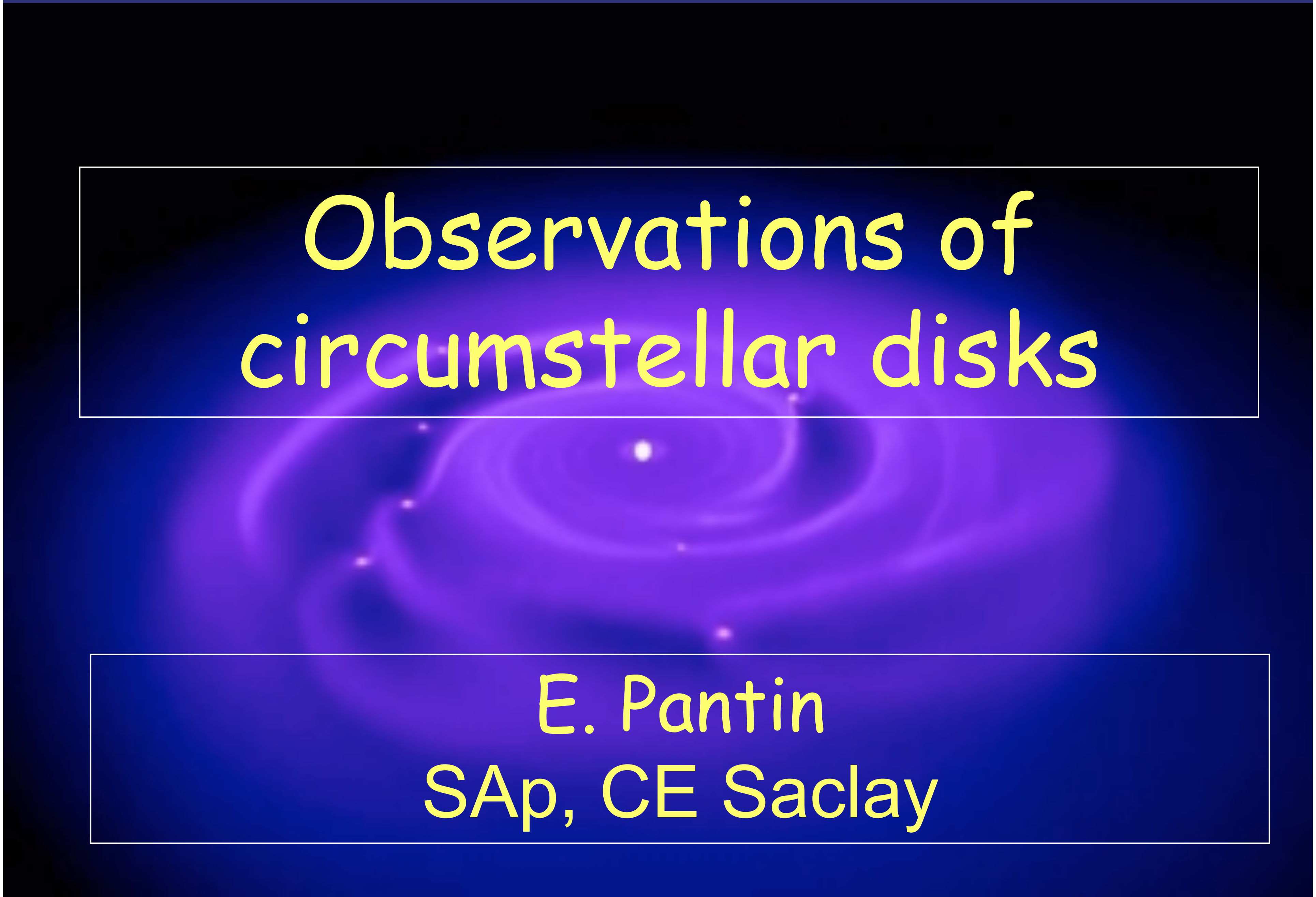


Observations of circumstellar disks

E. Pantin
SAp, CE Saclay

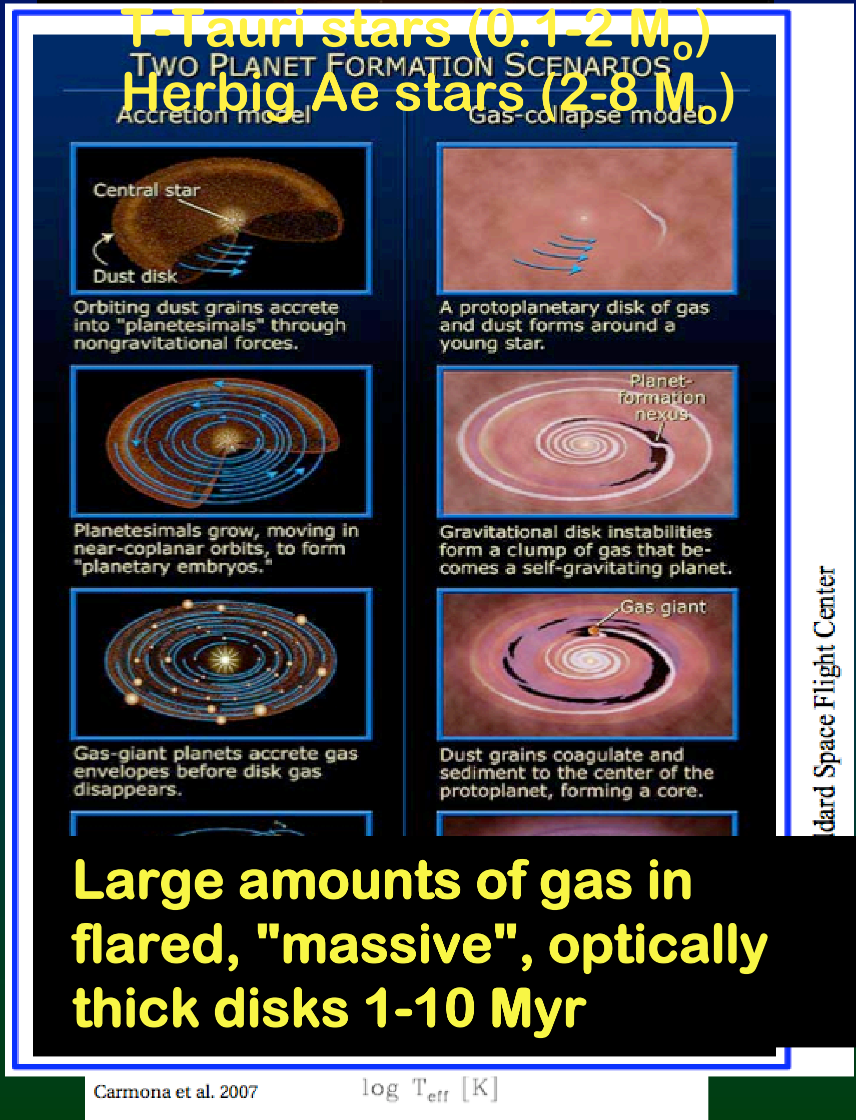
Disks everywhere !

Proto and post planetary disks

Proto-planetary disks:

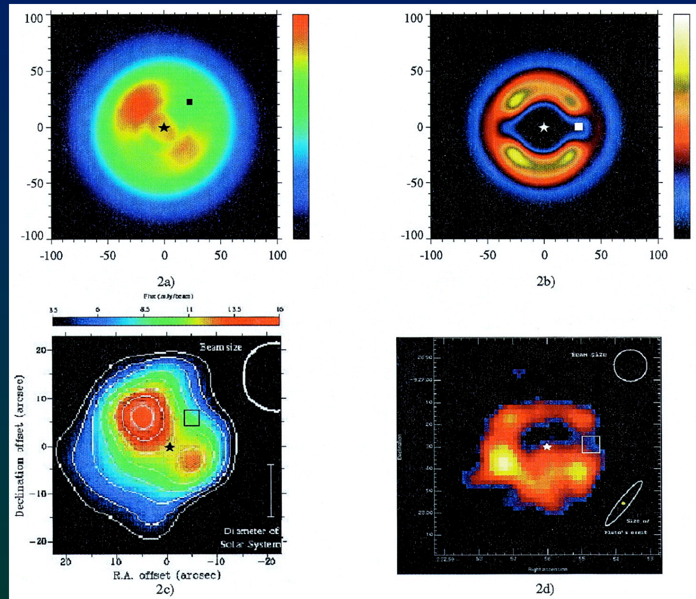
T-Tauri stars (0.1-2 M_o)

Herbig Ae stars (2-8 M_o)



Large amounts of gas in flared, "massive", optically thick disks 1-10 Myr

Post-planetary ("debris") disks



Little amounts of gas (?), in optically and geometrically thin disks 10Myr-1Gyr

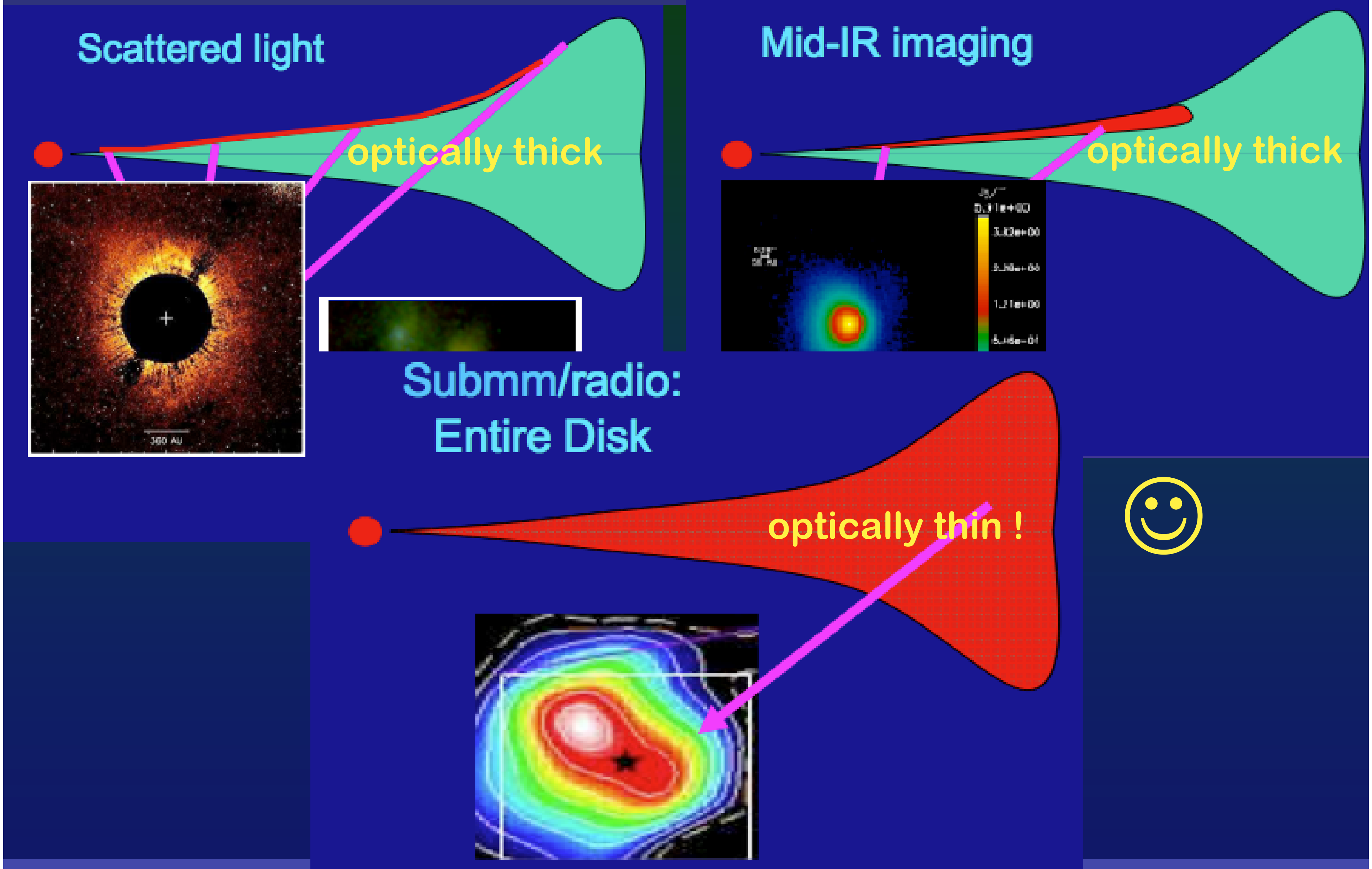
Proto-planetary disks

Dust Phase

- Ingredients for telluric planets and giants planetary core
- Grain settling and growth ➡ disk opacity
- Chemistry active mainly on grains surface !

➡ Physical conditions and timescales for planet formation !!

Dust phase



Scattered light
optically thick
360 AU
Mid-IR imaging
optically thick
Submm/radio:
Entire Disk
optically thin !

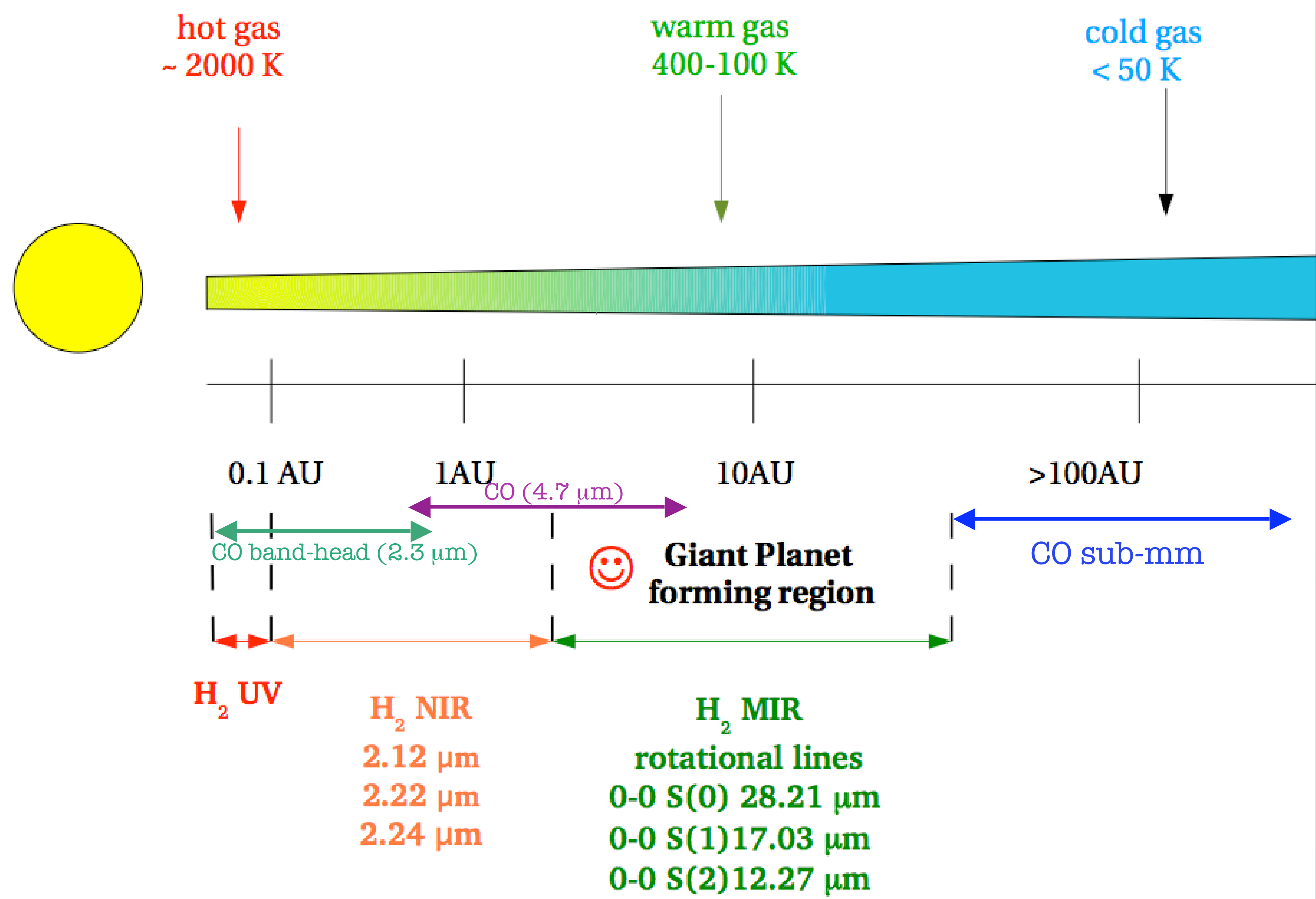
Gas Phase

Dust obs :
- Mass in dust only
- Broad features no kinematic information

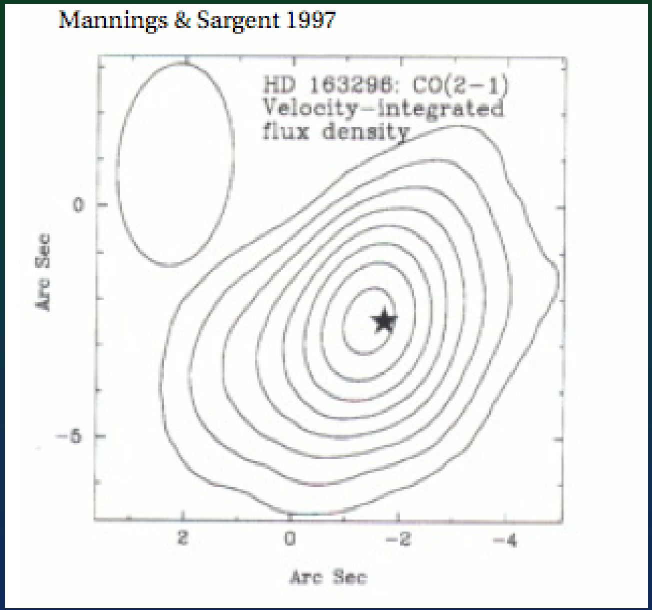
dust 1%

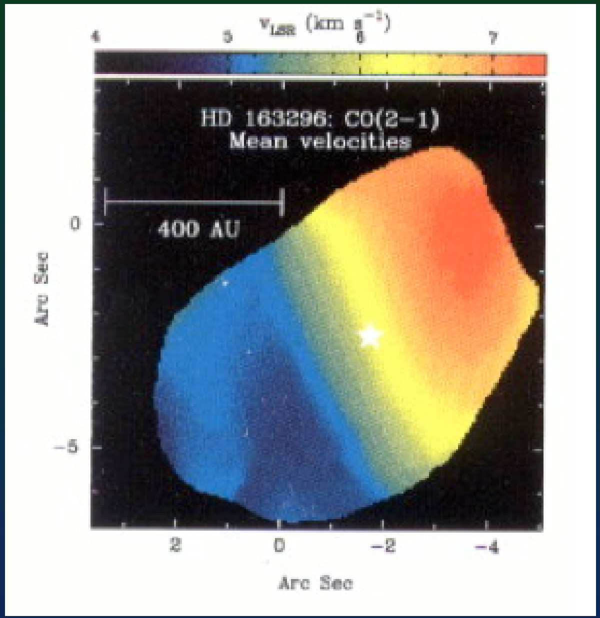
Gas 99%

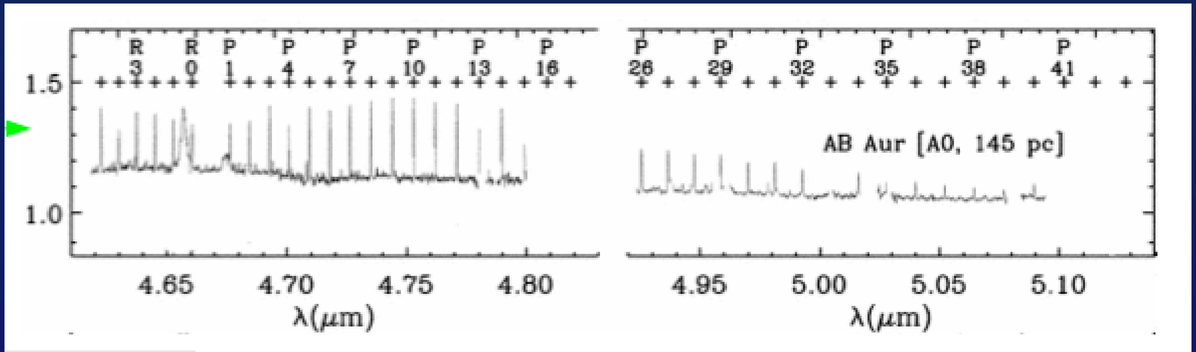
Gas emissionS from proto-planetary disks



Gas emissionS from proto-planetary disks





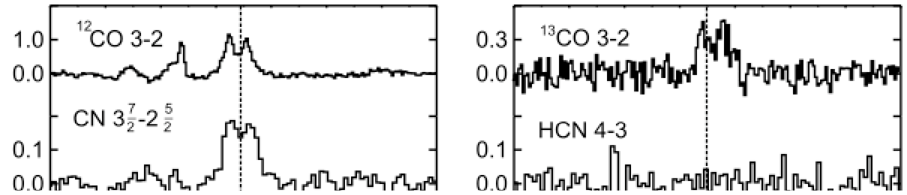


Gas emissionS from proto-planetary disks

Line	E_{upper} (K)	n^{a}_{crit} (cm^{-3})	ν (GHz)	Telescope	Beam (″)	Cal.[d]	$\int T_{mb}\,dv$ (K km s^{-1}) LkCa15	TW Hya	HD 163296	MWC
^{12}CO $J=2\to1$	16.6	2.7(3)	230.538	IRAM30m	10.7	...	1.82	...	...	...
^{12}CO $J=3\to2$	33.2	8.4(3)	345.796	JCMT	13.7	yes	1.17	1.98	3.78	2.88
^{13}CO $J=3\to2$	31.7	8.4(3)	330.587	JCMT	14.3	yes	0.39	0.24	0.94	0.57
$C^{18}O$ $J=2\to1$	15.8	2.7(3)	219.560	JCMT	21.5	yes	<0.20	...	...	...
$C^{18}O$ $J=3\to2$	31.6	8.4(3)	329.330	JCMT	14.3	yes	<0.14	...	...	...
HCO^+ $J=4\to3$	42.8	1.8(6)	356.734	JCMT	13.2	yes	0.26	1.26	1.10	0.35
$H^{13}CO^+$ $J=4\to3$	41.6	1.8(6)	346.998	JCMT	13.6	yes	<0.13	0.07	...	...
DCO^+ $J=5\to4$	51.8	3.0(6)	360.169	JCMT	13.1	yes	<0.10	0.11	...	...
CN $J=3\frac{7}{2}\to2\frac{5}{2}$	32.7	6.0(6)	340.248	JCMT	13.9	no	0.67	1.14	0.95	0.29
HCN $J=4\to3$	42.5	8.5(6)	354.506	JCMT	13.3	yes	0.25	0.49	<0.20	[illegible]
$H^{13}CN$ $J=4\to3$	41.4	8.5(6)	345.339	JCMT	13.6	no	...	<0.04	...	
HNC $J=4\to3$	43.5	8.5(6)	362.630	JCMT	13.0	no	...	<0.05	...	
DCN $J=5\to4$	52.1	4.8(7)[b]	362.046	JCMT	13.0	yes	...	<0.03	...	
CS $J=7\to6$	65.8	2.9(6)	342.883	JCMT	14.0	no	<0.08	...	...	
SO $J=8_8\to7_7$	87.7	1.8(6)	344.310	JCMT	13.7	no	...	<0.10	...	
H_2CO $J=2_{12}\to1_{11}$	21.9	1.0(5)	140.839	IRAM30m	17.5	...	0.17	...	<0.10	
H_2CO $J=3_{03}\to2_{02}$	21.0	4.7(5)	218.222	IRAM30m	11.3	...	0.14	...	<0.30	
H_2CO $J=3_{22}\to2_{21}$	68.1	2.3(5)	218.475	IRAM30m	11.3	...	<0.10	...	...	
H_2CO $J=3_{12}\to2_{11}$	33.5	4.5(5)	225.697	IRAM30m	10.9	...	0.10	...	<0.30	
H_2CO $J=3_{12}\to2_{11}$	33.5	4.5(5)	225.697	JCMT	22.2	no	...	<0.05	...	
H_2CO $J=5_{15}\to4_{14}$	62.5	1.7(6)	351.768	JCMT	13.4	yes	0.29	<0.04	<0.20	
CH_3OH $J=2_K\to1_K$	6.9	2.6(3)[c]	96.741	IRAM-30m	25.4	...	<0.05	...	<0.03	
CH_3OH $J=4_2\to3_1$ E^+	45.4	3.7(4)	218.440	IRAM30m	11.3	...	<0.10	...	...	
CH_3OH $J=5_K\to4_K$	34.8	4.5(4)	241.791	IRAM30m	10.2	...	<0.10	...	<0.10	
CH_3OH $J=7_K\to6_K$	65.0	1.3(5)	338.409	JCMT	13.9	yes	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	104.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

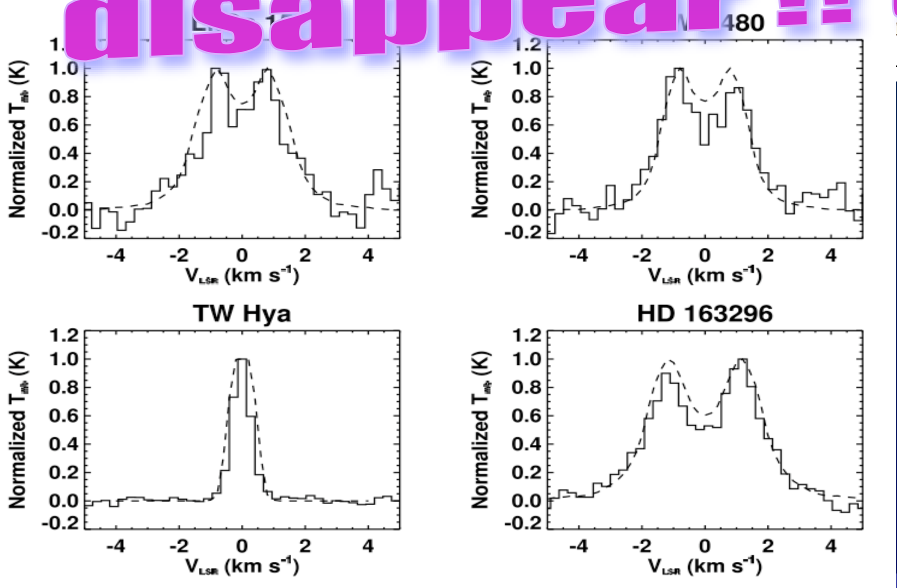
[illegible] ts indicate not observed. When a line is not detected, a 2σ upper limit on T_{mb} in a 0.3 km [illegible] computed and the same profile as the ^{13}CO $J=3\to2$ line is assumed. The beam size (HPBW) is comp[illegible]
IRAM-30m usin[illegible]
taken from Jans[illegible]
collisional rate [illegible]
Observation of [illegible]

Thi et al.: Molecules in protoplanetary disks



Species	$X = N/N(H_2)$ LkCa15	TW Hya	HD 163296	MWC 480	DM Tau This work[a]	DM Tau Dutrey et al.	IRAS 16293-2422[b]
CO	3.4(-07)	5.7(-08)	3.1(-07)	6.9(-07)	9.6(-06)	1.5(-05)	4.0(-05)
HCO^+	5.6(-12)	2.2(-11)[c]	7.8(-12)	1.0(-10)	7.4(-10)	7.4(-10)	1.4(-09)
$H^{13}CO^+$	<2.6(-12)	3.6(-13)	...	...	<3.6(-11)	<3.6(-11)	2.4(-11)
DCO^+	<2.31(-12)	7.8(-13)	...	...	...	...	1.3(-11)
CN	2.4(-10)	1.2(-10)	1.3(-10)	1.4(-10)	9.0(-0[illegible]	[illegible]	[illegible]
HCN	[illegible]	1.6[illegible]	<9[illegible]	[illegible]	[illegible].9(-10)	5[illegible]	[illegible]
[illegible]N	[illegible]	[illegible]	[illegible]	[illegible]	...	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.5(-10)	2.4(-10)	6.9(-11)
[illegible]	...	<7.1(-14)	...	...	...	...	1.3(-11)
CS	<8.5(-11)	...	...	...	2.4([illegible]	[illegible]	3.0(-09)
H_2C[illegible]	4.1([illegible]	[illegible]	[illegible]	[illegible]	2.4(-1[illegible]	[illegible]	7.0(-10)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	...	3.5(-10)
[illegible]	[illegible]	[illegible]	...	<1.5(-11)	<5.0(-09)	<2.0(-10)	...
[illegible]	[illegible]11)	<7.8(-12)	...	<1.0(-11)	...	...	...
[illegible]		<4.1(-11)	...	...	...	...	4.4(-09)

At some stage, the gas SHALL disappear !! (When ??)



Chemistry !!

Dynamics !!

Proto-planetary disks : ?Questions (scrambled) ?

- Structure of these disks ?
- What is the dust/gas ratio as a function of time ?
- When does the dust settling/coagulation start ?
- When does the gas phase disappear ?
- Chemistry in these disks ?
- At what ages of the systems are the planets formed ?

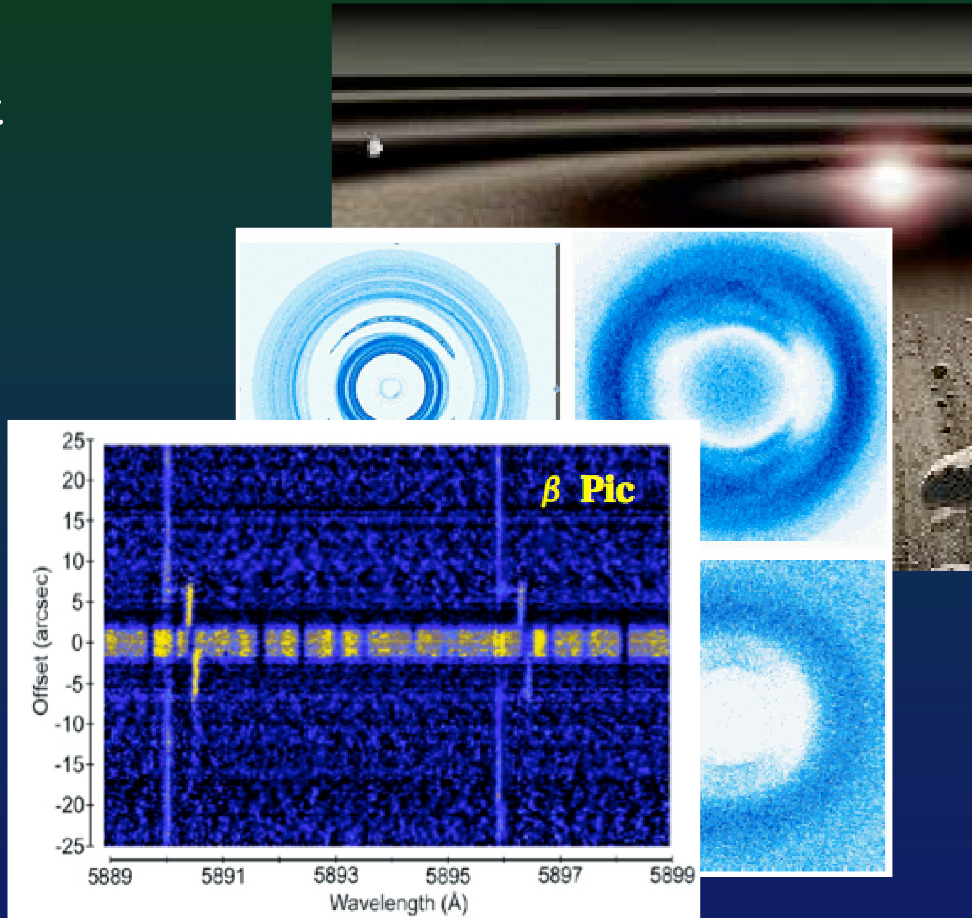
Debris disks

Debris disks

- Believed to be 2nd generation dust (only ?) disks, result of intense processes of fragmentation/evaporation of planetesimals

- Disk geometry is probably structured by planets (grav. resonances) ➡ indirect method of planet detection

- Gas phase ?



Resonance Na I doublet lines at 5990 and 5996 Å
Olofsson et al. 2001

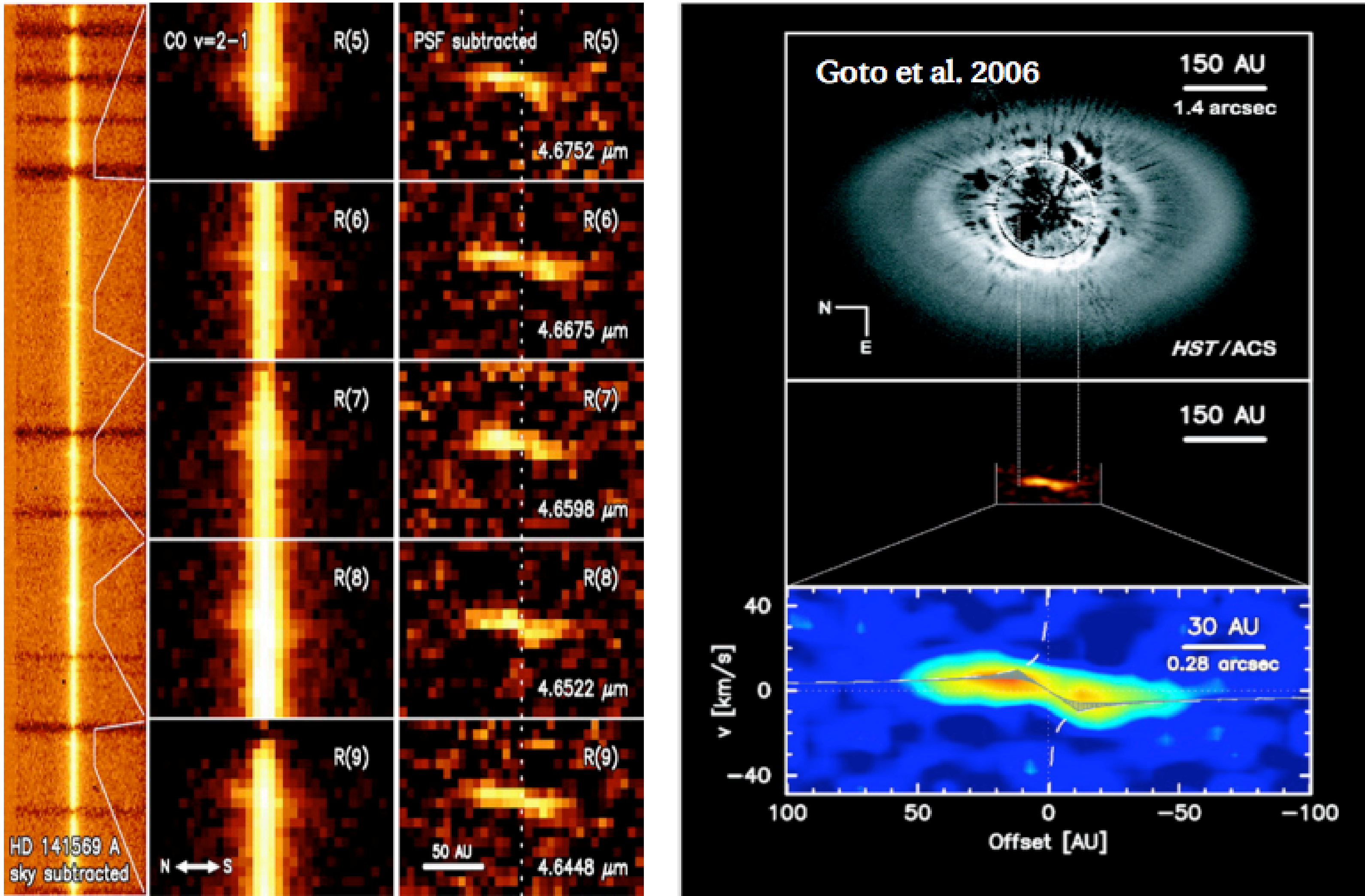
Questions

- Formation of these disks ?
- Gas phase ?
- Continuous transition between proto-planetary and post-planetary disks ?

Transition disks

Transition disks

Dynamics of the inner disk !!!



What shall be done from Antartica in the sub-mm range ?

1) The obvious :

Continuum osb . (dust phase) : Rout, dust sizes vs time, mass of the disks vs time.

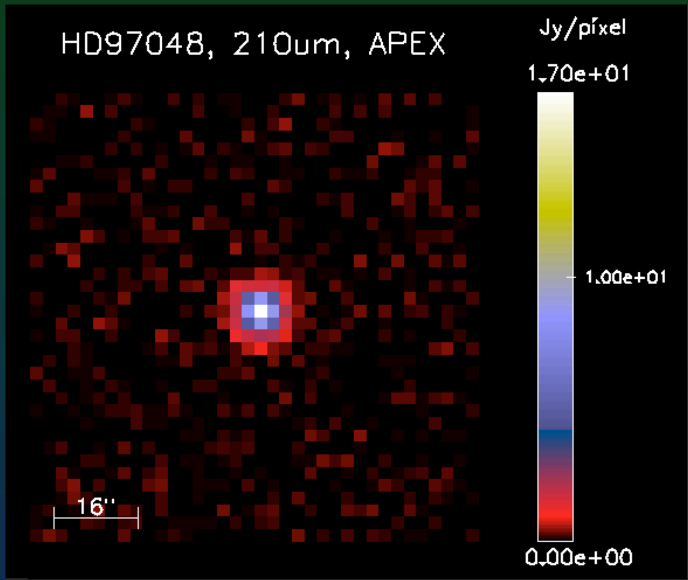
Lines observations : gas content vs time, dynamics, (?? gas disk == dust disk ??)

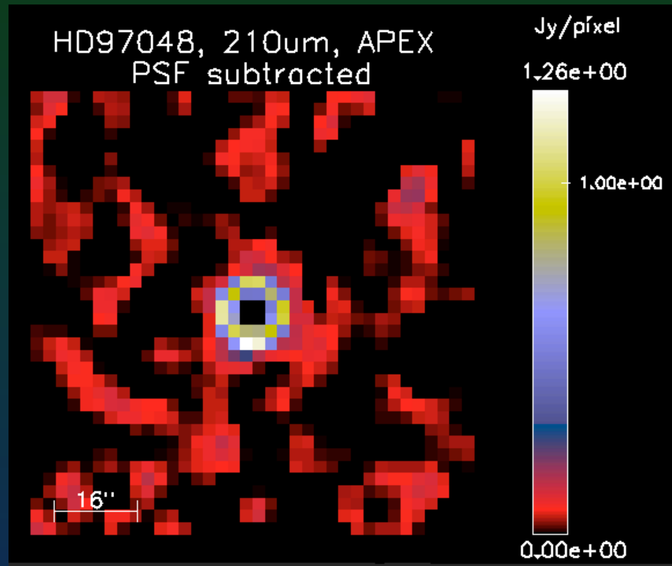
2) The less obvious :

1) Continuum : push limits in sensitivity to get "model/assumption free" physical quantities (T_{ex}, rel.abundances, ...)
Try resolving these disks (deconvolution needs sensitivity !)

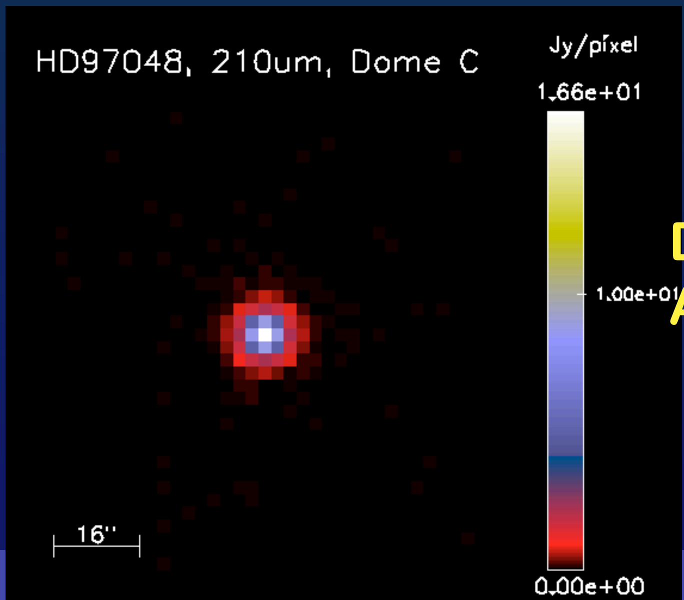
Lines observations :
better sensitivity ➡ better dynamics and comprehensive chemistry

2) The less obvious :

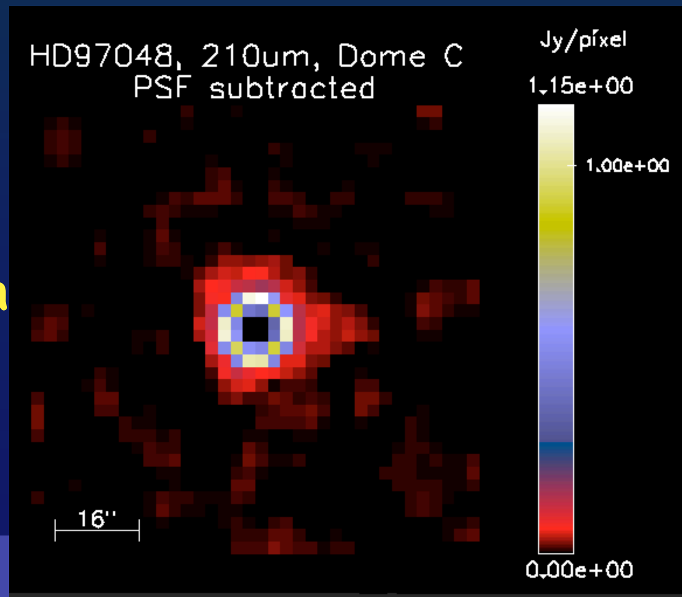




Chajnantor
APEX antenna



Dome C
APEX-like antenna



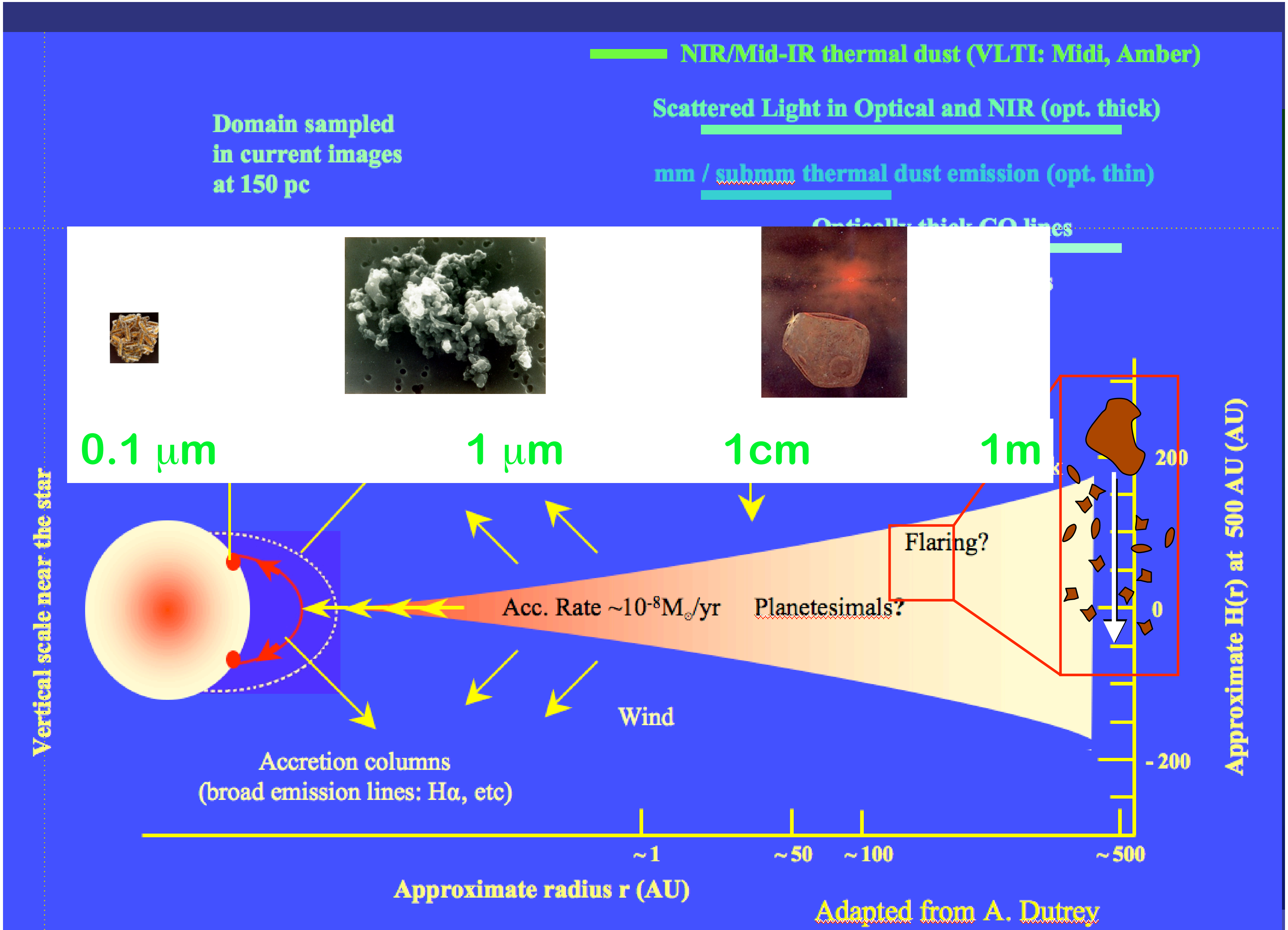
Conclusions/perspectives

Disks science can benefit a lot from Dome C submm observations :

- stability ➡ homogeneous/consistant datasets
- sensitivity allows to proceed a step forward in comprenhension of disks (physical conditions for planets formation)

Do not forget near and mid-infrared observations that can benefit a lot from Antartica conditions (warm gas, spectroscopy) !!!

The End


NIR/Mid-IR thermal dust (VLTI: Midi, Amber)
Domain sampled
in current images
at 150 pc
Scattered Light in Optical and NIR (opt. thick)
mm / submm thermal dust emission (opt. thin)
0.1 μm
1 μm
1cm
1m
200
0
- 200
Flaring?
Acc. Rate ~10-8M☉/yr
Planetesimals?
Wind
Accretion columns
(broad emission lines: Hα, etc)
Vertical scale near the star
Approximate H(r) at 500 AU (AU)
~1
~50
~100
~500
Approximate radius r (AU)
Adapted from A. Dutrey