Using Dust, Ice and Gas to probe the Large Range of Environments Around Low-Mass Protostars

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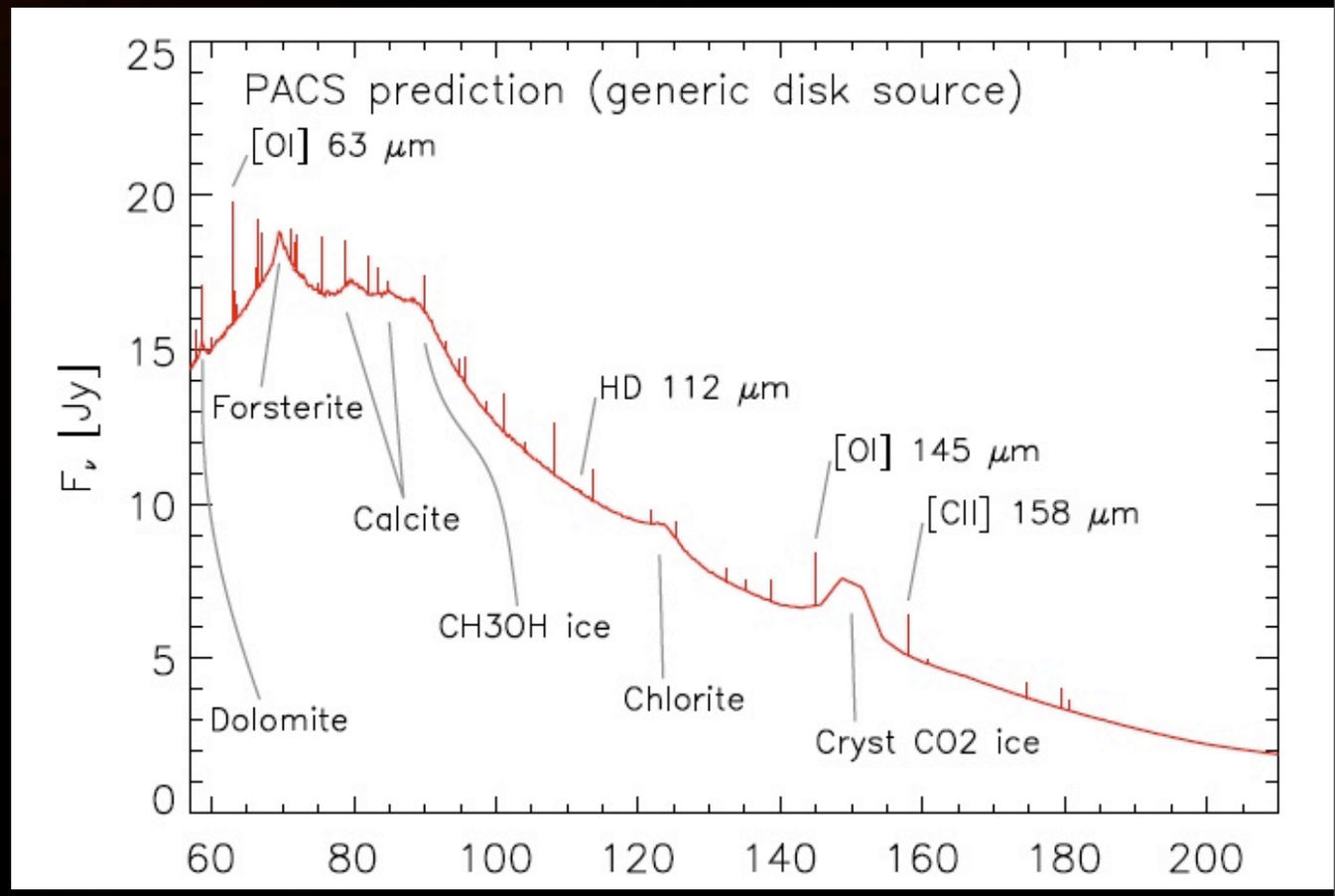
See also posters Sturm et al. (P2.25) Mulders et al. (P2.26) and Green et al. (P1.02)

DIGIT

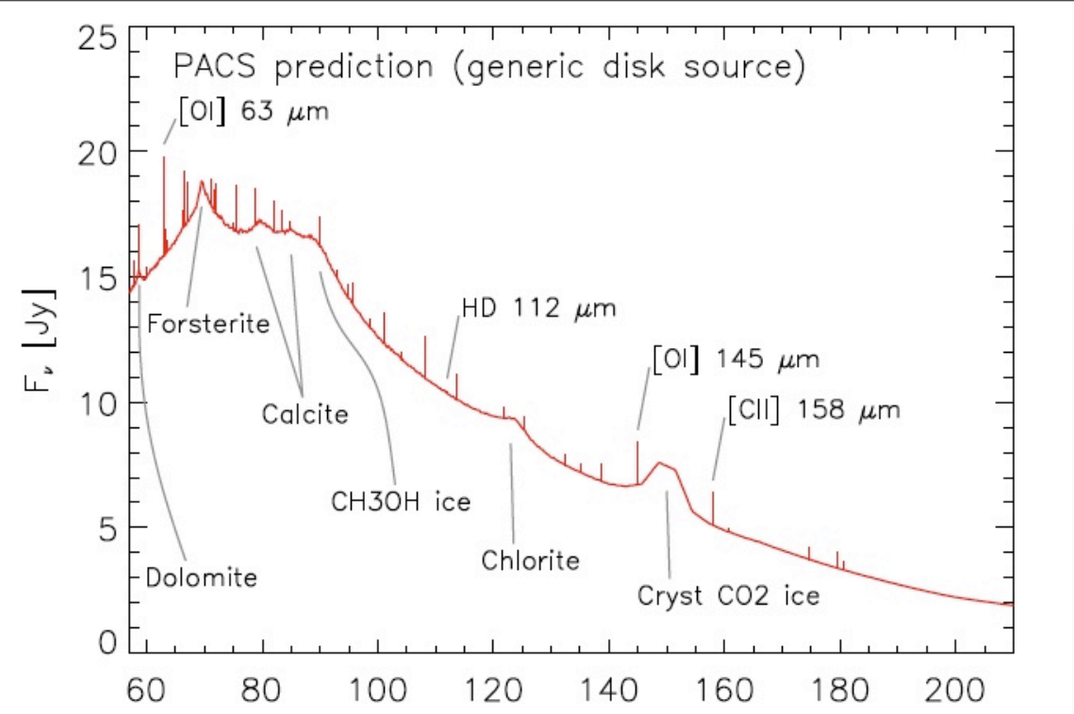
Probing protostellar evolution :
From embedded sources to disks

Dust evolution
Ice formation and evaporation
Gas FIR Spectroscopy tracing chemistry
In
Time



PACS Spectroscopy in DIGIT

Range scans from 53-210 micron



Line	λ (μm)	Excitation Energy
CO ladder	**90-200**	**500-3,000+**
H_2O low ex.	**150-190**	**<150**
H_2O high ex.	**55-210**	**>150**
Dust e.g. Forsterite/Calcite	**69(55-210)**	
(H_2O) ice	**62**	
[OI]	**63.2, 145.5**	
[CII]	**157.7**	
molecular (e.g. OH)	**55-210**	**large range**

Structure of an (embedded) protostar

Envelope
Disk
Outflow

Indirect
~~"Passive"~~ heating
Photon heating
C-shocks
J-shocks

Gas-phase chemistry
Evaporation of ice mantles
Gas-grain interaction

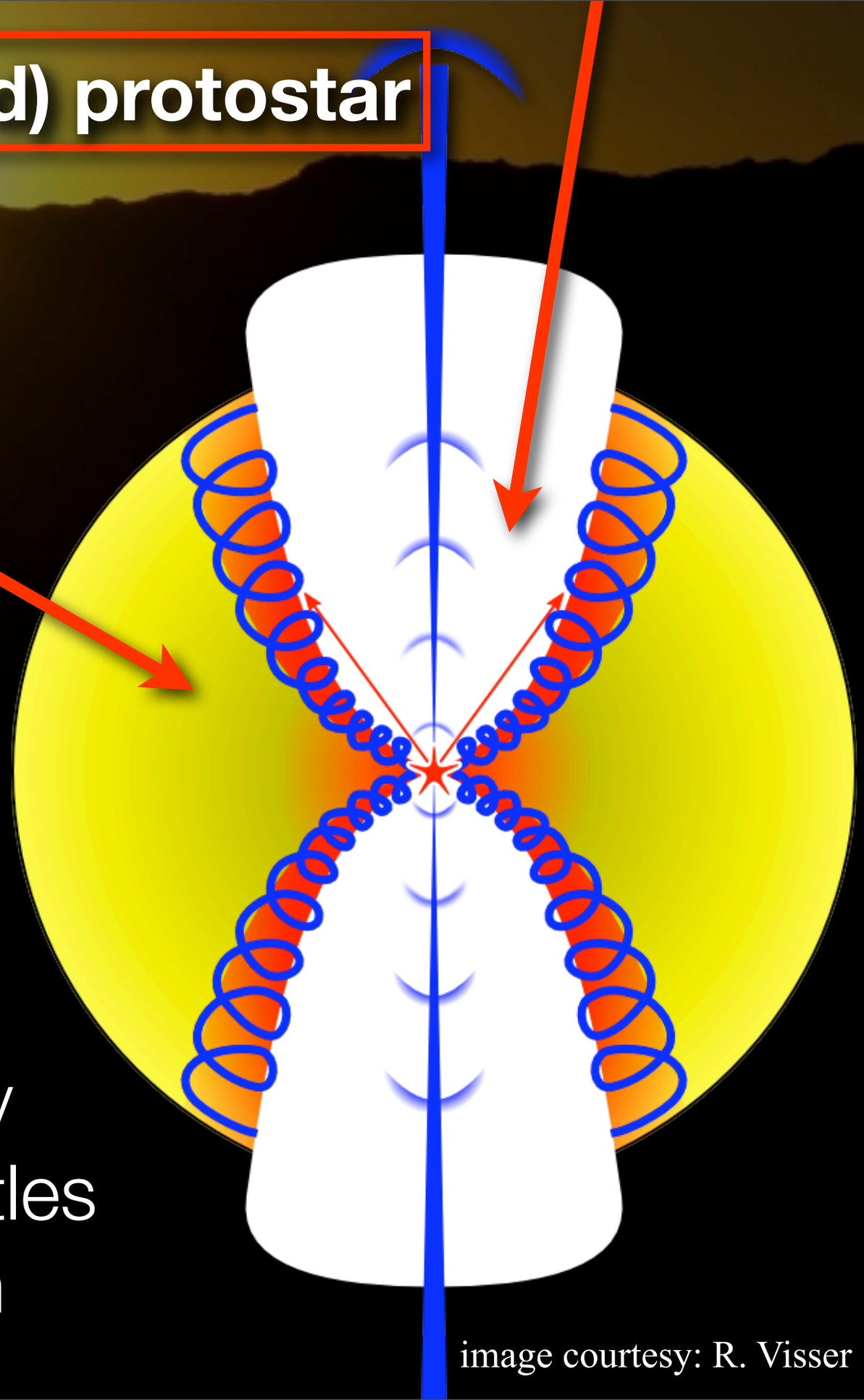


image courtesy: R. Visser

Structure of an (embedded) protostar

- Envelope
- Disk
- Outflow

- Indirect
- ~~"Passive"~~ heating
- Photon heating
- C-shocks
- J-shocks

- Gas-phase chemistry
- Evaporation of ice mantles
- Gas-grain interaction

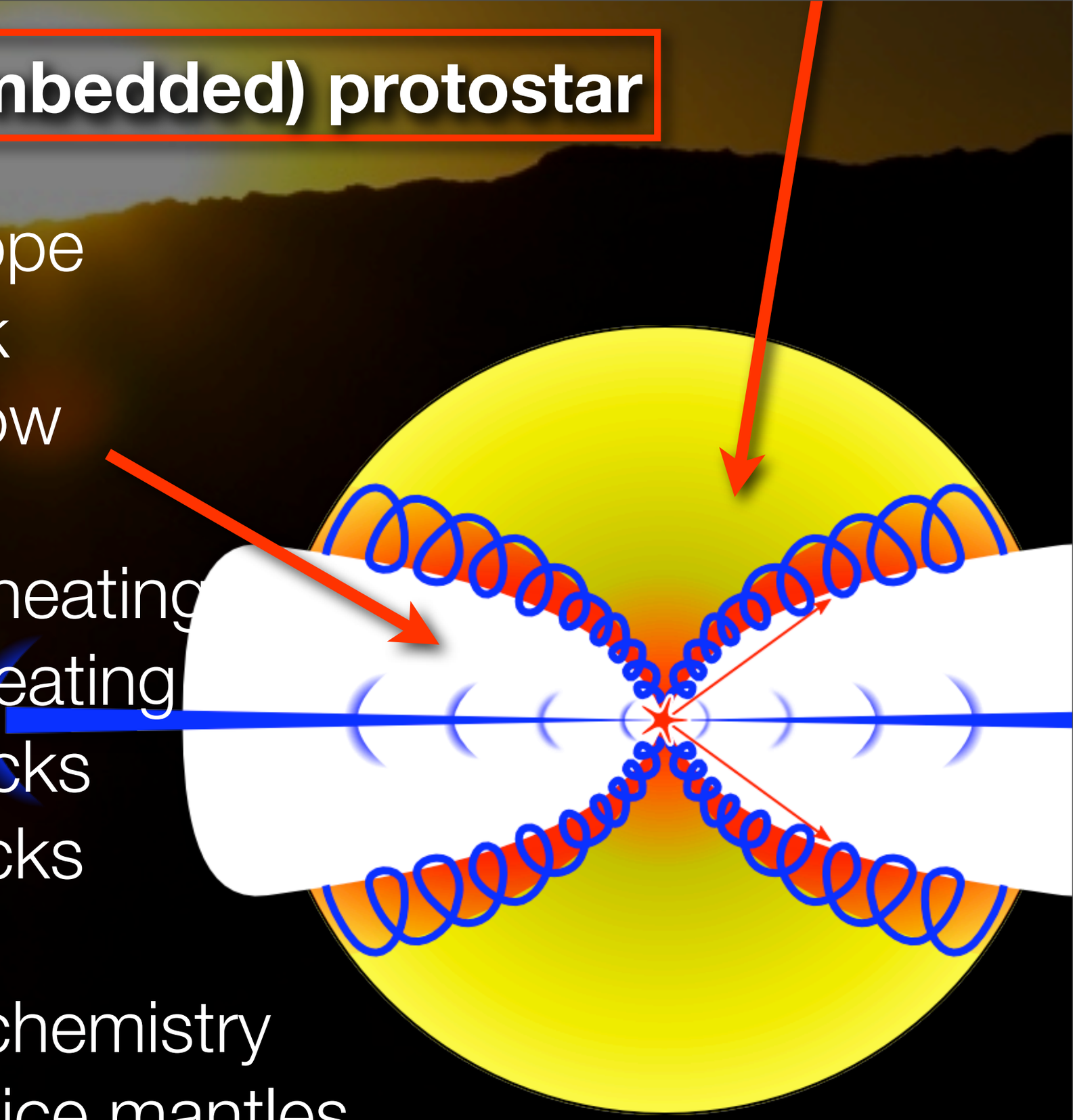


image courtesy: R. Visser

SDP

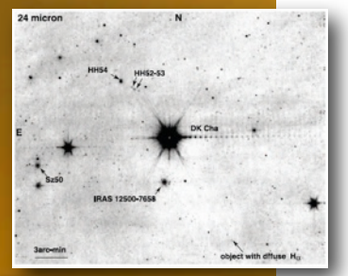
HH54

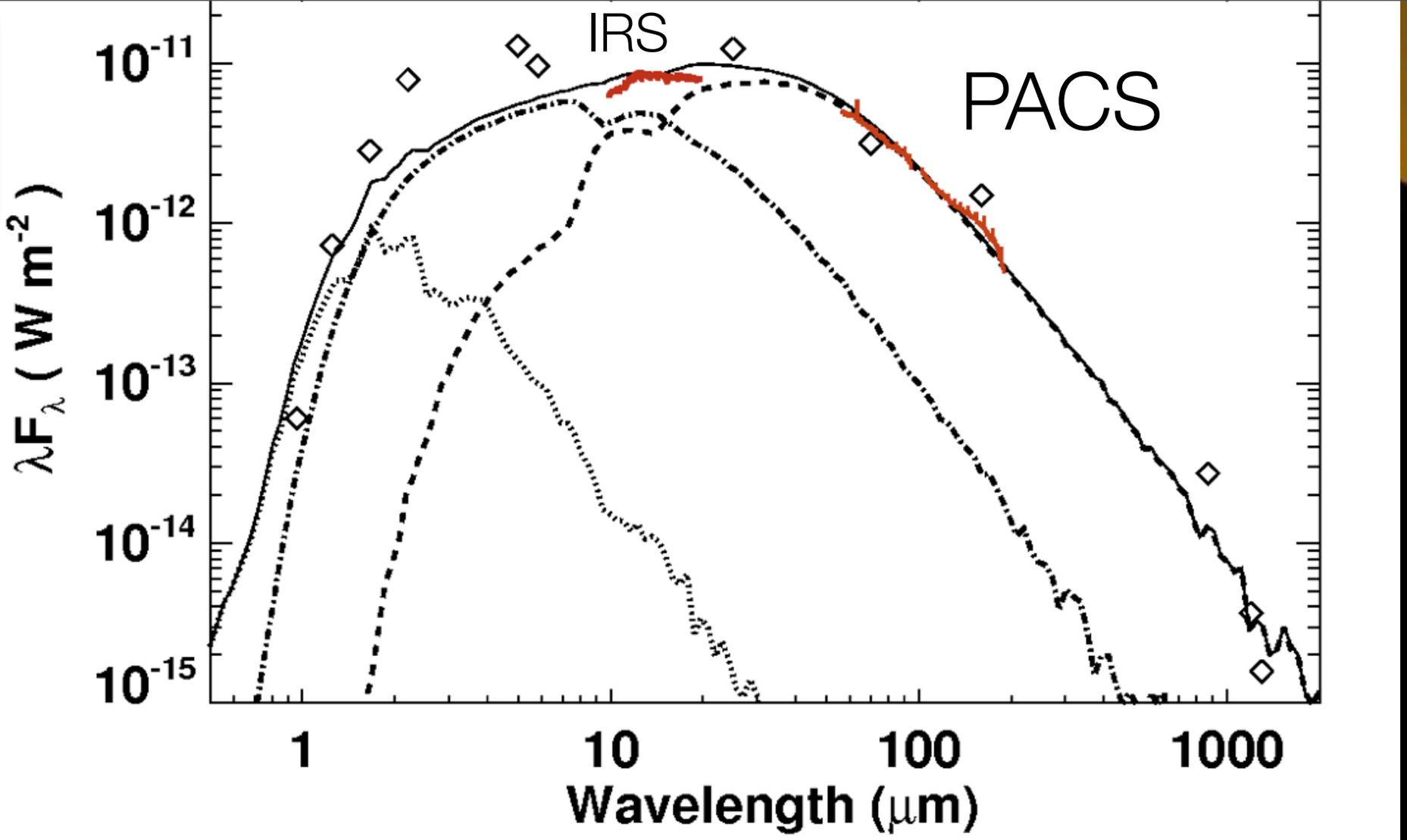
HH52-53

DK Cha

50

IRAS 12500-7658



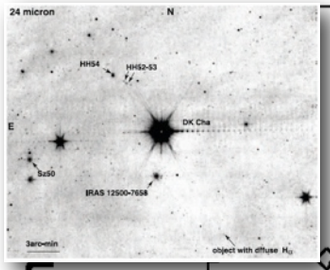


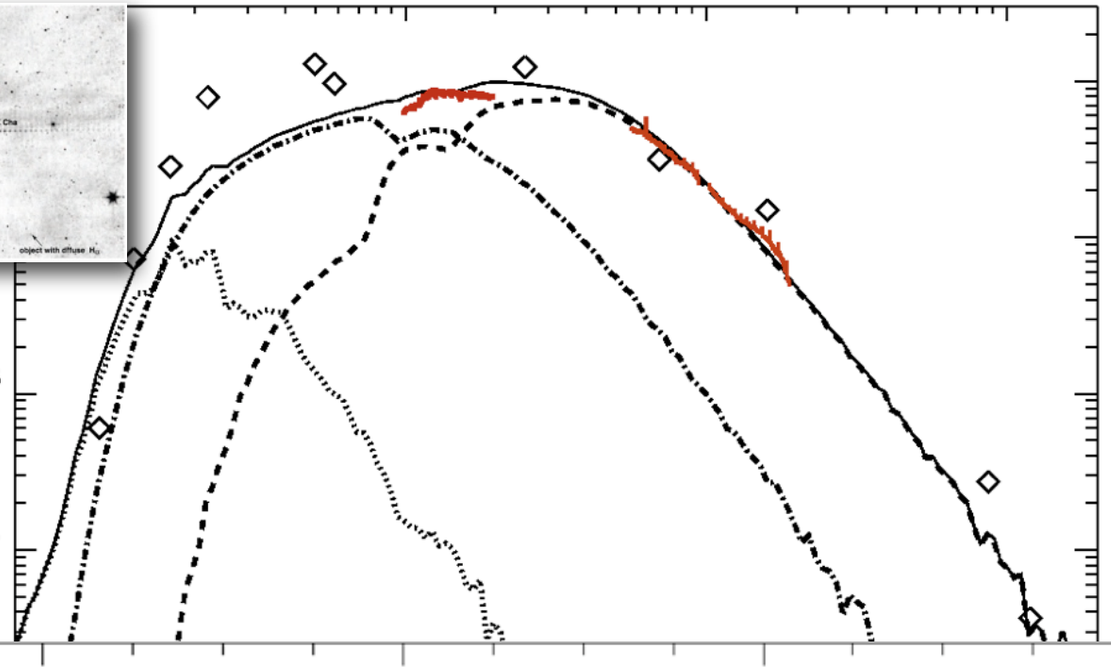
Model fit from Robitaille grid (Robitaille et al. 2007)
Not fitted to IRS/PACS! PACS cont. calibrated at 120 micron.

Face-on source

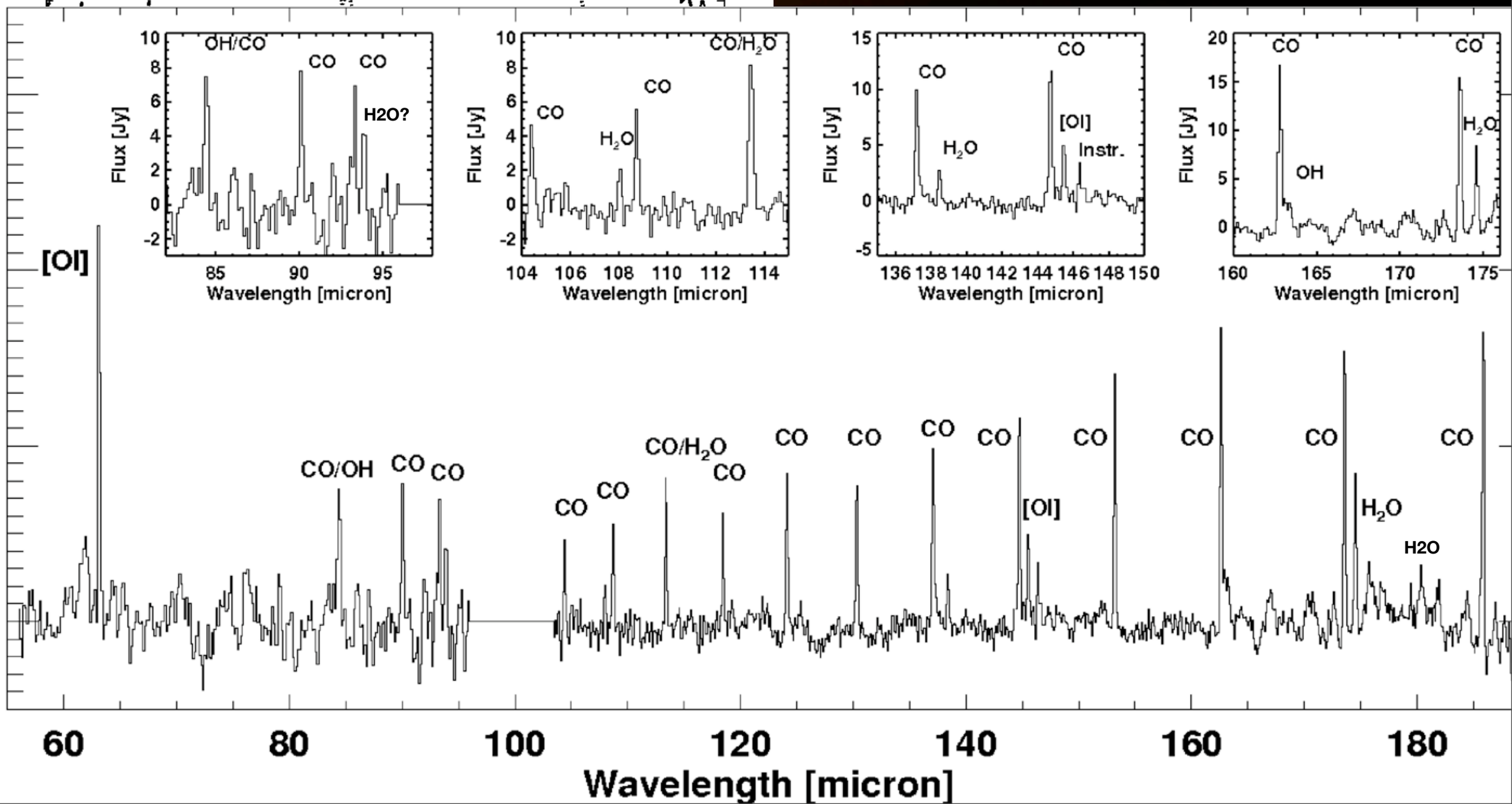
degr < 18º, L=29 L_o, M_{env} =0.03 , M_{disk} = 0.03

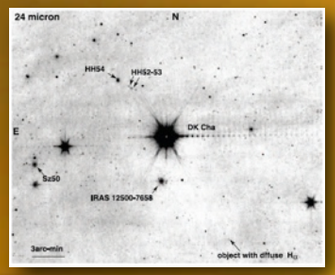
van Kempen et al. 2010, A&A special issue



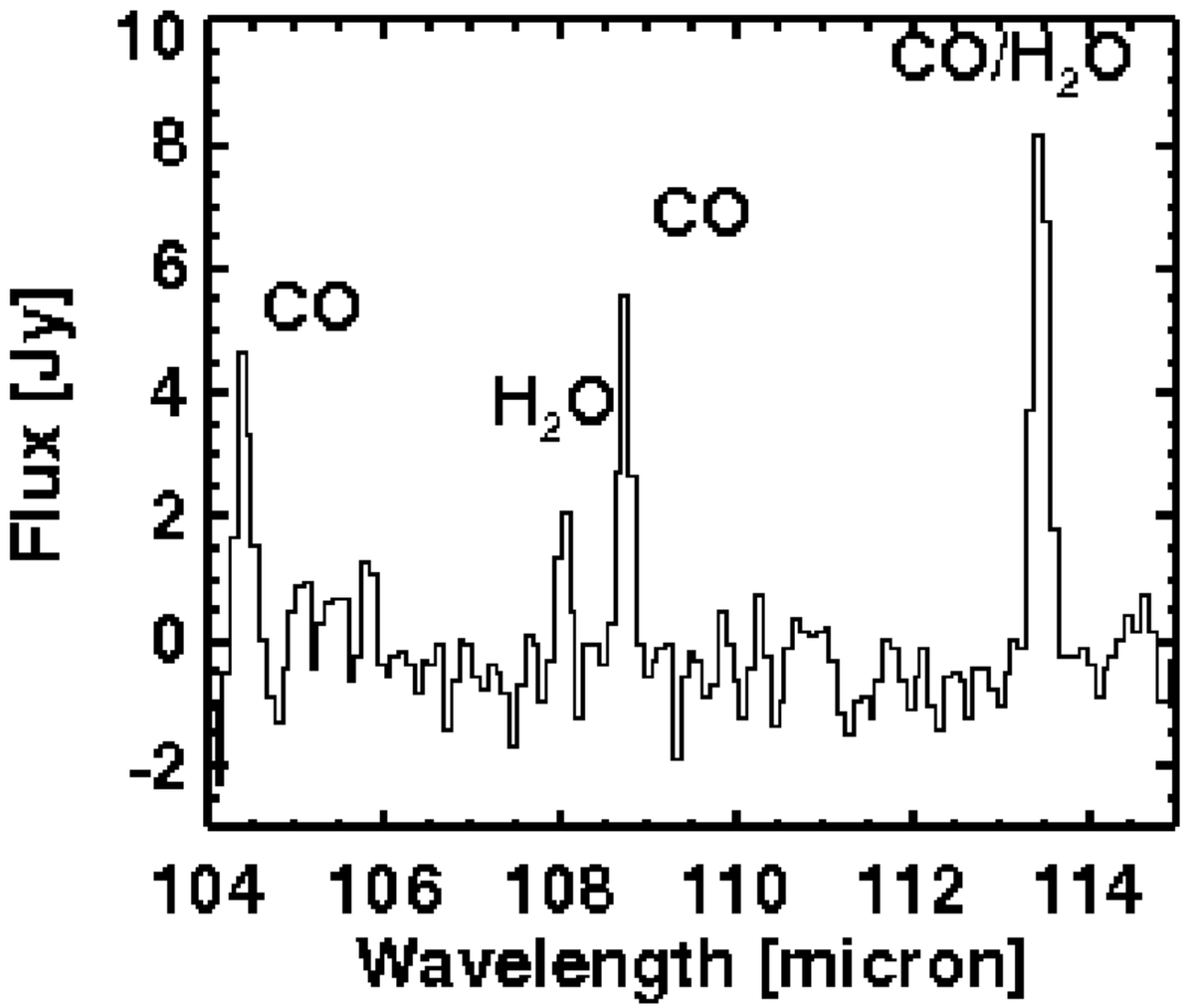


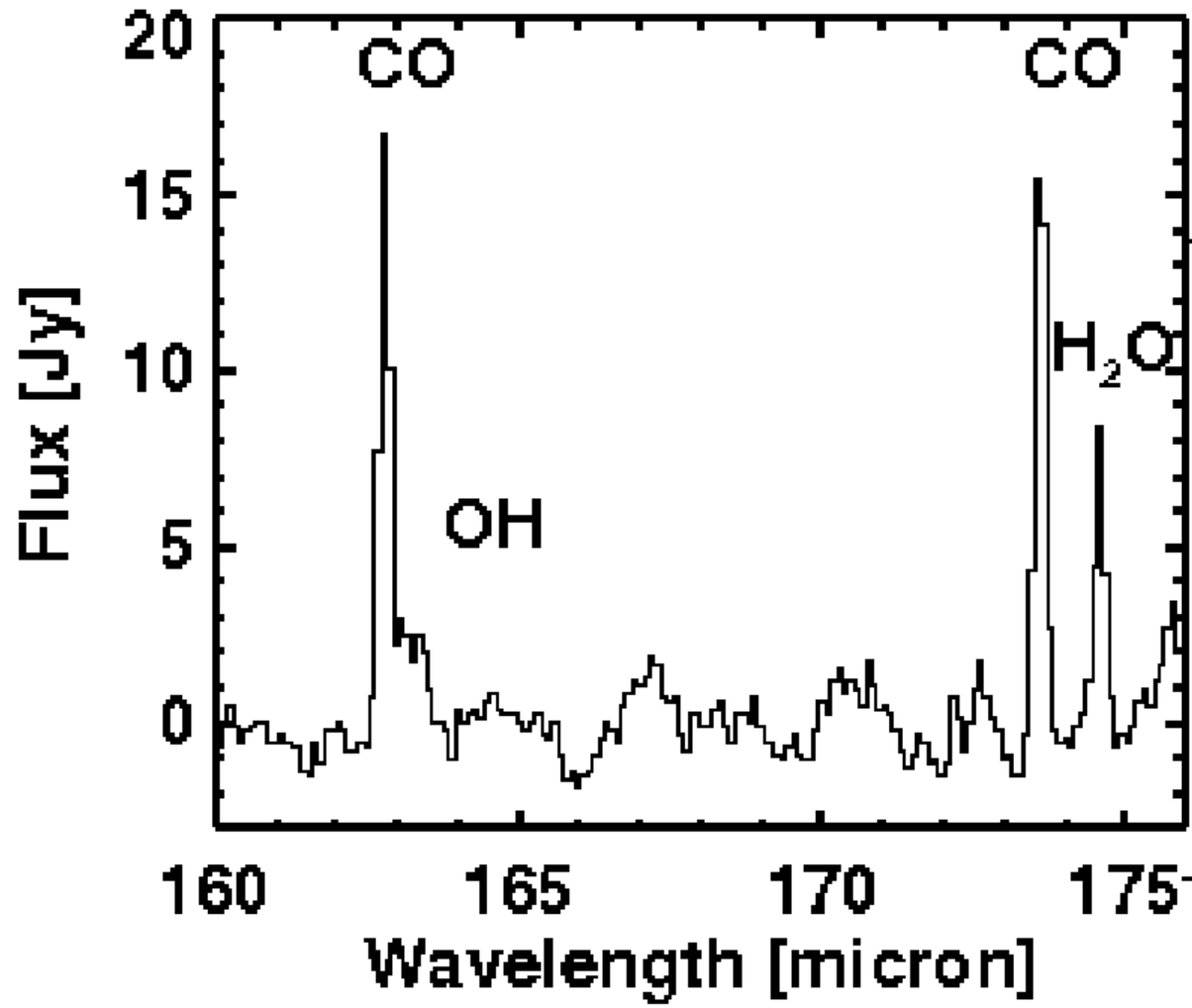
45 lines detected
CO (up to 38-37), H_2O, OH, [OI], [NII]

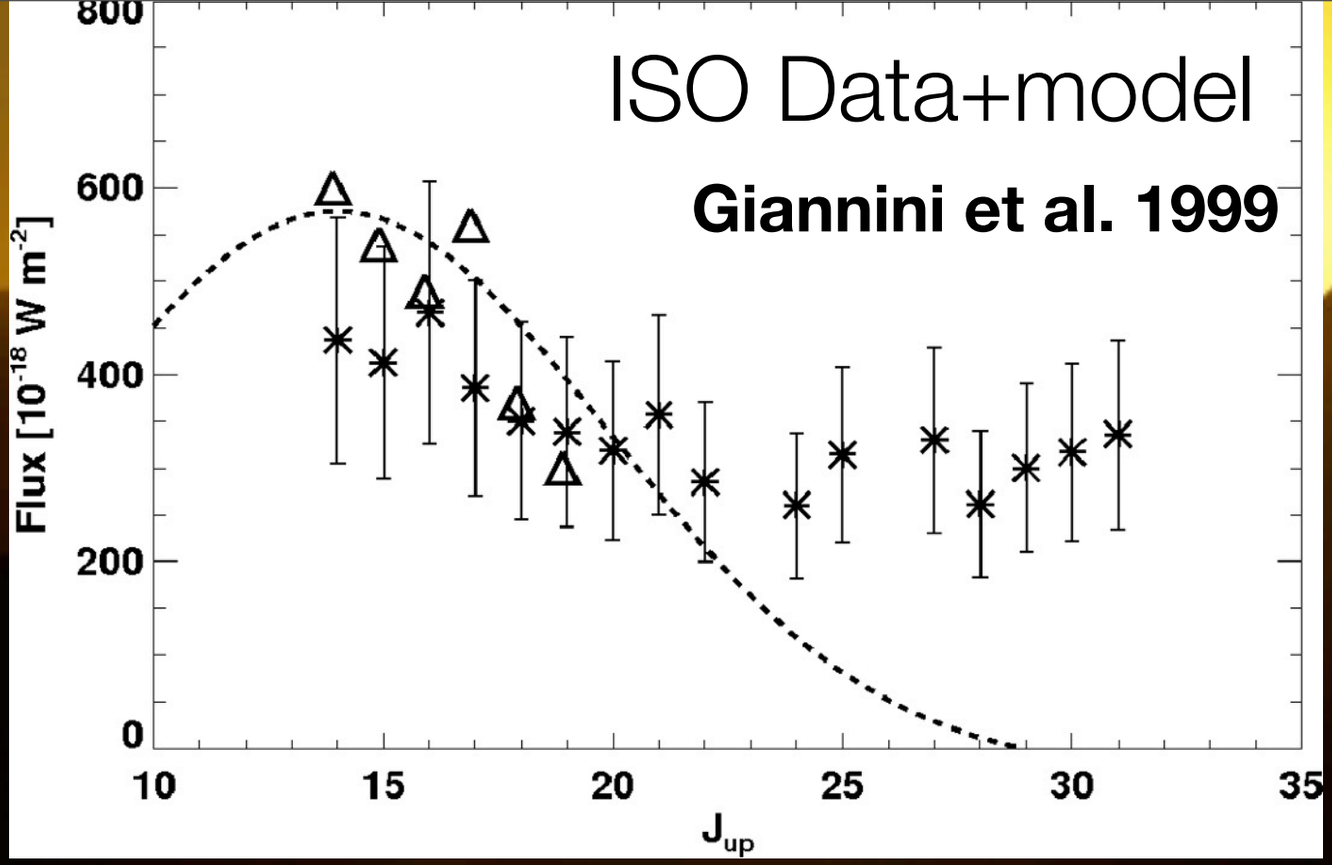


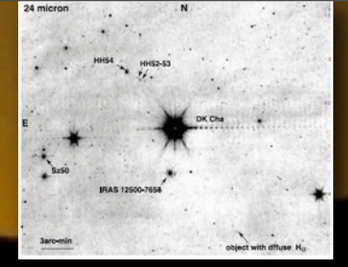


Zoom-in of CO and water lines

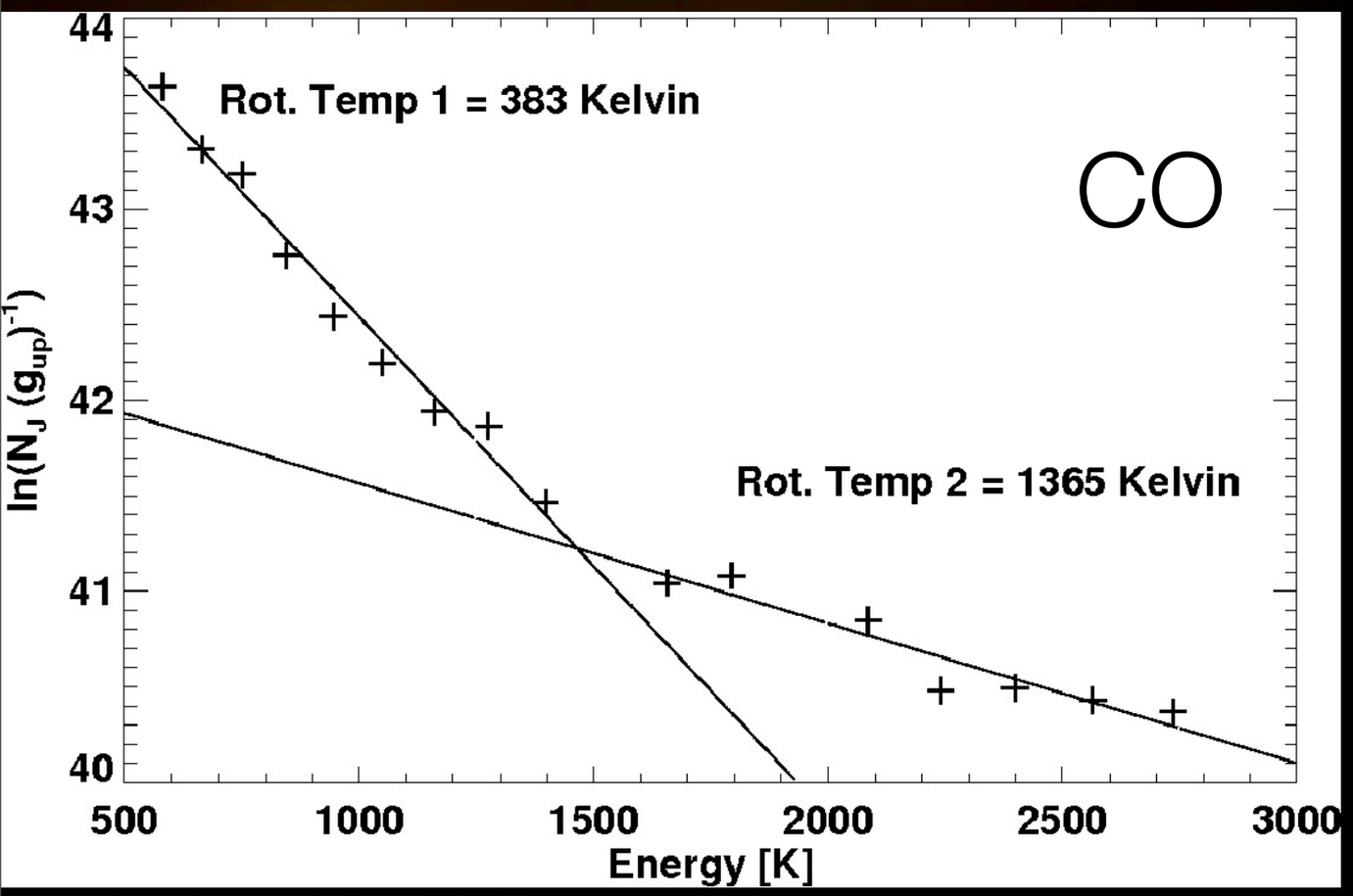








All PACS lines brighter (by 2-5 magn.) than indirect heating (spherical models) predicts. Already seen by ISO-LWS.

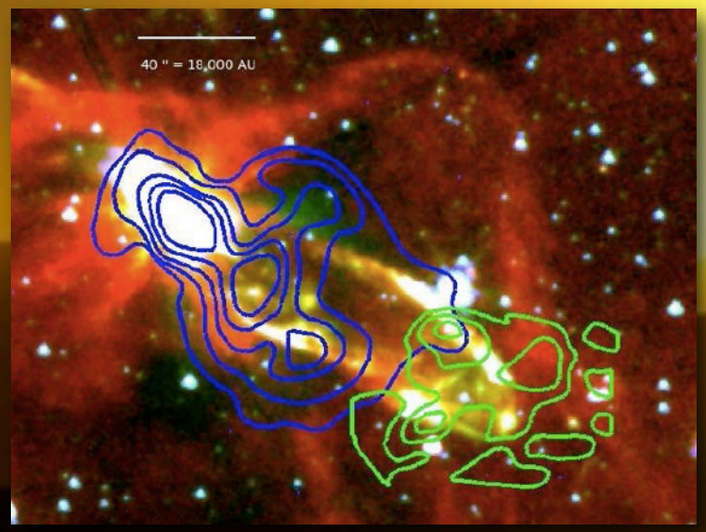


Not enough warm gas mass from CO 6-5/7-6 in LTE to produce CO 14-13 and higher.

40 " = 18,000 AU

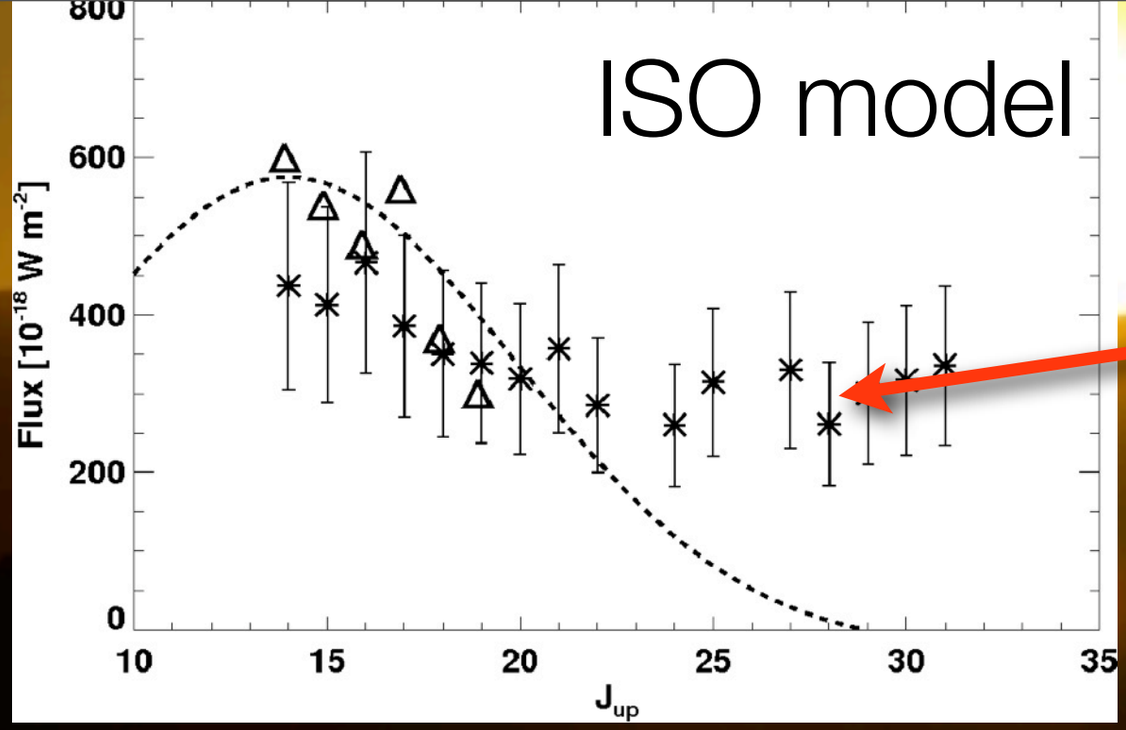
van Kempen et al. 2009
APEX-CHAMP+

CO 6-5
[CI]

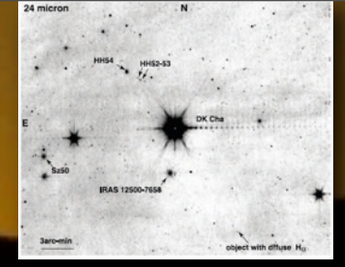


(van Kempen et al. 2009, 2010)
Method (Visser et al. in prep)
See talk by van Dishoeck, poster by Kristensen et al (P1.30)

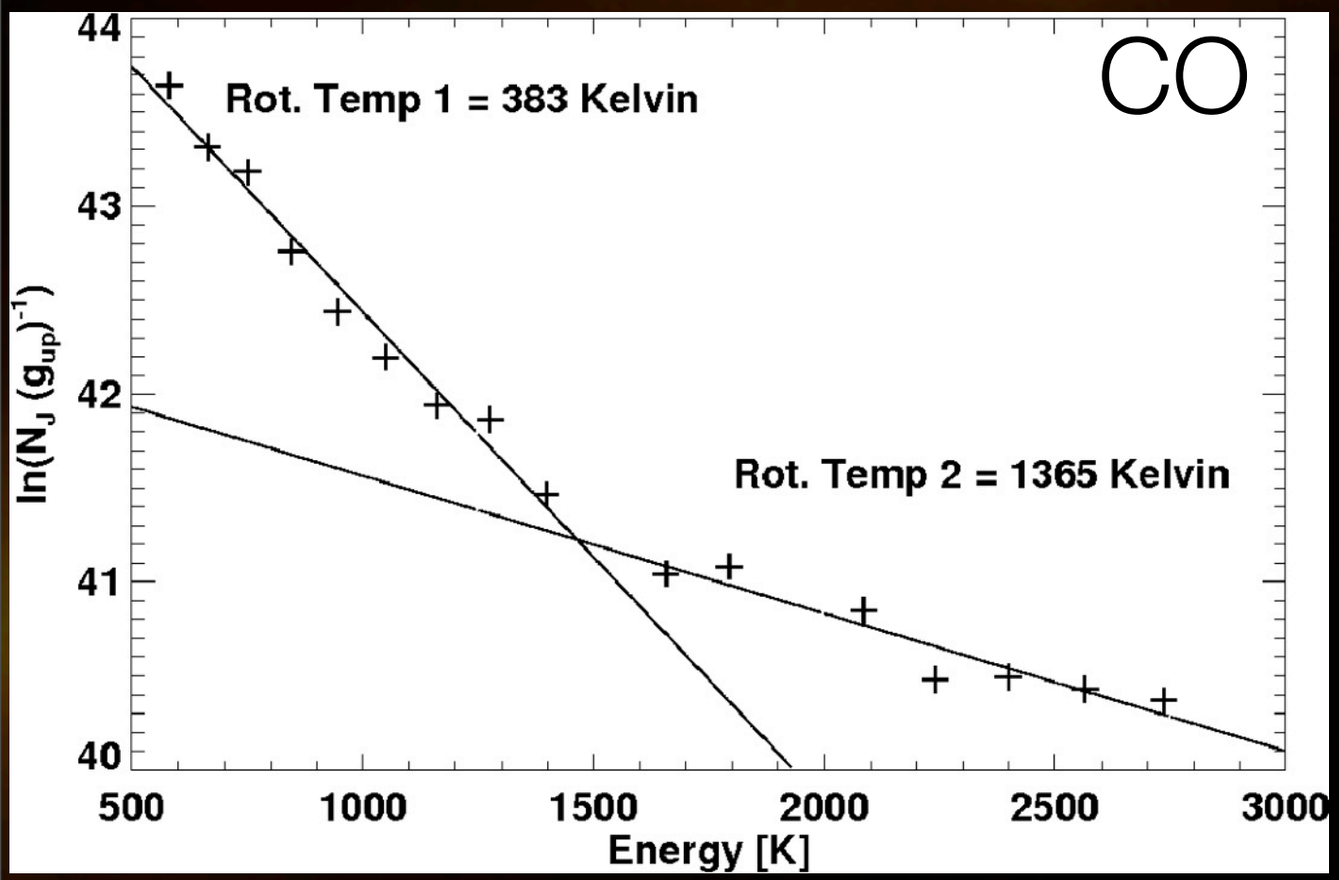
Heated Cavity walls
Cloud
Outflow Cavity
Envelope
Jet Shocks?
UV photons
Cavity Wall
Bow Shock
a
b



Giannini et al. 1999



Clear excess high-J CO line.



CO 23-22 and higher dominated by C-shocks ??

a. Shocks from outflow pressure
b. Geometry / FUV
c. extra FUV from Jet shocks
d. turbulence?

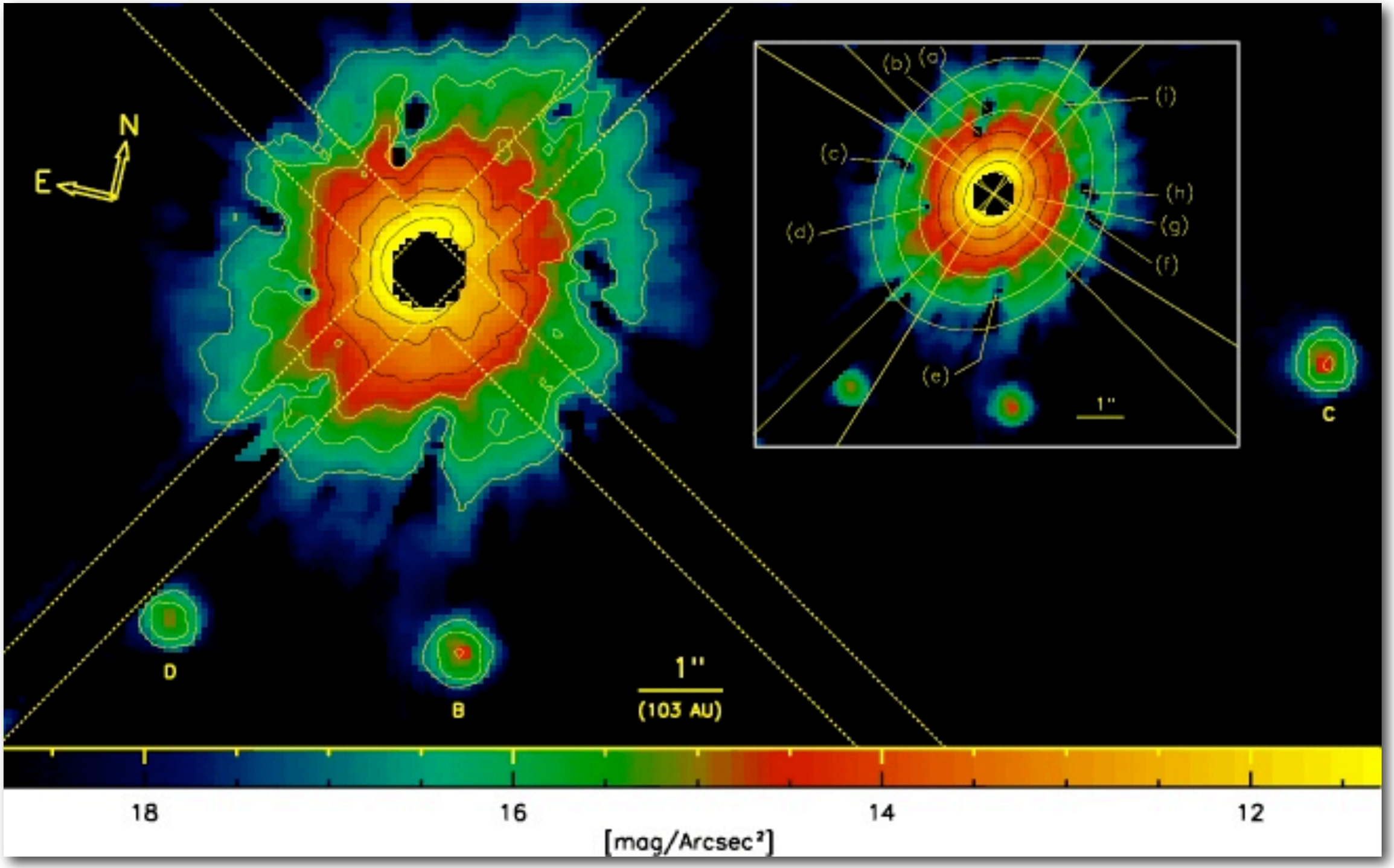
Gas Conclusions

a. Geometrical structure is important. Indirect heating through dust not sufficient to account for molecular emission.
b. Gas in PACS is tracing the energetics within an embedded protostar
c. Shocks and photon heating dominate at different excitations in CO
d. Water has a very complicated excitation that needs line profiles to understand.
e. OH, [OI], [NII] trace dissociative shocks

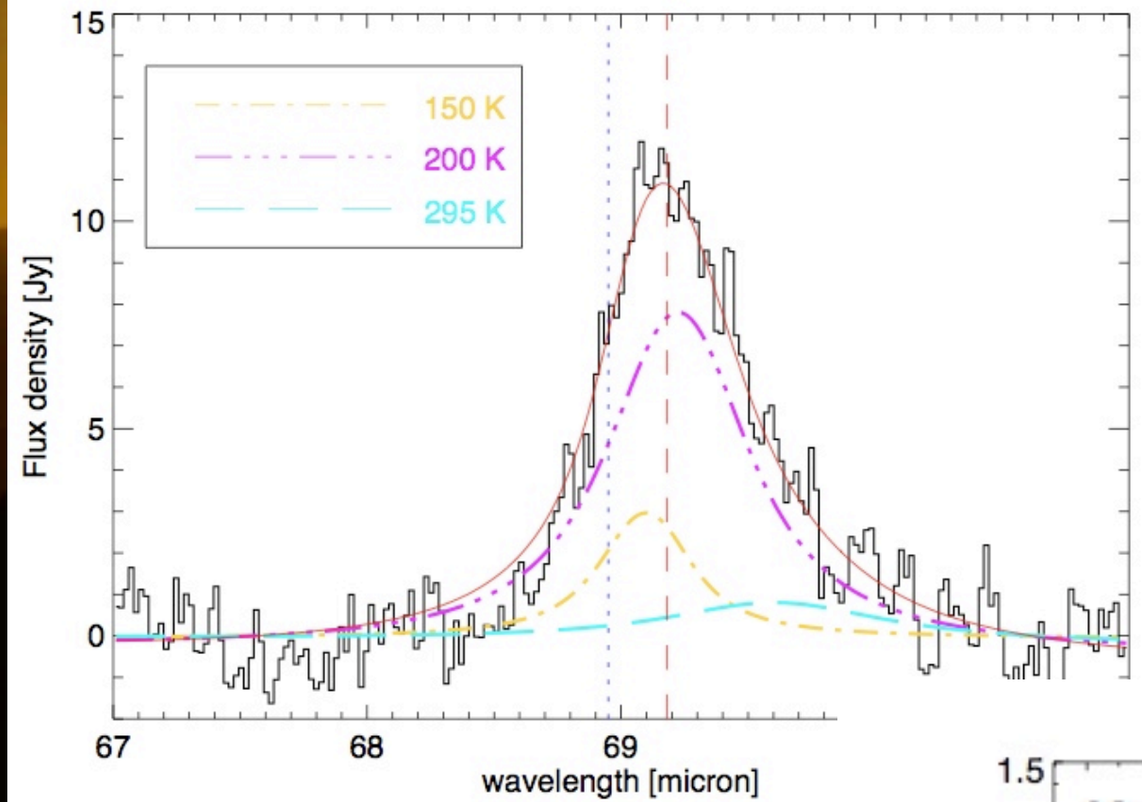
HIFI

(See van Dishoeck, van der Tak and Nisini talks + Kristensen poster (P1.30))

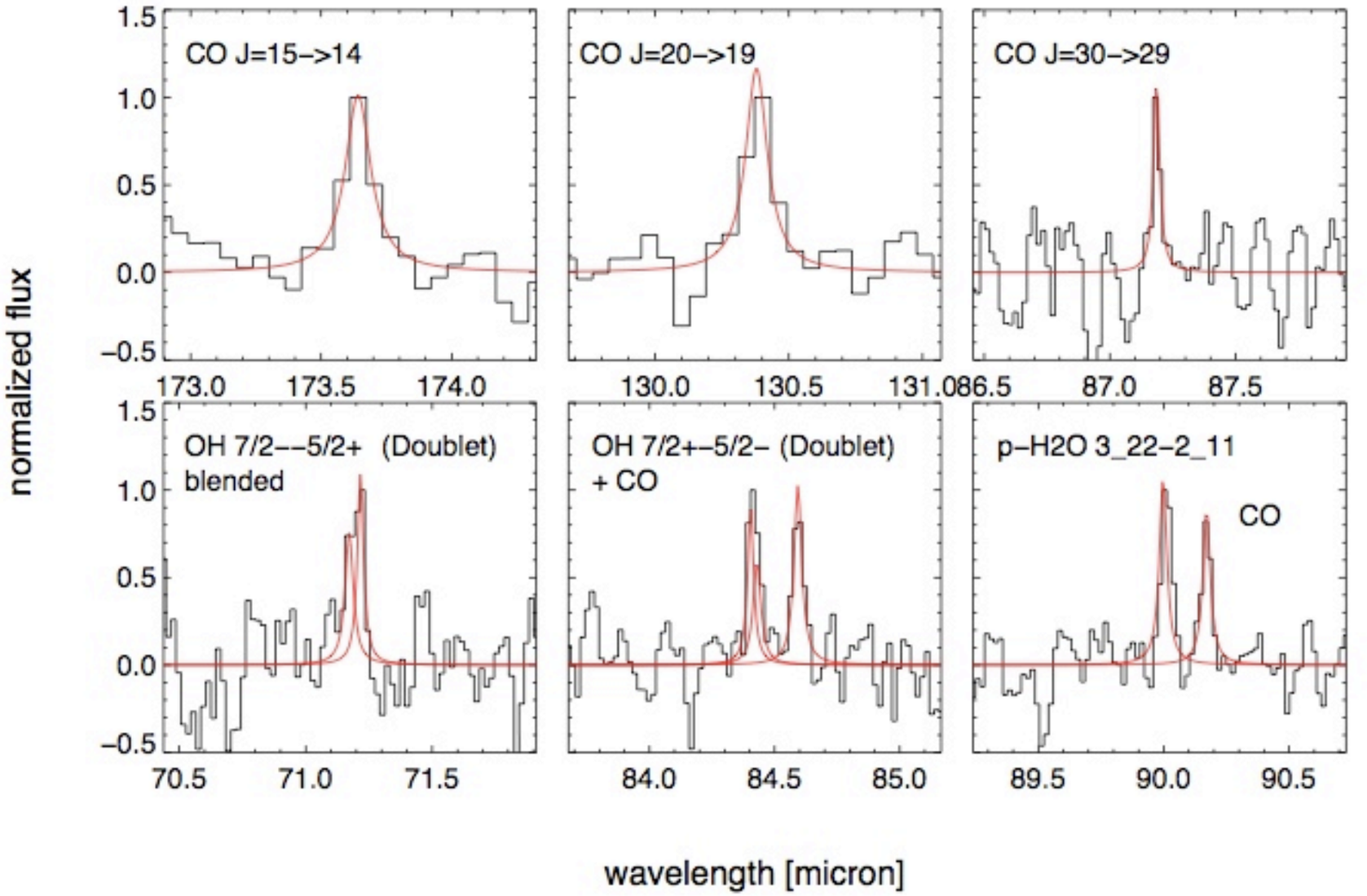
HD 100546

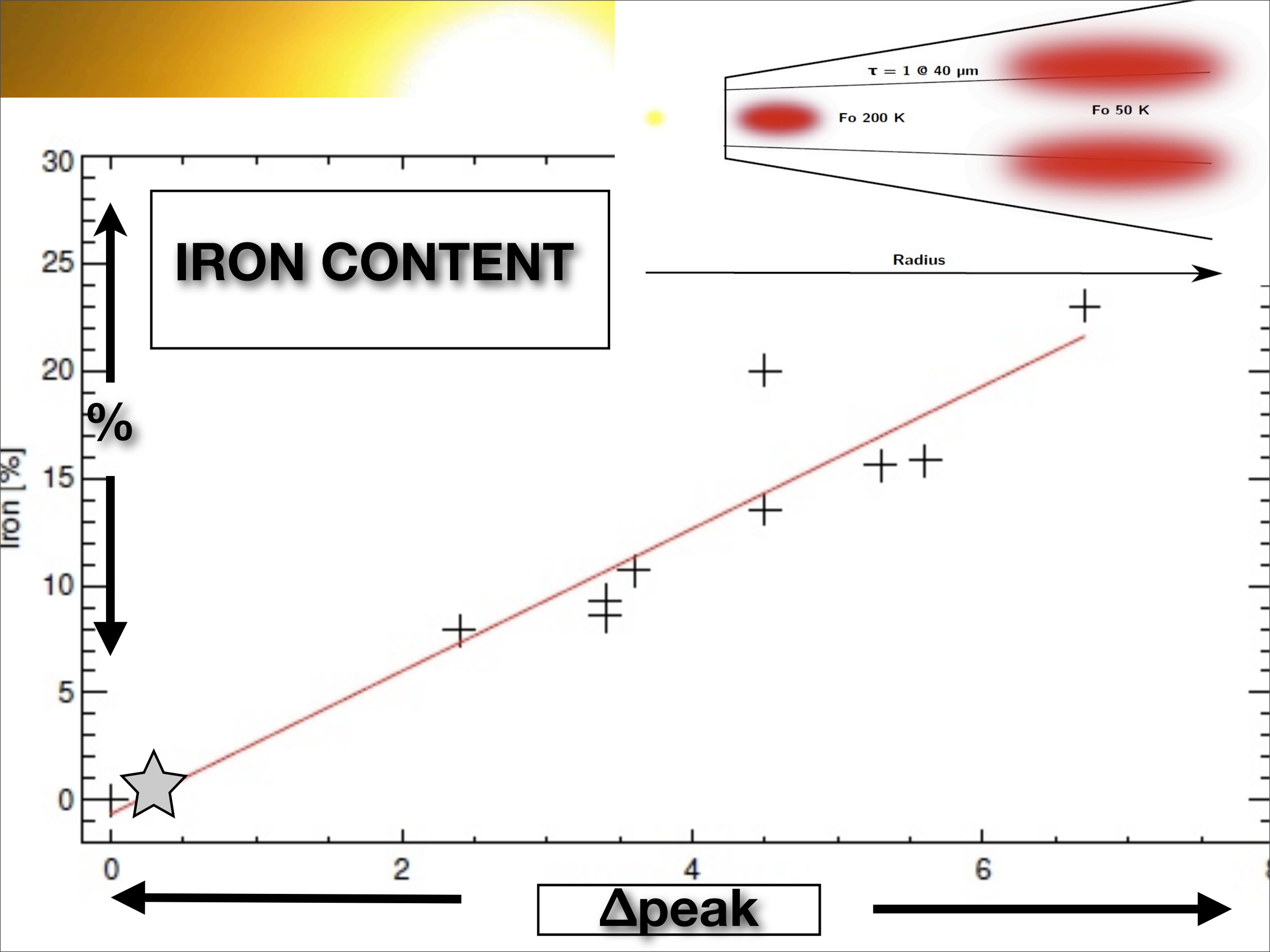


Sturm et al. 2010, A&A special issue



32 lines detected
CO (up to 31-30), H_2O, OH, [OI], [CII], but also forsterite



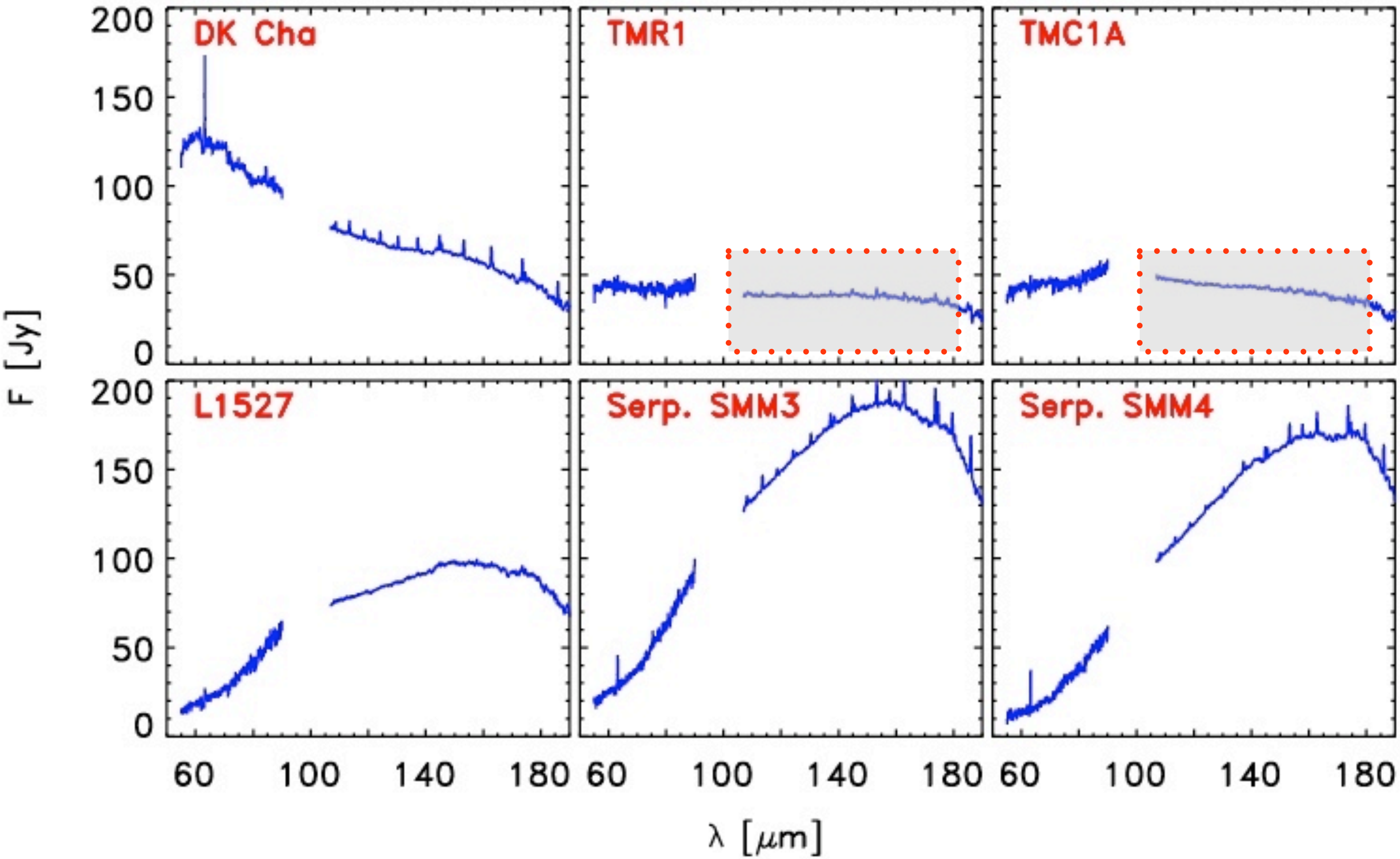

τ = 1 @ 40 μm
Fo 200 K
Fo 50 K
Radius
IRON CONTENT
%
Iron [%]
30
25
20
15
10
5
0
0
2
4
6
Δpeak

Dust Conclusions

a. Forsterite seen in HD 100546 with little to no iron (see Sturm et al. poster P2.25 and Mulders et al. P2.26)
b. Origin likely near star, although further out in disk is possible.
c. Gas seen in relative high excitation.

Solid State features need accurate spectral response functions.

Science observations recently started, all embedded



TMC 1A

TMR1

Flux [Jy]

Flux [Jy]

CO/o-H2O
o-H2O
CO
o-H2O/[NII]
p-H2O
CO
p-H2O
CO
o-H2O
o-H2O
o-H2O
CO
p-H2O
CO/p-H2O
CO
p-H2O
[CII]
p-H2O
CO
o-H2O
CO
o-H2O
o-H2O
p-H2O
CO

120
140
160
180

Wavelength [micron]

Low-mass (M= <1 M⊙) Stage 1

a. CO, H2O, OH seen
b. Shape of SED follows models
c. Possible lines

Future work: careful calibration.

Conclusions

PACS Range scans give a wealth of lines that trace energetics of low-mass protostars

Solid state features difficult to discern at the moment

Line and SED modelling in full swing and many sources incoming this summer/fall.

See also posters Sturm et al. (P2.25) Mulders et al. (P2.26) and Green et al. (P1.02)

Dust

Ice

Gas

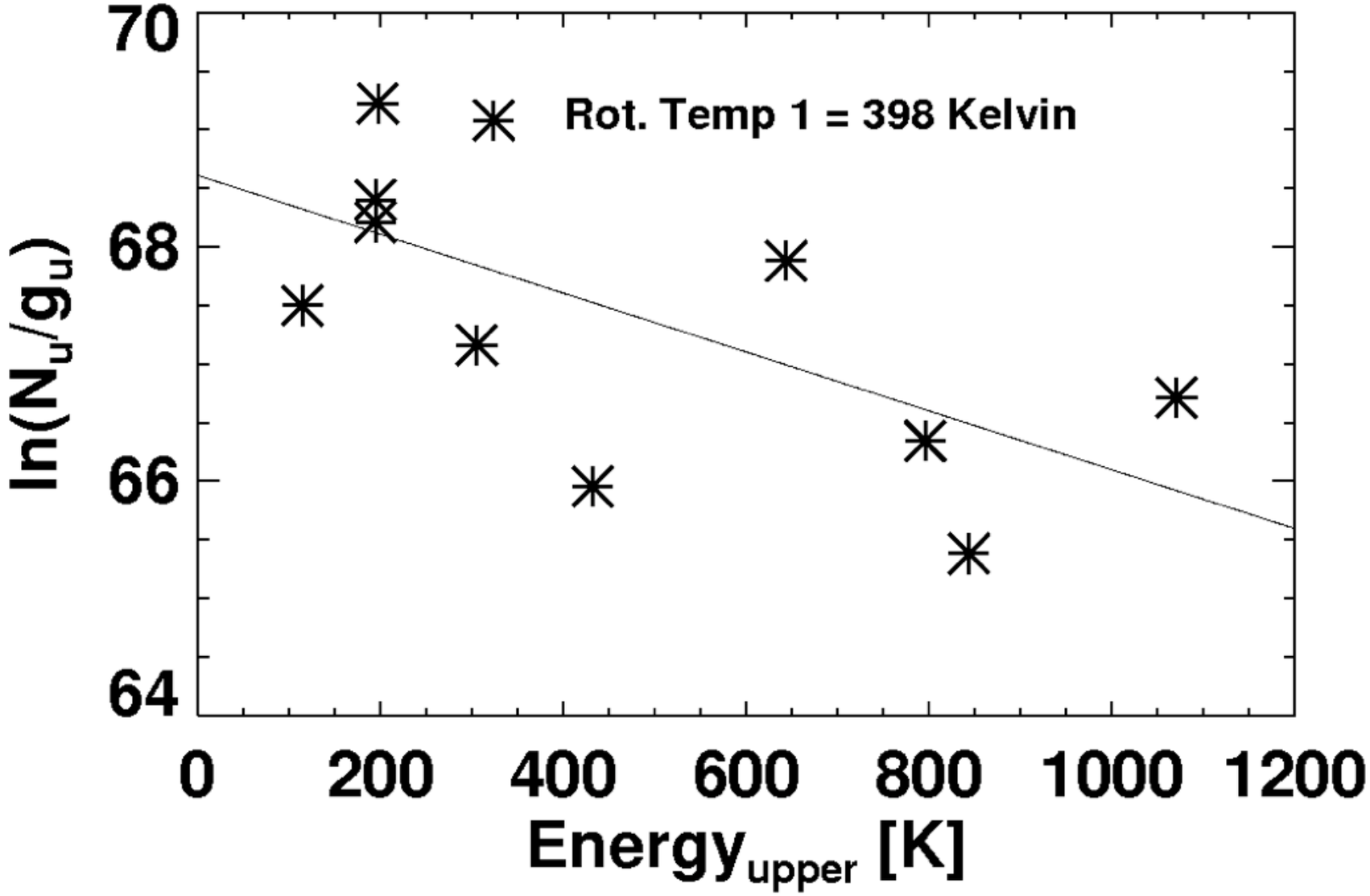
DIGIT

N
E
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
1"
C
D
B
1"
(103 AU)
18
16
14
12
[mag/Arcsec²]

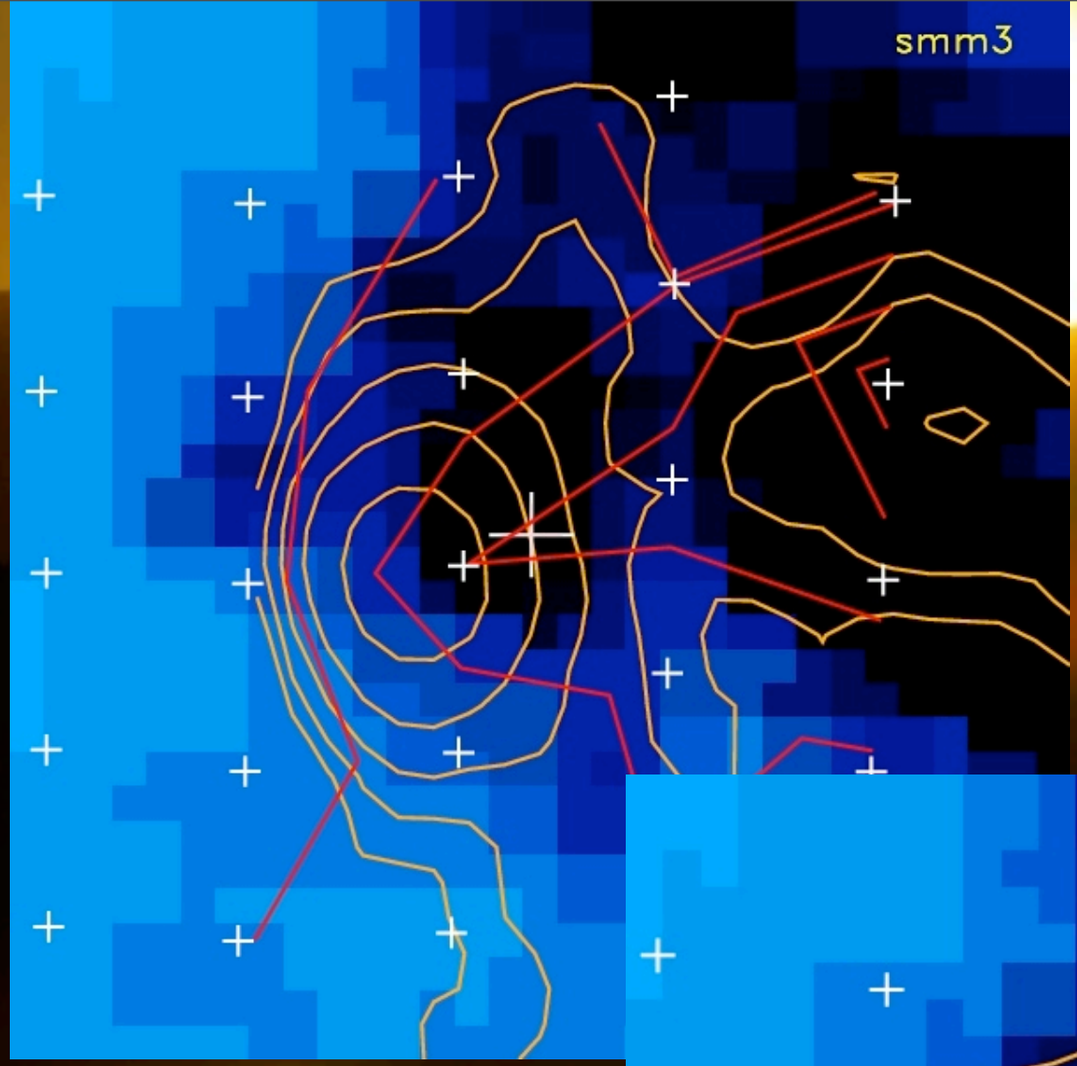
H_2O

All over the place

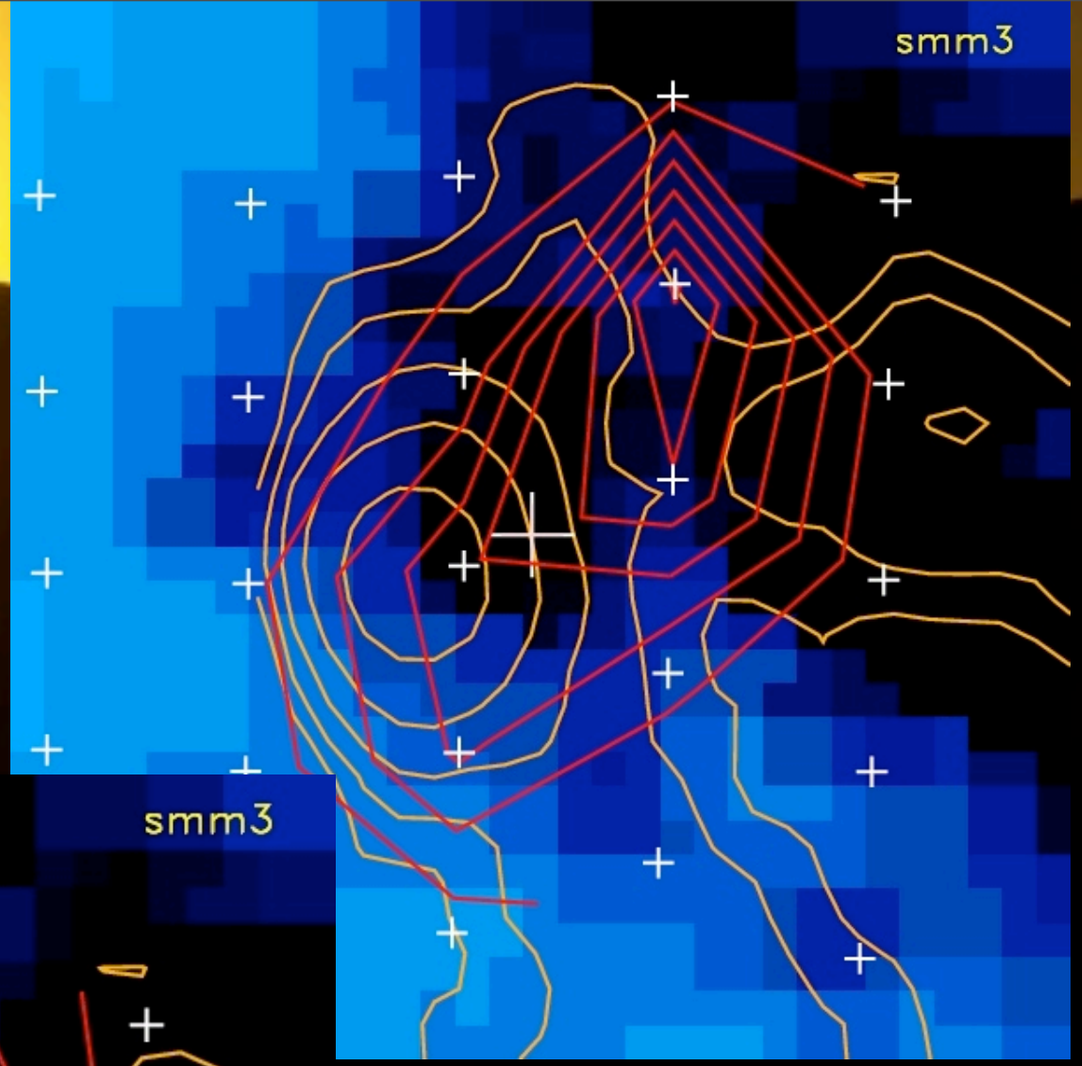
H_2O



All over the place

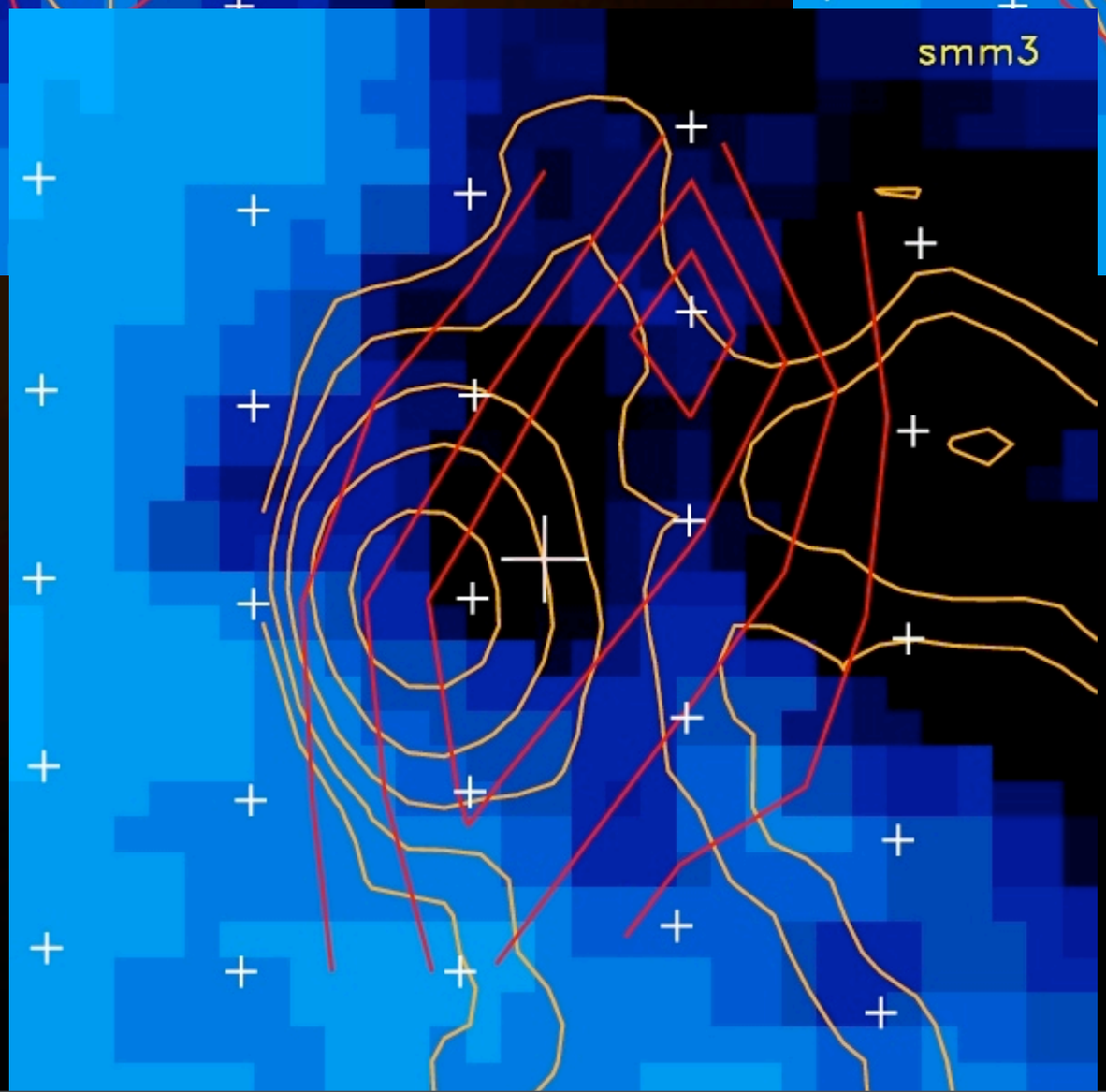


Continuum



[OI]

MIPS
SHARC-II



CO 17-16