# Depressing thoughts about interstellar dust...

*don't let'em bring you down!*

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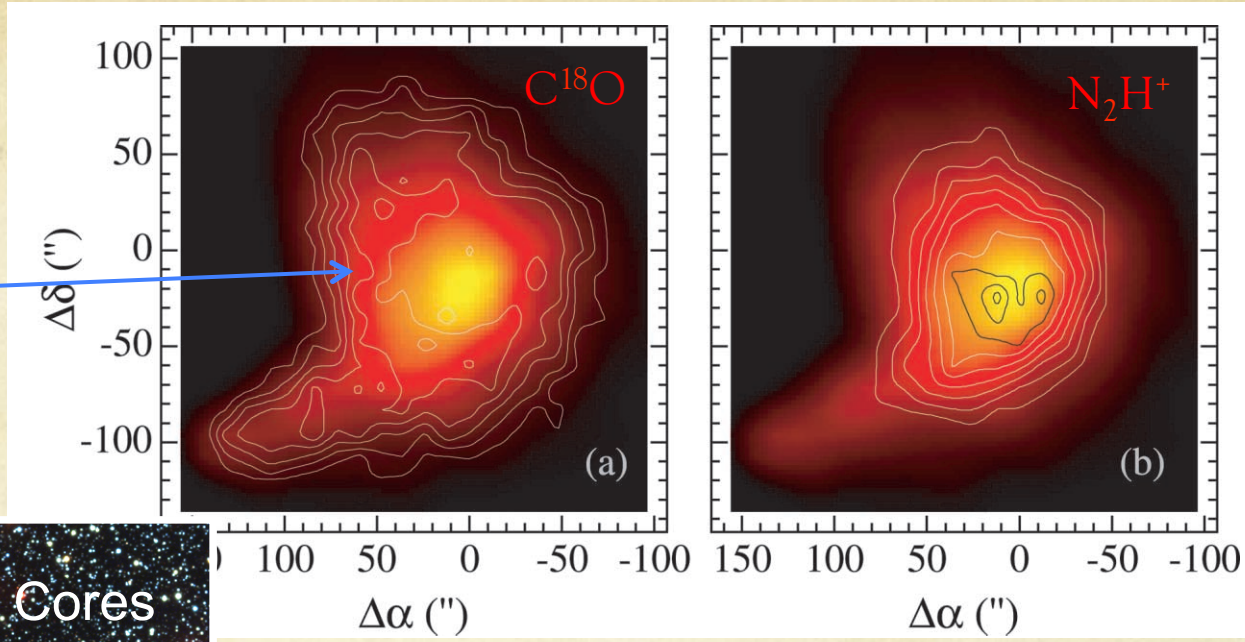
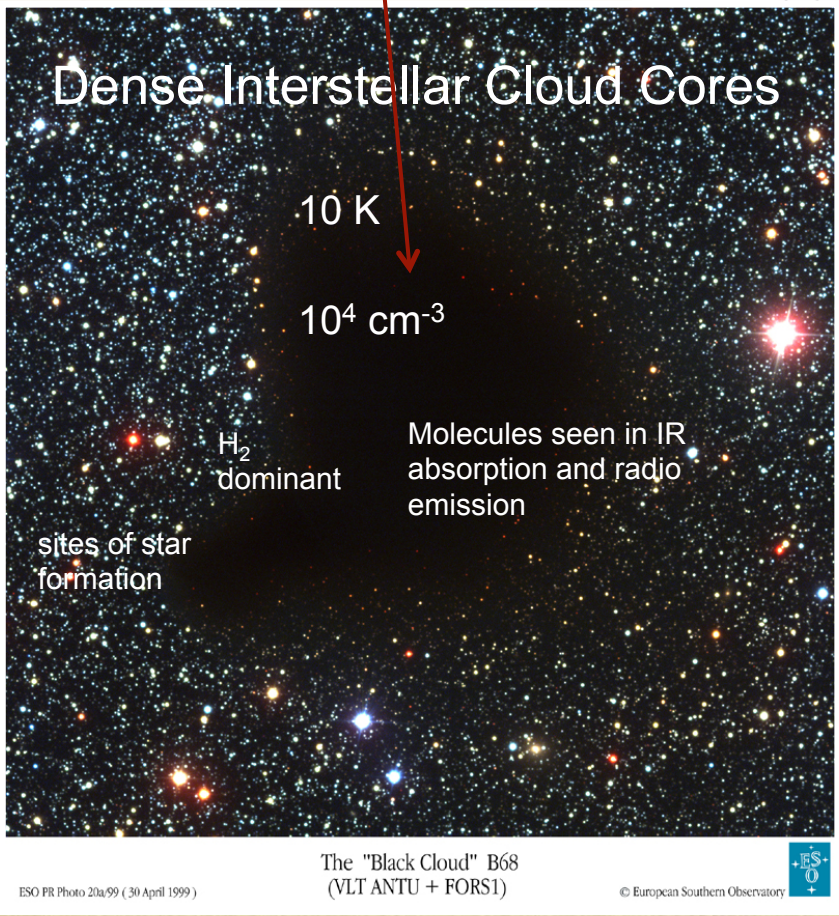
# B68

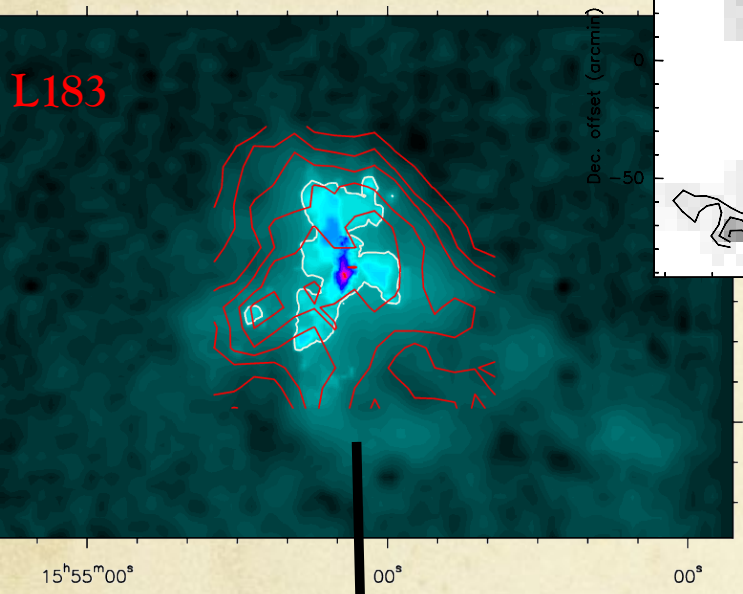


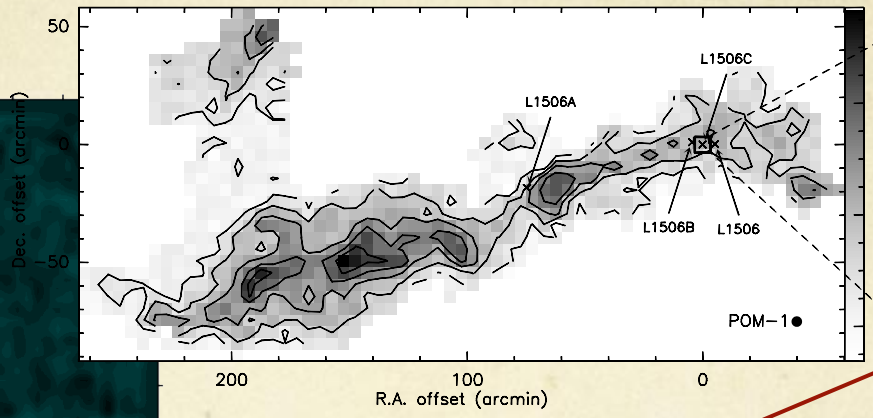



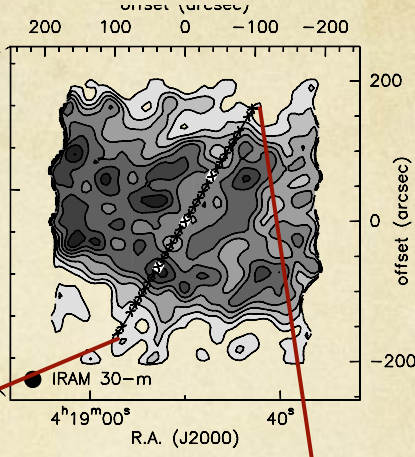

Clouds are made of gas and dust

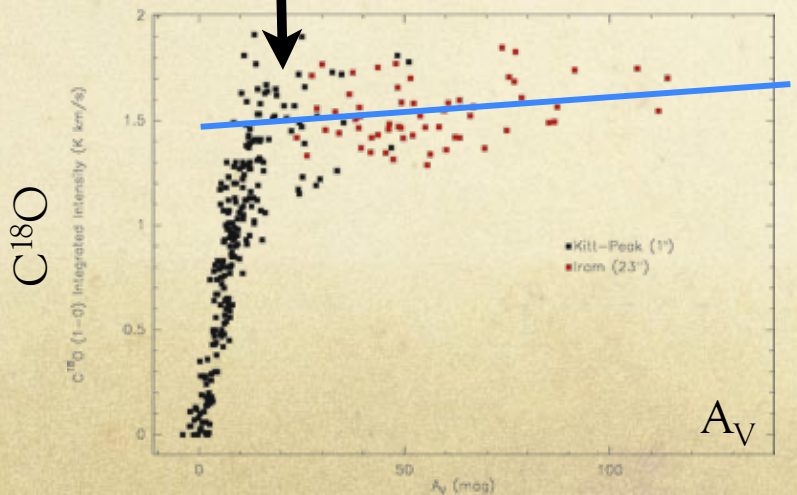
# Tracing the cloud mass is difficult!

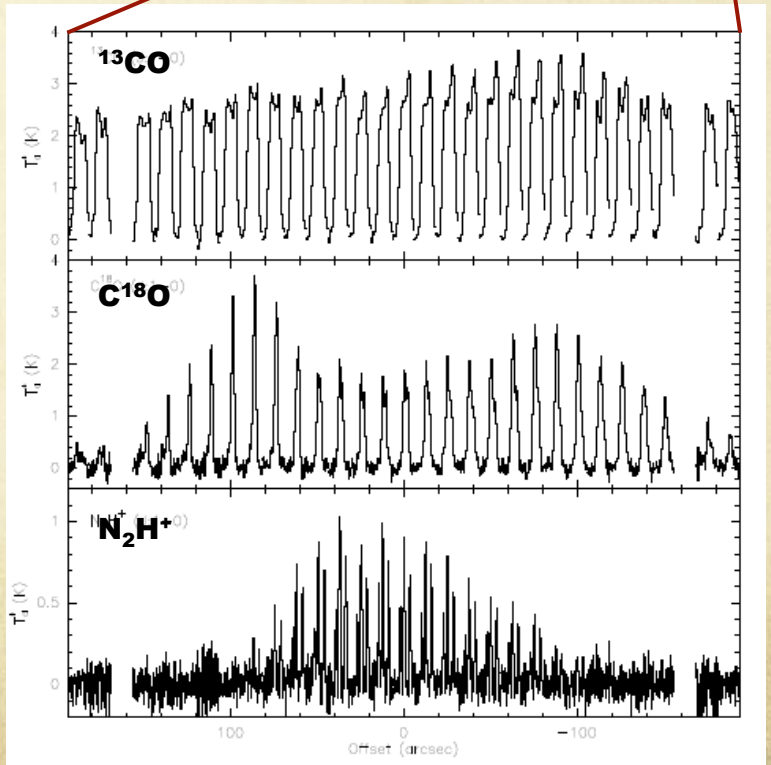
~~$H_2$~~, ~~He~~, CO,...



# What about dust ? Let's try...

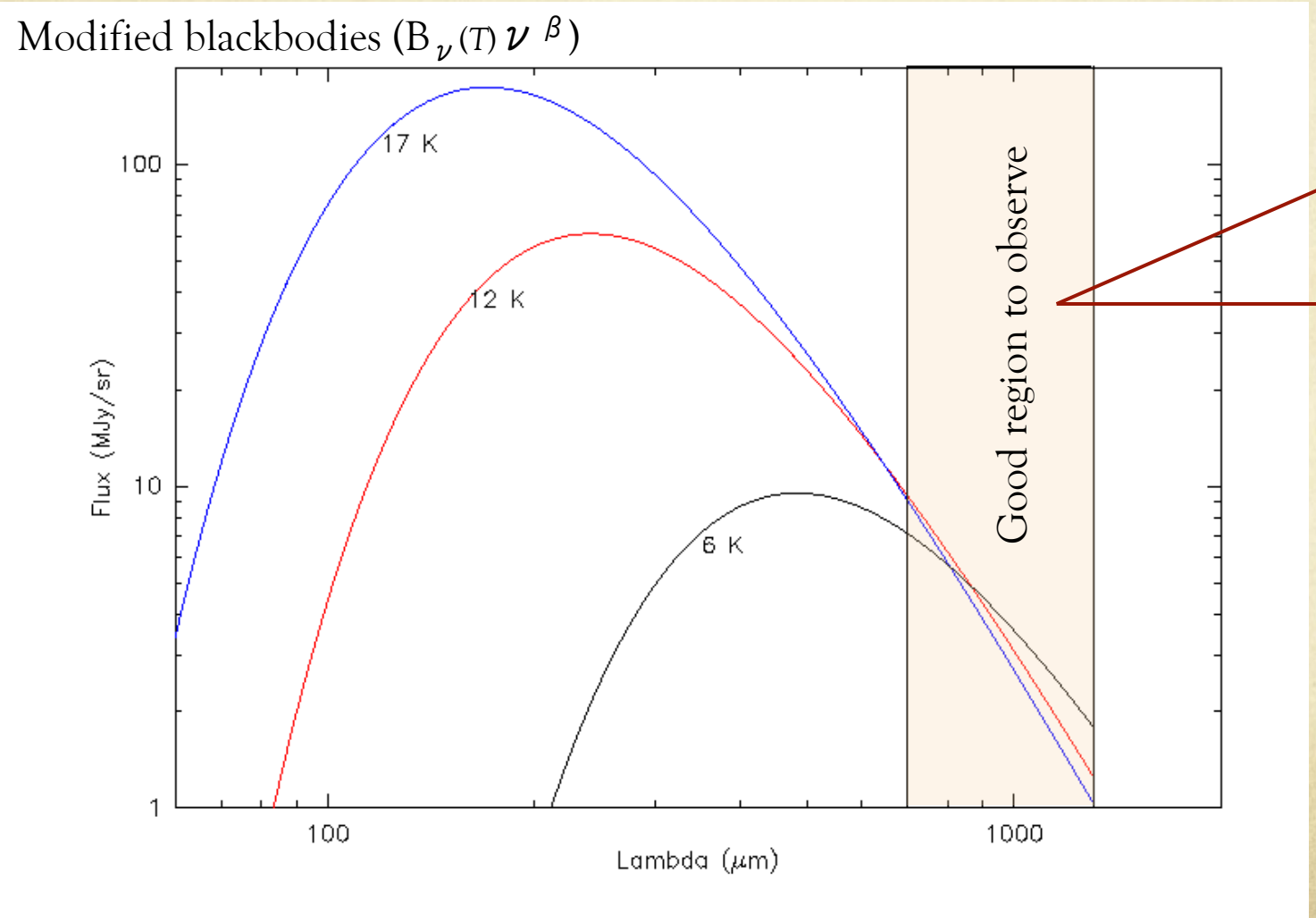
- Absorption
- Scattering

} Extinction

- Emission

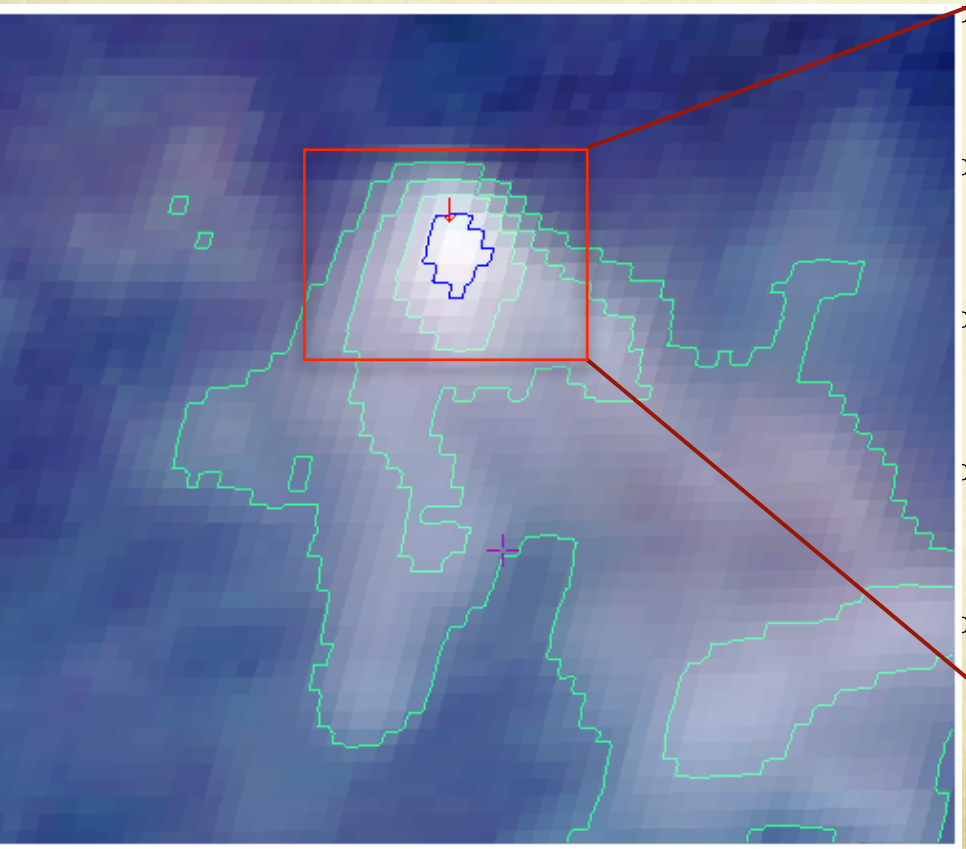
Is it easy ? We'll find out

# Dust in emission

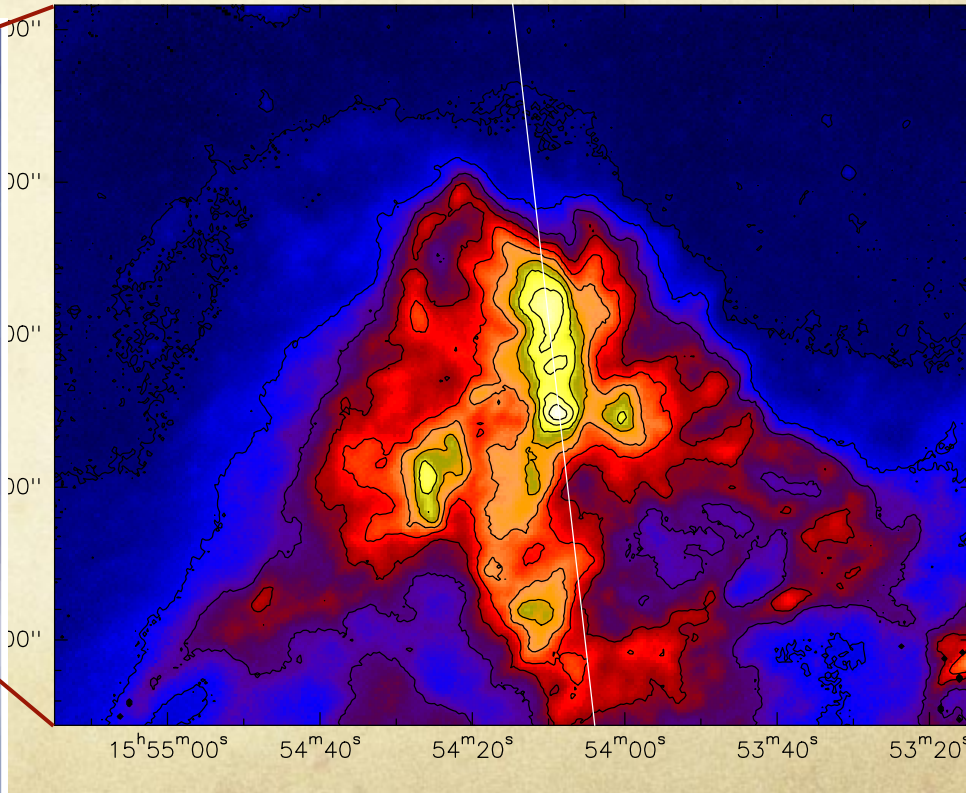


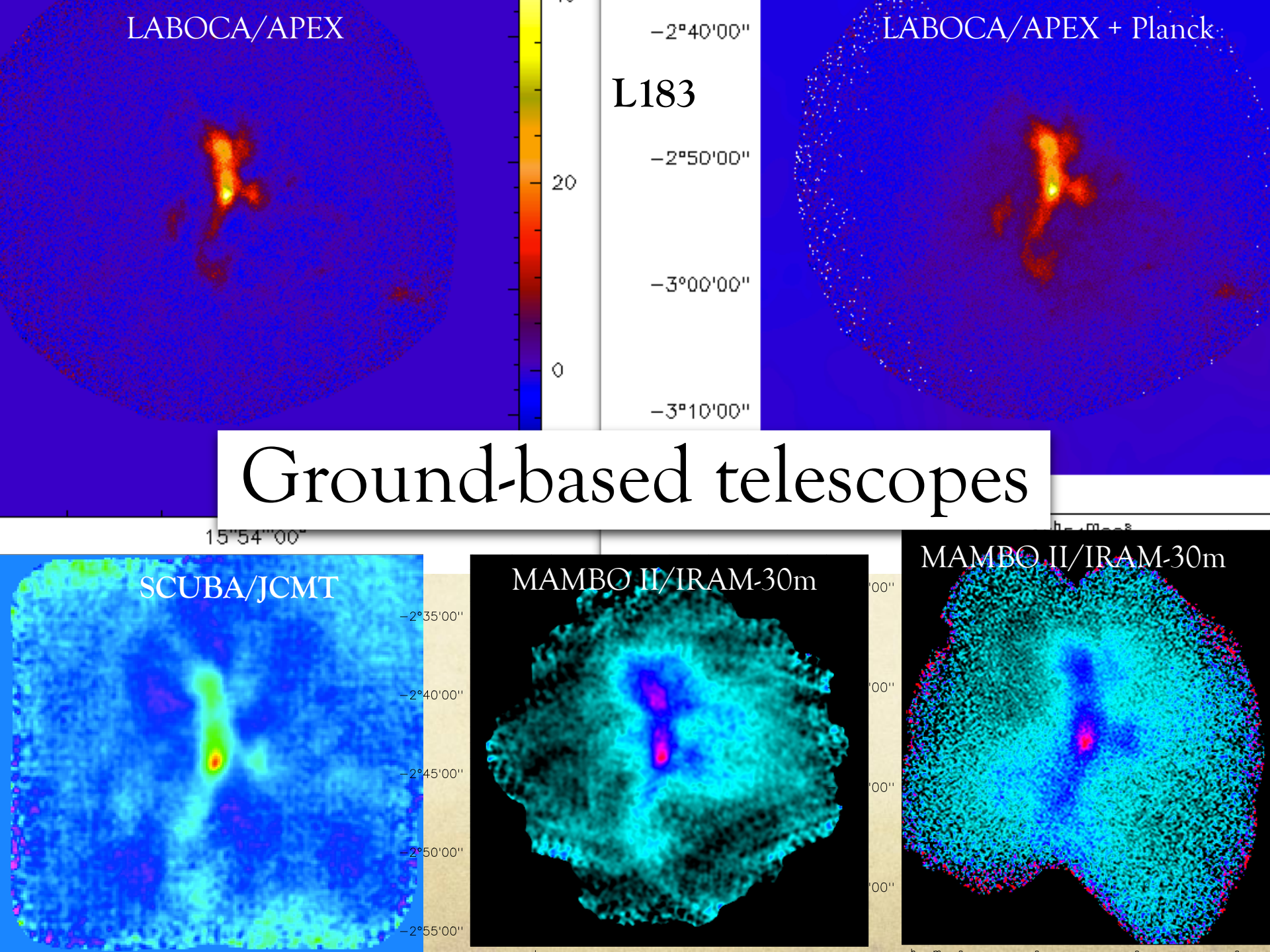
# Planck, sensitive, all sky, several wavelengths but ~5’ resolution

L183, seen by Planck, HFI



L183, seen by Herschel, SPIRE




LABOCA/APEX
L183
LABOCA/APEX + Planck
Ground-based telescopes
SCUBA/JCMT
MAMBO II/IRAM-30m
MAMBO II/IRAM-30m

# Ground based telescopes

- Filtering out the large scales (2' ~ 8')
- reconstruction : garbage in, garbage out
- interpretation not easy :

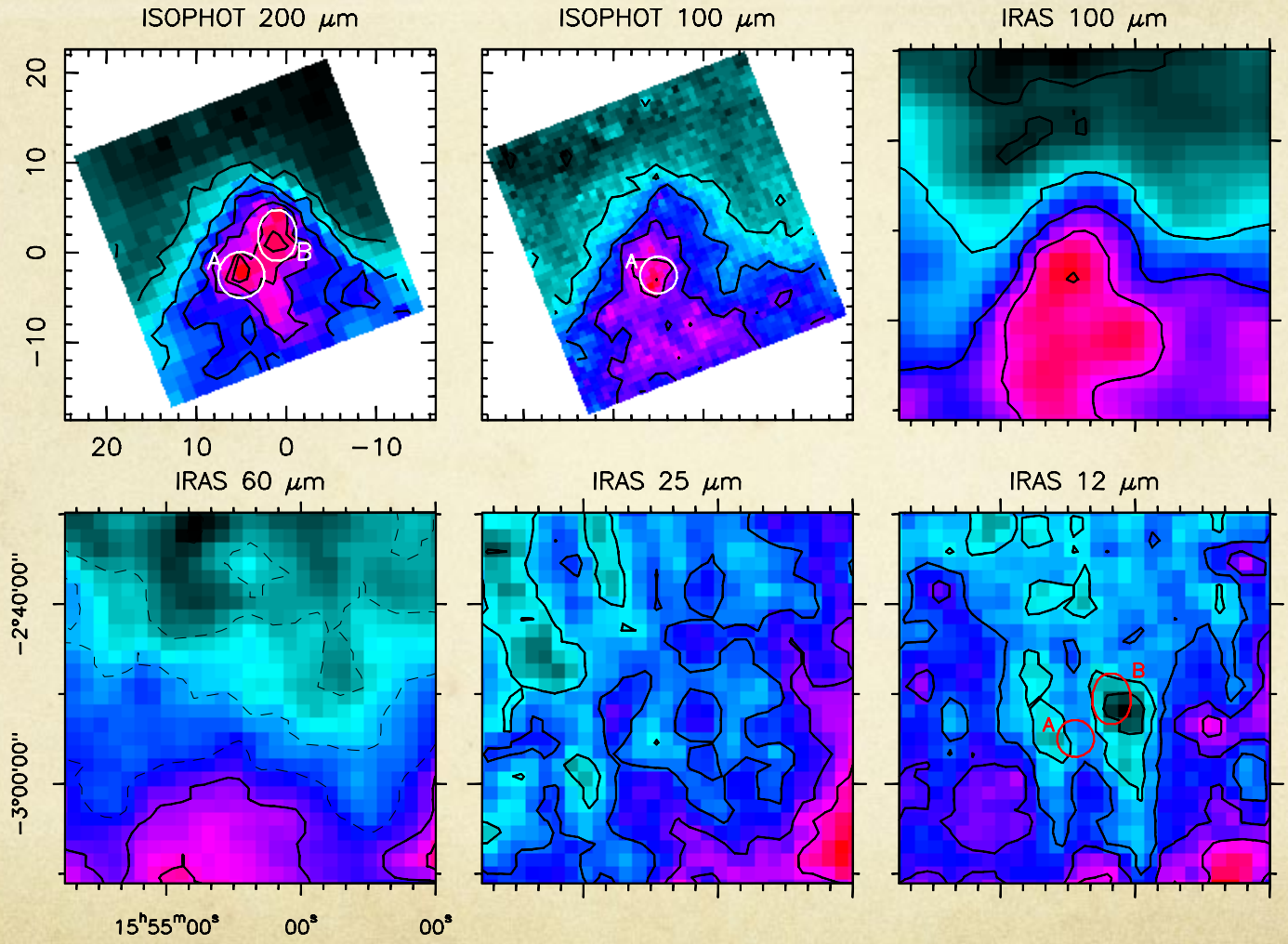
$$I_\nu = B_\nu(T) \times \tau_\nu$$

$$\tau_\nu = \kappa_\nu \mu m_H N(H_2)$$

$\mu = 2.33$, $m_H = 1.67 \times 10^{-24}$ g, $\kappa_\nu$ = ?? 0.005 – 0.01 $cm^2/g$

T = dust temperature = wild guess... + gradient

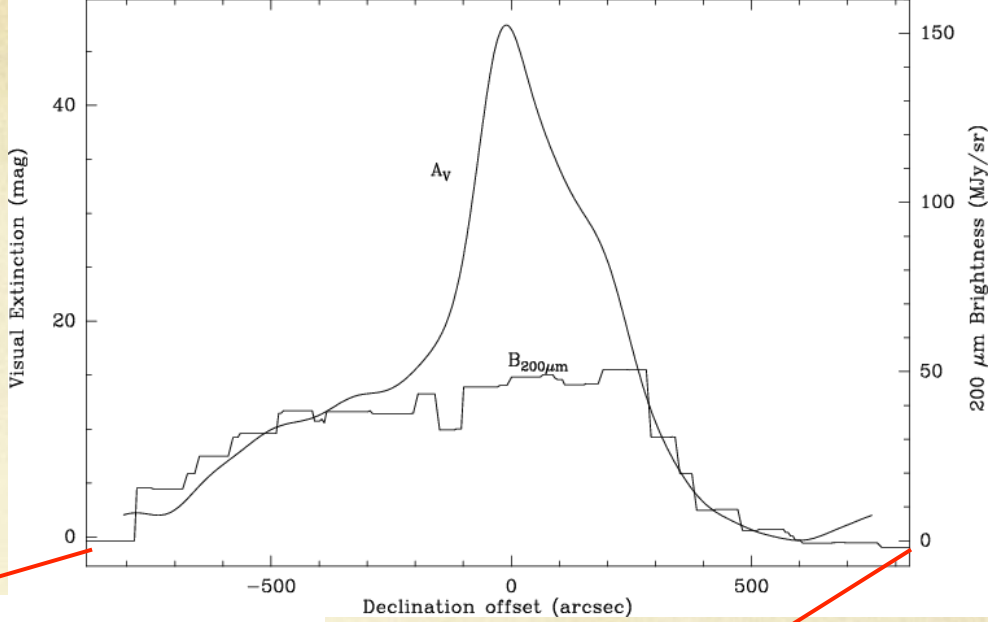
# Satellites then ?

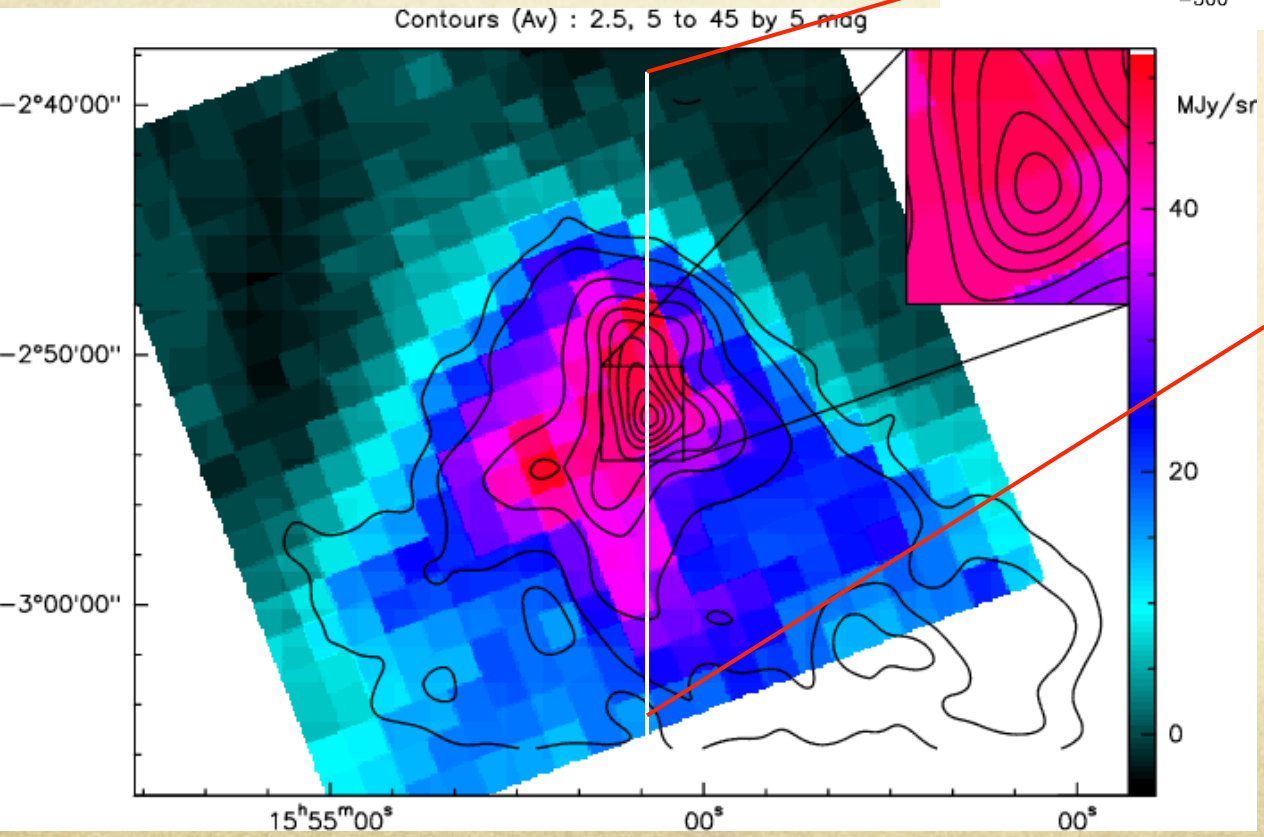



IRAS (prehistoric!) : 5’ resolution, 5% of the dust (100 μm)

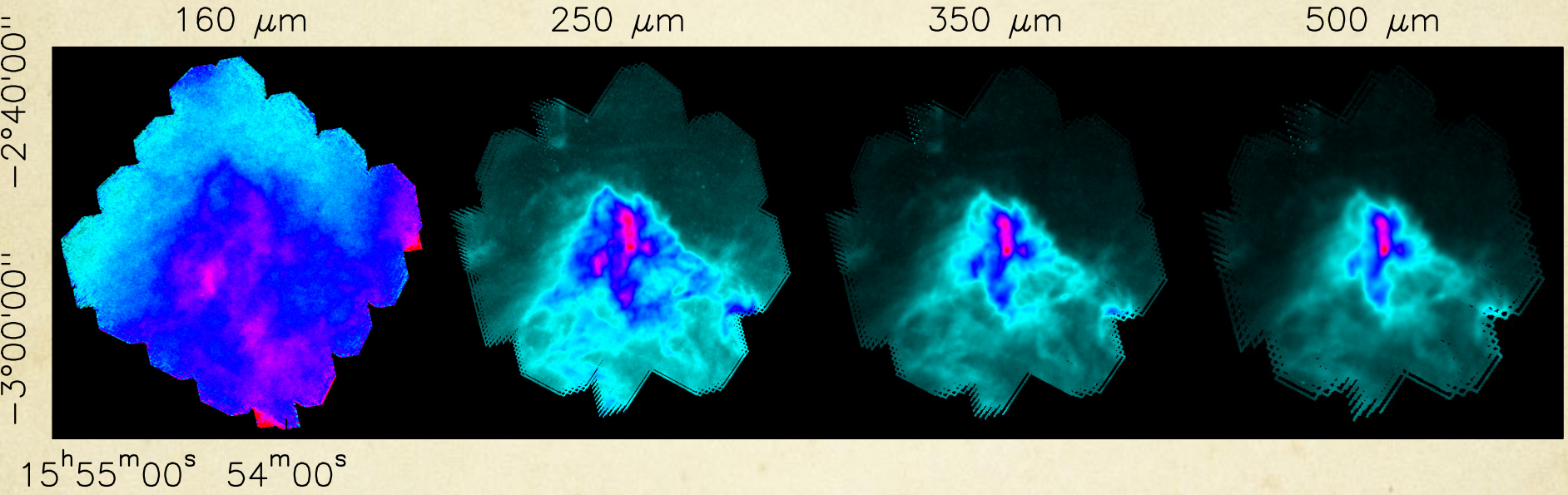
# ISO / ISOPHOT (200 μm, 90”)

L183



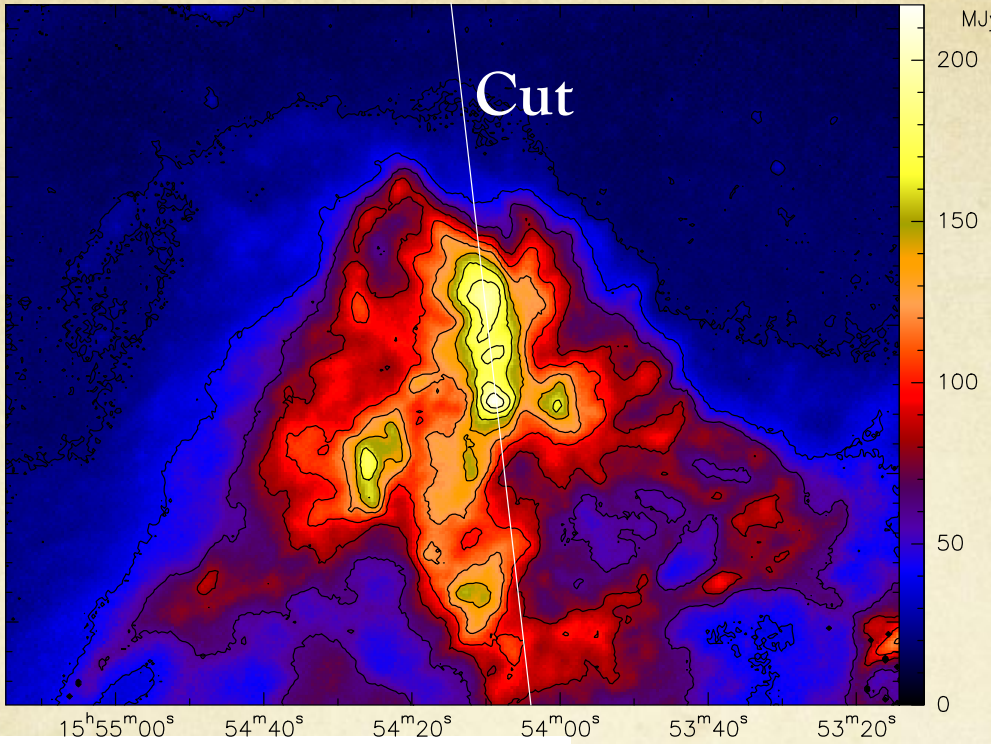



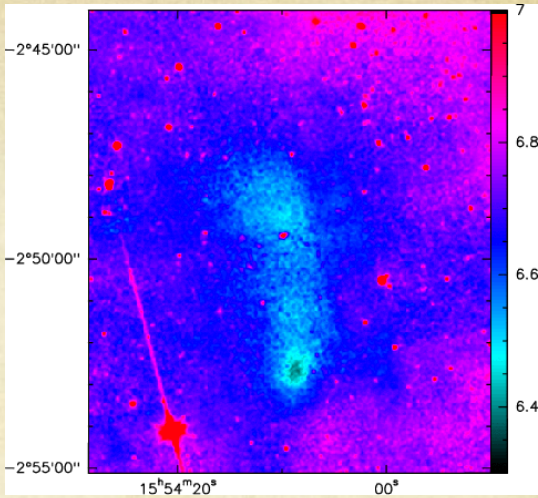
# Herschel : 70 – 500 µm!
# Yes, yes ? No...



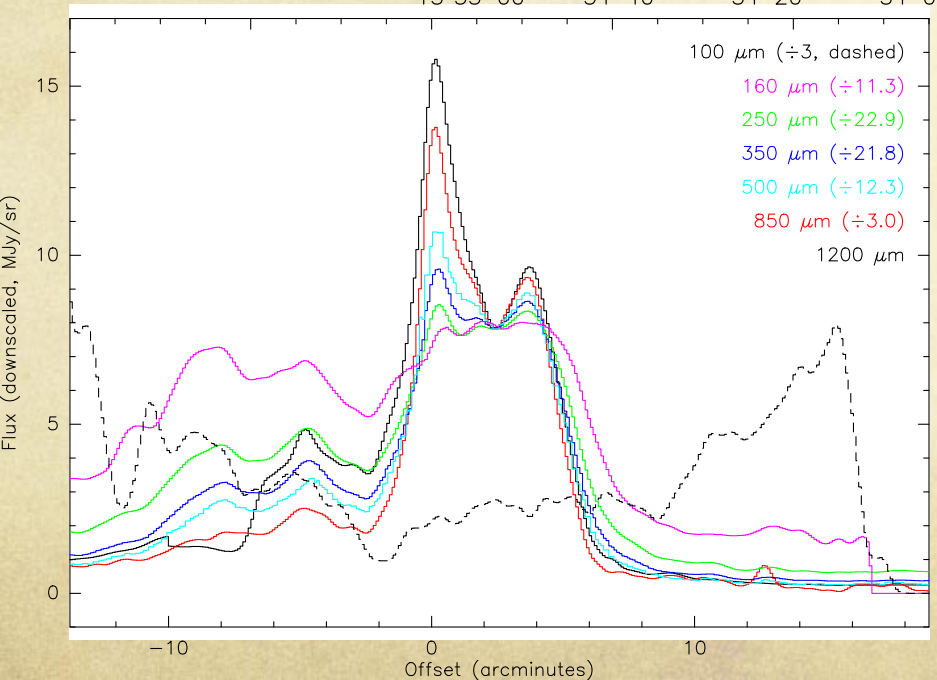

- 10 K dust peaks at 300 µm
- 6 K dust peaks at 500 µm
- So SPIRE the perfect tool to characterize cold dust ? Not exactly

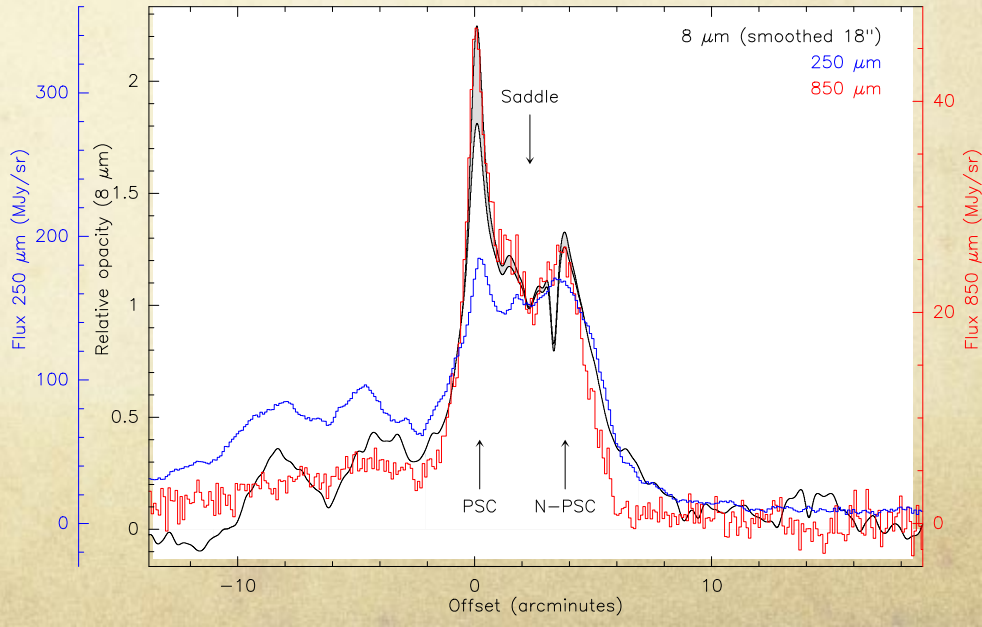
# L183 SPIRE 250 μm



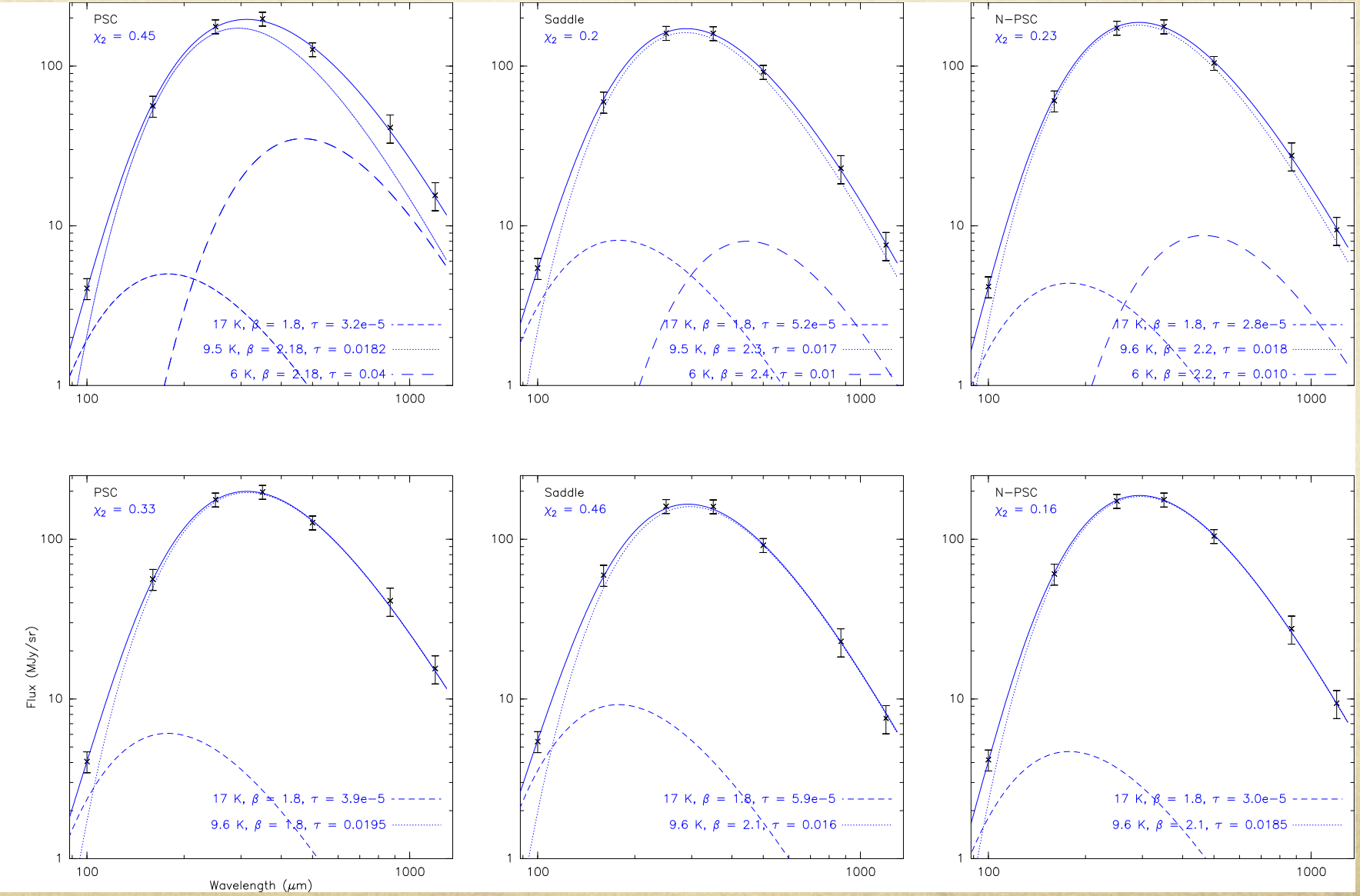




8 μm (zoom)



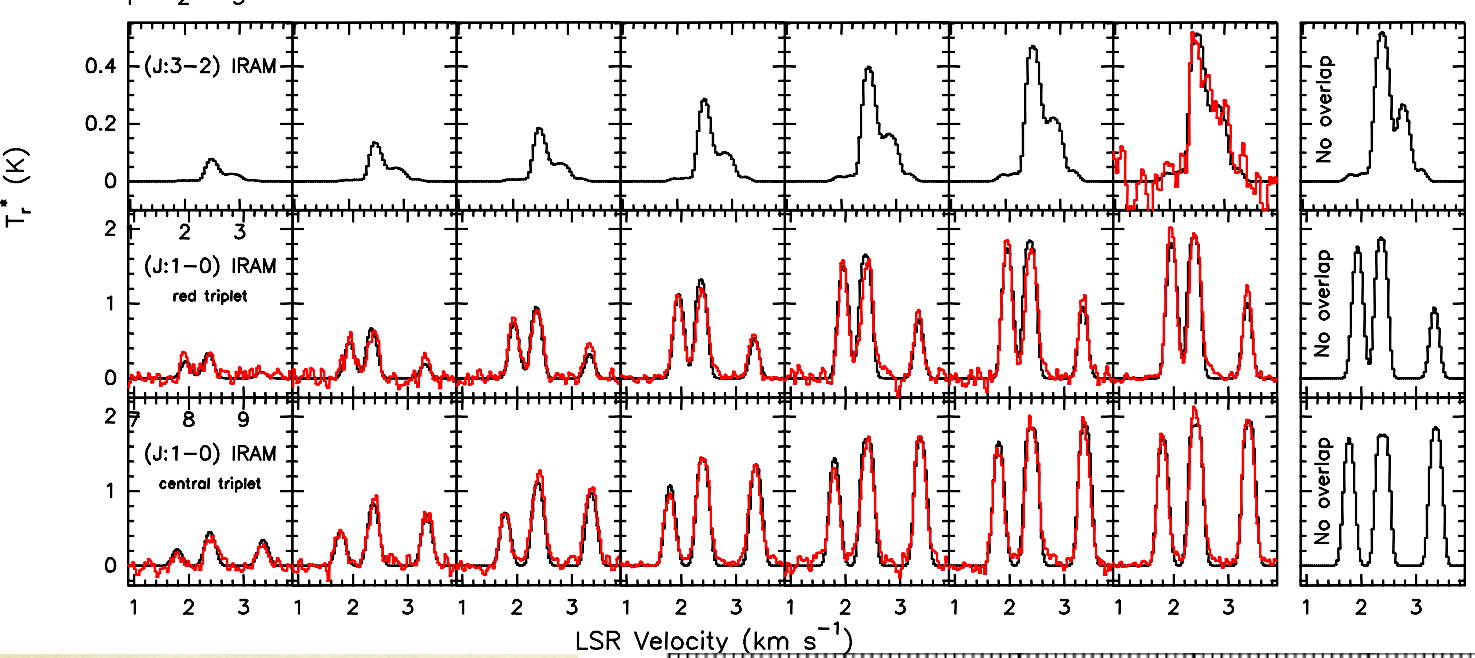



# Fitting Herschel + Laboca + Mambo



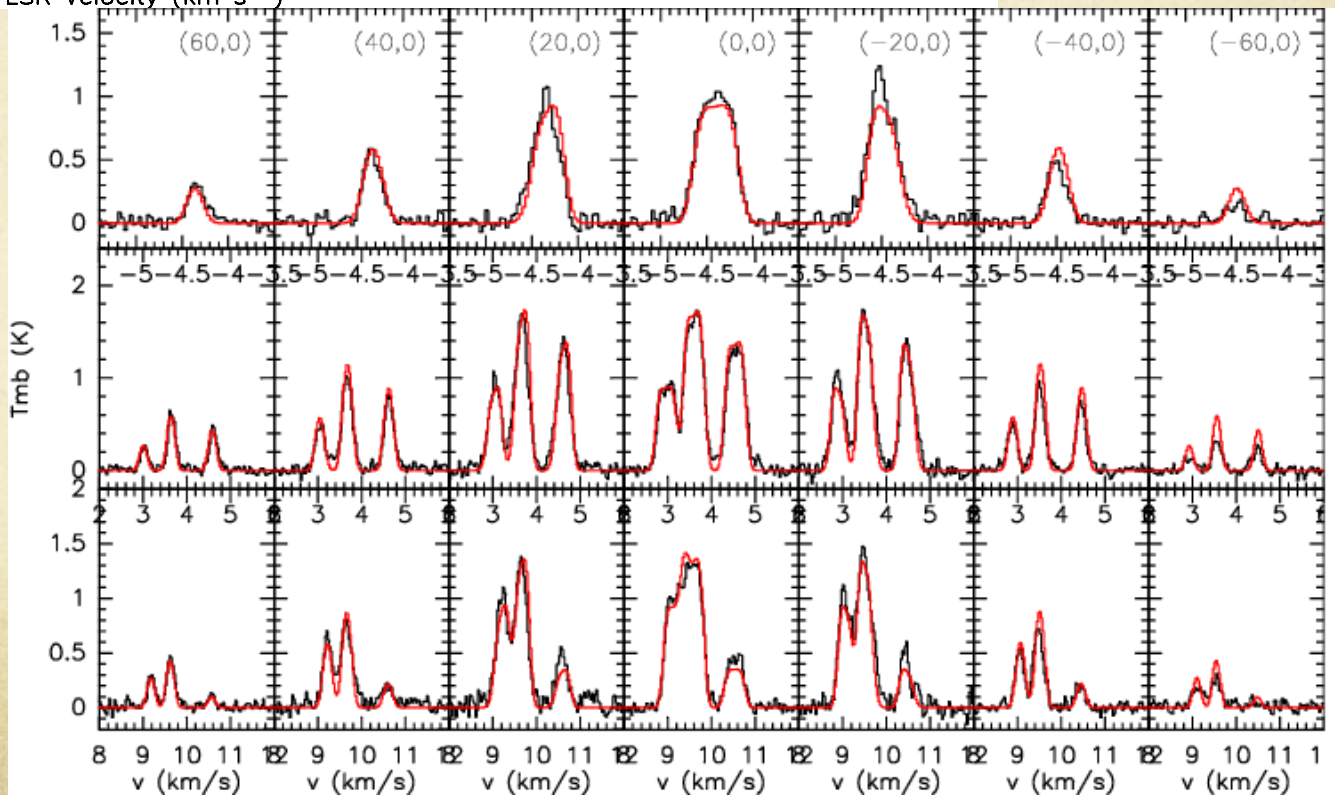
# Analysis of emission alone misses the cold dust

- Single BB → $N(H_2) = 4.5 \times 10^{22}$ cm$^{-2}$
- 2 BB (6 + 9.5 K) → $N(H_2) = 1.35 \times 10^{23}$ cm$^{-2}$
- $N(H_2)_{N2H+} = 1.0 \times 10^{23}$ cm$^{-2}$ + $N(H_2)_{C18O} = 2 \times 10^{22}$ cm$^{-2}$
- $T_{gas}(N_2H^+) = 6$ K, $n(H_2) > 10^6$ cm$^{-3}$
- Roy+ 2014 fit L1689B : 9.8 K, $3.5 \times 10^{22}$ cm$^{-2}$
- $N(H_2)_{N2H+} = 0.8 - 1.1 \times 10^{23}$ cm$^{-2}$, $T_{gas}(N_2H^+) = 6 \sim 8$ K




L183
$N_2H^+$

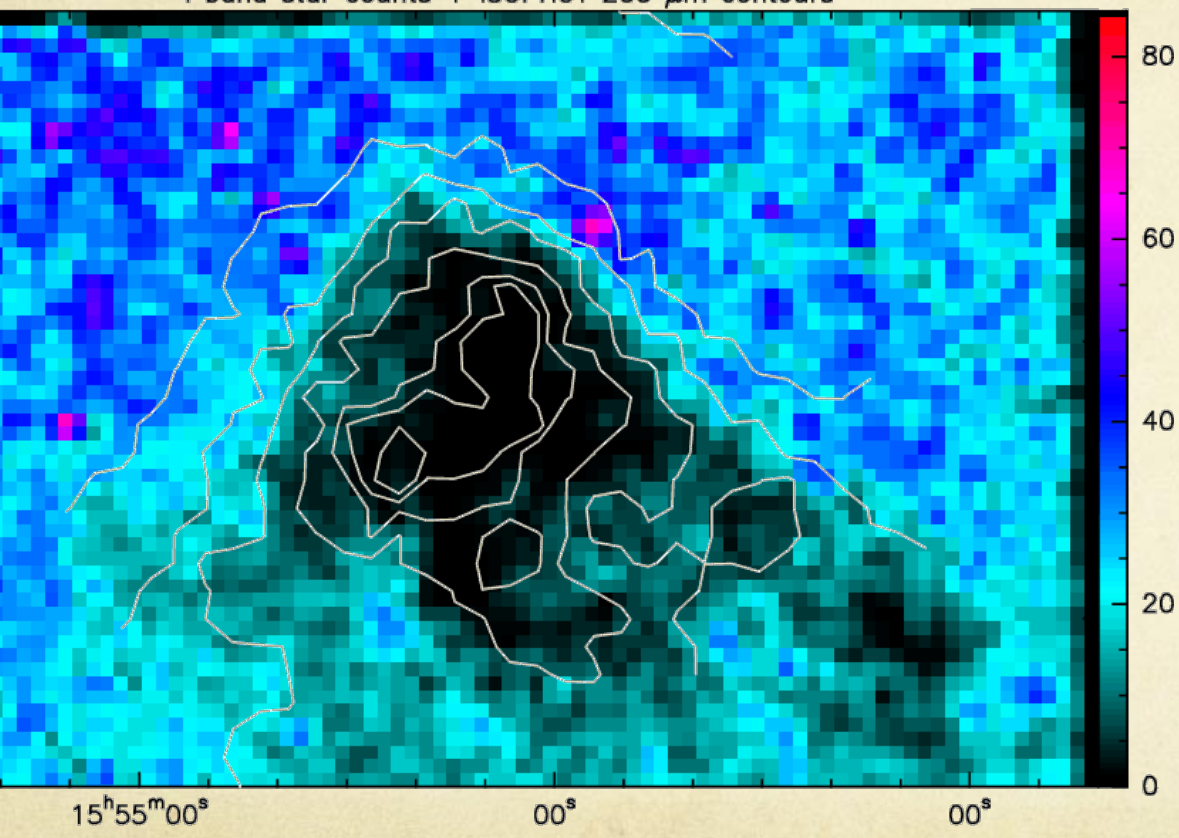
L1689B
$N_2H^+$



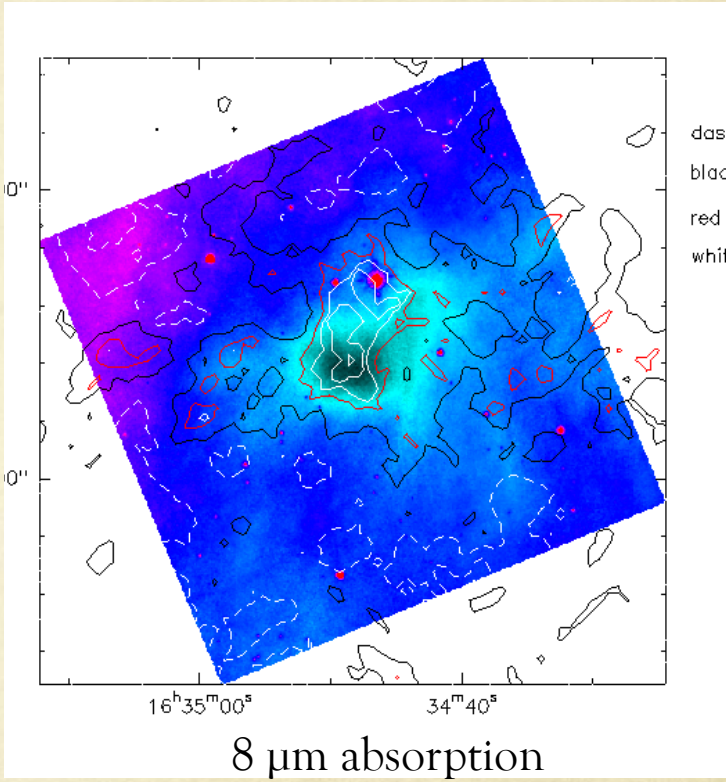
# Let's try *absorption*, then ? *not* $f(T_{dust})$ !!!

- Star counts ? Noisy (1 star / cell !!) but can be useful

L183



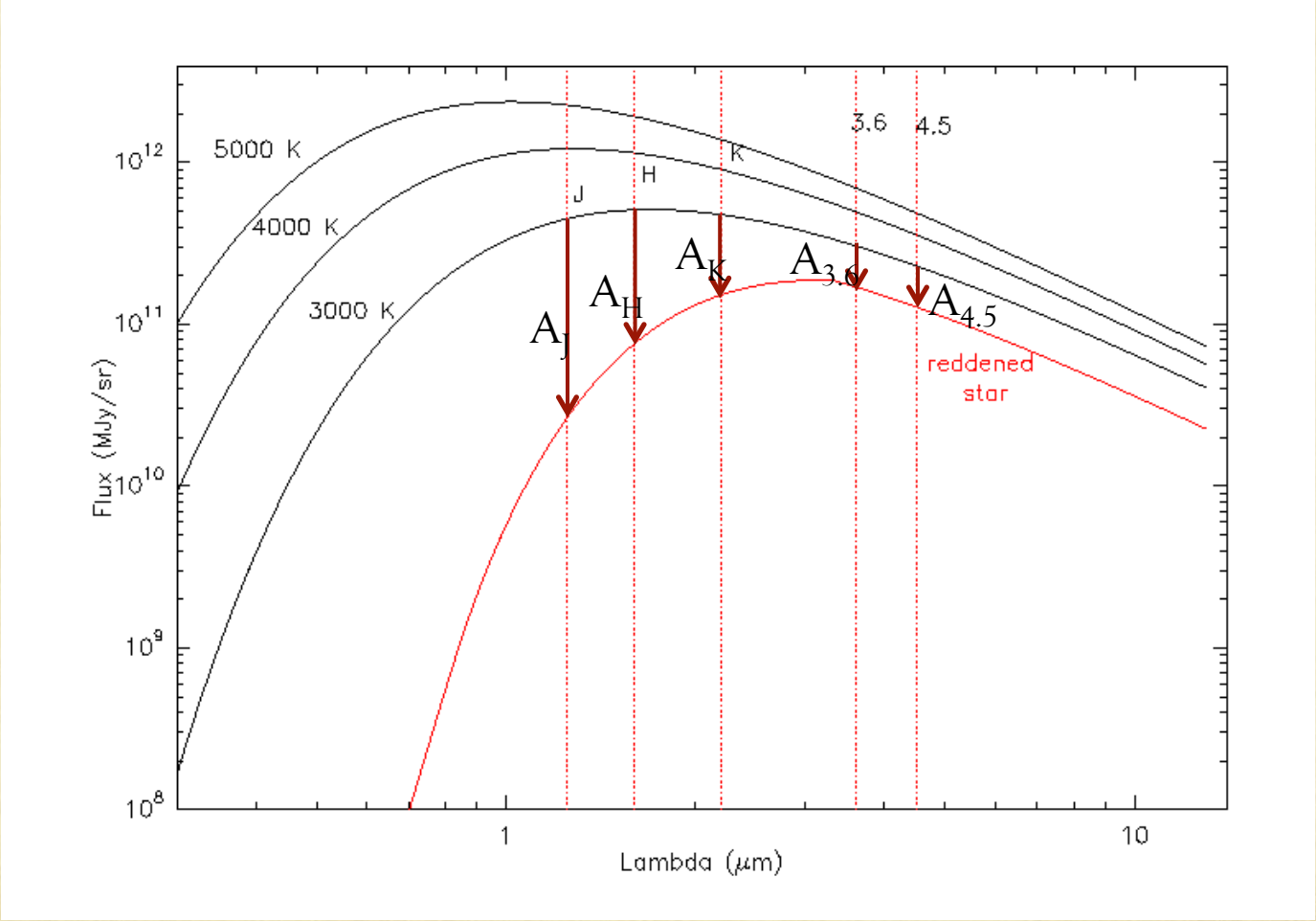

L1544




8 μm absorption

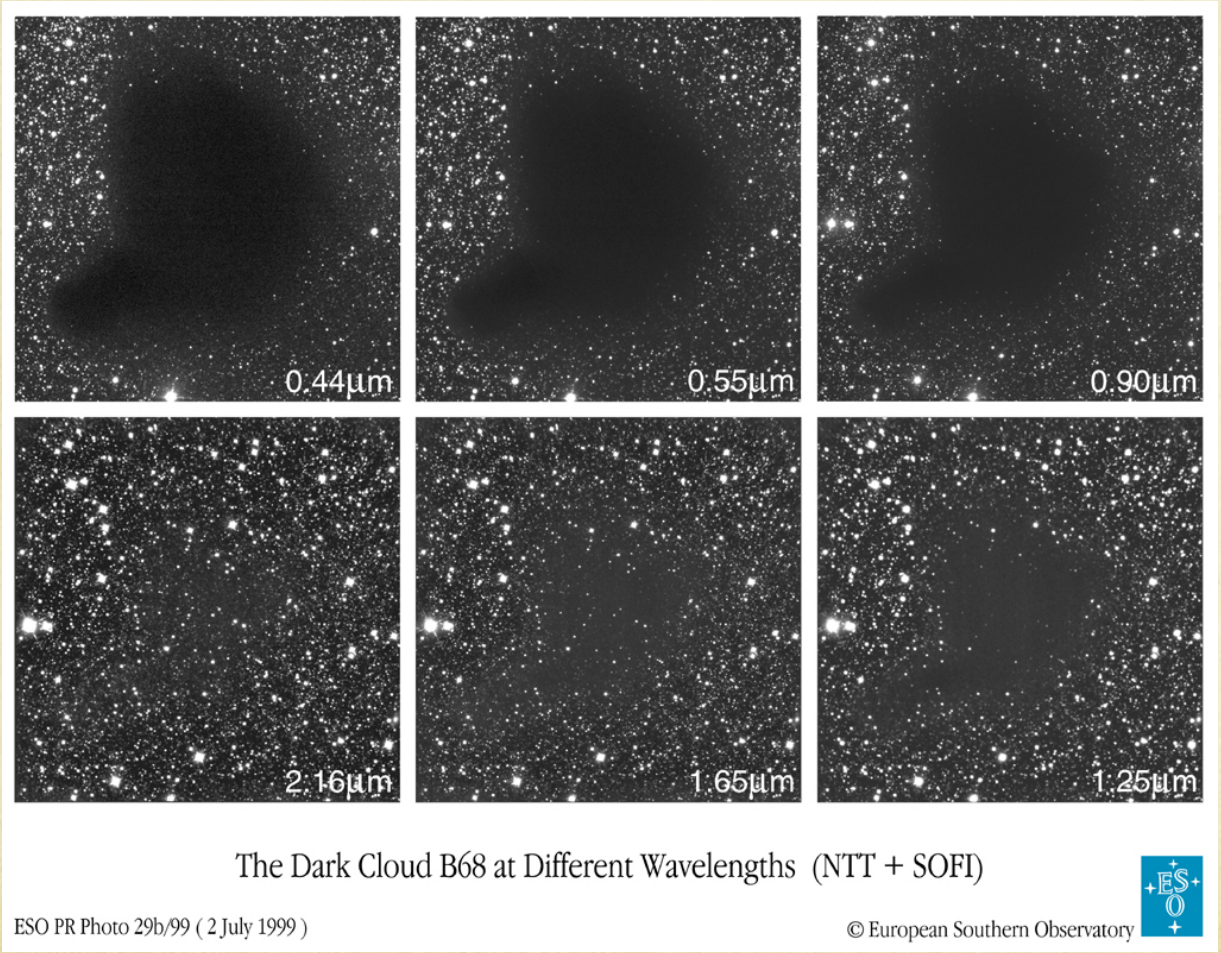
$$A_V = \left(\frac{1}{a}\log\frac{1}{D}\right) \times \left(\frac{A_I}{A_V}\right)^{-1} + \mathcal{Z}_{\rm cnt}$$

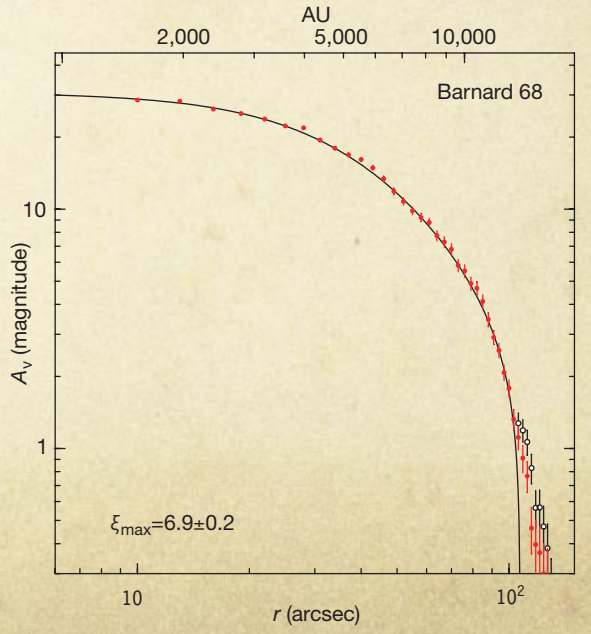
# Reddening (Lada's NICE method)




$$A_V = \left( \frac{A_H}{A_V} - \frac{A_{K'}}{A_V} \right)^{-1} \times (H - K') + \mathcal{Z}_{\mathrm{col}}$$

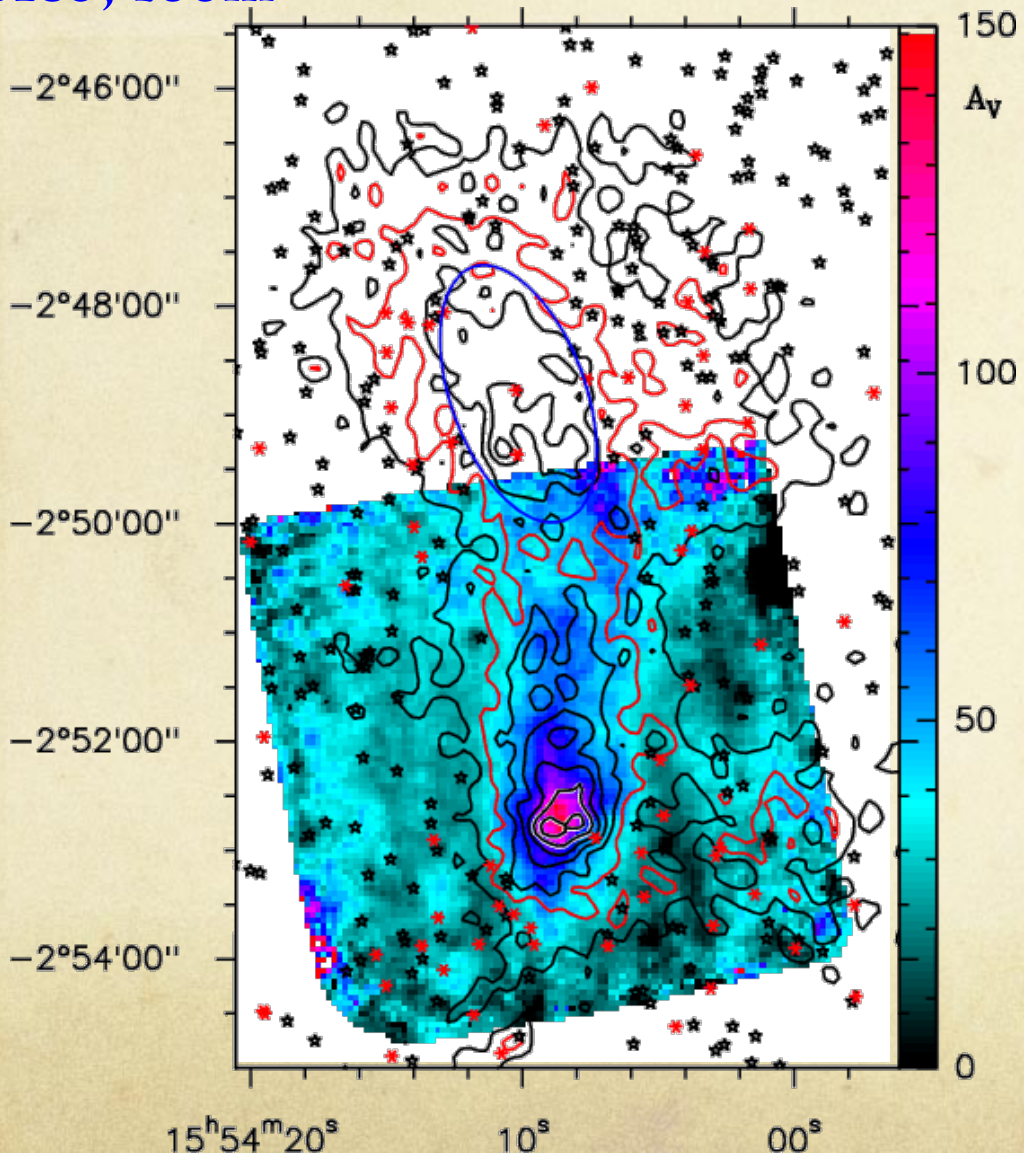
# Less noisy... but requires huge sensitivity in H band or many stars !



# Clouds outside galactic plane and deep extinction → no stars left!

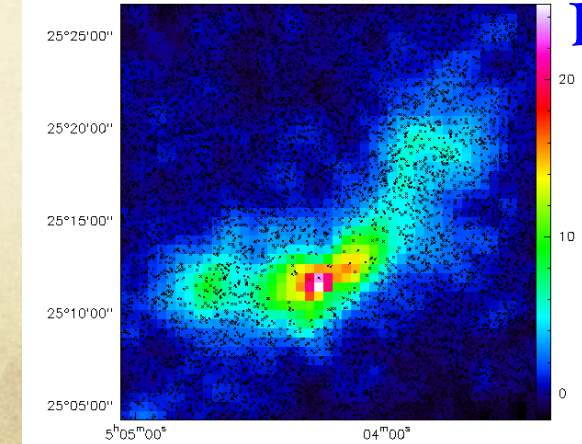
L183, zoom




* H + Ks stars
* Ks stars only
contours : mm dust emission
red contour ≈ 40 mag ($A_V$)
image : ISOCAM 7 µm absorption
3 hours integration

For a « survey », CFHT/WIRCAM
½ hour integration / field
$A_V \leq 20$–25 mag
Not mind blowing...

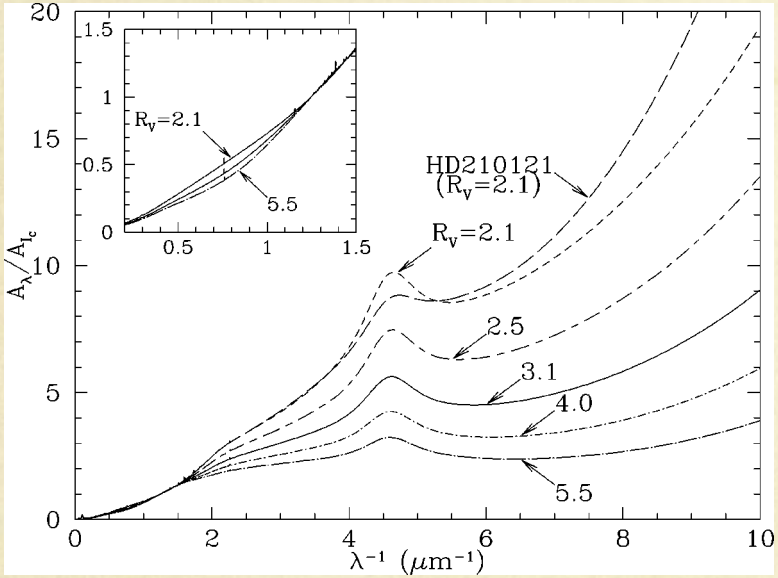
L1544



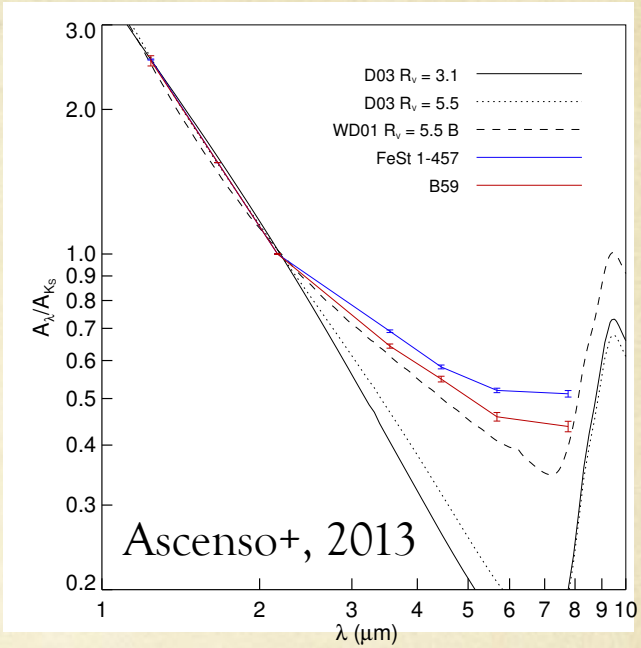
Problem : is E(J-K) or E(H-K) independent of the dust parameters ?

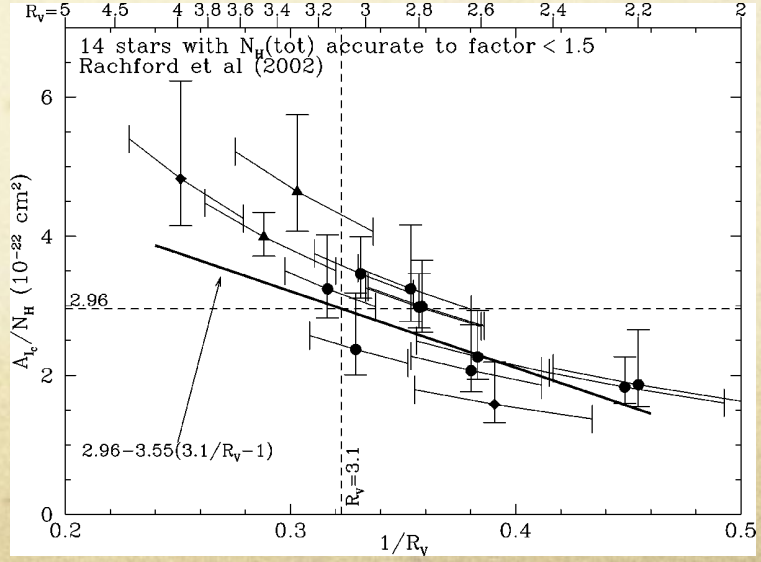
Most people claim they are. To make their life easier ?

1) Reddening law varies from 3.1 to 5.5 (line of sight average !)

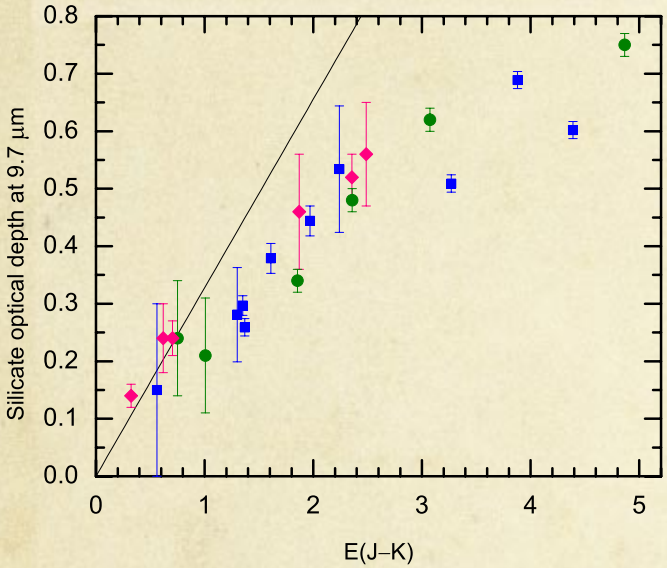



Draine ARAA 2003

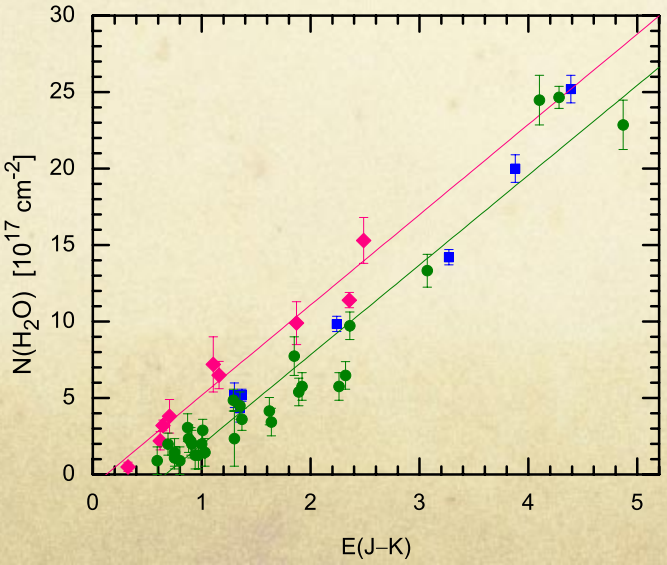


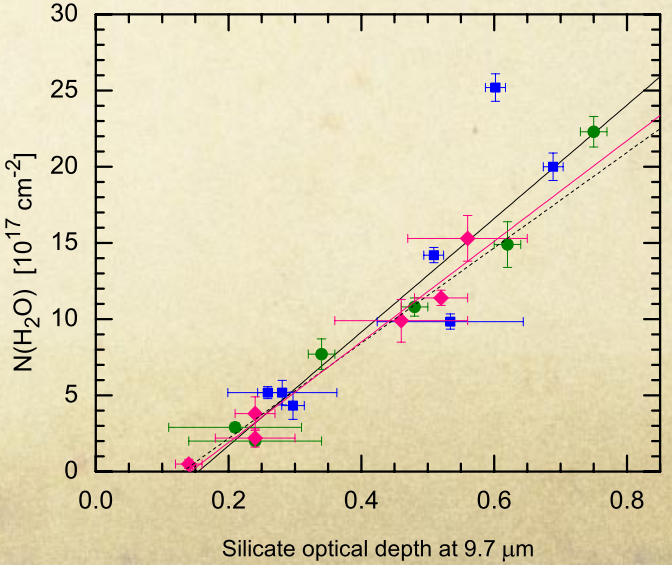



# Chiar+ 2007, Whittet+ 2013 disagree



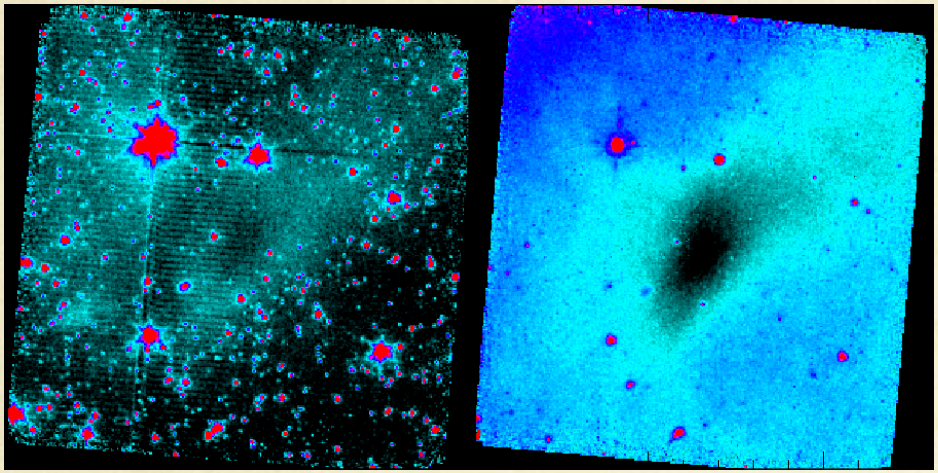

- E(J-K) increases faster than $\tau_{9.7\mu m}$
- If E(J-K) correct → $H_2O$ ice threshold varies
- if $\tau_{9.7\mu m}$ correct → $H_2O$ threshold constant



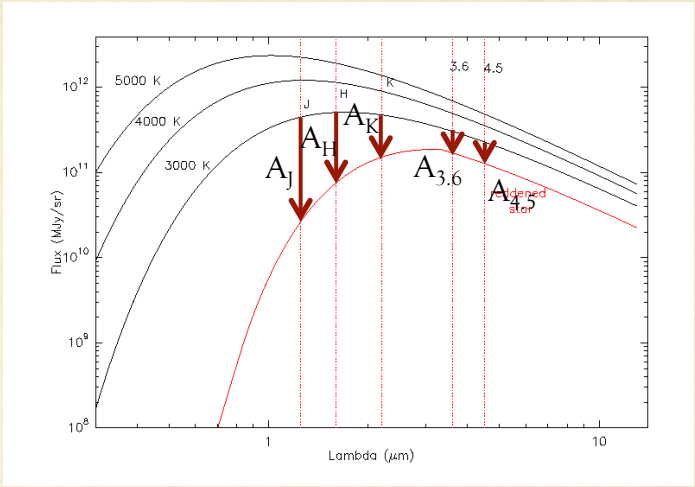



# Go to longer wavelengths ?
# →clouds become transparent

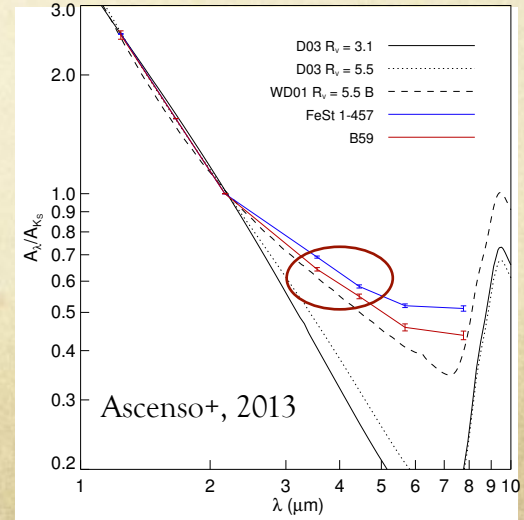
**L1544 as seen by Spitzer/IRAC**



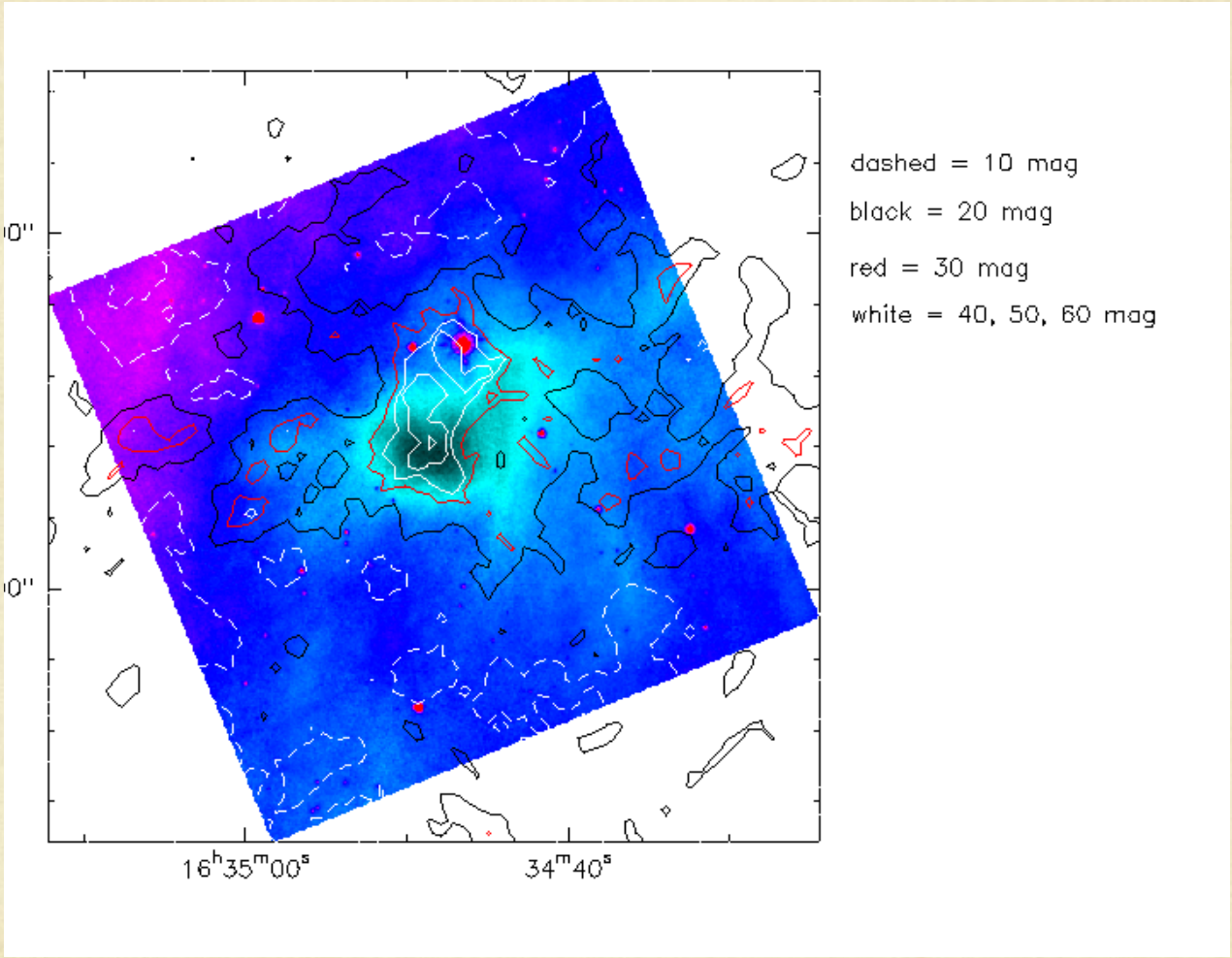
3.6 μm 8.0 μm




Reddening differential almost zero → noise!



# Star counts OK but bright stars problematic

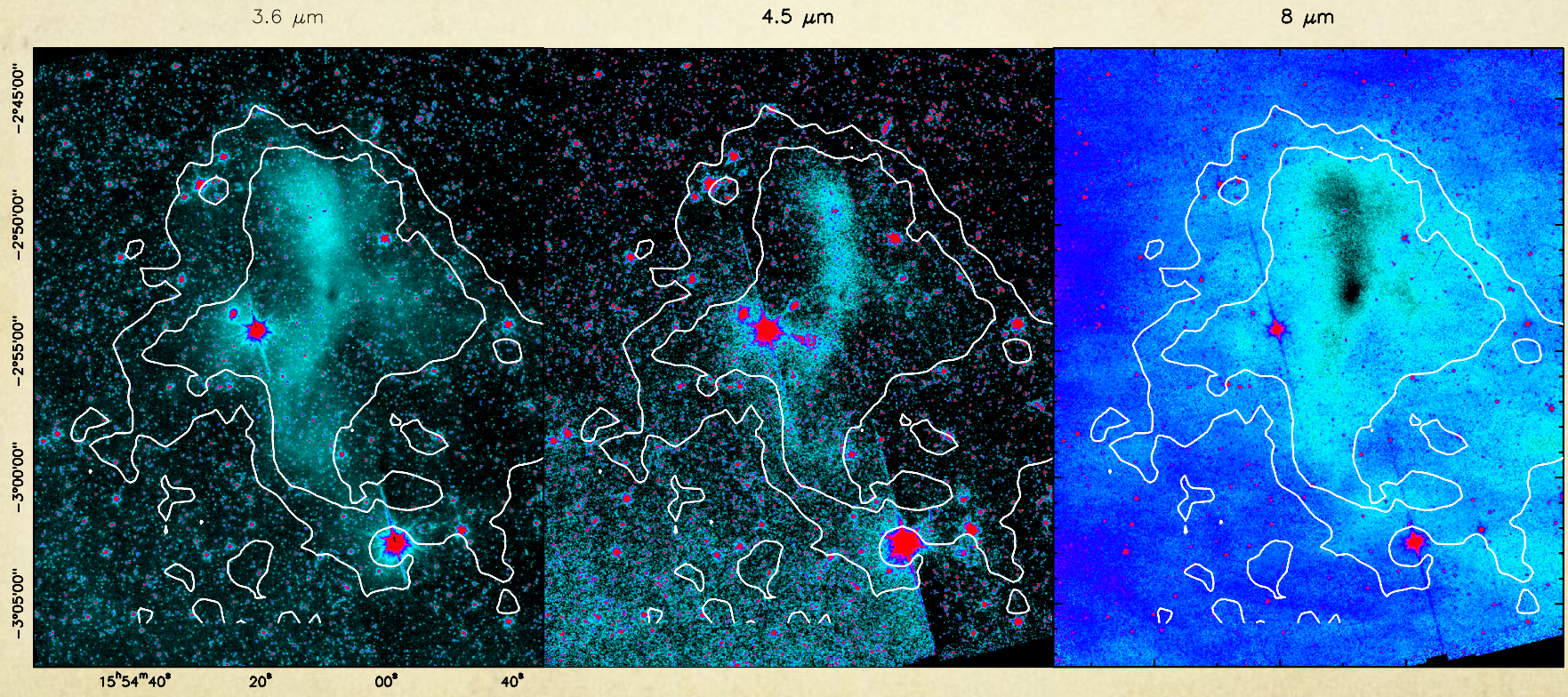



**L1544**

8 μm absorption + star counts at 3.6 μm

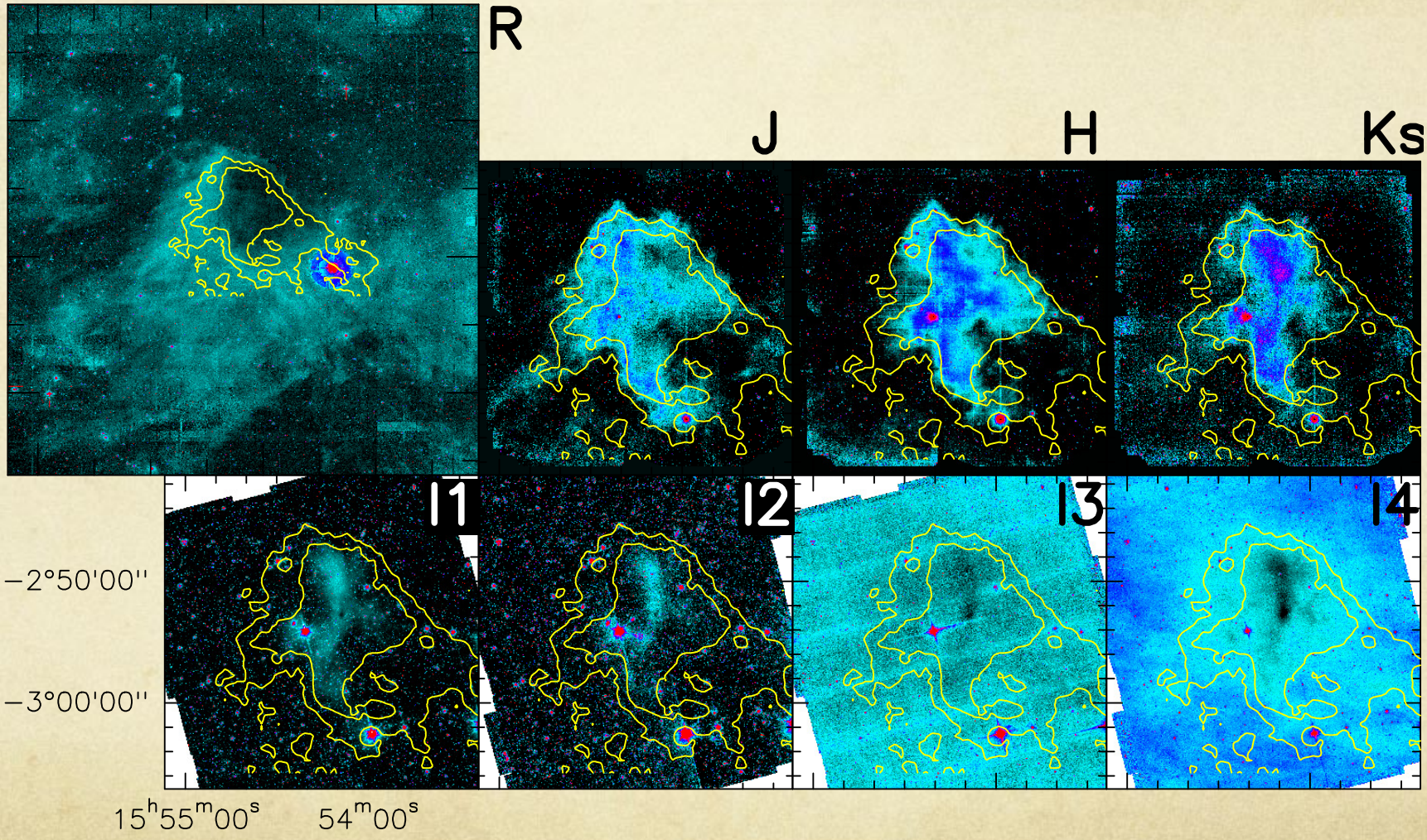
# A serendipitous discovery

## L183, seen by Spitzer/IRAC




Scattering of light at 3.6 and 4.5 μm ? Impossible ... except if $a_{grains} \approx 1$ μm !

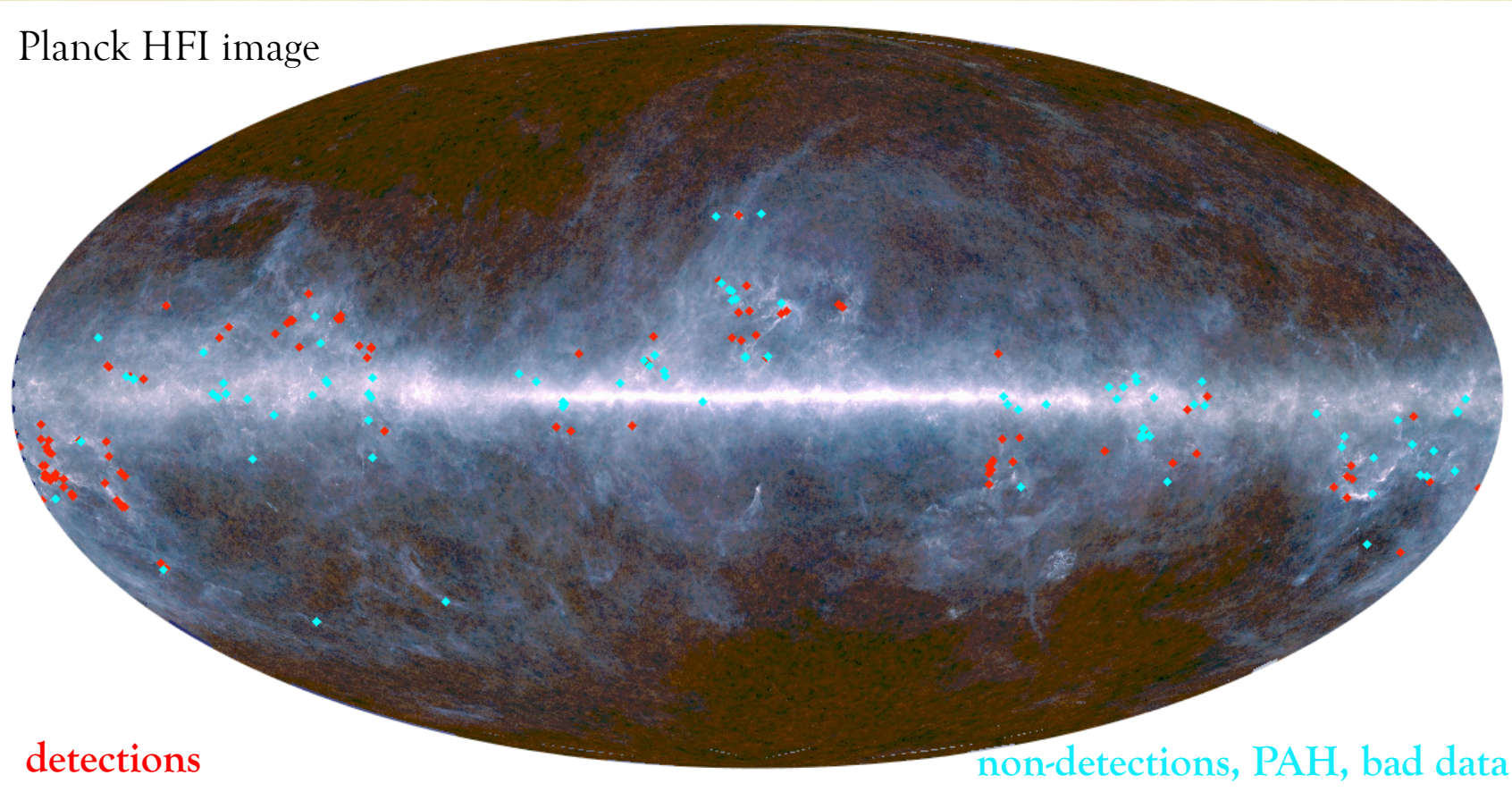
# In fact, scattering is common
# 1) in wavelength




L183, CFHT/MEGACAM + WIRCAM, Spitzer/IRAC

# 2) in the sky (Pagani+, Science, 2010)

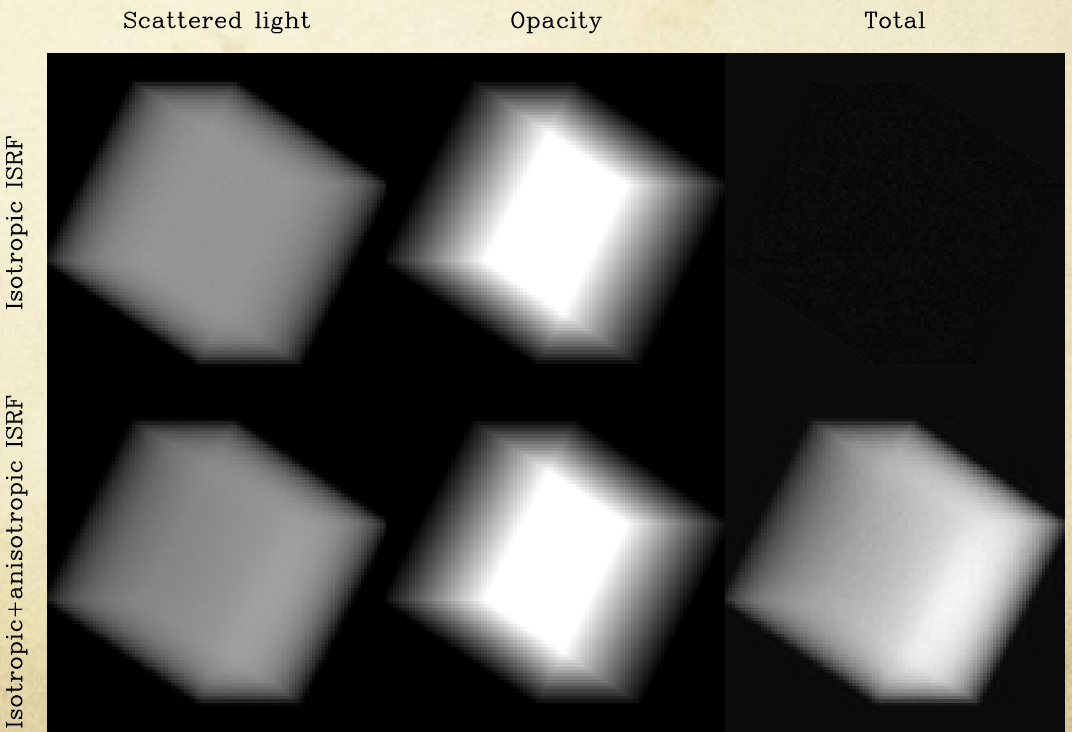
~200 cases, 50% detections, Lefèvre+ 2014, Paladini+ in prep



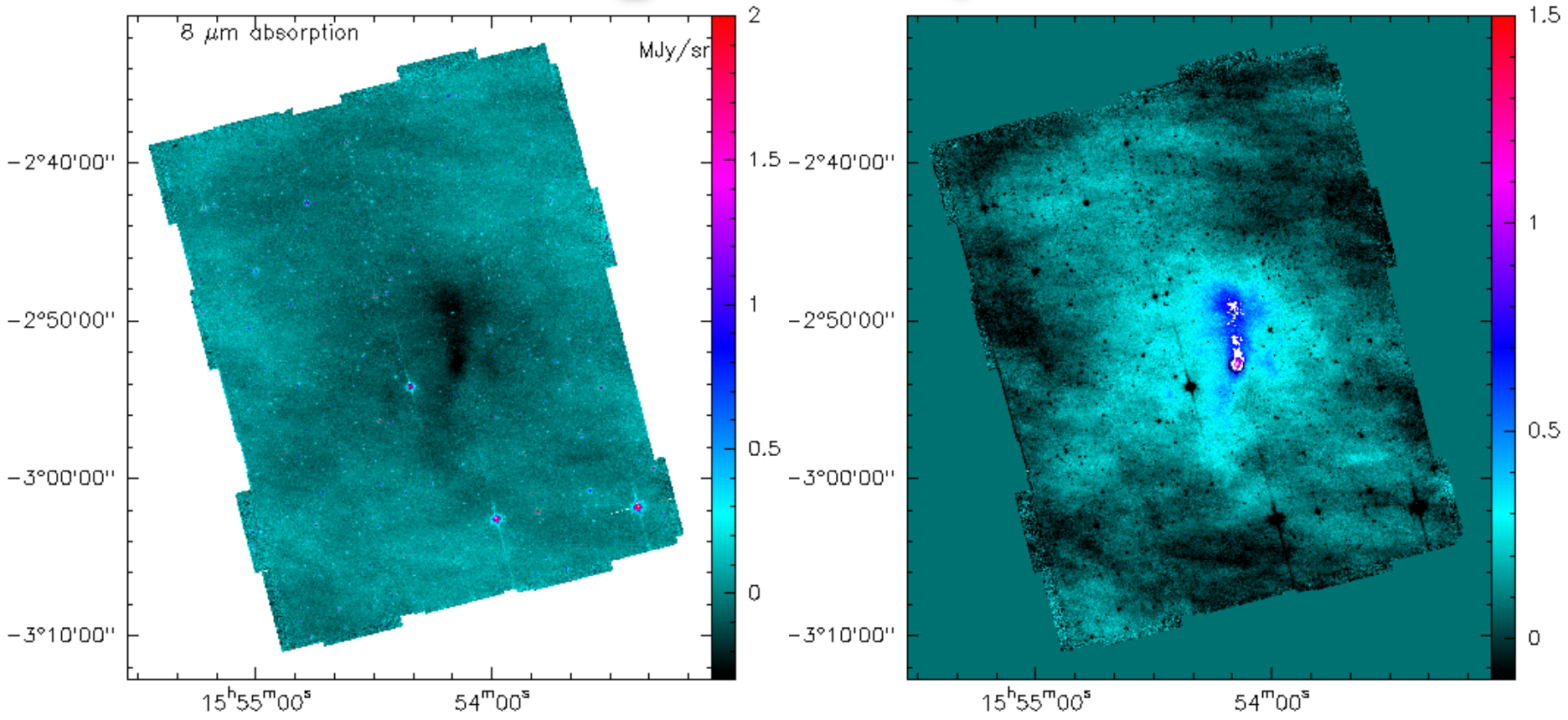
# Can we trace dust from scattering ?

- Juvela+ 2006 : JHK → limited to 20 mag ($A_V$)
- 3.6/4.5 µm → up to 60 mag ? Not clear yet
- Needs a 3D difficult modeling → **ask Charlène for a talk**
- Needs $I_{background}$
- Needs $ISRF_{anisotrope}$
- Grain size distribution
- Grain types
- Grain properties

compact, fluffy, porous...



# What about 8 µm absorption ?




Determination of $I_{background}$ ?
$I_{background}$ constant ?

Needs an external calibrator (dust emission ??? looping...)
Finally, scattering is NOT negligible → needs 3D modeling

# Conclusions

- Try to combine all wavelengths + molecular emission ($N_2H^+$ especially) → long, difficult, could be diverging
- long : it takes one PhD to model one cloud! Ask Charlène…
- difficult : many properties are degenerate, line of sight variations, ISRF unknown

# Hope

- WISH satellite : 1–5 µm cameras, mag = 24 in 30 sec !
- spectrometer on board to measure $H_2O$, CO and $CO_2$ ices
- Could cover $2000°^2$ in one month
- Combine with 3.6 µm deep observations for reddening from Spitzer (available ?)
- still need a lot of ingredients but probably the easiest way

**Don't let this bring you down!**