Exposing the gas of planet-forming circumstellar disks

Alexis Brandeker

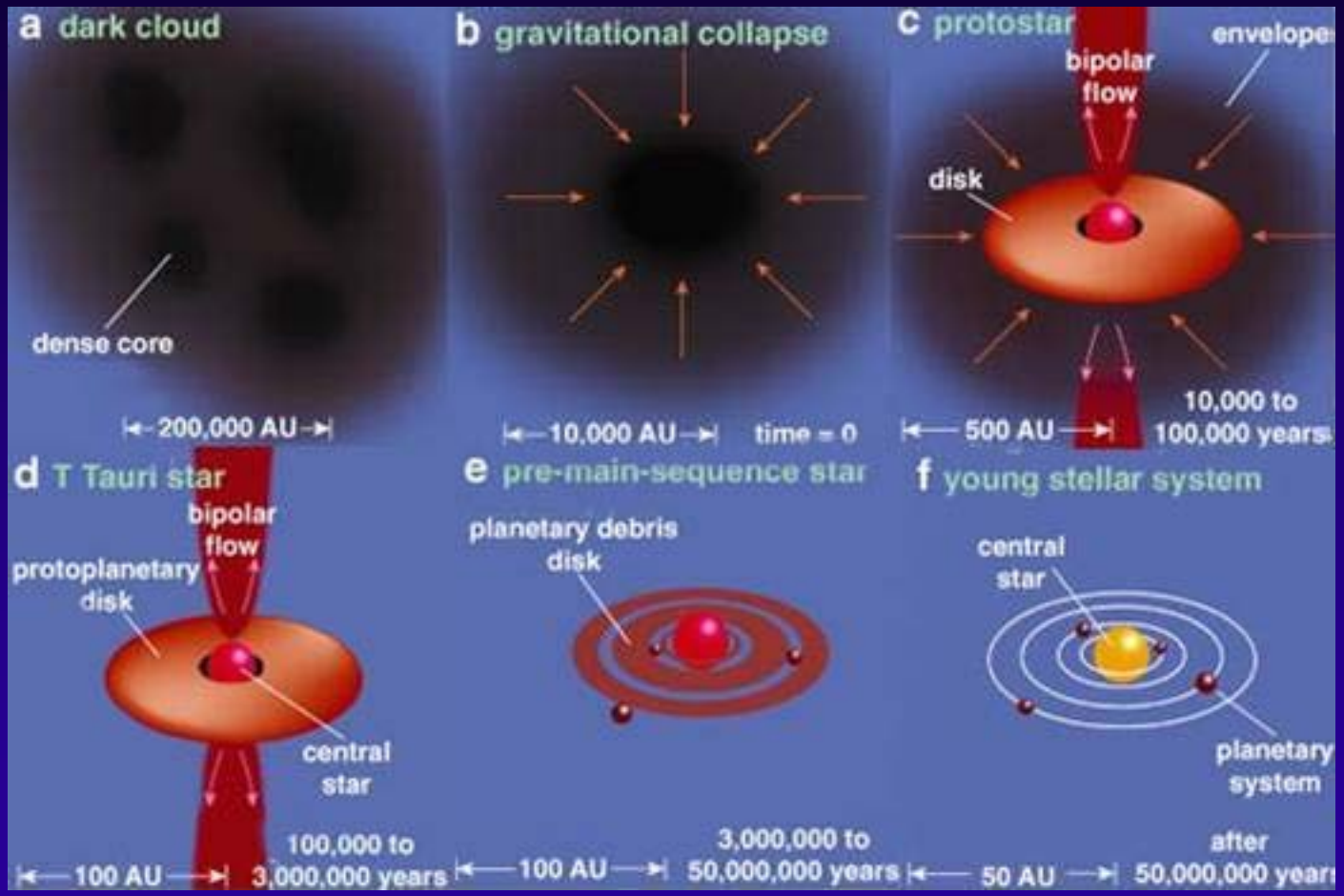
Stockholm Observatory

SRS meeting, Stockholm, 2010-03-25

Contents

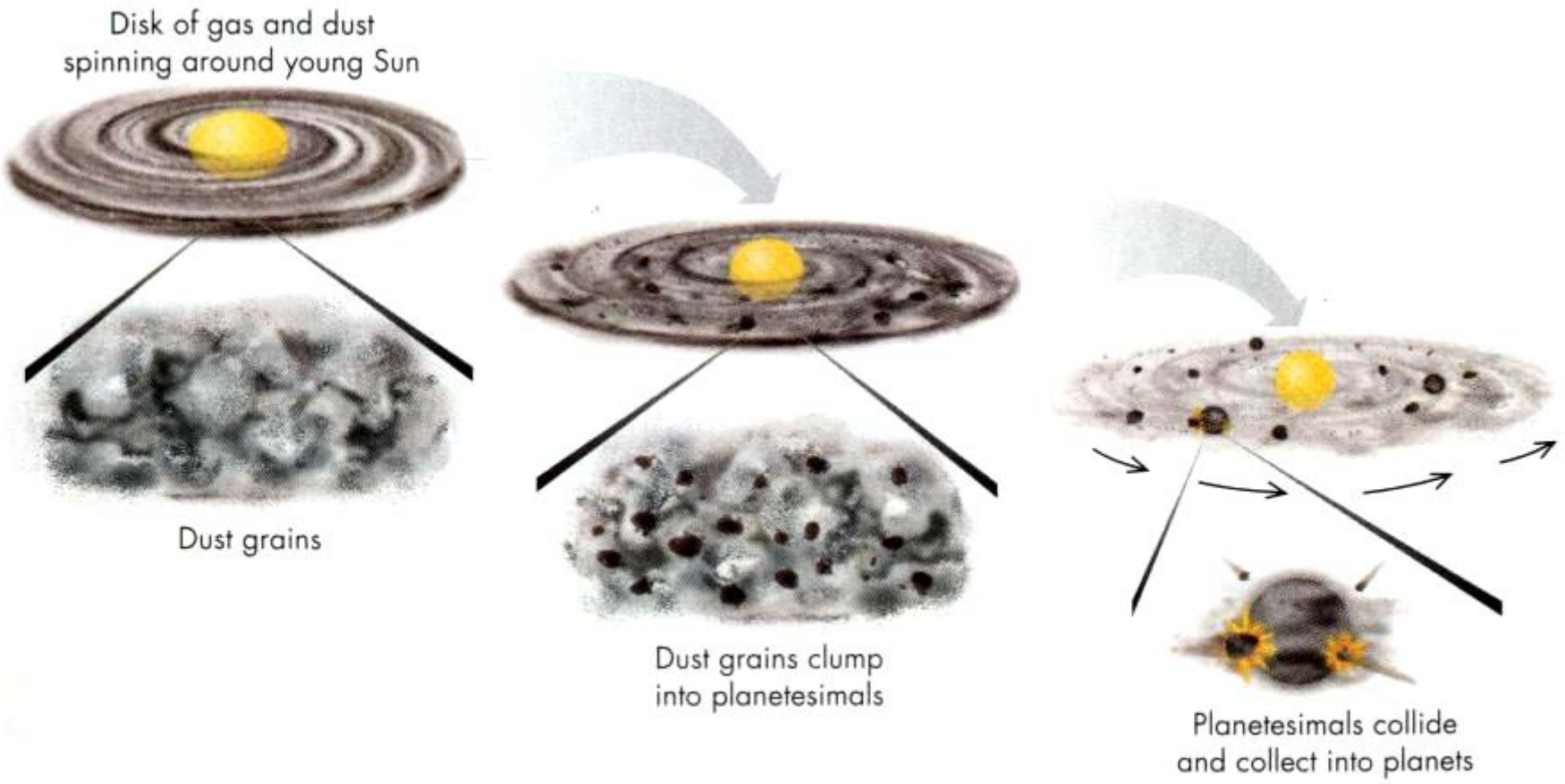
- The solar system formation process, the relevance to the gas disk
- The problem of detecting gas
- Peculiarities of a well-studied disk
- Importance of Herschel

General picture



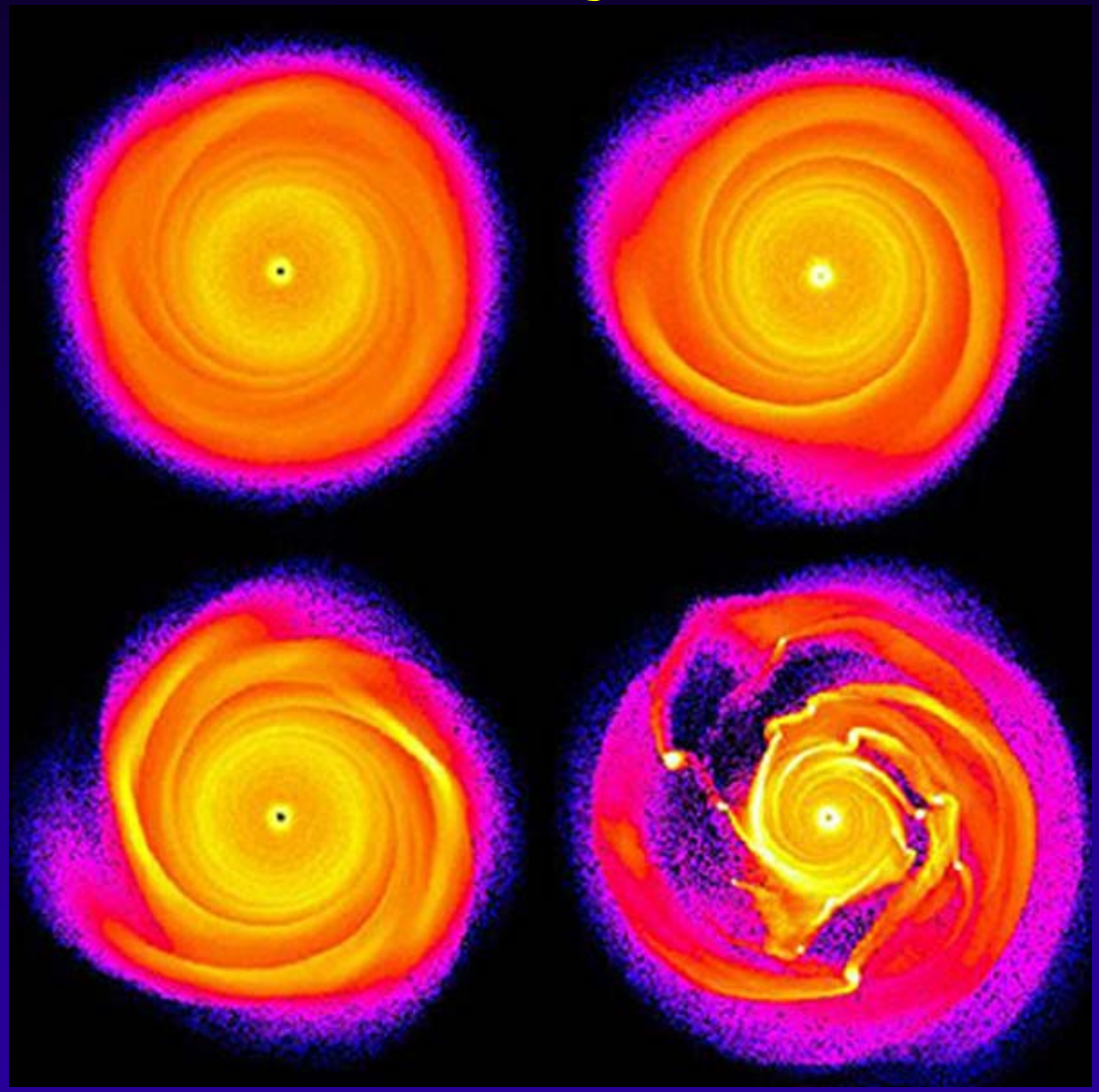
http://ssc.spitzer.caltech.edu/documents/compendium/galsci/

Pair-wise accretion



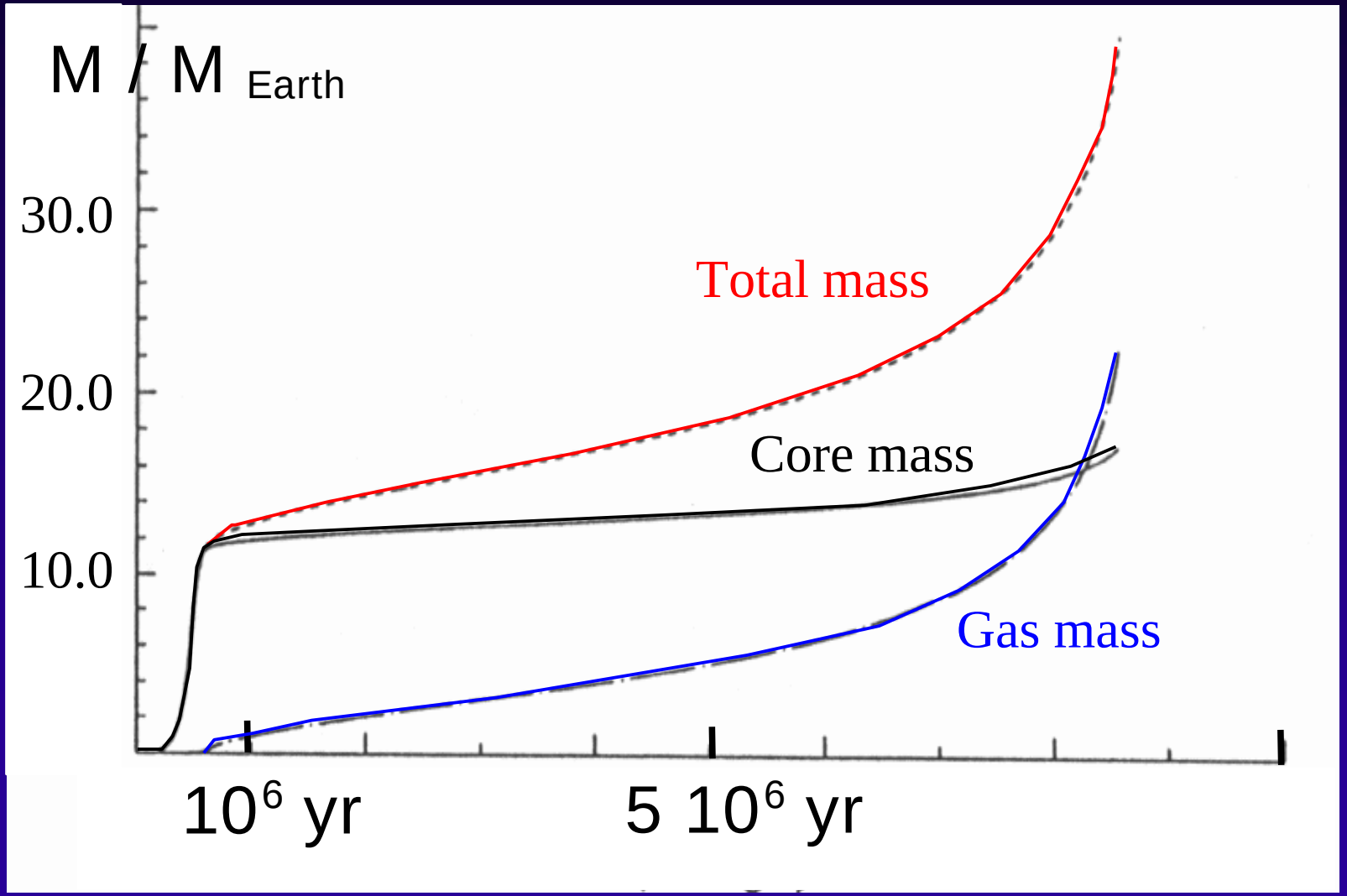
http://www.astro.psu.edu/users/niel/astro1/slideshows/class43/

Gravitationally unstable disk



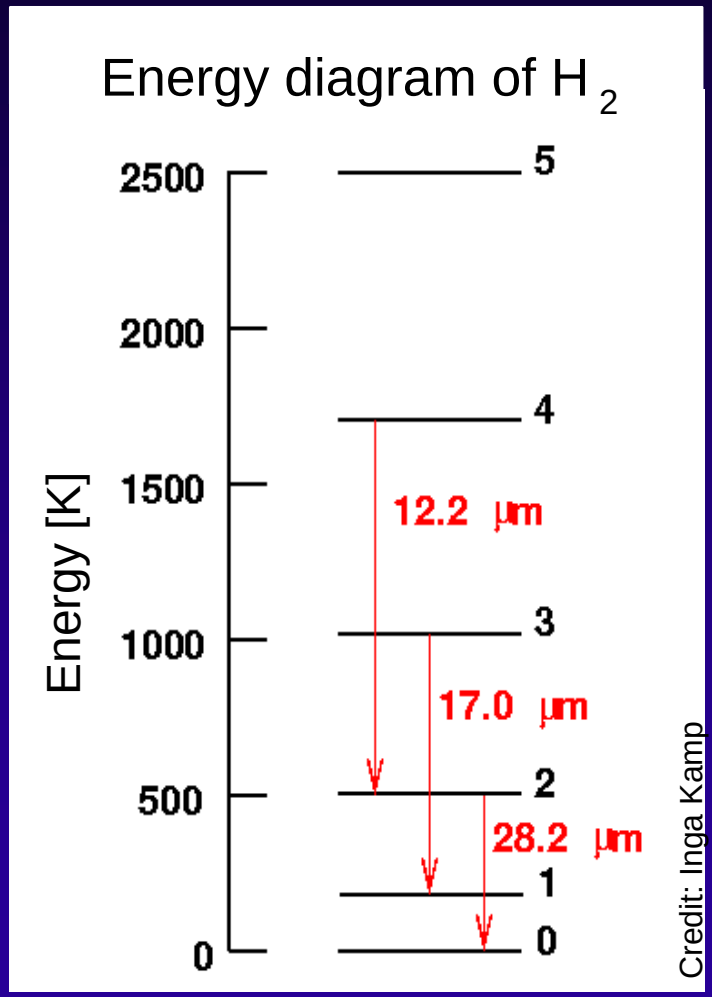
http://www.fas.org/irp/imint/docs/rst/Sect20/

Pair-wise accretion



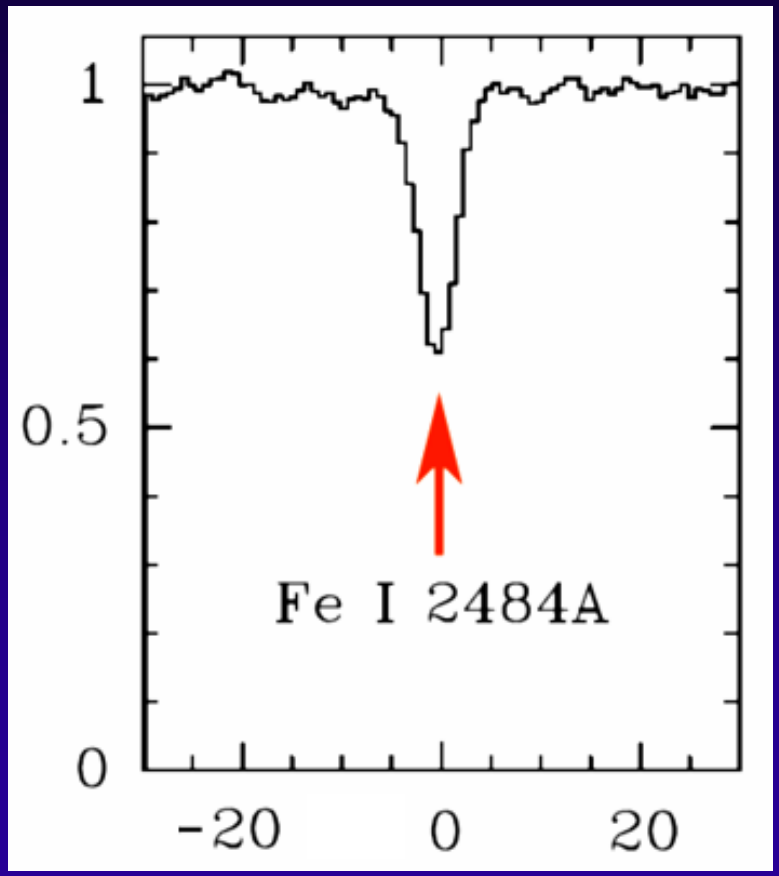
Pollack et al. 1996

Observationial difficulties



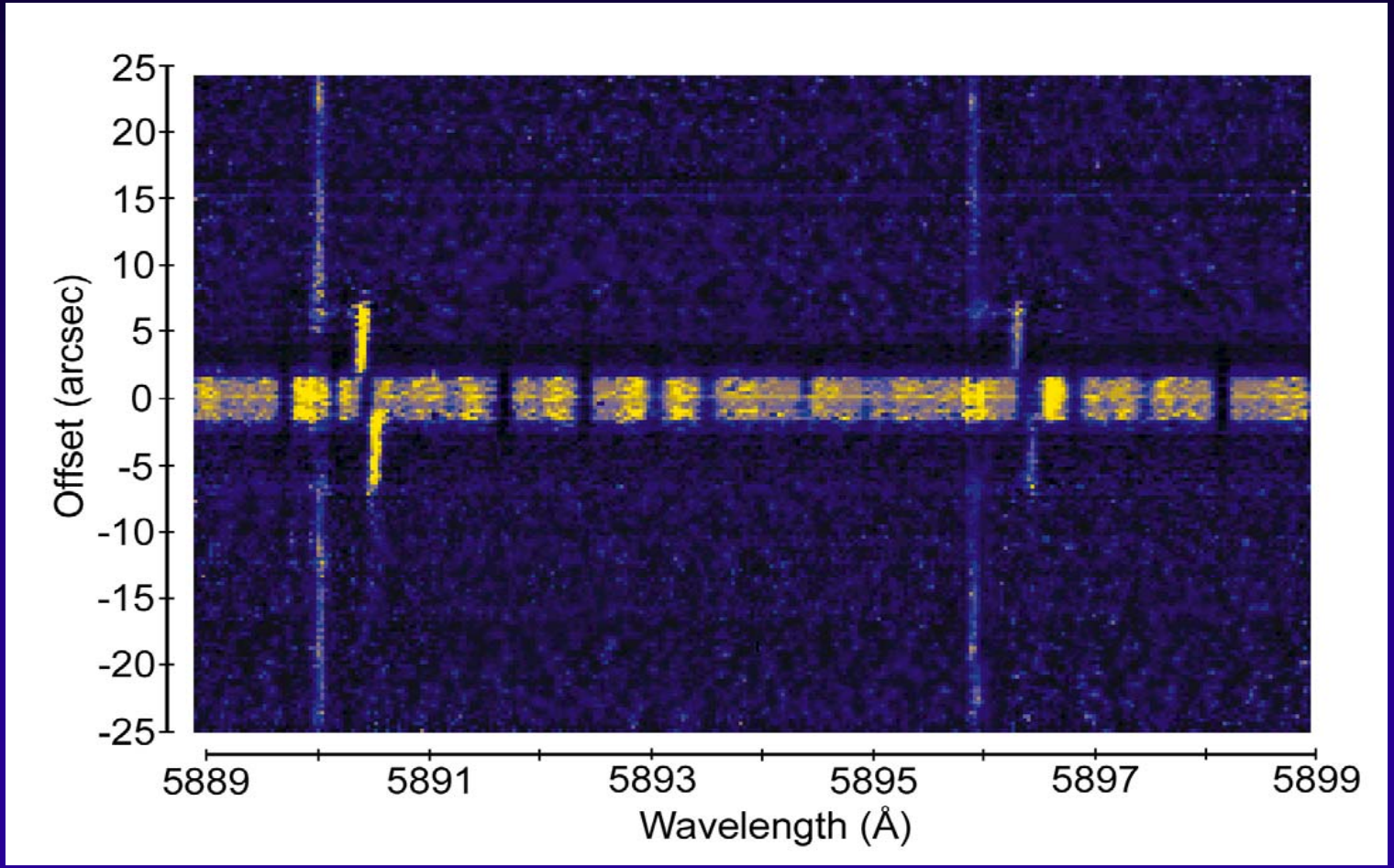
Favourable case: β Pictoris

- β Pictoris found to be "shell" star by Slettebak (1975, ApJ, 197:137)



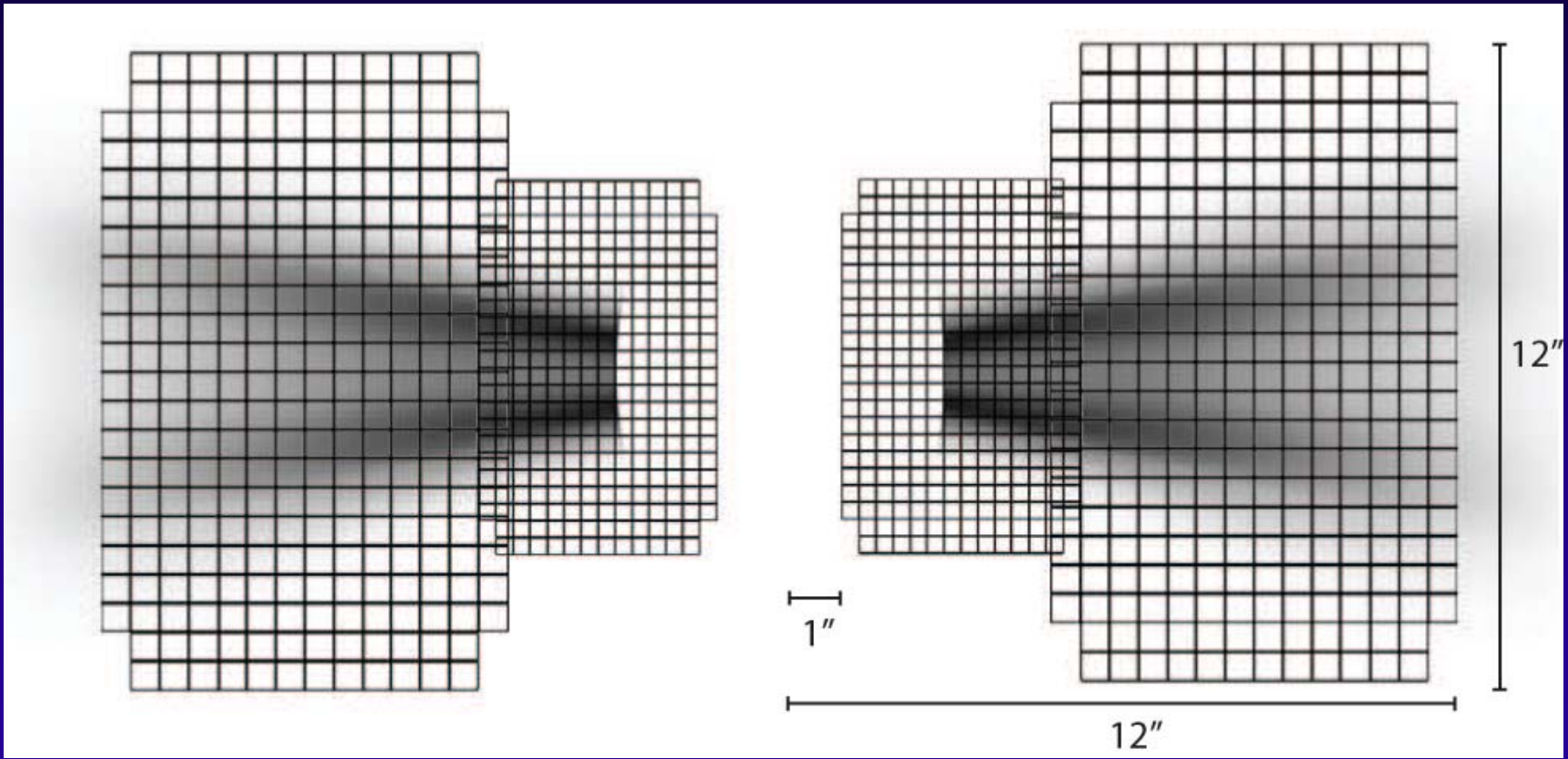
Lagrange et al. 1998, A&A 330:1091

Diagnostic tool

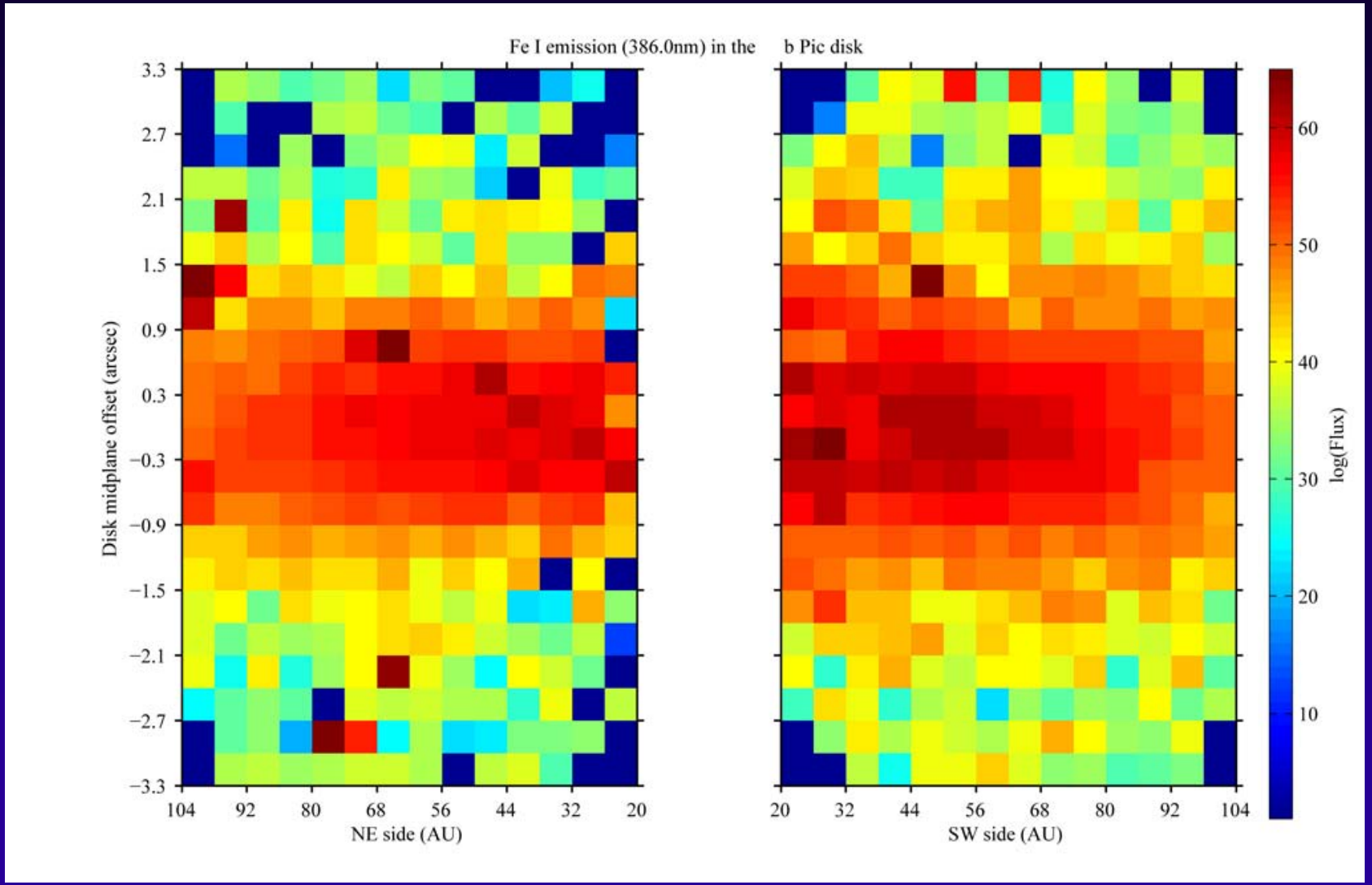


NTT/EMMI Olofsson et al. 2001, ApJ 563:L77

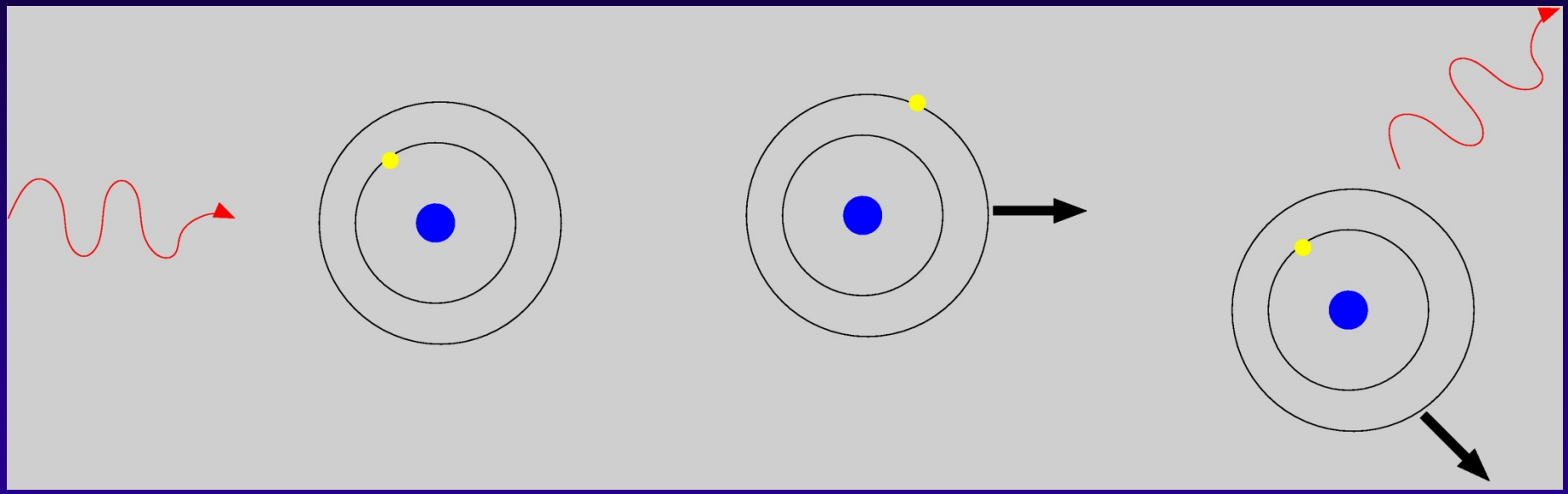
FLAMES/GIRAFFE/ARGUS



Preliminary results: Fe I 3860



Radiation force



On average, atoms move in direction of incident radiation

Fernández et al. 2006, ApJ 643:509

TABLE 1

RADIATION FORCE COEFFICIENTS

Ion	$\beta^{a,b}$	Ion	β^{b}	Ion	$\beta^{a,b}$	Ion	$\beta^{a,b}$
H I	$(1.6\pm0.1)10^{-3}$	F III	$(5.0\pm1.0)10^{-9}$	S II	$(9.0\pm1.0)10^{-5}$	V I	72 ± 4
Ne III	$(9.0\pm2.0)10^{-4}$	Na I	360 ± 20	Cl I	$(3.3\pm0.1)10^{-2}$	V II	4.4 ± 0.2
C II	$(2.3\pm0.2)10^{-3}$	C III	$(8.5\pm0.9)10^{-6}$	Al II	0.36 ± 0.05	V III	0
N I	$(2.1\pm0.1)10^{-4}$	Al III	12 ± 1	Ca I	330 ± 40	Cr I	93 ± 5
N II	$(7.5\pm0.5)10^{-6}$	Si I	6.0 ± 0.6	Ca II	50 ± 10	Cr II	$(6.0\pm3.0)10^{-7}$
N III	$(7.0\pm1.0)10^{-6}$	Si II	9 ± 9	Ca III	...	Cr III	...
O I	$(3.3\pm0.2)10^{-4}$	Si III	$(5.8\pm0.6)10^{-4}$	Sc I	220 ± 20	Mn I	28 ± 3
O II	$(3.1\pm0.7)10^{-9}$	P I	3.4 ± 0.6	Sc II	$(1.3\pm0.4)10^{3}$	Mn II	7 ± 1
O III	$(6.5\pm0.6)10^{-7}$	P II	$(2.2\pm0.3)10^{-3}$	Sc III	$(9.0\pm3.0)10^{-2}$	Mn III	...
F I	0	P III	$(5.0\pm2.0)10^{-4}$	Ti I	97 ± 5	Fe I	27 ± 2
F II	$(3.5\pm0.9)10^{-6}$	S I	0.56 ± 0.09	Ti II	28 ± 2	Fe II	5.0 ± 0.3
				Ti III	$(5.0\pm0.1)10^{-4}$	Fe III	$(3.0\pm0.6)10^{-7}$
						Co I	16 ± 1
						Co II	0
						Co III	$(4.0\pm2)10^{-7}$
						Ni I	26 ± 2
						Ni II	$(7.0\pm2.0)10^{-2}$
						Ni III	$(3.0\pm2.0)10^{-7}$
						p[c]	4.4×10^{-11}
						e[c]	0.27

[a] $\beta = 0$ means that no ground state transitions are known in the range $1000\text{Å} < \lambda < 50000\text{Å}$

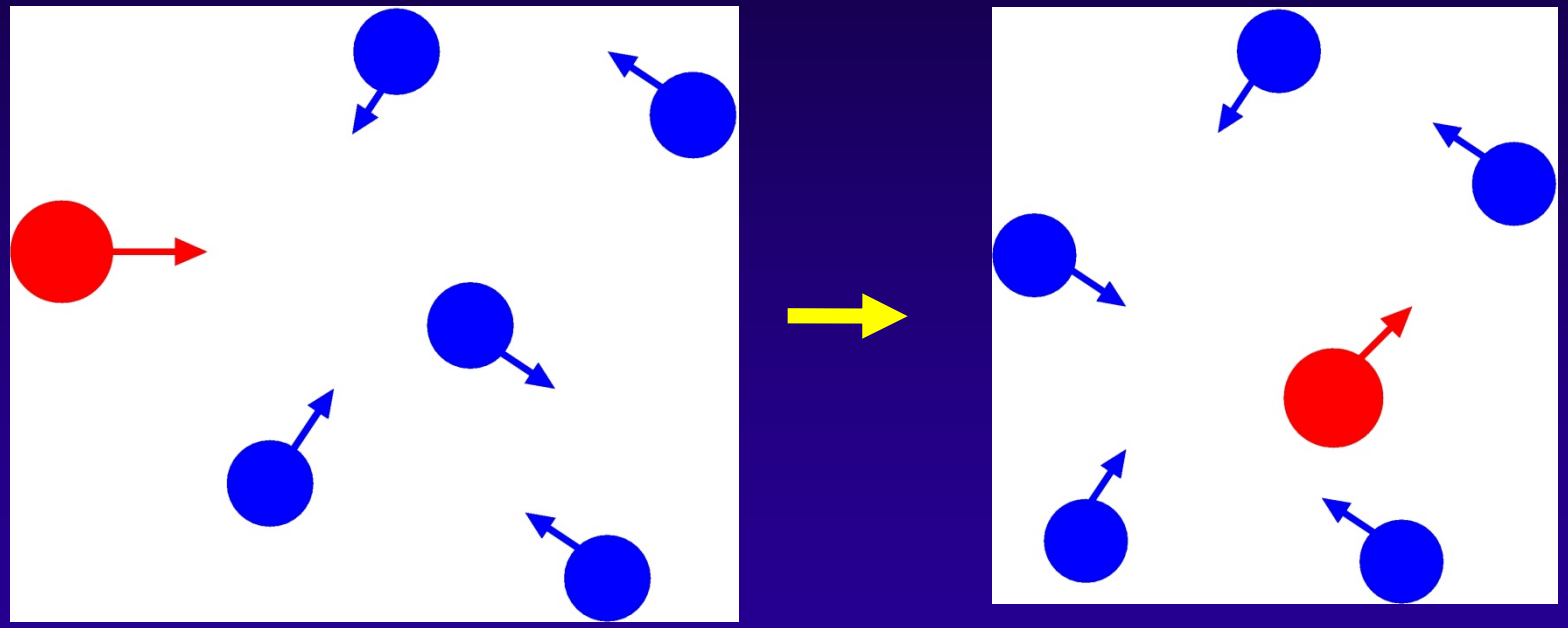
[b] Empty entries mean that no atomic data was available

[c] Proton and electron value calculated using Thomson cross section

Collisional braking: principle

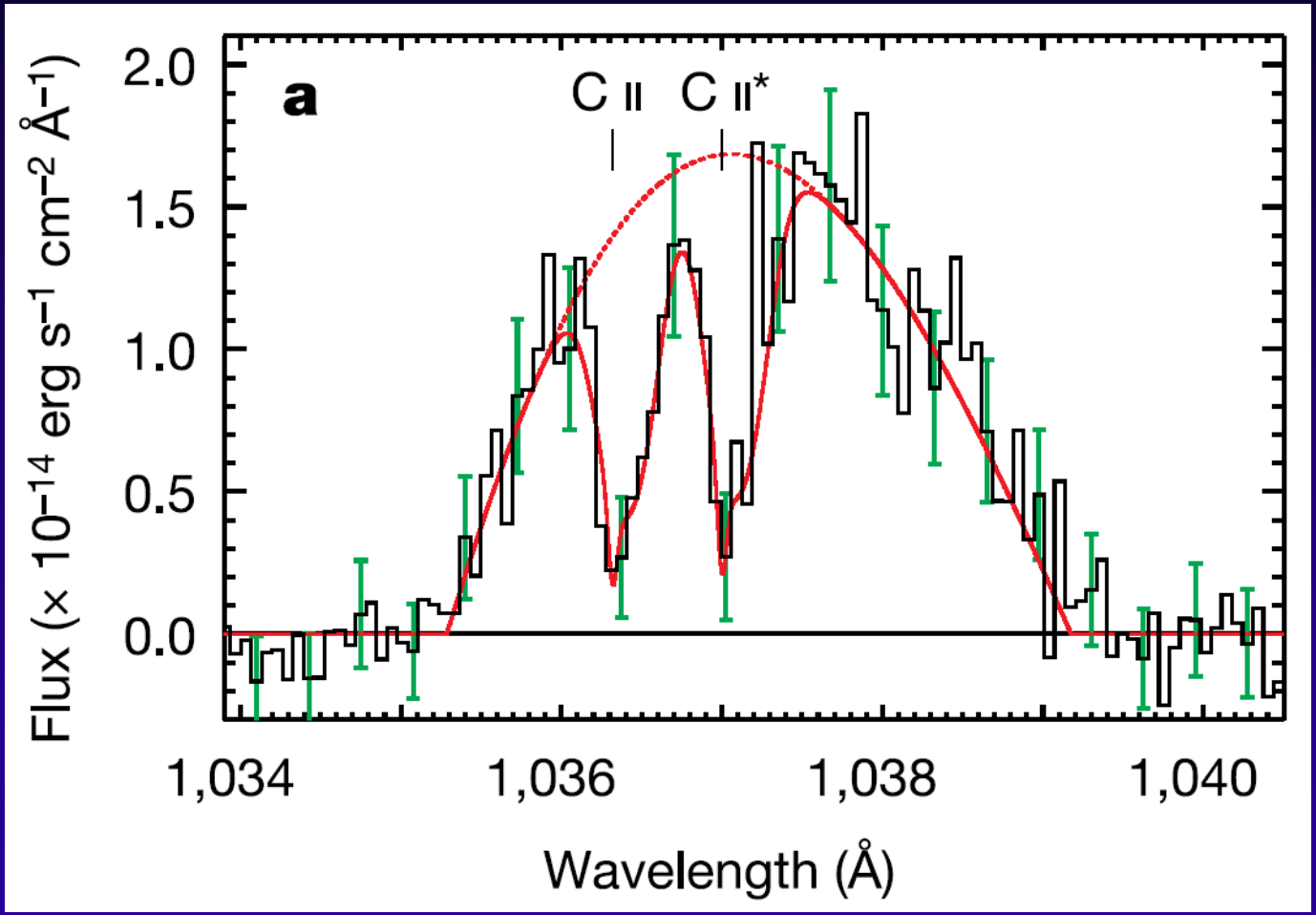
before

after



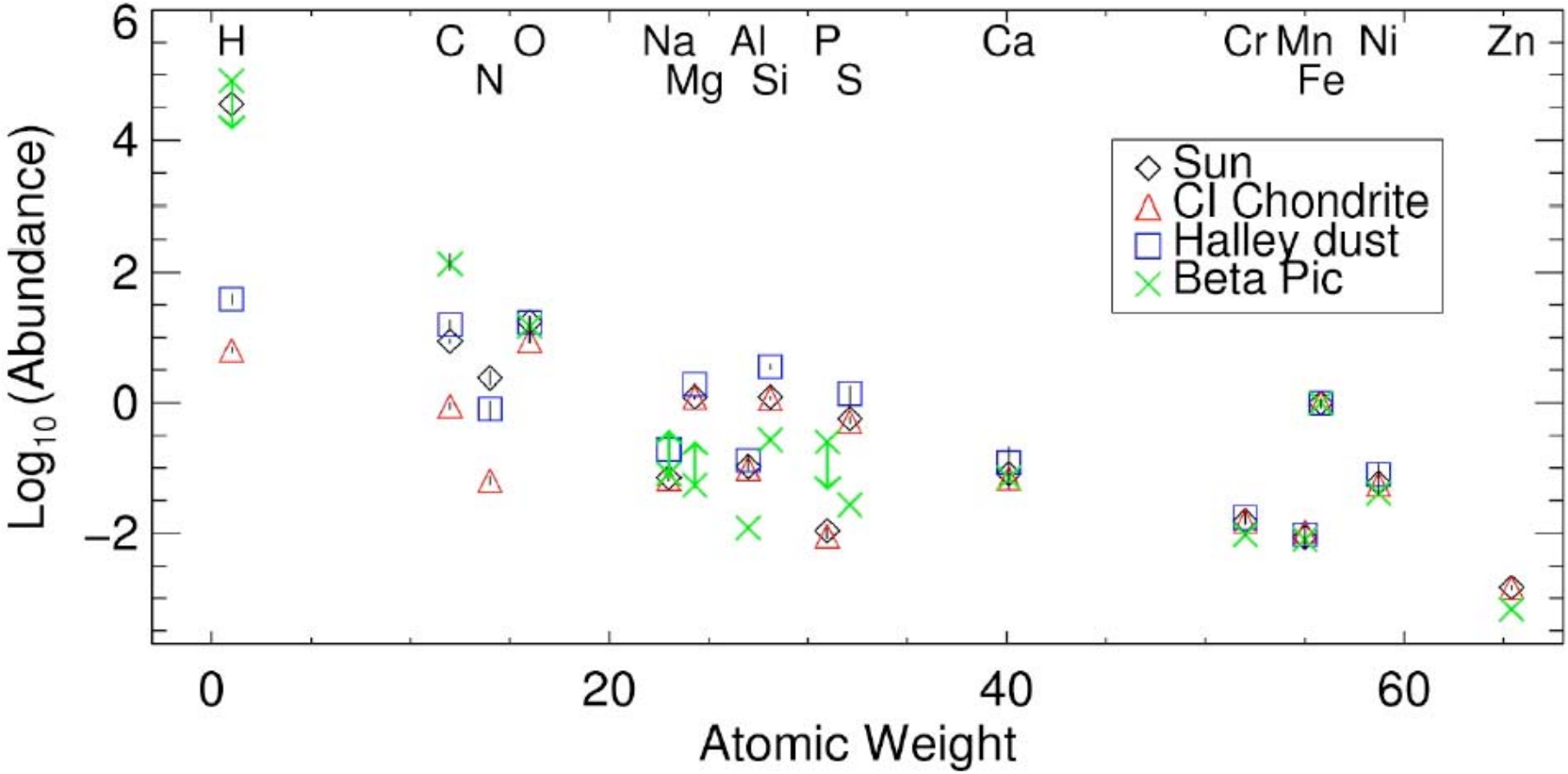
Collision frequency – Braking inertia

FUSE: Carbon absorption



Roberge et al. 2006, Nature 441:724

β Pictoris gas disk composition



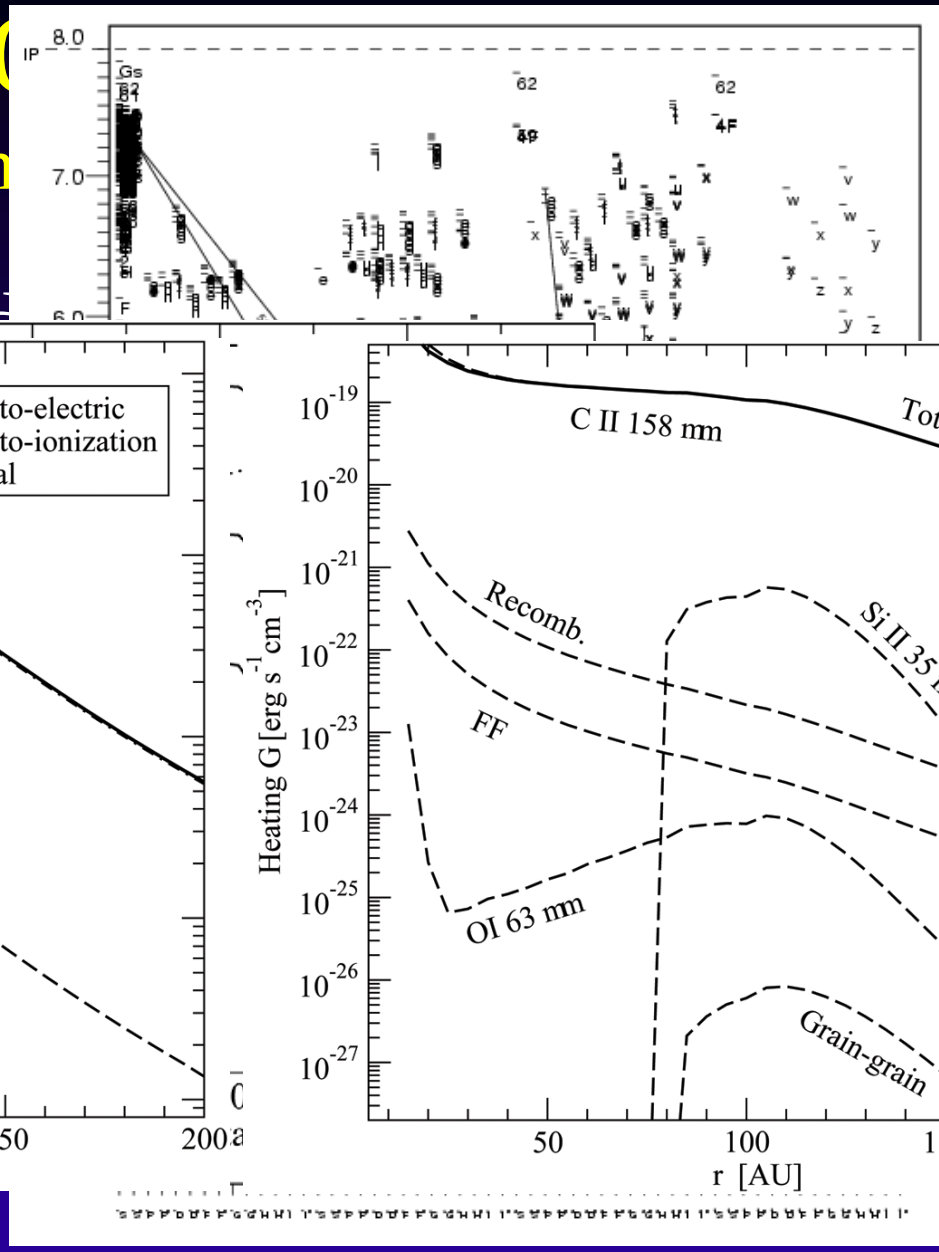
Roberge et al. 2006, Nature 441:724

Herschel and the fantastic 6 (β Pic, α Psa, ε Eri, Vega, AU Mic, τ Cet)

- Guarantee Time programme to thoroughly observe the F6
- PI: Göran Olofsson
- PACS, SPIRE, HIFI
- 61 hours

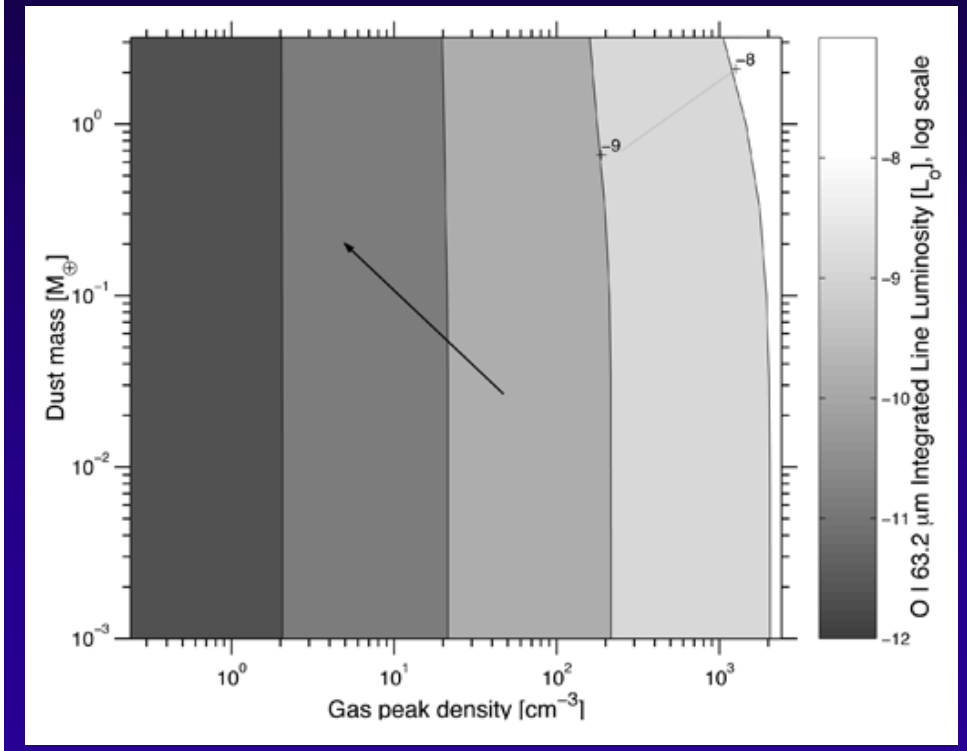
(optically thin therm ode)

- Optimised

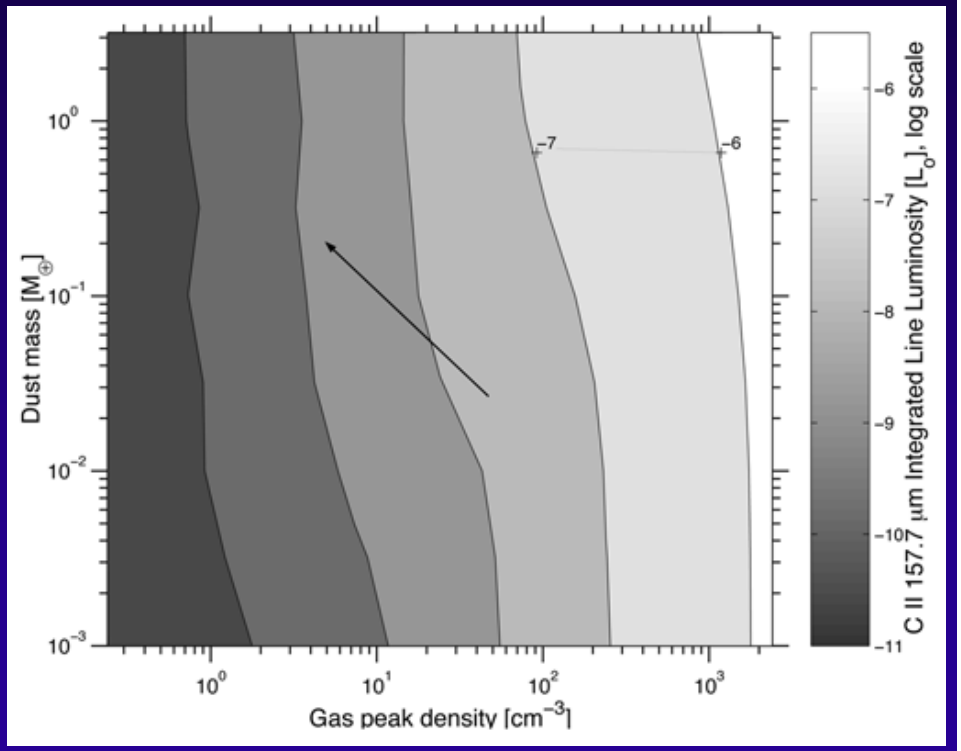


Line luminosity

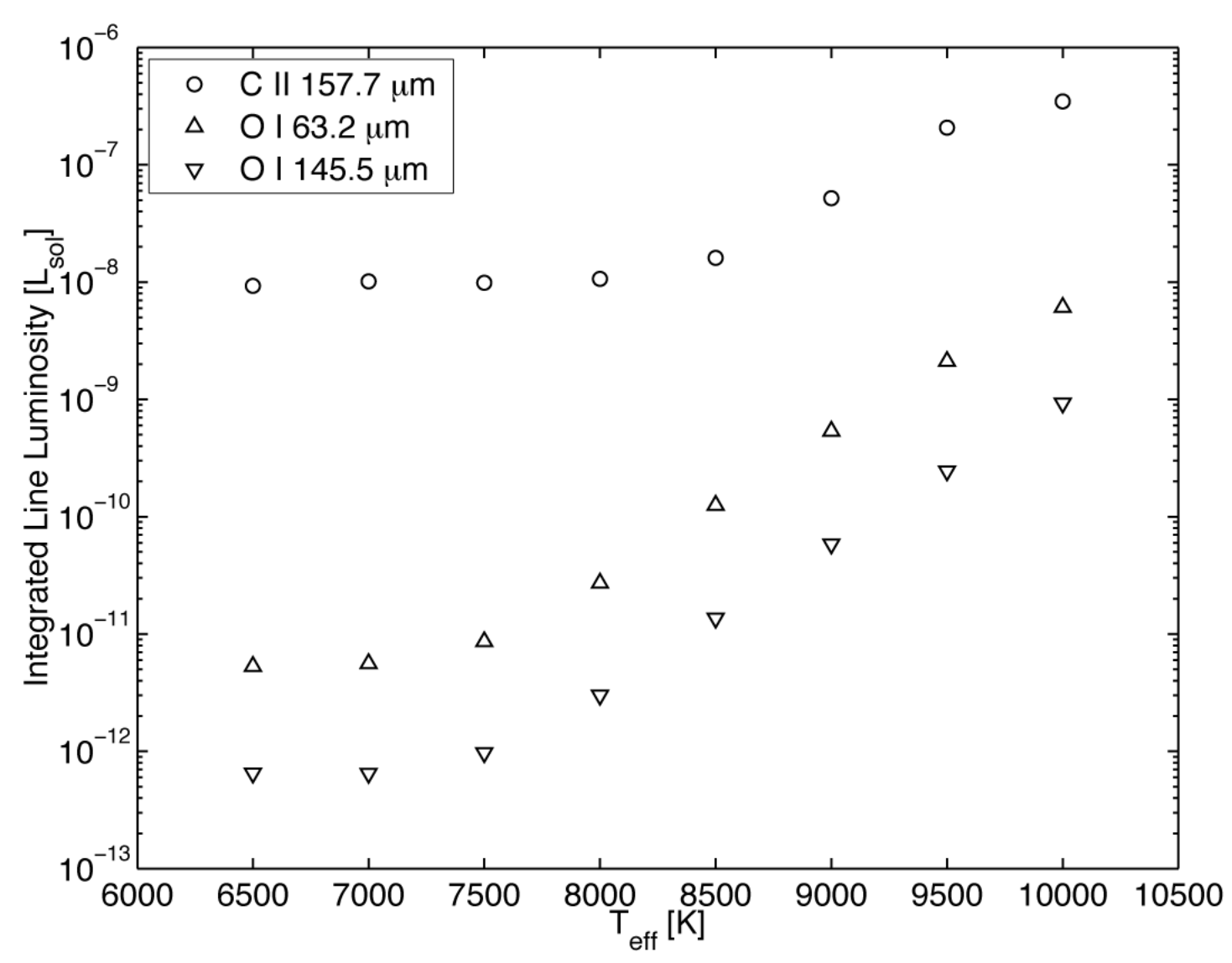
O I 63.2μm



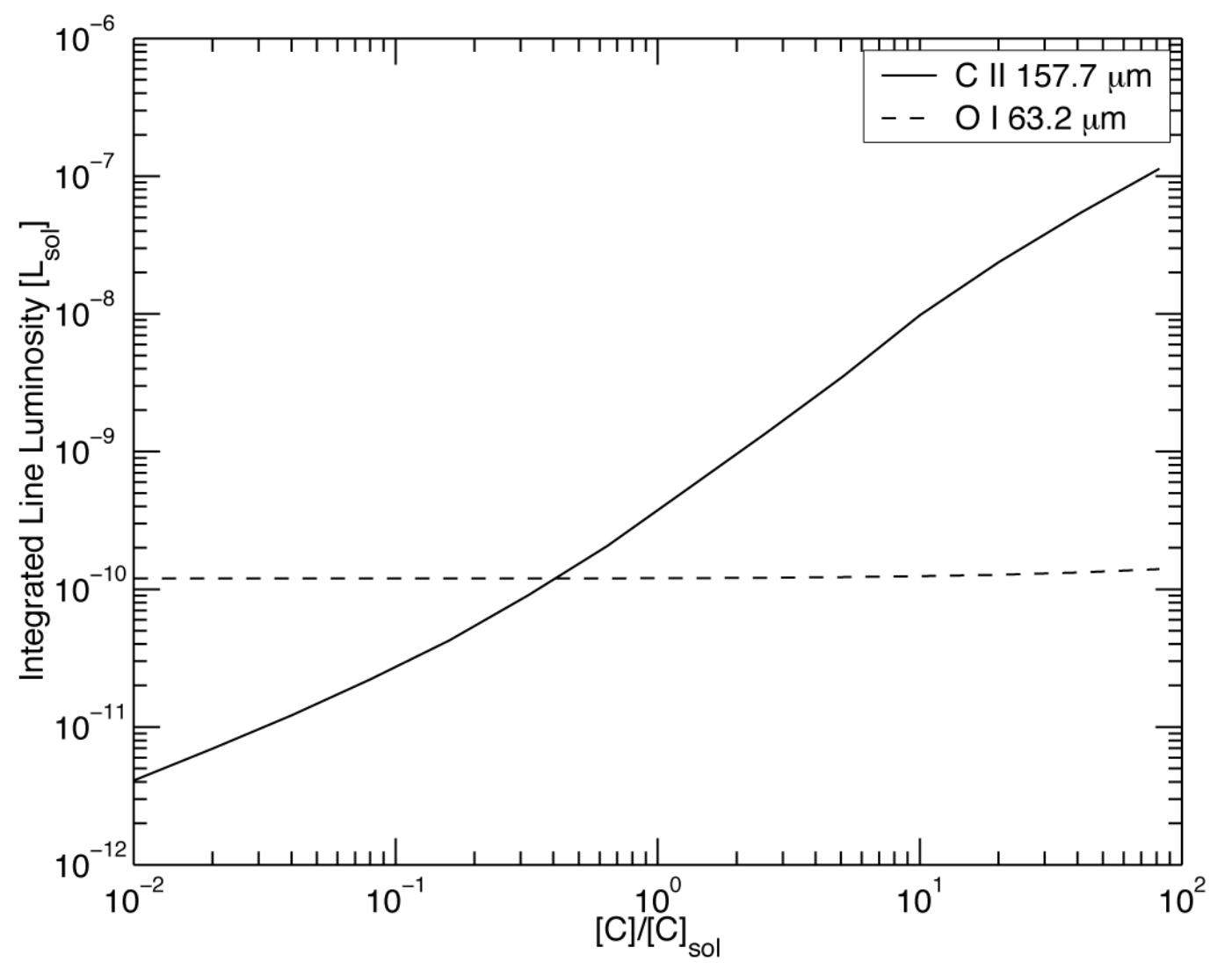
C II 157.7μm



Line luminosity



Line luminosity



GASPS

(gas in protoplanetary systems)

- Herschel key programme to look for gas around young stars (1-30 Myr)
- CII 157 μm and OI 63 μm in 274 objects
- Follow up in OI 145 μm and H_2O
- 400 hours

Conclusions

- In carbon rich, β Pic-like disks, Herschel will find a lot more CII 157 μm than OI 63 μm
- We will soon have a better idea about giant planet formation timescales

Line luminosity