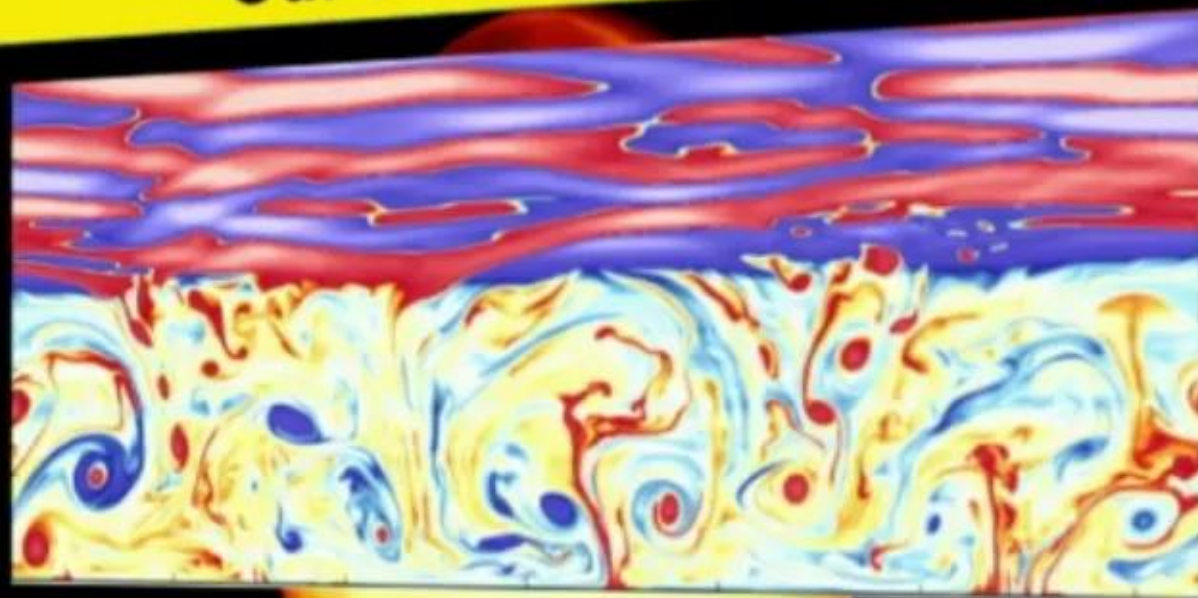


Our toolkit: Dedalus



A fully parallelized pseudospectral differential equation solver, in python, with intuitive and flexible equation implementation

$$\frac{\partial c}{\partial t} + \nabla \cdot (uc) = \nabla \cdot (k \nabla c) + \sum_{rxn} (\mathcal{P} - \mathcal{L})$$

$$\begin{aligned} dt(c) + dx(u*c) + dz(u*c) &= dx(k*dx(c)+k*dz(c)) + dz(k*dx(c)+k*dz(c)) + PL_sum \\ &= dx(k*dx(c)+k*dz(c)) + dz(k*dx(c)+k*dz(c)) + K*rho*(c_eq - c) \end{aligned}$$

$$\begin{aligned} dz(c) + dx(u*c) + dz(u*c) &= dx(k*dx(c)+k*dz(c)) + dz(k*dx(c)+k*dz(c)) \\ &= dx(k*dx(c)+k*dz(c)) + dz(k*dx(c)+k*dz(c)) + K*rho*(c_eq - c) \end{aligned}$$

1
00:00:10,900 --> 00:00:08,150
my name is Bailey word well I work for

2
00:00:12,740 --> 00:00:10,910
ben Brown and Jeff oishi here on campus

3
00:00:15,020 --> 00:00:12,750
and what I'm going to be talking to you

4
00:00:16,519 --> 00:00:15,030
about today is dynamics in chemistry of

5
00:00:18,410 --> 00:00:16,529
X planet and here's to dehydration

6
00:00:20,510 --> 00:00:18,420
simulations that's the talk title I came

7
00:00:21,620 --> 00:00:20,520
up with several months ago I decided I

8
00:00:23,570 --> 00:00:21,630
should probably give you a talk title

9
00:00:24,830 --> 00:00:23,580
that is actually informative about what

10
00:00:26,870 --> 00:00:24,840
I'm trying to convey in this talk and

11
00:00:28,250 --> 00:00:26,880
what I want you to learn about in this

12
00:00:29,990 --> 00:00:28,260
talk is why you should care about jovian

13
00:00:32,840 --> 00:00:30,000

planets or gas giants when you're

14

00:00:35,930 --> 00:00:32,850

interested in astrobiology so to start

15

00:00:37,400 --> 00:00:35,940

off with the major focus for people who

16

00:00:39,470 --> 00:00:37,410

are studying exoplanets right now is the

17

00:00:41,540 --> 00:00:39,480

F coming telescope jwst or the james

18

00:00:42,889 --> 00:00:41,550

webb space telescope and the reason why

19

00:00:44,209 --> 00:00:42,899

we're so excited about this telescope is

20

00:00:46,160 --> 00:00:44,219

this telescope is a next-generation

21

00:00:47,389 --> 00:00:46,170

infrared telescope which means that it's

22

00:00:50,810 --> 00:00:47,399

going to be focusing on the light that

23

00:00:52,160 --> 00:00:50,820

exoplanets are brightest in so when

24

00:00:53,840 --> 00:00:52,170

you're observing an exoplanet and you

25

00:00:55,069 --> 00:00:53,850

want to observe its atmospheric spectro

26

00:00:57,080 --> 00:00:55,079

so you want to get an idea of its

27

00:00:59,599 --> 00:00:57,090

composition what you're looking at is

28

00:01:01,279 --> 00:00:59,609

you're looking at the small variations

29

00:01:03,560 --> 00:01:01,289

induced in the transit due to the light

30

00:01:06,469 --> 00:01:03,570

due to the planet absorbing excess of the

31

00:01:09,050 --> 00:01:06,479

star's light or absorbing less of the

32

00:01:11,210 --> 00:01:09,060

star's light and so those excesses

33

00:01:12,859 --> 00:01:11,220

change the typical transit depths where

34

00:01:14,450 --> 00:01:12,869

you're looking at a typical transit for

35

00:01:16,310 --> 00:01:14,460

a jovian planets on the order of one

36

00:01:19,280 --> 00:01:16,320

percent for an earth-like planets on the

37

00:01:21,499 --> 00:01:19,290

order of about a hundred percent or

38

00:01:23,600 --> 00:01:21,509

forty hundredth of a percent for if it's

39

00:01:25,399 --> 00:01:23,610

around an m-dwarf if you're looking at

40

00:01:26,780 --> 00:01:25,409

Mysterio differences those are on the

41

00:01:29,420 --> 00:01:26,790

order for those percents of those

42

00:01:31,310 --> 00:01:29,430

percents and so it suddenly becomes much

43

00:01:33,160 --> 00:01:31,320

much harder to get details about an

44

00:01:35,929 --> 00:01:33,170

earth-like planet than a Jovian planet

45

00:01:37,190 --> 00:01:35,939

the other thing is that on JWC we're

46

00:01:40,609 --> 00:01:37,200

limited for time because the entire

47

00:01:42,469 --> 00:01:40,619

astronomy community is using jwst and so

48

00:01:44,780 --> 00:01:42,479

if you break down the timescale of its

49

00:01:48,350 --> 00:01:44,790

primary mission we have about 300 days

50

00:01:49,670 --> 00:01:48,360

to observe exoplanets what that means is

51
00:01:52,160 --> 00:01:49,680
that we can characterize the atmospheric

52
00:01:55,789 --> 00:01:52,170
structure for 150 jovian planets or

53
00:01:57,499 --> 00:01:55,799
three years like planets and so

54
00:01:59,270 --> 00:01:57,509
especially because we're only going to

55
00:02:01,310 --> 00:01:59,280
discover these arts like targets two

56
00:02:02,840 --> 00:02:01,320
years in TJ WCS mission we're going to

57
00:02:04,160 --> 00:02:02,850
be observing a lot of jovian planets and

58
00:02:05,980 --> 00:02:04,170
I want you to realize that that's

59
00:02:09,139 --> 00:02:05,990
actually going to be a good thing for us

60
00:02:10,850 --> 00:02:09,149
so let me take an aside for one second

61
00:02:12,830 --> 00:02:10,860
and explain the minimum a solar nebula

62
00:02:13,640 --> 00:02:12,840
model so the minimum mass so a nebula

63
00:02:16,759 --> 00:02:13,650

model is our Bay

64

00:02:18,589 --> 00:02:16,769

a starting point for the evolution of

65

00:02:21,770 --> 00:02:18,599

the solar system from where it was

66

00:02:23,690 --> 00:02:21,780

forming what we do is we take the mass

67

00:02:26,479 --> 00:02:23,700

and the composition of every planet we

68

00:02:27,679 --> 00:02:26,489

smear it out along its orbit and we had

69

00:02:30,410 --> 00:02:27,689

basically interpolate between those

70

00:02:31,759 --> 00:02:30,420

points and say this is what the third

71

00:02:33,949 --> 00:02:31,769

planetary disc of the solar system look

72

00:02:34,940 --> 00:02:33,959

like but when we're looking at so

73

00:02:36,979 --> 00:02:34,950

planets we're looking at a whole range

74

00:02:38,990 --> 00:02:36,989

of kinds of stars with different levels

75

00:02:41,479 --> 00:02:39,000

of heavy heavy element composition or

76

00:02:43,699 --> 00:02:41,489

metallicities and so we don't have a

77

00:02:44,899 --> 00:02:43,709

good idea of how they're protoplanetary

78

00:02:46,809 --> 00:02:44,909

disks should look except for something

79

00:02:49,580 --> 00:02:46,819

through things like Alma observations

80

00:02:52,250 --> 00:02:49,590

what we can use to jump in between that

81

00:02:53,930 --> 00:02:52,260

is jovian planets when we look at the

82

00:02:56,930 --> 00:02:53,940

composition of jovian planets we get

83

00:02:58,610 --> 00:02:56,940

data points across the disk for what the

84

00:02:59,960 --> 00:02:58,620

composition is and this can allow us to

85

00:03:02,059 --> 00:02:59,970

make inferences for what the composition

86

00:03:03,289 --> 00:03:02,069

of earth-like planets should be based on

87

00:03:05,240 --> 00:03:03,299

the relationship between the jovian

88

00:03:07,970 --> 00:03:05,250

planets metallicity and the metallicity

89

00:03:09,949 --> 00:03:07,980

of these stars so when we're looking at

90

00:03:11,390 --> 00:03:09,959

jovian planets composition we

91

00:03:14,119 --> 00:03:11,400

specifically focus on something called

92

00:03:16,190 --> 00:03:14,129

the carbon oxygen ratio and there's two

93

00:03:17,809 --> 00:03:16,200

ways of deriving this ratio one way is

94

00:03:19,369 --> 00:03:17,819

to take the observer's route and to

95

00:03:21,680 --> 00:03:19,379

observe all the carbon bearing molecules

96

00:03:24,500 --> 00:03:21,690

and all the oxygen very molecules some

97

00:03:25,699 --> 00:03:24,510

of them up take the ratio the other way

98

00:03:27,770 --> 00:03:25,709

to do this is to take the theorists

99

00:03:30,949 --> 00:03:27,780

route and do Ford modeling so you model

100

00:03:31,970 --> 00:03:30,959

the elemental abundances see how that

101

00:03:34,220 --> 00:03:31,980

carries through to the molecular

102

00:03:36,830 --> 00:03:34,230

abundances and compare the spectra and

103

00:03:38,180 --> 00:03:36,840

do a fit the problem with this is that

104

00:03:39,949 --> 00:03:38,190

when you're doing the theoretical model

105

00:03:42,110 --> 00:03:39,959

you actually have to assume some way the

106

00:03:43,789 --> 00:03:42,120

elemental abundances tie to molecular

107

00:03:45,199 --> 00:03:43,799

abundances and you can say that

108

00:03:47,360 --> 00:03:45,209

everything is nice and in thermal

109

00:03:49,580 --> 00:03:47,370

chemical equilibrium or you can say that

110

00:03:50,659 --> 00:03:49,590

it's complex and the dynamics affect how

111

00:03:55,849 --> 00:03:50,669

much of everything you're going to see

112

00:03:57,080 --> 00:03:55,859

and assume that kind of model so when

113

00:03:58,309 --> 00:03:57,090

we're trying to assume that the dynamics

114

00:04:00,050 --> 00:03:58,319

affects things because we know from

115

00:04:01,430 --> 00:04:00,060

Jupiter that the dynamics do affect the

116

00:04:03,199 --> 00:04:01,440

concentrations of molecules that you're

117

00:04:04,879 --> 00:04:03,209

seeing we use an approximation called

118

00:04:06,680 --> 00:04:04,889

the quenching approximation and what the

119

00:04:09,050 --> 00:04:06,690

quenching approximation does is it uses

120

00:04:10,520 --> 00:04:09,060

in analytical theory called mixing like

121

00:04:12,319 --> 00:04:10,530

theory which describes how the

122

00:04:15,259 --> 00:04:12,329

atmosphere boils essentially it

123

00:04:16,610 --> 00:04:15,269

describes how it convex and for the

124

00:04:18,409 --> 00:04:16,620

typical reaction we consider which is

125

00:04:20,539 --> 00:04:18,419

the carbon monoxide methane in a row

126

00:04:22,519 --> 00:04:20,549

conversion reaction when we do is we say

127

00:04:23,690 --> 00:04:22,529

there's a certain time scale that

128

00:04:25,730 --> 00:04:23,700

describes the motion of the atmosphere

129

00:04:26,430 --> 00:04:25,740

at a certain time scale that describes

130

00:04:28,620 --> 00:04:26,440

the

131

00:04:30,150 --> 00:04:28,630

reactions and when those time scales are

132

00:04:31,410 --> 00:04:30,160

equal the motions of the atmosphere are

133

00:04:34,470 --> 00:04:31,420

going to interfere with the ability of

134

00:04:35,850 --> 00:04:34,480

these molecules to react we can then do

135

00:04:37,320 --> 00:04:35,860

a lot of maths and partial differential

136

00:04:38,280 --> 00:04:37,330

equations arrived with a profile how

137

00:04:39,570 --> 00:04:38,290

everything is going to go up in the

138

00:04:42,360 --> 00:04:39,580

atmosphere if you want to do that math

139

00:04:44,730 --> 00:04:42,370

later that's fine taking it by word and

140

00:04:47,790 --> 00:04:44,740

we can make the assumption that the time

141

00:04:49,410 --> 00:04:47,800

scale or these are the scale at which

142

00:04:50,640 --> 00:04:49,420

the time scale will chemical reaction is

143

00:04:52,890 --> 00:04:50,650

slowing down as you go up in the

144

00:04:54,420 --> 00:04:52,900

atmosphere is very very small compared

145

00:04:56,160 --> 00:04:54,430

to the rate at which the dynamics of

146

00:04:59,700 --> 00:04:56,170

the atmosphere are changing and when you

147

00:05:01,380 --> 00:04:59,710

do that everything right here on the

148

00:05:03,180 --> 00:05:01,390

right-hand side drops off and becomes

149

00:05:05,160 --> 00:05:03,190

one and you just get that the

150

00:05:06,750 --> 00:05:05,170

composition above the clench point where

151

00:05:09,390 --> 00:05:06,760

the time scales are equal is constant

152

00:05:13,320 --> 00:05:09,400

and so that creates differences like you

153

00:05:15,240 --> 00:05:13,330

see here where you have a nice squirrel

154

00:05:18,090 --> 00:05:15,250

to the carbon dioxide for this one and a

155

00:05:20,580 --> 00:05:18,100

nice straight line right here and so

156

00:05:22,050 --> 00:05:20,590

that vary significantly impacts what

157

00:05:23,580 --> 00:05:22,060

kind of abundance is we infer for these

158

00:05:25,560 --> 00:05:23,590

planets because it's an order of

159

00:05:29,130 --> 00:05:25,570

magnitude difference in the

160

00:05:30,930 --> 00:05:29,140

concentration but there's something else

161

00:05:33,480 --> 00:05:30,940

we have to consider and that's the

162

00:05:36,120 --> 00:05:33,490

Jovian atmospheres aren't just a fully

163

00:05:38,460 --> 00:05:36,130

convecting they have a conductive zone

164

00:05:40,620 --> 00:05:38,470

at the bottom and that convective zone

165

00:05:42,540 --> 00:05:40,630

drives dynamics in an upper radiative

166

00:05:44,130 --> 00:05:42,550

zone it arrived something called gravity

167

00:05:46,800 --> 00:05:44,140

waves which have a very different mixing

168

00:05:48,420 --> 00:05:46,810

behavior than the convection and when we

169

00:05:50,159 --> 00:05:48,430

try to apply something like the punch

170

00:05:52,920 --> 00:05:50,169

approximation to the radiative zone

171

00:05:56,760 --> 00:05:52,930

there is no theoretical basis for it to

172

00:05:59,220 --> 00:05:56,770

apply now that's okay if our

173

00:06:01,710 --> 00:05:59,230

observations that have the light coming

174

00:06:04,980 --> 00:06:01,720

from the convection zone but simulations

175

00:06:07,140 --> 00:06:04,990

of jay davis t show that they don't they

176

00:06:09,120 --> 00:06:07,150

actually we're if red is where all the

177

00:06:10,530 --> 00:06:09,130

light is coming from they are coming

178

00:06:12,120 --> 00:06:10,540

from very high up in the radiative zone

179

00:06:14,550 --> 00:06:12,130

which means that we have to consider the

180

00:06:17,310 --> 00:06:14,560

mixing due to the gravitational waves

181

00:06:20,100 --> 00:06:17,320

and that's what I'm focusing on so I'm

182

00:06:22,260 --> 00:06:20,110

looking at how we can apply our

183

00:06:24,030 --> 00:06:22,270

understanding of gravity waves to

184

00:06:25,230 --> 00:06:24,040

chemical disequilibrium and therefore

185

00:06:29,250 --> 00:06:25,240

getting better abundances for these

186

00:06:31,830 --> 00:06:29,260

planets the way I do this is I use a

187

00:06:33,270 --> 00:06:31,840

code called Daedalus now Daedalus isn't

188

00:06:36,480 --> 00:06:33,280

something like a fully developed GCM

189

00:06:39,779 --> 00:06:36,490

code that super that is focused on one

190

00:06:40,360 --> 00:06:39,789

thing it's a you can see if my very

191

00:06:42,129 --> 00:06:40,370

wordy sent

192

00:06:43,780 --> 00:06:42,139

here a fully paralyzed pseudo spectral

193

00:06:45,100 --> 00:06:43,790

differential equation solver implement

194

00:06:47,290 --> 00:06:45,110

in Python with intuitive and flexible

195

00:06:49,180 --> 00:06:47,300

equation implementation that is my grant

196

00:06:51,520 --> 00:06:49,190

proposal sentence I'm sorry for lifting

197

00:06:53,890 --> 00:06:51,530

it upon you basically what it means is

198

00:06:55,450 --> 00:06:53,900

that this code can solve any set of

199

00:06:57,430 --> 00:06:55,460

partial differential equations and

200

00:06:59,350 --> 00:06:57,440

integrate them in time efficiently and

201
00:07:01,420 --> 00:06:59,360
what that means is when we're trying to

202
00:07:03,790 --> 00:07:01,430
work on it with an atmosphere we want to

203
00:07:05,800 --> 00:07:03,800
solve the fluids equations we can do

204
00:07:08,950 --> 00:07:05,810
this in a way that is both simple to

205
00:07:10,840 --> 00:07:08,960
implement very flexible and is intuitive

206
00:07:13,570 --> 00:07:10,850
for a user because you can take an

207
00:07:15,550 --> 00:07:13,580
equation like this and implement it like

208
00:07:18,670 --> 00:07:15,560
this where it's very easy to see which

209
00:07:20,260 --> 00:07:18,680
terms match to which terms and so that's

210
00:07:22,900 --> 00:07:20,270
useful because we can add things like

211
00:07:27,340 --> 00:07:22,910
this equation where we have tracers that

212
00:07:30,840 --> 00:07:27,350
in that simulate chemical reactants so

213
00:07:34,480 --> 00:07:30,850

what my experiment is is I'm taking

214

00:07:36,580 --> 00:07:34,490

polynomials and mimicking a temperature

215

00:07:39,189 --> 00:07:36,590

pressure profile like that of Jupiter

216

00:07:40,930 --> 00:07:39,199

I'm mimicking chemical abundance

217

00:07:43,870 --> 00:07:40,940

profiles like that we derive for Jupiter

218

00:07:46,810 --> 00:07:43,880

with a tan function and then I'm adding

219

00:07:48,580 --> 00:07:46,820

some tracers so I'm adding a tracer that

220

00:07:50,170 --> 00:07:48,590

doesn't react at all so it's just

221

00:07:52,990 --> 00:07:50,180

following the fluid motions showing how

222

00:07:55,420 --> 00:07:53,000

we thanks mix and I'm adding a tracer

223

00:07:58,360 --> 00:07:55,430

that has some reaction term so it's

224

00:07:59,710 --> 00:07:58,370

produced and it's lost and I'm sorry to

225

00:08:02,650 --> 00:07:59,720

all what chemists in the room what I'm

226

00:08:05,050 --> 00:08:02,660

doing is I'm saying that most reactions

227

00:08:06,940 --> 00:08:05,060

are fast compared to a single reaction

228

00:08:09,850 --> 00:08:06,950

and that does work for the quench

229

00:08:11,050 --> 00:08:09,860

approximation and I could show you the

230

00:08:13,779 --> 00:08:11,060

mathematical proof to say that that's

231

00:08:15,430 --> 00:08:13,789

okay but it makes them something there's

232

00:08:19,510 --> 00:08:15,440

something that is easy to grapple for an

233

00:08:20,830 --> 00:08:19,520

astronomer so what I do is I say that I

234

00:08:23,080 --> 00:08:20,840

have an abstract chemical reaction

235

00:08:25,300 --> 00:08:23,090

defined by a chemical reynolds number

236

00:08:27,129 --> 00:08:25,310

and that's just the ratio of the

237

00:08:29,290 --> 00:08:27,139

diffusion time to the chemical time

238

00:08:30,700 --> 00:08:29,300

scale and I say if the chemical time

239

00:08:33,850 --> 00:08:30,710

scale is on the same time scale as the

240

00:08:36,760 --> 00:08:33,860

dynamics what happens this is where we

241

00:08:39,850 --> 00:08:36,770

get to my very preliminary results these

242

00:08:42,490 --> 00:08:39,860

are starting this whole thing off pretty

243

00:08:45,750 --> 00:08:42,500

recently so what you can see here is

244

00:08:48,880 --> 00:08:45,760

this is the same setup as I had in my

245

00:08:51,940 --> 00:08:48,890

slide talking about Daedalus so at the

246

00:08:54,010 --> 00:08:51,950

bottom there is a conductive zone at the

247

00:08:56,410 --> 00:08:54,020

top there is a radiative zone

248

00:08:57,460 --> 00:08:56,420

this graph right here is showing a

249

00:08:59,230 --> 00:08:57,470

mixing a measure so it's showing

250

00:09:02,200 --> 00:08:59,240

enstrophy for those of you to do physics

251

00:09:03,610 --> 00:09:02,210

that's vorticity squared but basically

252

00:09:06,880 --> 00:09:03,620

what showing is how strongly things are

253

00:09:09,340 --> 00:09:06,890

mixing up here i have my passive tracer

254

00:09:10,720 --> 00:09:09,350

and down here i have my tracer that has

255

00:09:13,660 --> 00:09:10,730

some sort of reaction going on and i

256

00:09:14,920 --> 00:09:13,670

know this color scheme is terrible i was

257

00:09:17,140 --> 00:09:14,930

trying to pick out very small scale

258

00:09:19,110 --> 00:09:17,150

motions for the reactive tracer but

259

00:09:21,730 --> 00:09:19,120

what's interesting that you're seeing is

260

00:09:25,060 --> 00:09:21,740

okay here those little fluctuations are

261

00:09:26,290 --> 00:09:25,070

gravity waves up here you can see that

262

00:09:28,590 --> 00:09:26,300

we started off with a lot of stuff in

263

00:09:31,480 --> 00:09:28,600

the bottom and nothing at the top and

264

00:09:33,970 --> 00:09:31,490

nothing for the passive tracer gets

265

00:09:35,760 --> 00:09:33,980

through to the top so it doesn't get

266

00:09:39,040 --> 00:09:35,770

carried into the radiative zone at all

267

00:09:41,740 --> 00:09:39,050

for the reacting tracer the top of the

268

00:09:44,230 --> 00:09:41,750

radiative zone does get penetrated a

269

00:09:46,570 --> 00:09:44,240

little bit but we don't have some point

270

00:09:49,060 --> 00:09:46,580

in the bottom getting held constant all

271

00:09:50,530 --> 00:09:49,070

the way through and this means that the

272

00:09:54,790 --> 00:09:50,540

punch approximation as far as we can

273

00:09:57,430 --> 00:09:54,800

tell so far doesn't work for a radiative

274

00:09:58,180 --> 00:09:57,440

zone this is very preliminary because as

275

00:09:59,590 --> 00:09:58,190

you can tell some of these

276

00:10:02,350 --> 00:09:59,600

concentrations become negative for the

277

00:10:04,420 --> 00:10:02,360

reacting scalar that is something that I

278

00:10:05,890 --> 00:10:04,430

know how to fix but has not been run yet

279

00:10:09,730 --> 00:10:05,900

because the my super computer is not

280

00:10:11,530 --> 00:10:09,740

obeying me right now but I think both of

281

00:10:12,640 --> 00:10:11,540

these both of the passive tracer and

282

00:10:16,630 --> 00:10:12,650

reactive tracer have implement

283

00:10:18,310 --> 00:10:16,640

interesting implications for emission

284

00:10:19,810 --> 00:10:18,320

like jwst and we have a lot of work to

285

00:10:20,920 --> 00:10:19,820

do before it gets up in the air we start

286

00:10:28,840 --> 00:10:20,930

observing these driving atmospheres

287

00:10:37,790 --> 00:10:35,960

questions hi can you hear me yep um I

288

00:10:40,580 --> 00:10:37,800

was wondering why you want to use Jovian

289

00:10:42,950 --> 00:10:40,590

atmospheres to trace the disk structure

290

00:10:44,780 --> 00:10:42,960

rather than something like Alma so you

291

00:10:46,370 --> 00:10:44,790

can you definitely can use all that but

292

00:10:48,260 --> 00:10:46,380

almost talking when you're looking at

293

00:10:51,350 --> 00:10:48,270

with Alma you're looking at disks that

294

00:10:53,030 --> 00:10:51,360

are typically fairly young whereas

295

00:10:55,580 --> 00:10:53,040

driven atmospheres give you a point in

296

00:10:57,530 --> 00:10:55,590

time farther in the history of the

297

00:10:58,880 --> 00:10:57,540

evolution of these disks it also gives

298

00:11:01,160 --> 00:10:58,890

you a lot of data points because you can

299

00:11:02,720 --> 00:11:01,170

observe a lot of jovian planets so it's

300

00:11:03,920 --> 00:11:02,730

kind of a complementary method to being

301

00:11:04,880 --> 00:11:03,930

able to do nice observations with

302

00:11:19,430 --> 00:11:04,890

something like Alma that can really

303

00:11:20,900 --> 00:11:19,440

reserved resolve molecules Thanks so

304

00:11:22,700 --> 00:11:20,910

does your model account for forming

305

00:11:24,440 --> 00:11:22,710

things like Hayes's that definitely mess

306

00:11:26,750 --> 00:11:24,450

with the retrieved abundances and

307

00:11:28,880 --> 00:11:26,760

probably some of the reactivity so I'm

308

00:11:31,000 --> 00:11:28,890

interested in moving on to Hazel's and

309

00:11:33,140 --> 00:11:31,010

clouds in further along on my PhD

310

00:11:35,060 --> 00:11:33,150

partially because to do that I have to

311

00:11:37,430 --> 00:11:35,070

think about nucleation processes and

312

00:11:38,840 --> 00:11:37,440

phase transitions and at the moment I

313

00:11:40,160 --> 00:11:38,850

want to understand a simpler case where

314

00:11:42,050 --> 00:11:40,170

I just have it reacting a tracer that's

315

00:11:56,750 --> 00:11:42,060

interconverting with eight with

316

00:12:00,810 --> 00:11:59,040

does your reactive tracer is it

317

00:12:02,490 --> 00:12:00,820

exothermic or endothermic as far as the

318

00:12:06,000 --> 00:12:02,500

reaction properties so because we're not

319

00:12:07,440 --> 00:12:06,010

considering really so what we don't have

320

00:12:08,760 --> 00:12:07,450

any terms for energy released by the

321

00:12:10,740 --> 00:12:08,770

reaction because it's assume that the

322

00:12:11,700 --> 00:12:10,750

energy release is very small that's

323

00:12:14,340 --> 00:12:11,710

another thing that I'm planning on

324

00:12:17,100 --> 00:12:14,350

adding and in the future currently the

325

00:12:19,050 --> 00:12:17,110

there is no back reaction of D tracer on

326

00:12:21,420 --> 00:12:19,060

the dynamics at all it doesn't affect

327

00:12:23,220 --> 00:12:21,430

the major fluid so it doesn't affect the

328

00:12:25,050 --> 00:12:23,230

molecular hydrogen and it doesn't

329

00:12:26,880 --> 00:12:25,060

release any energy releasing energy is

330

00:12:28,830 --> 00:12:26,890

the next step after we understand some

331

00:12:31,350 --> 00:12:28,840

of the implications of how reacting at

332

00:12:32,880 --> 00:12:31,360

all changes where the tracer is located

333

00:12:38,490 --> 00:12:32,890

okay so it's just in your inner

334

00:12:44,150 --> 00:12:38,500

converting between species okay any

335

00:12:49,920 --> 00:12:47,490

I'm missing something but what exactly

336

00:12:51,660 --> 00:12:49,930

do you mean by gravity waves okay so

337

00:12:54,720 --> 00:12:51,670

gravity waves are basically

338

00:12:59,100 --> 00:12:54,730

perturbations in the density that get

339

00:13:06,210 --> 00:12:59,110

carried by the gravity got it not actual

340

00:13:10,110 --> 00:13:06,220

spatial we got time for one more unless

341

00:13:12,570 --> 00:13:10,120

he just asked your question how do you

342

00:13:15,060 --> 00:13:12,580

set up the initial concentrations and

343

00:13:17,400 --> 00:13:15,070

the other boundary conditions so

344

00:13:19,230 --> 00:13:17,410

currently the initial concentrations are

345

00:13:20,850 --> 00:13:19,240

something that imply and what's right

346

00:13:22,350 --> 00:13:20,860

now I'm putting everything in the

347

00:13:24,390 --> 00:13:22,360

convection zone and just seeing if I can

348

00:13:26,400 --> 00:13:24,400

get anything up to the radiative zone

349

00:13:27,960 --> 00:13:26,410

and as part of the reason we're reaching

350

00:13:29,700 --> 00:13:27,970

negative concentrations right now is

351

00:13:32,070 --> 00:13:29,710

that the initial conditions I don't

352

00:13:34,560 --> 00:13:32,080

think work very well with my reaction

353

00:13:36,060 --> 00:13:34,570

law and I need to adjust how I'm doing

354

00:13:39,270 --> 00:13:36,070

the reaction to have an extra loss term

355

00:13:41,070 --> 00:13:39,280

for the equilibrium profile but in the

356

00:13:42,510 --> 00:13:41,080

future I'm going to also flip that over

357

00:13:44,910 --> 00:13:42,520

and see if anything get from the

358

00:13:46,440 --> 00:13:44,920

radiative zone and over and in terms of

359

00:13:48,780 --> 00:13:46,450

boundary conditions rather than

360

00:13:50,670 --> 00:13:48,790

constraining the concentrations of our

361

00:13:52,980 --> 00:13:50,680

reactant we're actually constraining its

362

00:13:55,230 --> 00:13:52,990

gradient so we're saying that there's no

363

00:13:57,780 --> 00:13:55,240

diffusion of that molecule across the

364

00:13:59,250 --> 00:13:57,790

boundary the right hands the right and

365

00:14:00,240 --> 00:13:59,260

left hand side boundary conditions

366

00:14:02,400 --> 00:14:00,250

rather than the top and bottom are