

00:09:01,620 --> 00:08:58,350

because the chemical depletion happens

180

00:09:04,140 --> 00:09:01,630

sorry mostly the outer part of this

181

00:09:08,820 --> 00:09:04,150

query capillary rotation of capillary

182

00:09:13,520 --> 00:09:08,830

velovsky is smaller so for the chemical

183

00:09:17,280 --> 00:09:13,530

evolution model busy how does it work

184

00:09:19,200 --> 00:09:17,290

the inner part were depleted I mean most

185

00:09:21,330 --> 00:09:19,210

of a mission comes from the in there

186

00:09:22,800 --> 00:09:21,340

sorry the outer part is deeply there

187

00:09:25,110 --> 00:09:22,810

most of a mission actually comes from

188

00:09:28,530 --> 00:09:25,120

the inner part of this we're on the

189

00:09:30,720 --> 00:09:28,540

Kepler the loskis much higher all right

190

00:09:39,110 --> 00:09:30,730

I notice all details so i'll leave the

191

00:09:43,100 --> 00:09:41,160

i'm going to use my privilege and ask

192

00:09:45,240 --> 00:09:43,110

you the first question right what is the

193

00:09:48,060 --> 00:09:45,250

dominant parameter in your model that

194

00:09:50,400 --> 00:09:48,070

determines where the lines go optically

195

00:09:51,840 --> 00:09:50,410

thick in terms of a you I mean you you

196

00:09:54,240 --> 00:09:51,850

have a radius out from the central star

197

00:09:56,220 --> 00:09:54,250

where they go optically thick but what

198

00:10:00,600 --> 00:09:56,230

part of the model determines where where

199

00:10:04,380 --> 00:10:00,610

that is oh very compare the lpo tests

200

00:10:05,970 --> 00:10:04,390

just based on the chemistry so we have

201
00:10:07,650 --> 00:10:05,980
the chemical evolution model is actually

202
00:10:11,579 --> 00:10:07,660
a one-point model so we follow the

203
00:10:14,010 --> 00:10:11,589
chemical evolution is a is a 50 x 40

204
00:10:15,600 --> 00:10:14,020
grade so it follows the evolution for a

205
00:10:18,540 --> 00:10:15,610
few million years for every single point

206
00:10:21,060 --> 00:10:18,550
of the disk and then we integrate to get

207
00:10:23,490 --> 00:10:21,070
off till death yeah so that estimation

208
00:10:27,780 --> 00:10:23,500
was for a facedown GL make sure we also

209
00:10:30,230 --> 00:10:27,790
have other more detailed prediction

210
00:10:37,890 --> 00:10:30,240
coming up in the Latin profile paper

211
00:10:42,820 --> 00:10:41,380
so you mentioned that the CEO depletion

212
00:10:45,790 --> 00:10:42,830
as a result of complex organic ice

213
00:10:48,610 --> 00:10:45,800

formation what's driving that reaction

214

00:10:52,620 --> 00:10:48,620

that's a great question and I look back

215

00:10:55,269 --> 00:10:52,630

like black backups life for them oh

216

00:10:58,300 --> 00:10:55,279

that's the network just flex over in

217

00:11:01,510 --> 00:10:58,310

case anyone is interested and so it

218

00:11:05,019 --> 00:11:01,520

turns out the reaction term scouts

219

00:11:07,570 --> 00:11:05,029

limited by ionization so for roughly

220

00:11:09,310 --> 00:11:07,580

about 28 you on me play so this is the

221

00:11:12,310 --> 00:11:09,320

key figure that's a contribution of

222

00:11:14,740 --> 00:11:12,320

extra ionization basically for red and

223

00:11:17,590 --> 00:11:14,750

yellow that means that's where extra

224

00:11:20,470 --> 00:11:17,600

ionization dominance and then in the

225

00:11:22,480 --> 00:11:20,480

interior I would say within one scale

226

00:11:25,590 --> 00:11:22,490

height of exist that's where cosmic ray

227

00:11:28,990 --> 00:11:25,600

and secondary huy fong house donuts and

228

00:11:30,850 --> 00:11:29,000

that's a great question because a Elsa

229

00:11:33,400 --> 00:11:30,860

and pipe organs group and four atoms

230

00:11:36,310 --> 00:11:33,410

they've been proposing that cosmic rays

231

00:11:38,500 --> 00:11:36,320

can be shouted by the magnetic field of

232

00:11:42,430 --> 00:11:38,510

the central star were the disc so if

233

00:11:44,740 --> 00:11:42,440

that happens that will turn down the

234

00:11:49,030 --> 00:11:44,750

reaction rate by law so we are testing

235

00:11:52,960 --> 00:11:49,040

of that situation too and our point 22

236

00:11:55,930 --> 00:11:52,970

else's I think her chosen five papers so

237

00:11:59,740 --> 00:11:55,940

they try to constrain the cosmic ray and

238

00:12:08,260 --> 00:11:59,750

kazmir ionization rates by observing mo

239

00:12:10,960 --> 00:12:08,270

lang co Venice it was really nice talk

240

00:12:12,310 --> 00:12:10,970

so do you expect the the time scales the

241

00:12:14,800 --> 00:12:12,320

reactions you're considering are going

242

00:12:16,960 --> 00:12:14,810

to be fast enough the dynamics aren't

243

00:12:22,449 --> 00:12:16,970

important oh that's that's a good

244

00:12:24,670 --> 00:12:22,459

question um so I see the time scales for

245

00:12:27,220 --> 00:12:24,680

freestyle and gas phase reactions are

246

00:12:31,300 --> 00:12:27,230

definitely at not and for green surface

247

00:12:33,430 --> 00:12:31,310

reactions I mean green for green surface

248

00:12:34,750 --> 00:12:33,440

reactions they happen much faster than

249

00:12:36,790 --> 00:12:34,760

the dynamic of time scale so they're

250

00:12:38,949 --> 00:12:36,800

fine and I think there is one particular

251
00:12:42,160 --> 00:12:38,959
kind of reactions now i can remember

252
00:12:44,220 --> 00:12:42,170
which kind that could be relevant so you

253
00:12:46,320 --> 00:12:44,230
might want to consider mixing or

254
00:12:50,430 --> 00:12:46,330
transportation for that but for us with

255
00:12:53,130 --> 00:12:50,440
which Richard we track the change in

256
00:12:56,910 --> 00:12:53,140
density temperature and the change of

257
00:13:00,740 --> 00:12:56,920
column densities yeah one model of one

258
00:13:03,990 --> 00:13:00,750
group they're trying to combine the

259
00:13:07,380 --> 00:13:04,000
there's one group we're trying to

260
00:13:11,250 --> 00:13:07,390
combine the dynamic and the chemistry

261
00:13:14,550 --> 00:13:11,260
together pro demo the code scoper demo

262
00:13:16,590 --> 00:13:14,560
so they have the problem is so busy they

263
00:13:18,840 --> 00:13:16,600

calculate the thermal structure like

264

00:13:21,030 --> 00:13:18,850

citation chemistry coherently the

265

00:13:23,610 --> 00:13:21,040

problem is the only have parametric

266

00:13:26,280 --> 00:13:23,620

models so in our case we actually have

267

00:13:28,890 --> 00:13:26,290

MRI turbulence in the dismal dough so

268

00:13:32,310 --> 00:13:28,900

the first paper was based on a my