The Emissivity Spectral Index of Dust in Starless Cores

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ALMA

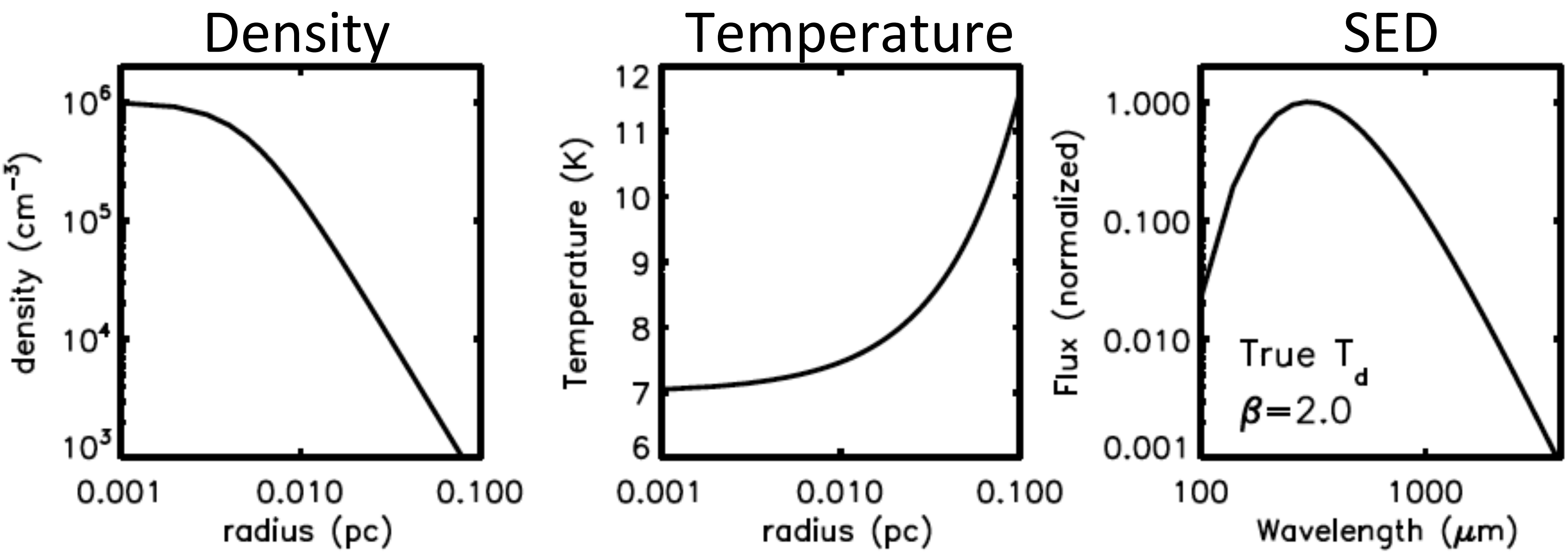
Dust Emission

$$S_\nu = \Omega B_\nu(T_d)\kappa_\nu \mu m_H N_{H_2}$$

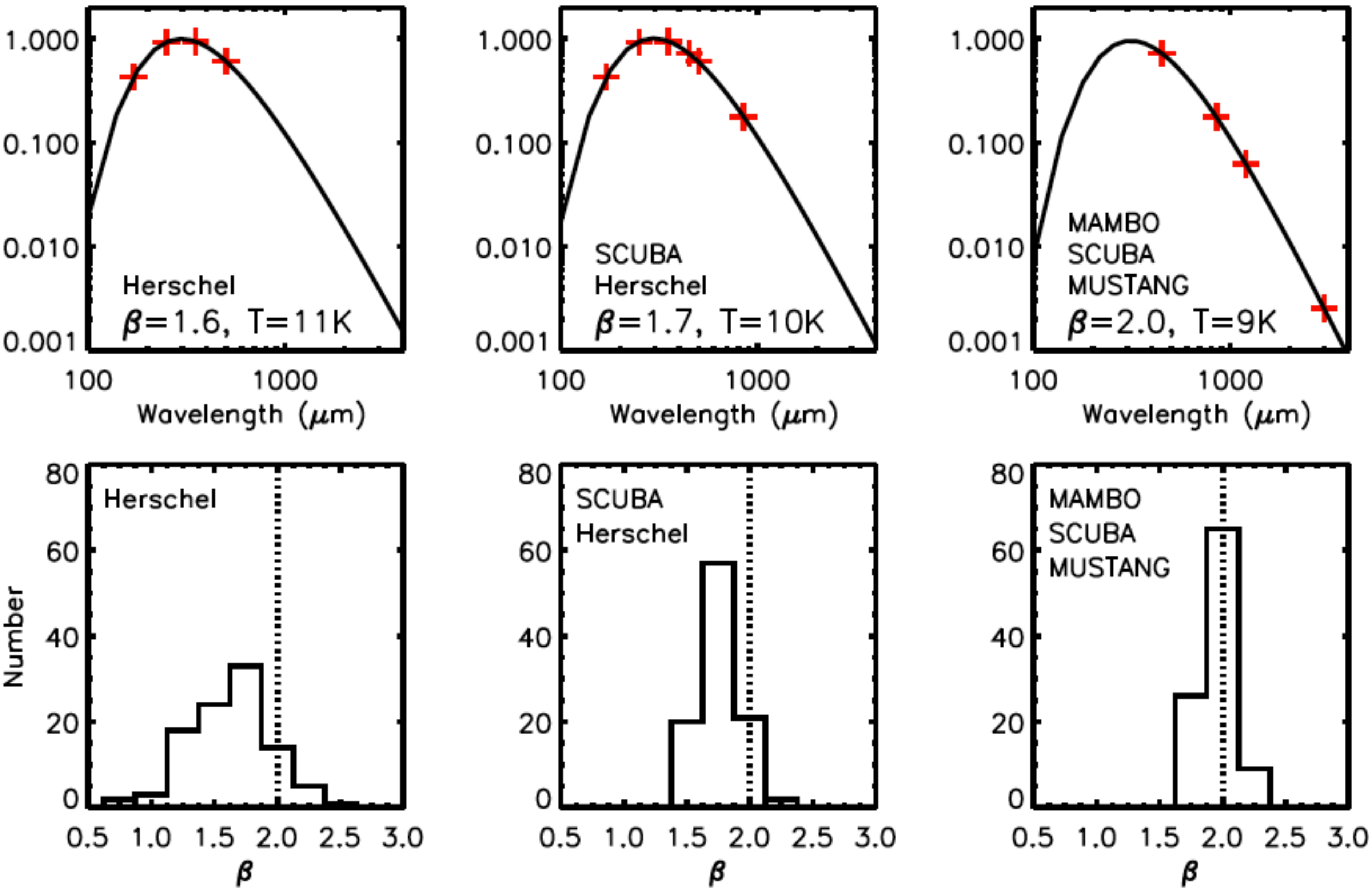
$$B_\nu(T_d) = \frac{2h\nu^3}{c^2}\frac{1}{\exp(h\nu/kT_d) - 1}$$

$$\kappa_\nu = \kappa_{230}\left(\frac{\nu}{230\mathrm{GHz}}\right)^\beta$$

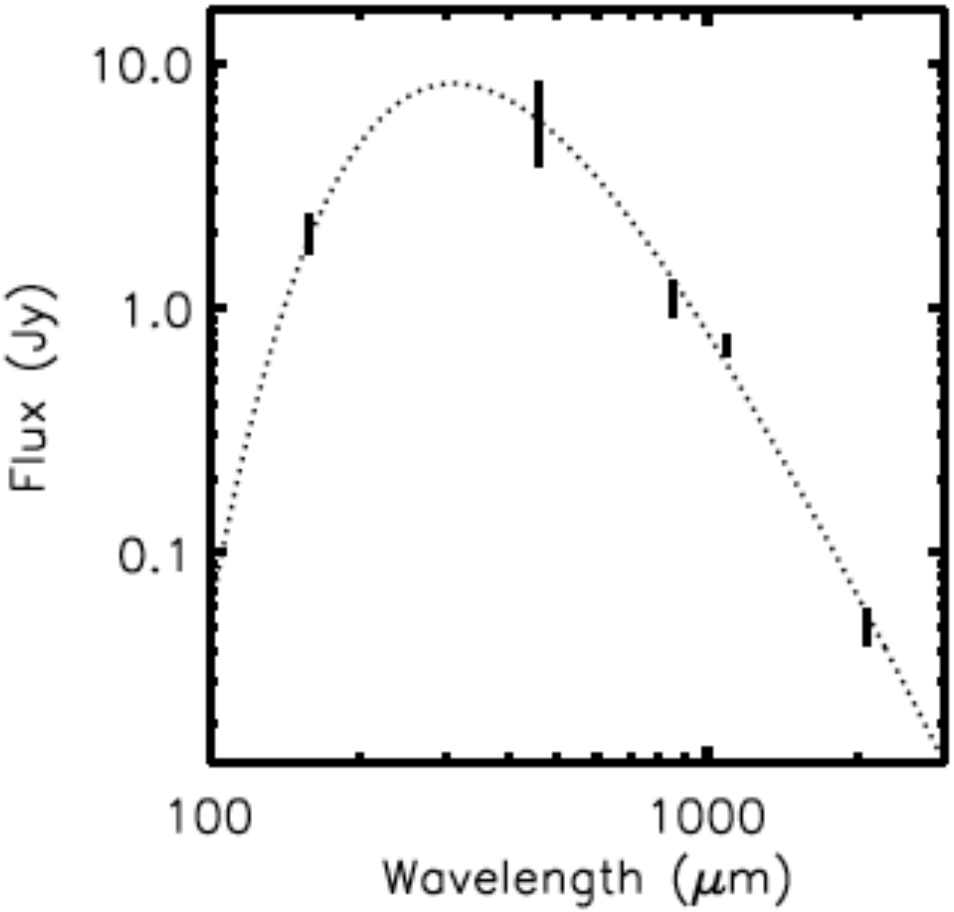
Profiles of a Typical Starless Core

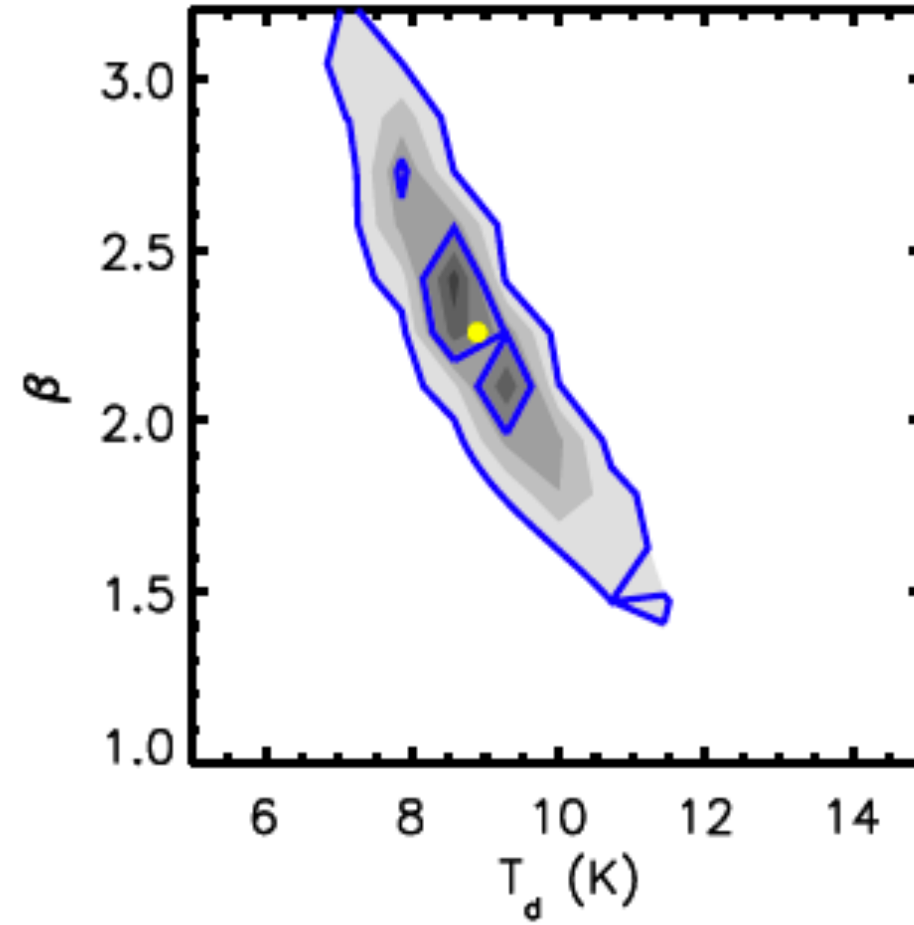


SED Fits Assuming Constant β,T



SED Fits Assuming Constant β,T: Starless Core TMC-1C





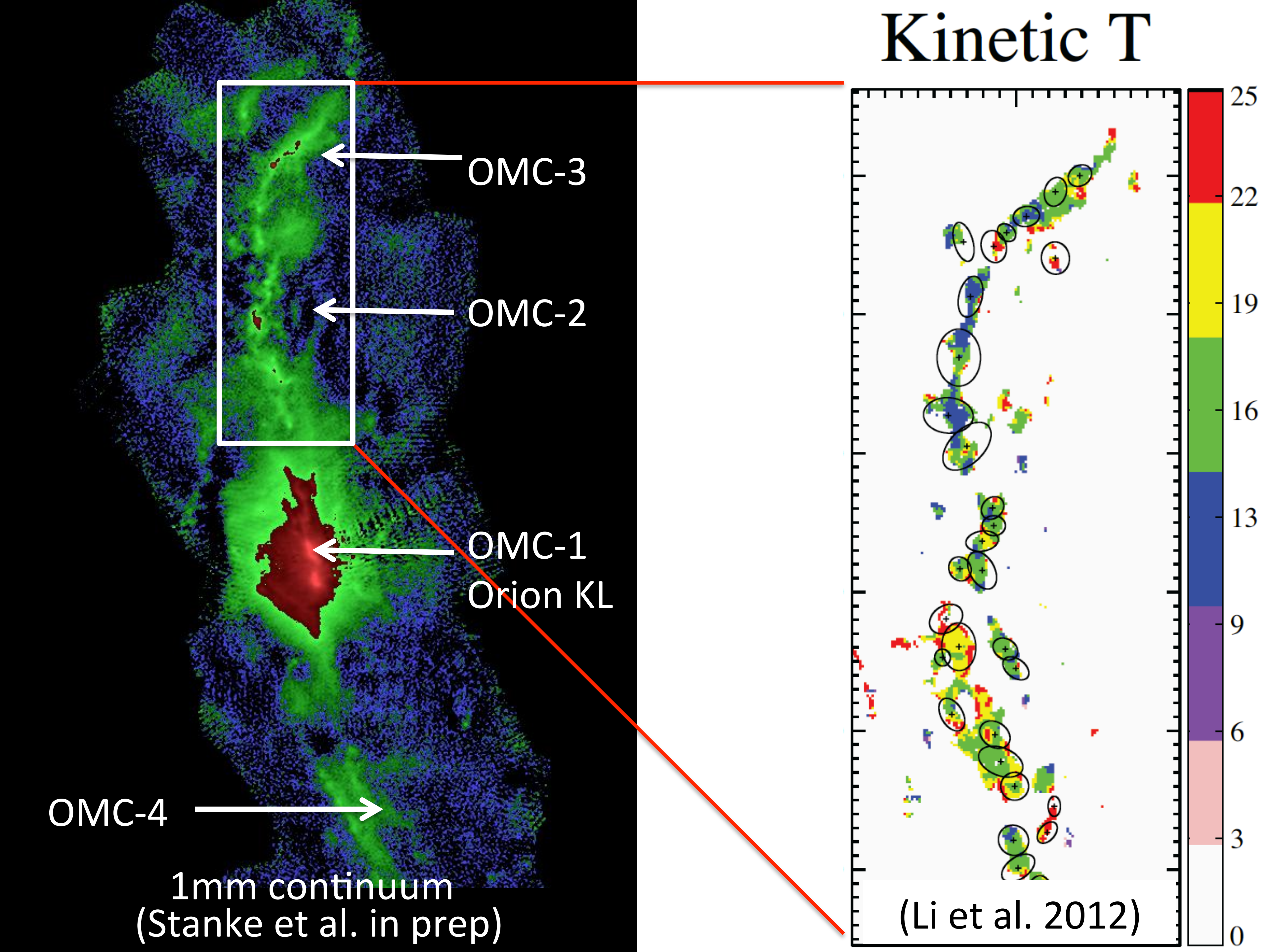
(Schnee et al. 2010)

Ideas For This Talk

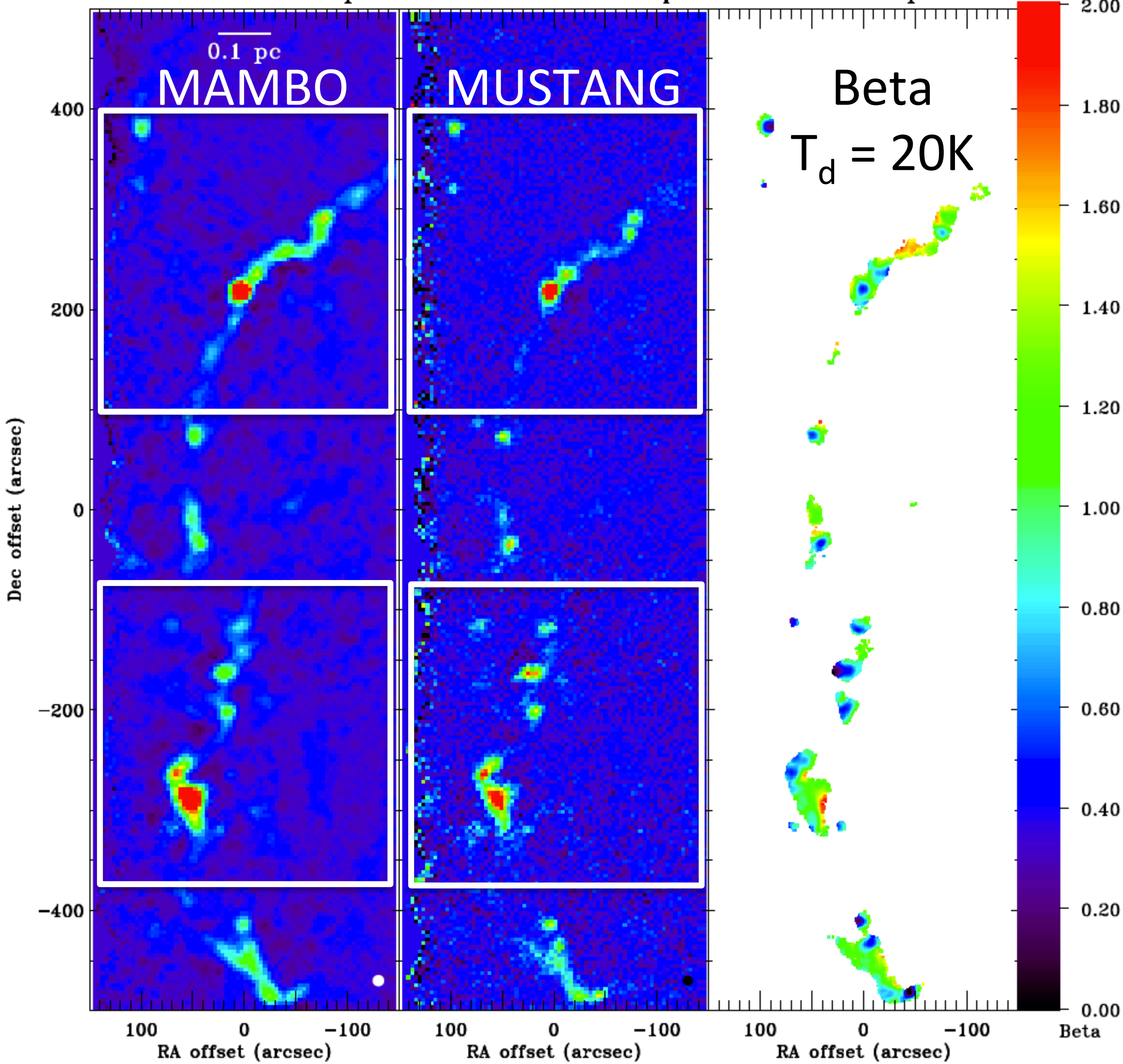
- Make maps on the Rayleigh-Jeans tail of SED
  - Worry less about line-of-sight temperature variations
  - Worry more about spatial filtering
  - Worry more about free-free and spinning dust emission
  - Observations of Orion (OMC-2/3)
- Map dust emission and NH_3 (1,1) and (2,2)
  - NH_3 give an independent temperature
  - Herschel SPIRE/FTS maps to determine β
  - Observations of nearby starless & protostellar cores

OMC-2/3

- Richest star-forming filament with 500 pc
  - Assumed distance of 414 pc
  - T_d = 17 K (Lis et al. 1998; Li et al. 2012)
  - M = 1100 $M_\odot$ (Lis et al. 1998)
  - Typical density: n ~ 10^4 cm^{-3} (Johnstone & Bally 1999)
- MAMBO 1.2mm observations: 11” resolution
  - (Stanke et al. in prep; Davis et al. 2009)
- MUSTANG 3.3mm observations: 10” resolution
  - (Schnee et al. in prep)
- SCUBA-2 FTS 850 µm observations: 14” resolution
  - (Friesen et al. proposed)



Kinetic T
OMC-3
OMC-2
OMC-1
Orion KL
OMC-4
1mm continuum
(Stanke et al. in prep)
(Li et al. 2012)
25
22
19
16
13
9
6
3
0

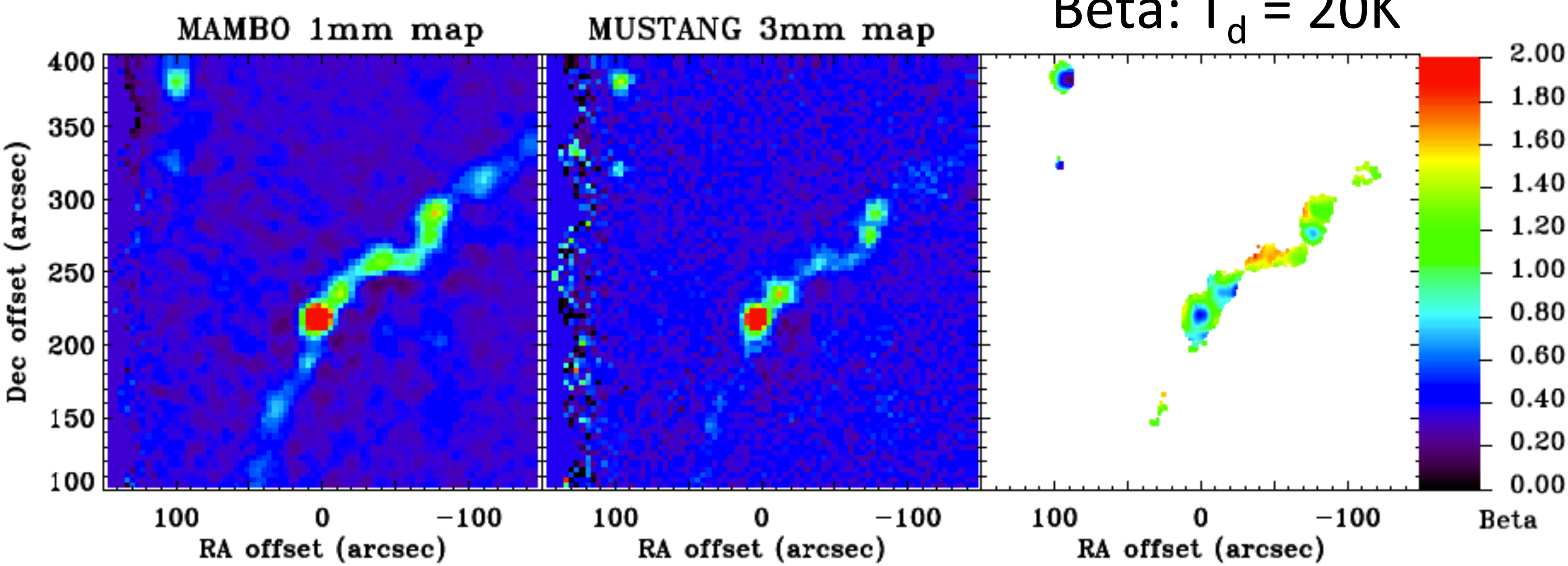


0.1 pc
MAMBO
MUSTANG
Beta
T_d = 20K
Dec offset (arcsec)
400
200
0
−200
−400
100
0
−100
RA offset (arcsec)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Beta

Northern Filament

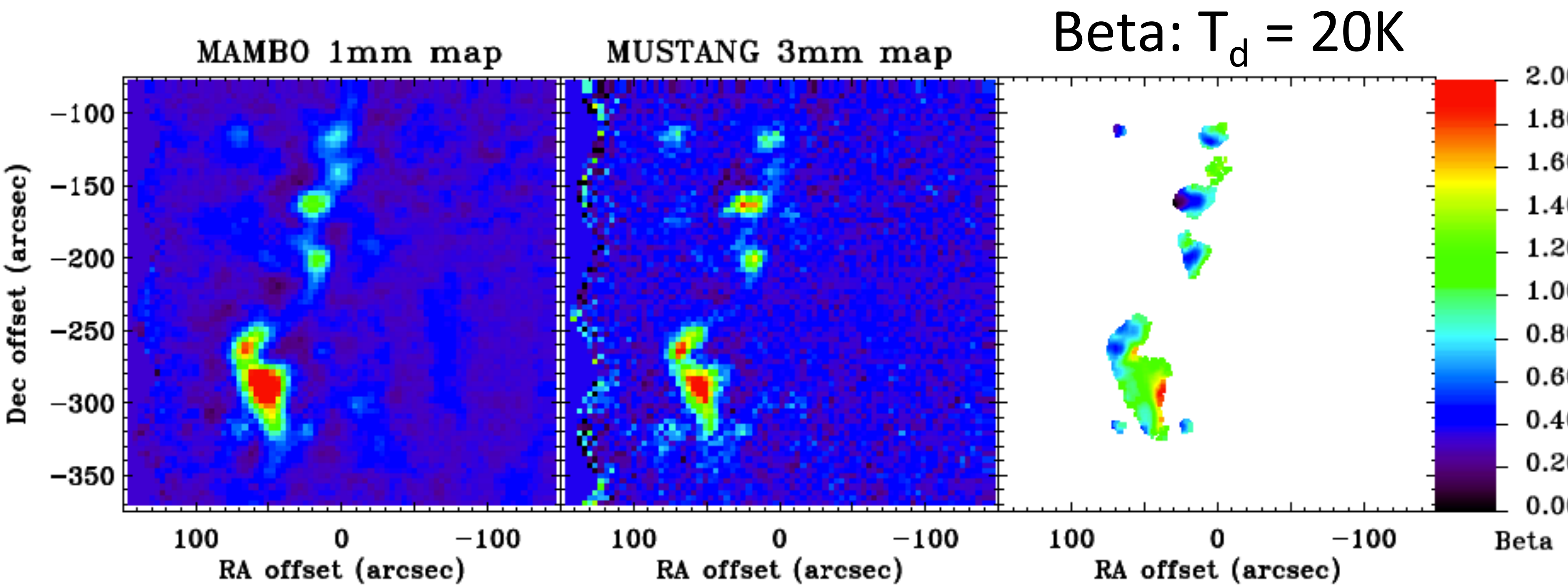
10” ≈ 0.02pc or 4000 AU

Beta: T_d = 20K



(Schnee et al. in prep)

Southern Filament



(Schnee et al. in prep)

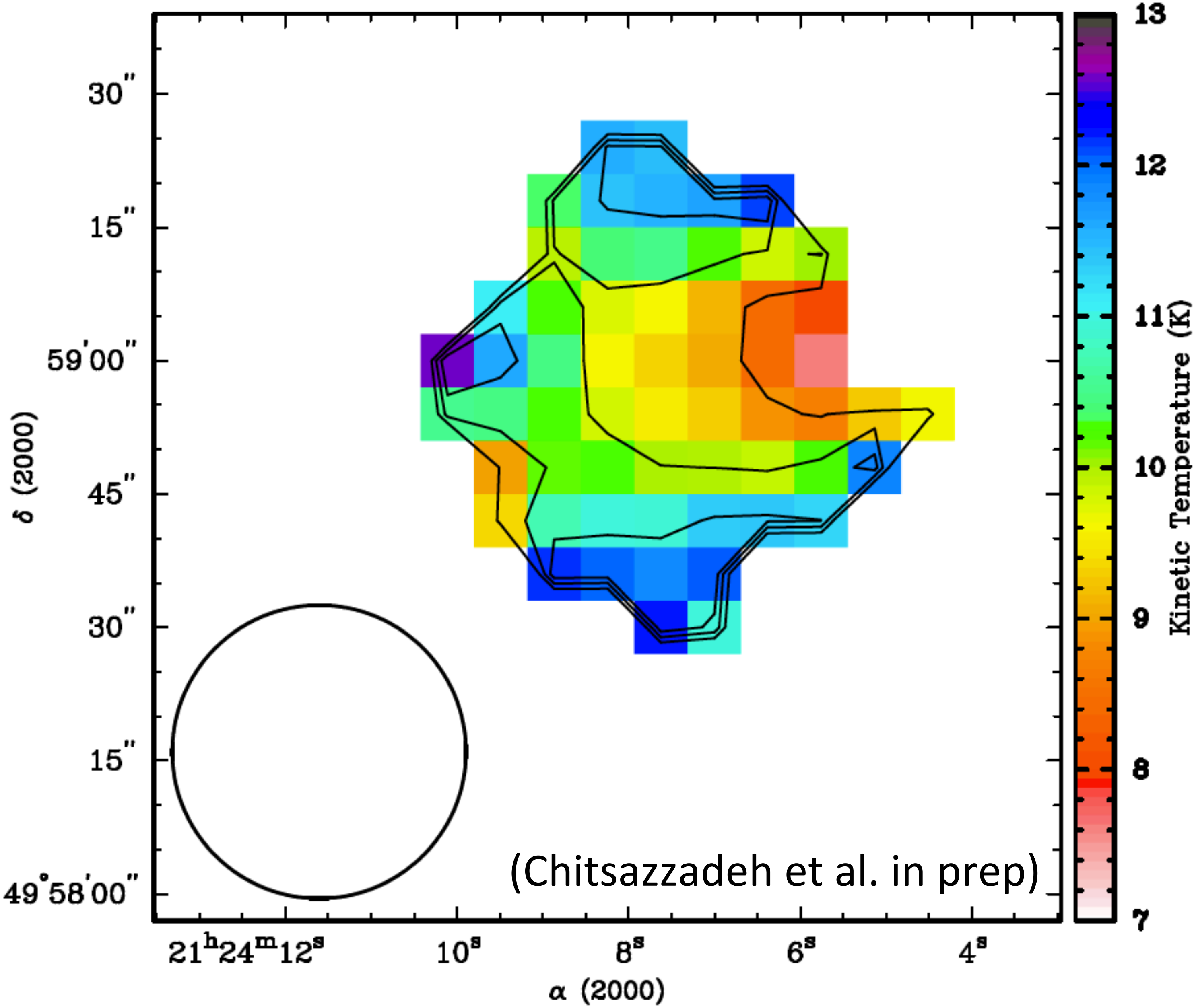
OMC-2/3 Region Conclusions

- Preliminary analysis of SCUBA and MUSTANG maps show that
  - $\beta \approx 1.0$-1.5 along the filaments
  - B < 1 in regions with star formation
    - Sign of grain growth and/or other emission mechanisms?
- Sadavoy et al. find $\beta \approx 2$ in filaments and $\beta \approx 1.6$ in cores in Perseus
- Further analysis still needs to be done
  - Free-free emission
  - SCUBA-2 (FTS) observations
  - Combination with temperature map

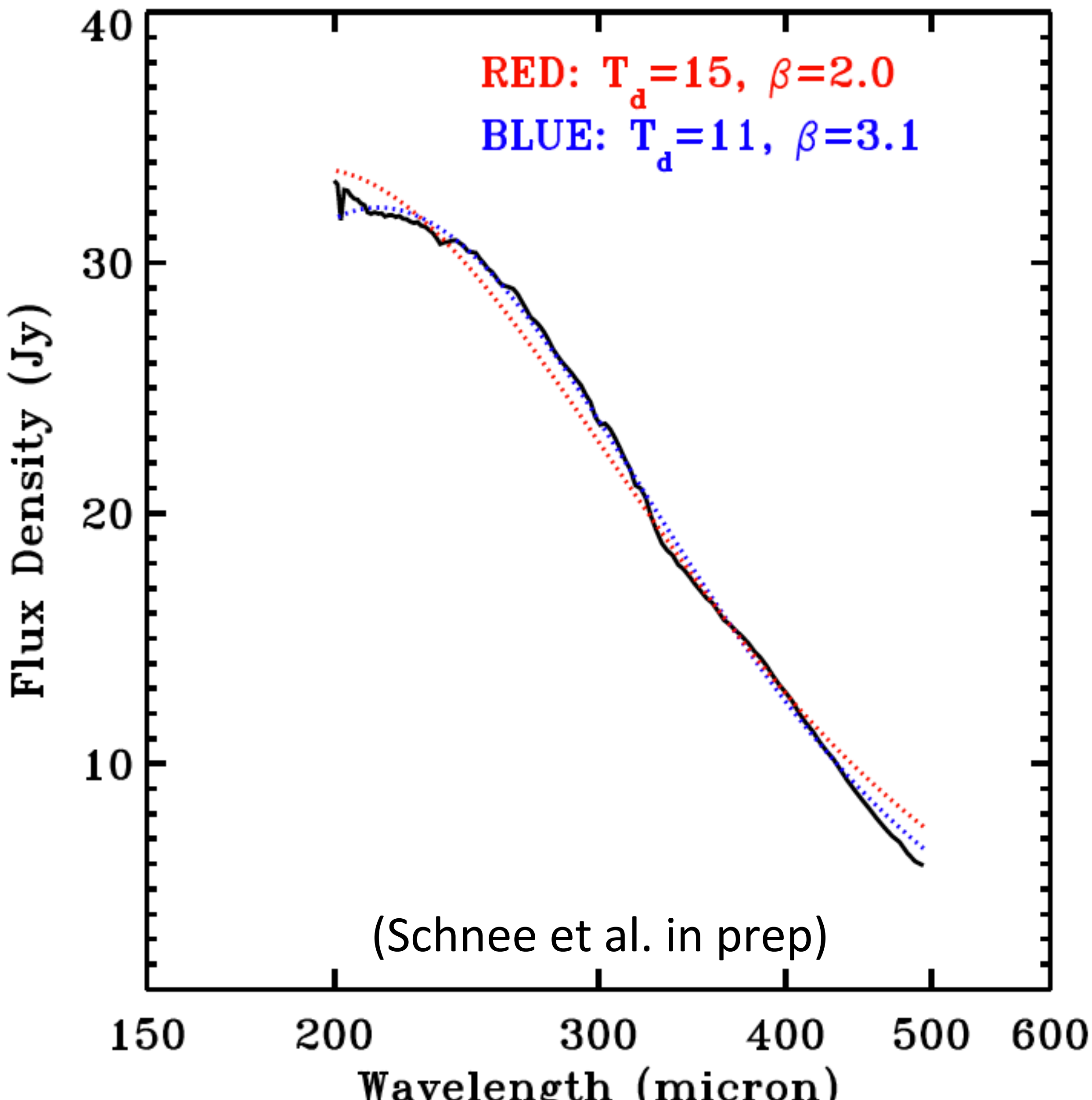
Herschel SPIRE FTS observations

- Low resolution SEDs from 200 – 600 μm
  - (Schnee et al. in prep; Chitsazzadeh et al. in prep)
- GBT NH_3 (1,1) and (2,2) observations
  - (Chitsazzadeh et al. in prep)
- Observations of 12 nearby starless cores / VeLLOs

Temperature Map of L1014



SED of the Protostar L1014



Conclusions

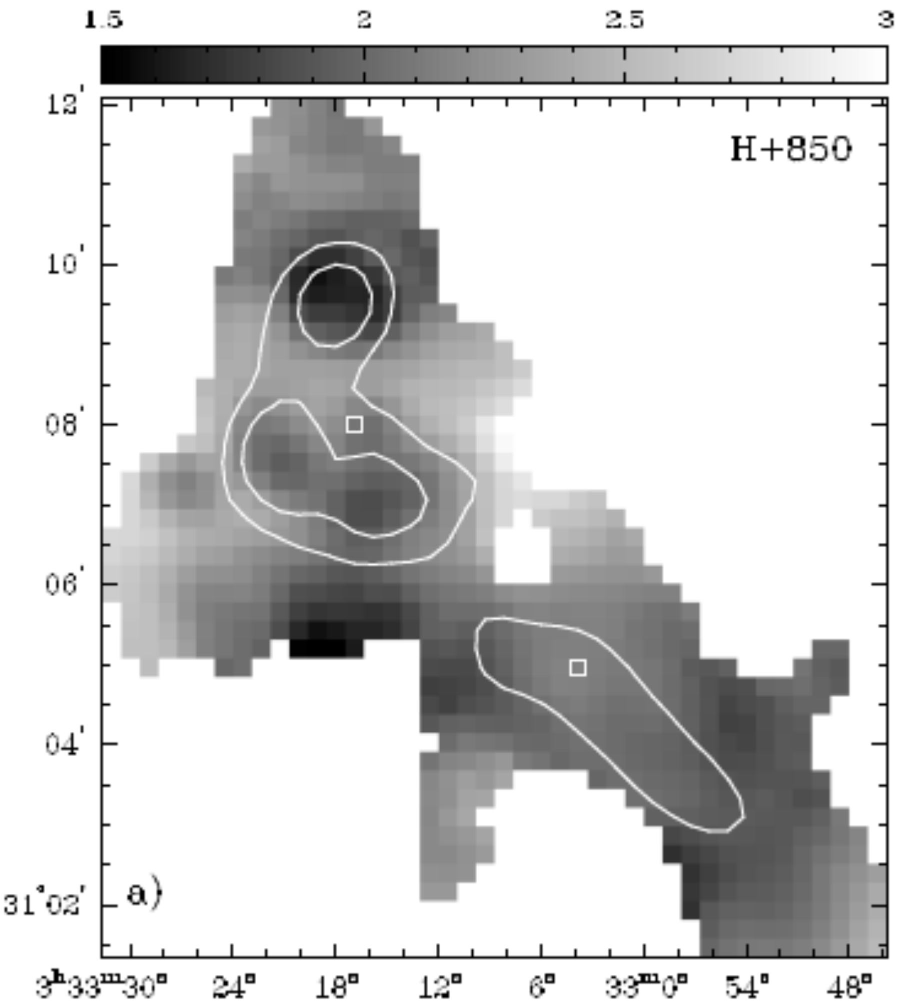
- In general, it is hard to use SEDs to derive dust temperature and the emissivity spectral index
- We have begun GBT and Herschel observations of dense cores
  - GBT NH_3 (1,1) and (2,2) yields temperature
  - Herschel SPIRE/FTS yields spectral index
- We have begun observations of OMC-2/3
  - Bolometer maps at 850μm, 1.2mm, 3mm
  - Will be used to derive β on RJ-tail

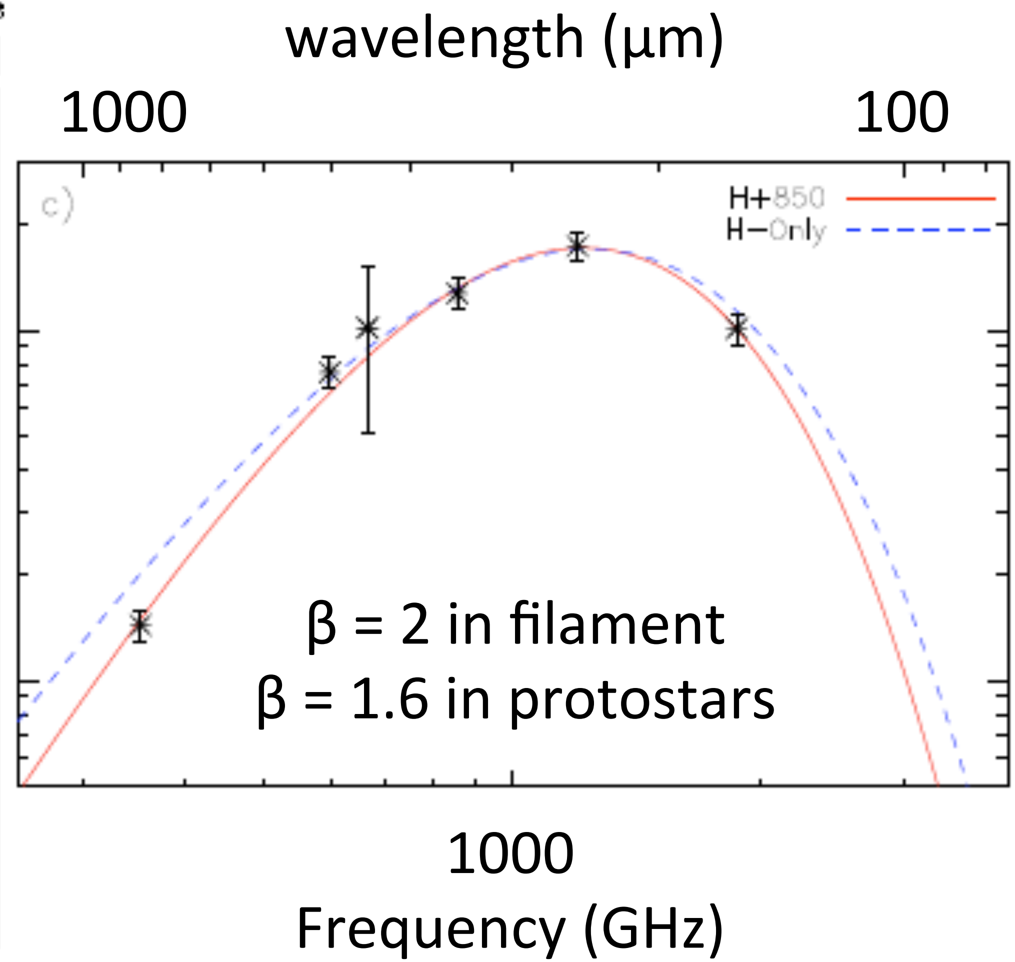
The End

Thank you for your time!

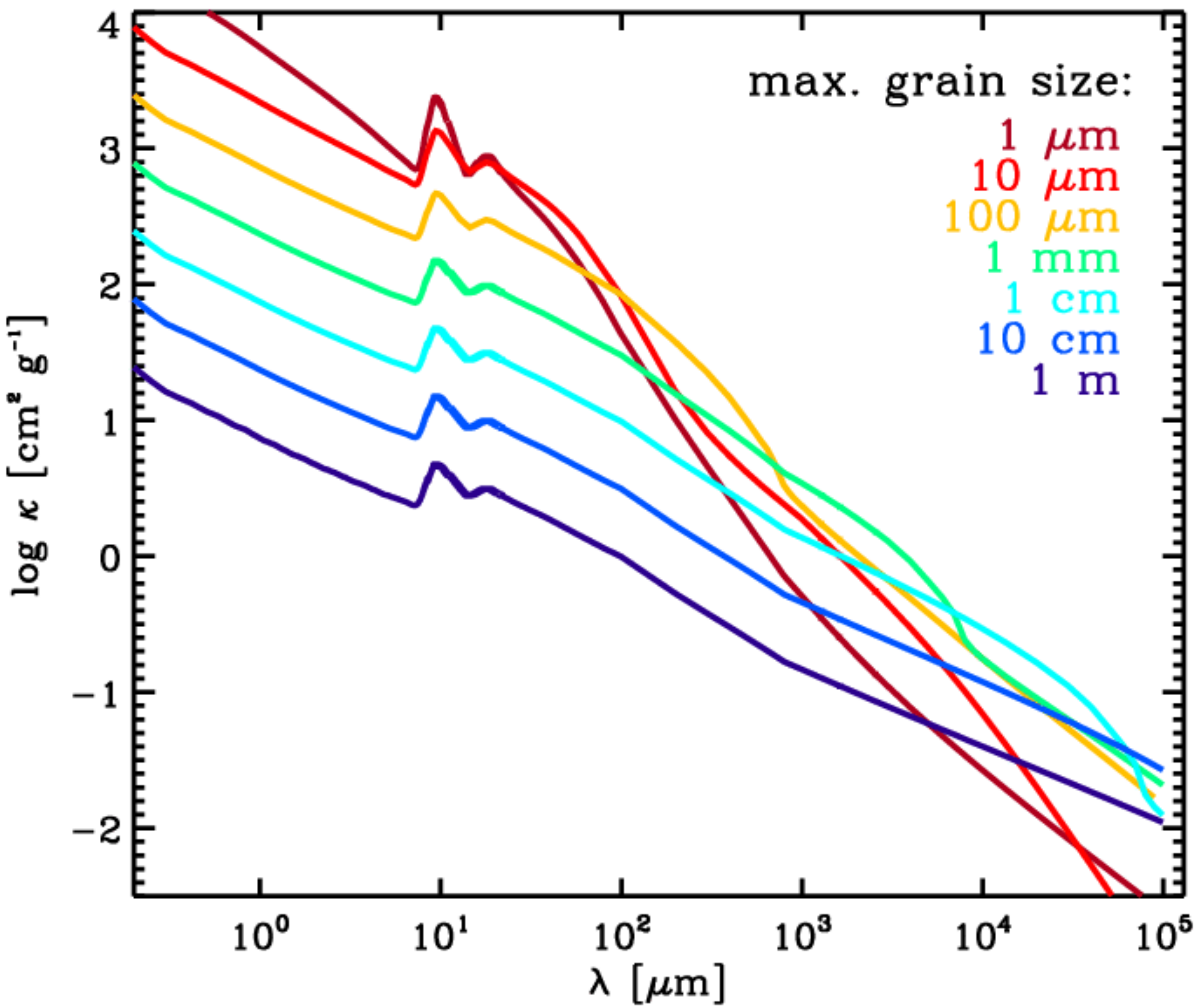
Map and SED of Perseus B1-a
Herschel + SCUBA-2 data

(Sadavoy et al. 2013)

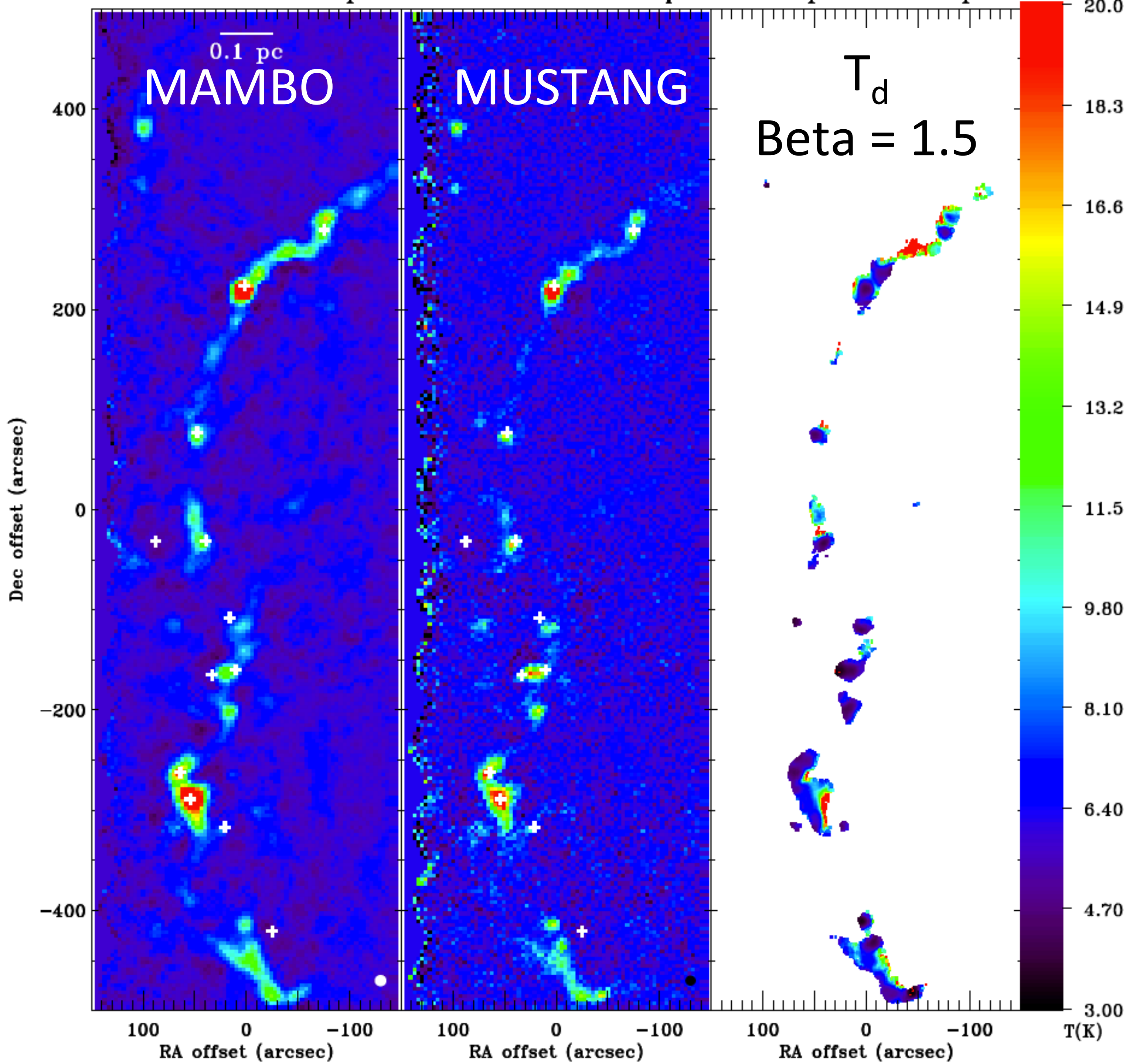




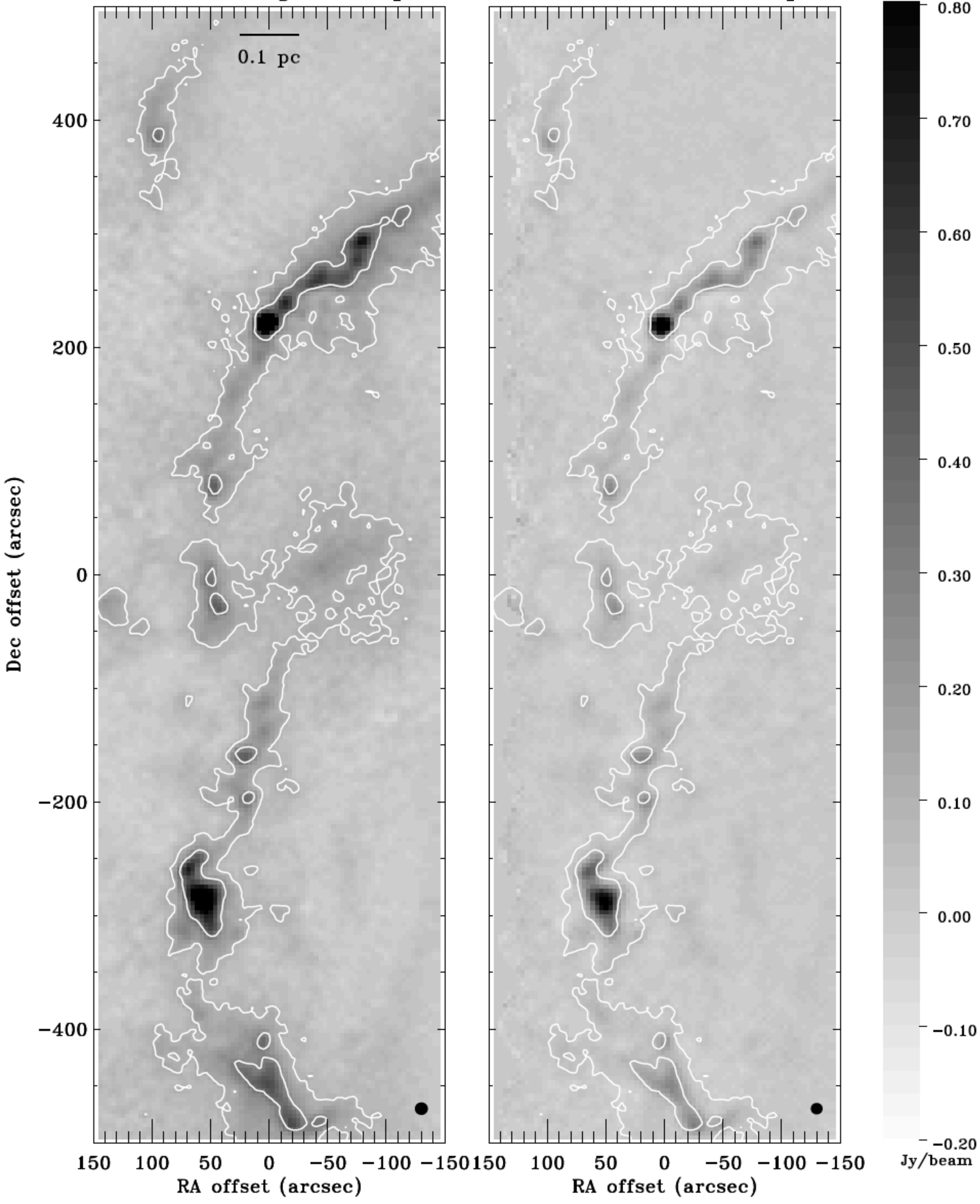
Grain Growth



(Figure from D. Wilner's AAS talk 2011; Draine 2006)



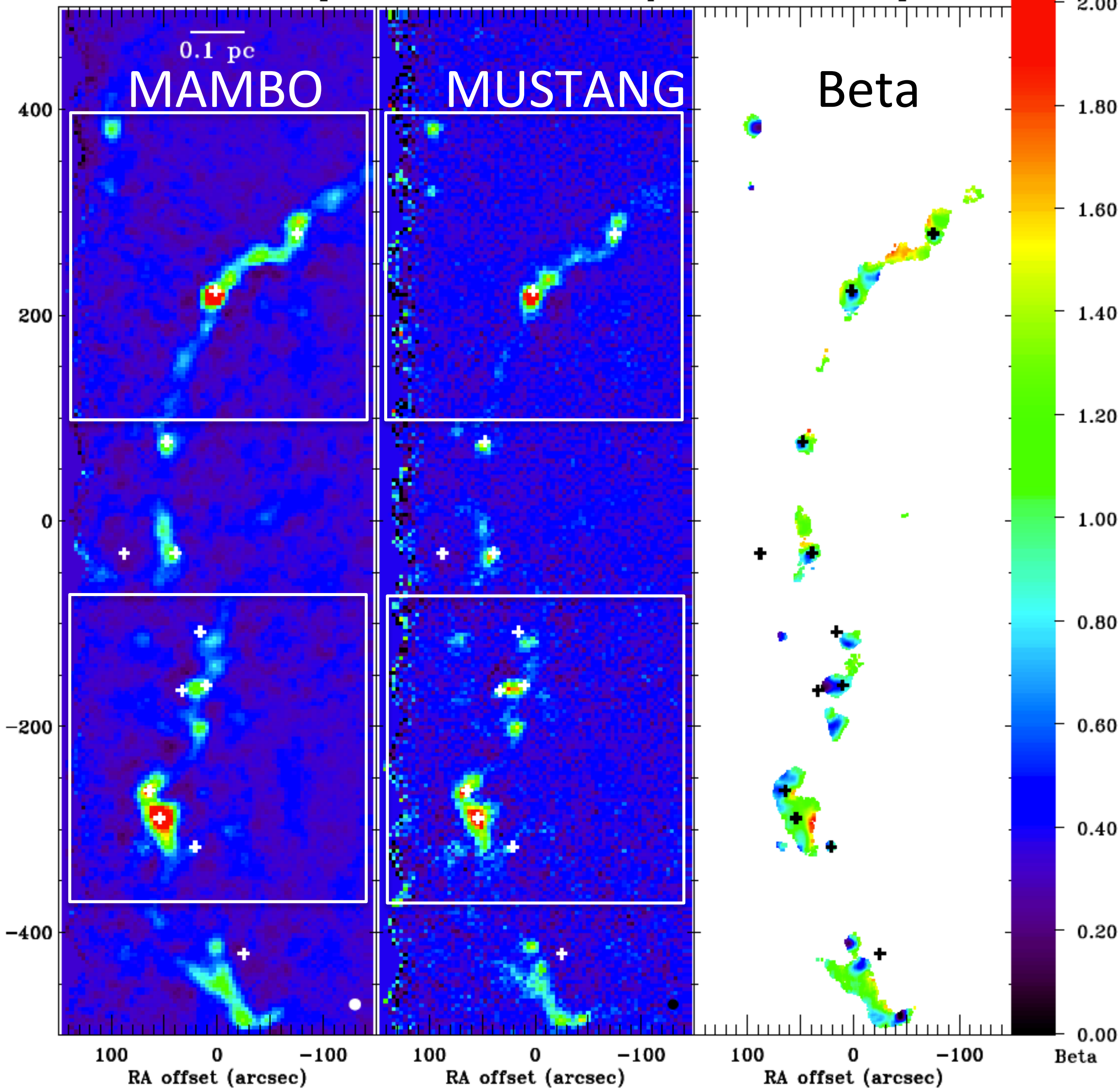
0.1 pc
MAMBO
MUSTANG
T_d
Beta = 1.5
Dec offset (arcsec)
RA offset (arcsec)
RA offset (arcsec)
RA offset (arcsec)
400
200
0
−200
−400
100
0
−100
20.0
18.3
16.6
14.9
13.2
11.5
9.80
8.10
6.40
4.70
3.00
T(K)



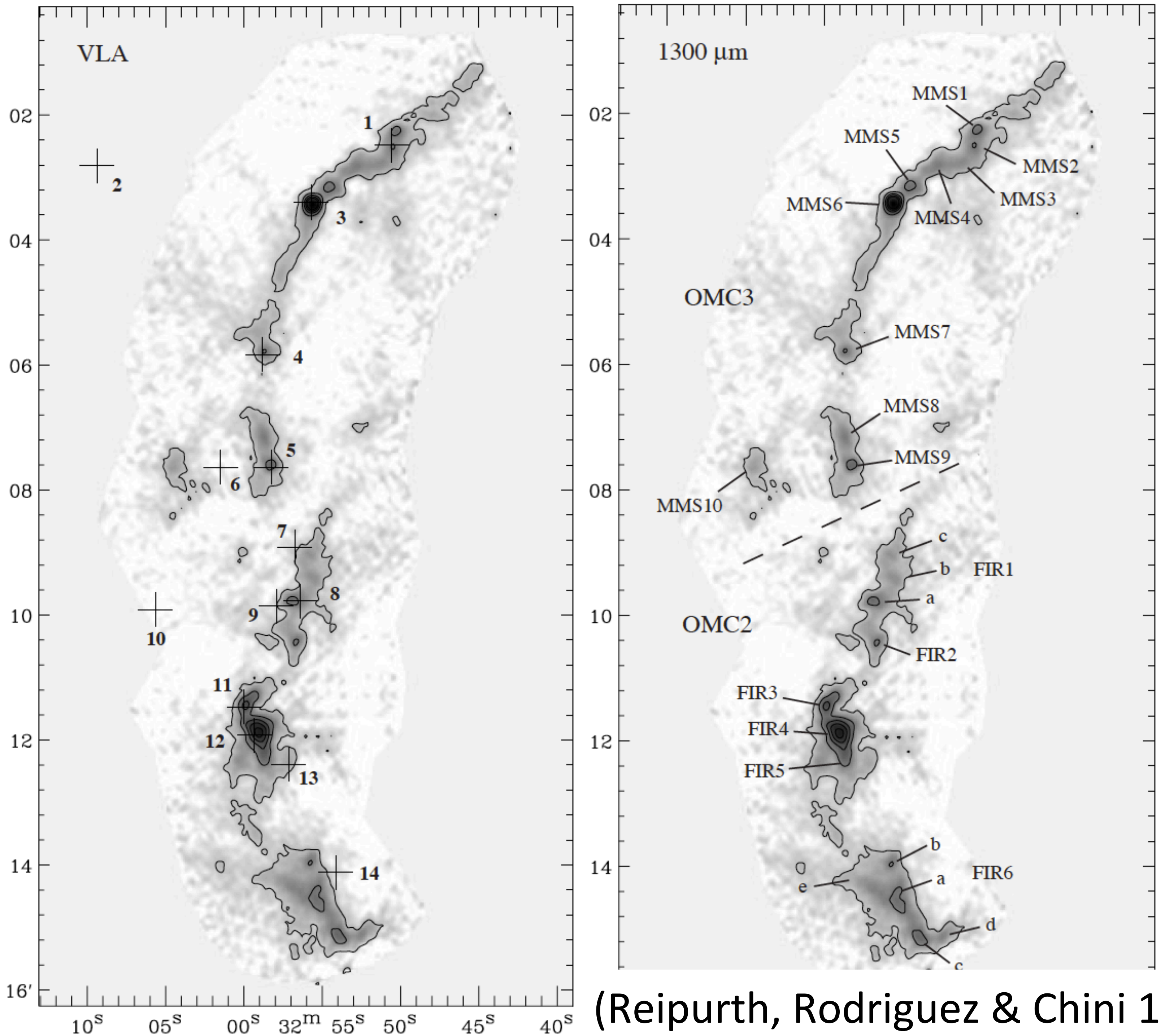
MAMBO 1mm map of OMC 2/3

left: original
right: filtered

(Schnee et al. in prep)



0.1 pc
MAMBO
MUSTANG
Beta
400
200
0
−200
−400
100
0
−100
RA offset (arcsec)
RA offset (arcsec)
RA offset (arcsec)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Beta



(Reipurth, Rodriguez & Chini 1999)

Grain Growth Timescales

(Chakrabarti & McKee 2005)

$$t_{\rm coag} \sim \frac{1}{n\sigma v_{\rm rel}} = 6\times 10^{6}\ {\rm yr}\left(\frac{10^{5}\ {\rm cm^{-3}}}{n_{\rm H}}\right)\left(\frac{a}{0.1\ \mu{\rm m}}\right)\left(\frac{1\ {\rm m\ s^{-1}}}{v_{\rm rel}}\right)$$

$$\frac{t_{\rm coag}}{t_{\rm ff}} \sim 2000\left(\frac{10^{5}\ {\rm cm^{-3}}}{n_{\rm H}}\right)^{1/2}\left(\frac{a}{5\ \mu{\rm m}}\right)\left(\frac{1\ {\rm m\ s^{-1}}}{v_{\rm rel}}\right).$$

Planck Spectrum of OMC-3