Cold Dust in M33

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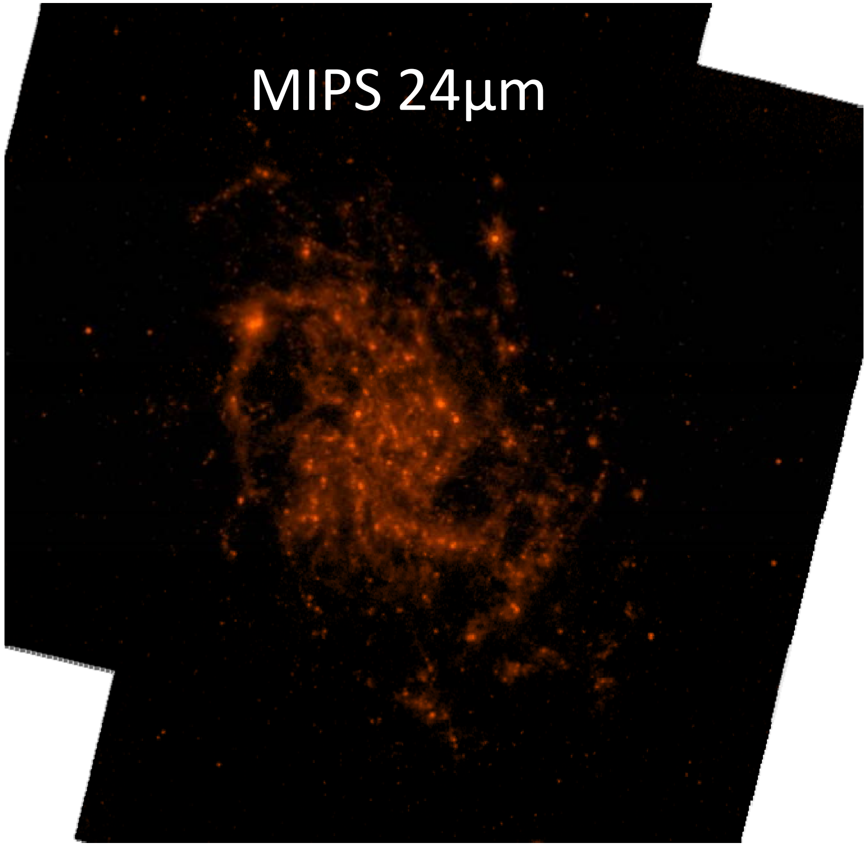
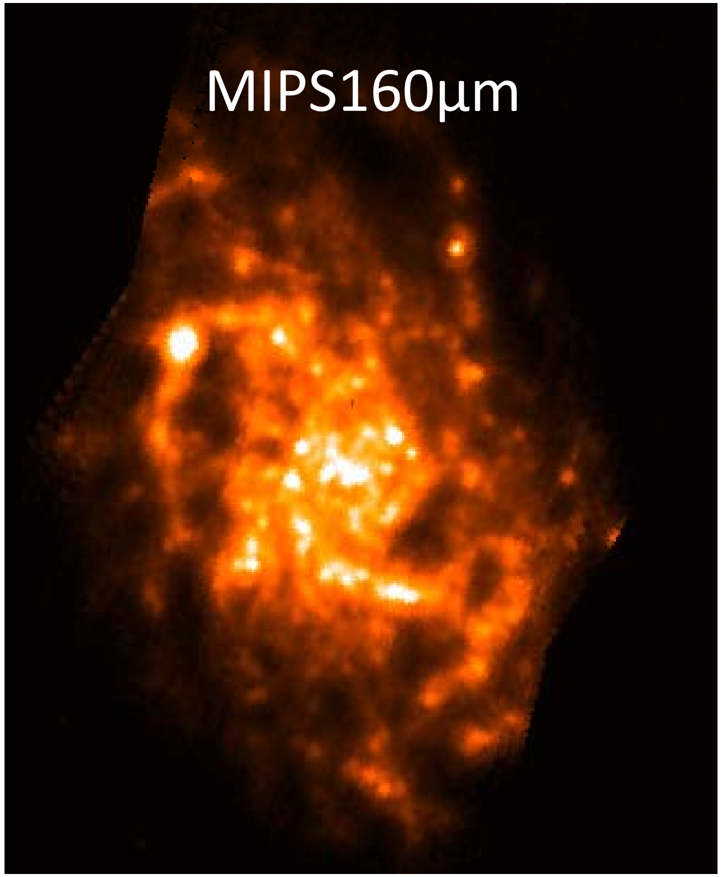
2010 Apr. 28-29, Dust workshop @ IPMU





Warm dust

✓Most power from small scales (Tabatabaei'08), corr. w/ Hα

→ warm dust heated by OB stars

Colder dust component

✓SF region + extended component (~50%)

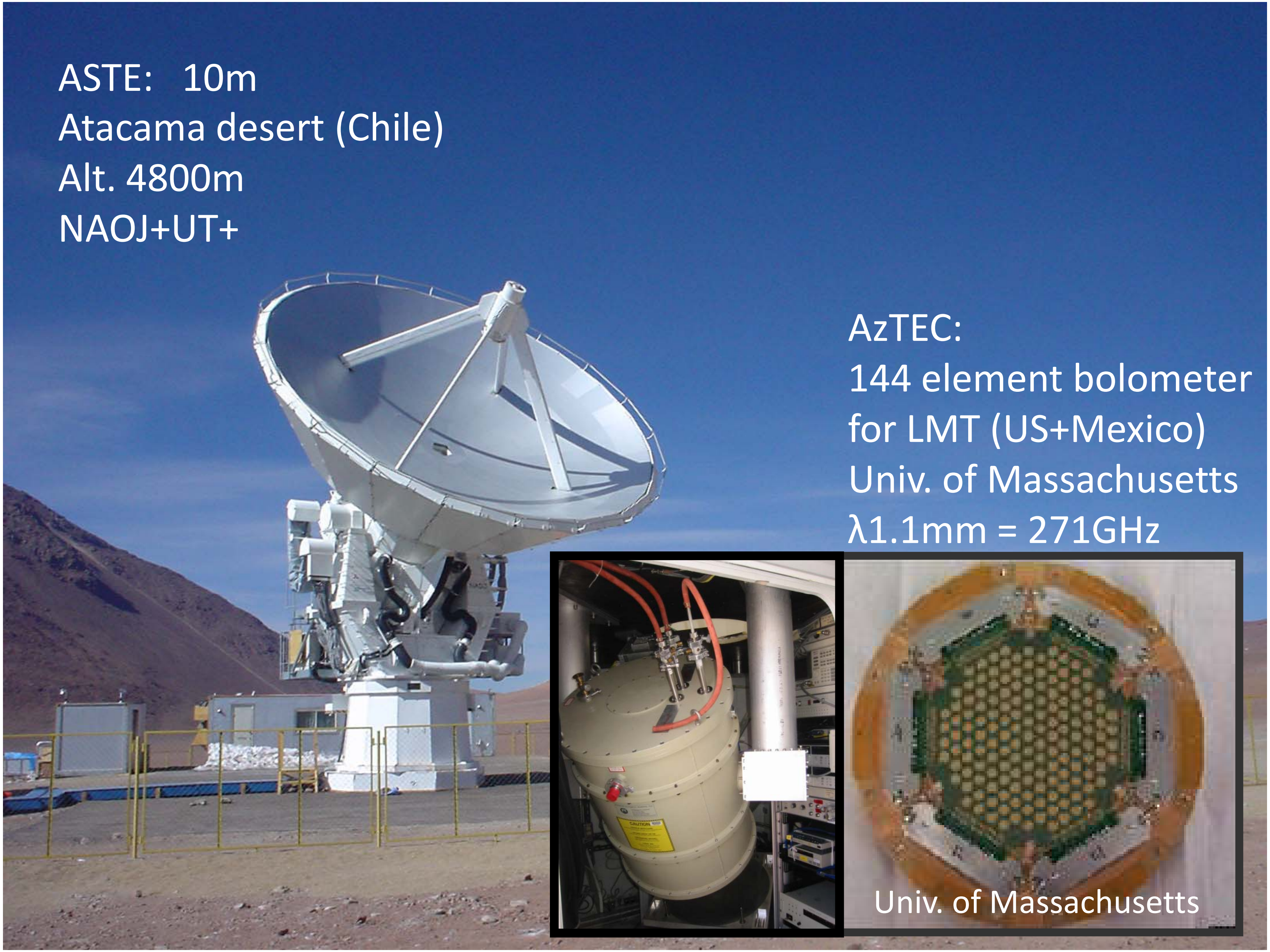
✓Extended component heated by non-massive stars

what about in SF regions

→ **just more dust ? Or higher temperature ?**

✓Tabatabaei'08 find spatial correlation w/ Hα, and significant 160μm power at small scales

→ claim 160μm heated by UV from massive stars


ASTE: 10m
Atacama desert (Chile)
Alt. 4800m
NAOJ+UT+
AzTEC:
144 element bolometer
for LMT (US+Mexico)
Univ. of Massachusetts
λ1.1mm = 271GHz
Univ. of Massachusetts

M33

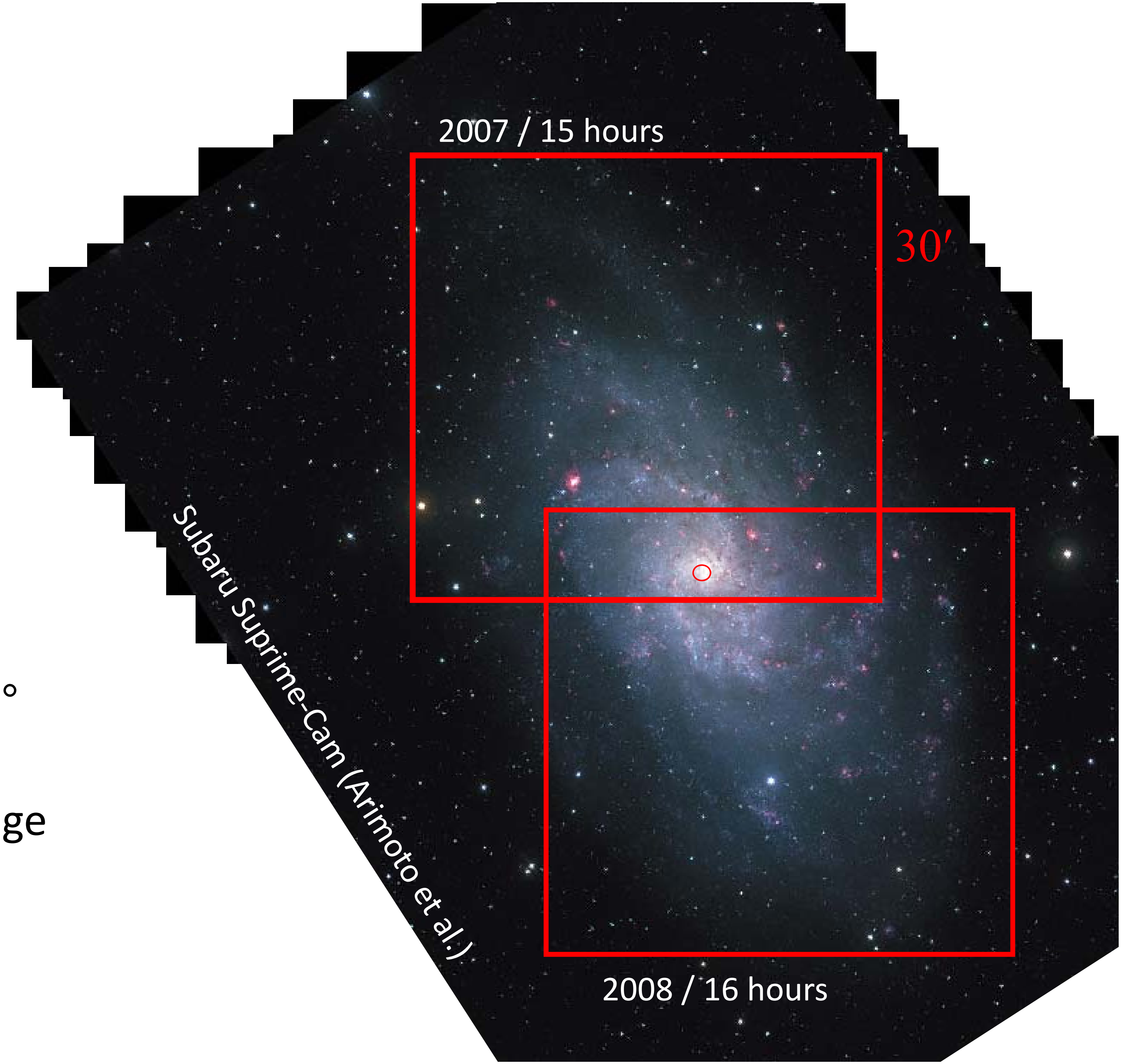
D = 840 kpc

1″ = 4 pc
30″ = 120 pc

Inclination 51°

Scd, small bulge

70′ × 40′

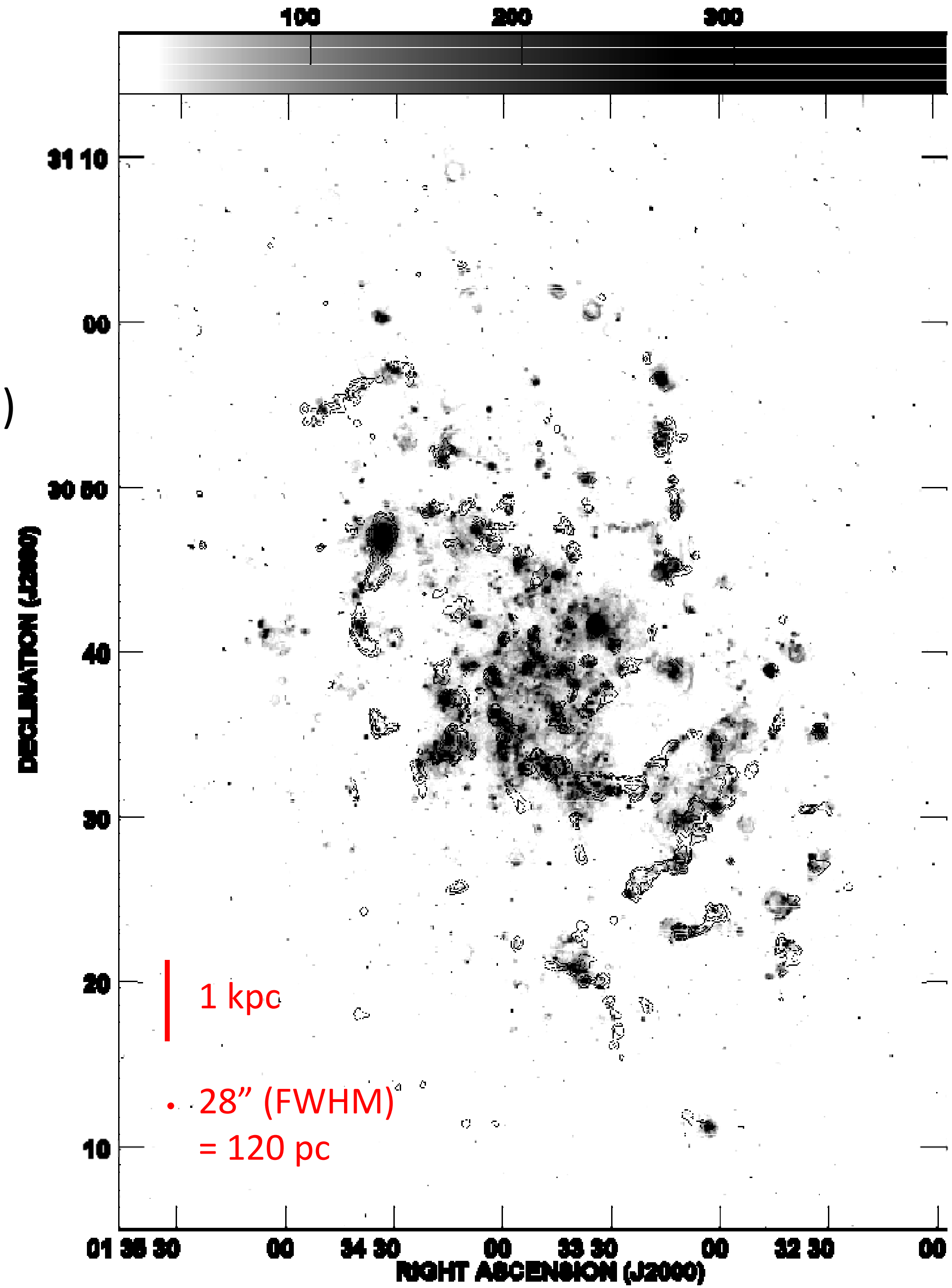


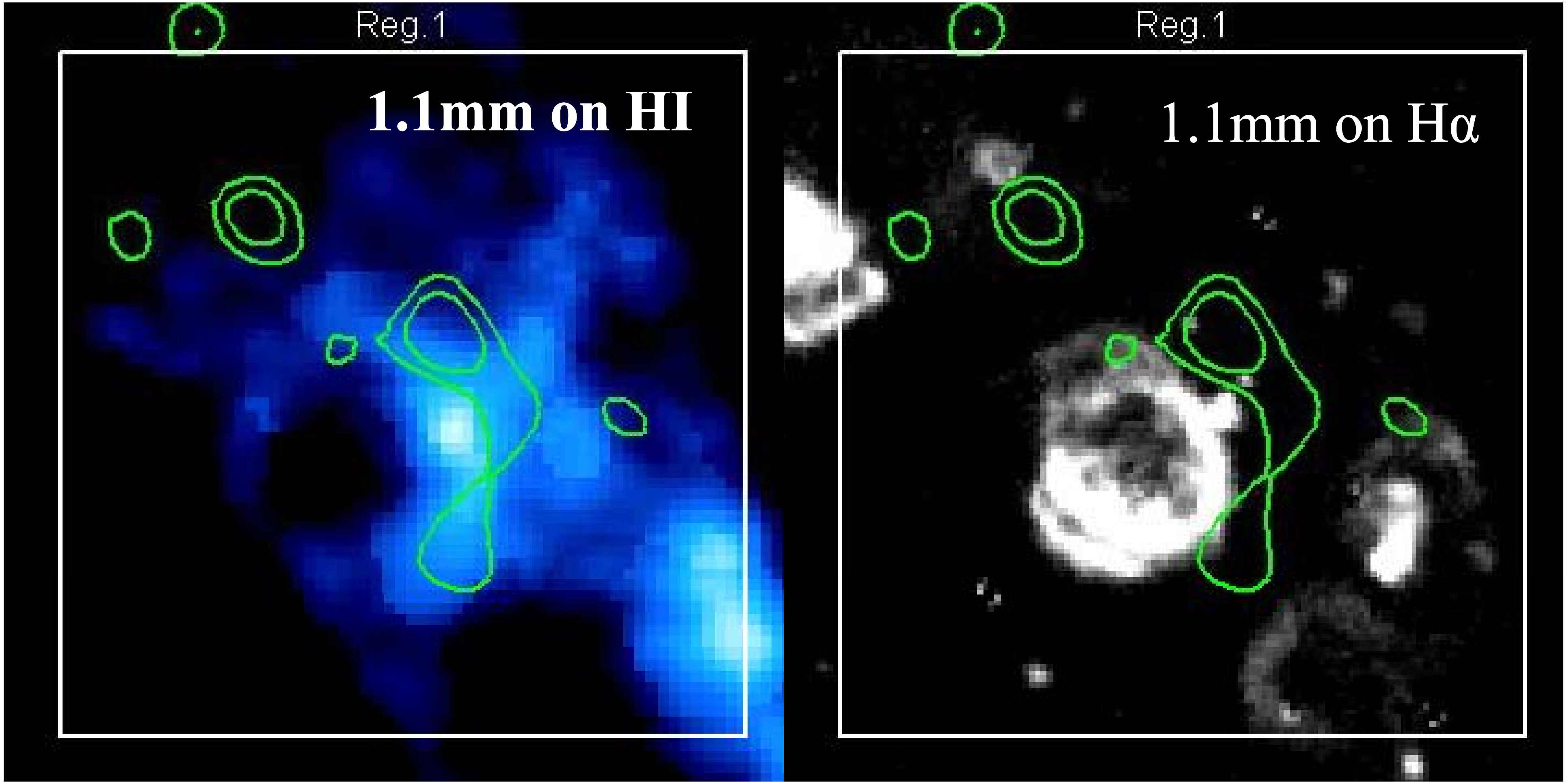
Result

- 1σ noise = 4.3 - 4.6 mJy b^{-1}
  = ~$600M_{\odot}$(κ=1.14cm^2g^{-1})
- 1.1mm contour on Hα

- clear spiral structure, most 1.1mm clumps associated with Hα

classical interpretation
→ dust heated by OB stars





No contribution from free-free bremsstrahlung

Global Dust SED

- two component fit using global flux (ISO, Spitzer, ASTE)

$$F_\nu \propto \nu^\beta \{aB_\nu(T_{\rm warm}) + bB_\nu(T_{\rm cold})\}$$

→β= 2.45 best fit

T_{warm}= **48** K

T_{cold} = **17** K

→β= 2.0 fixed

T_{warm} = **52** K

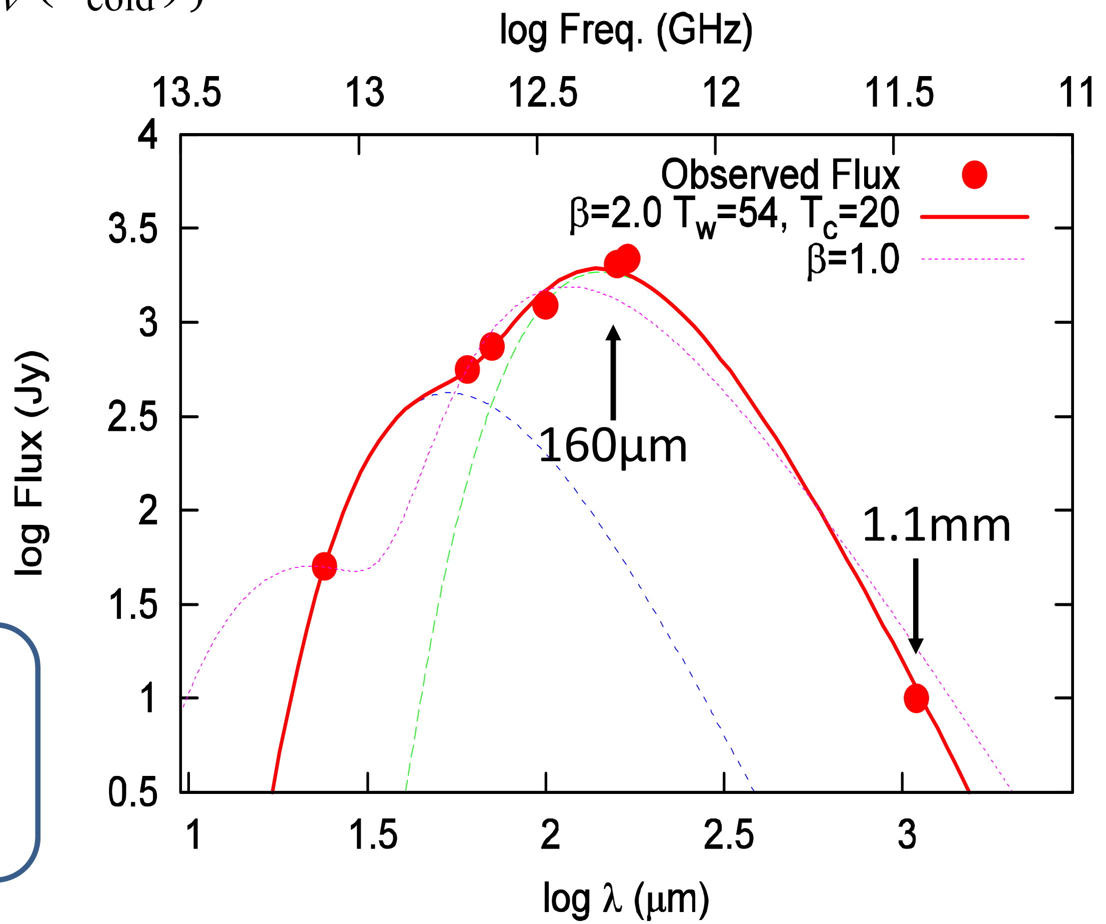
T_{cold} = **20** K

Doubling 1.1mm flux,
(c.f., Tabatabaei 08:
extended 160micron ~ 50%)

→β=2±0.3

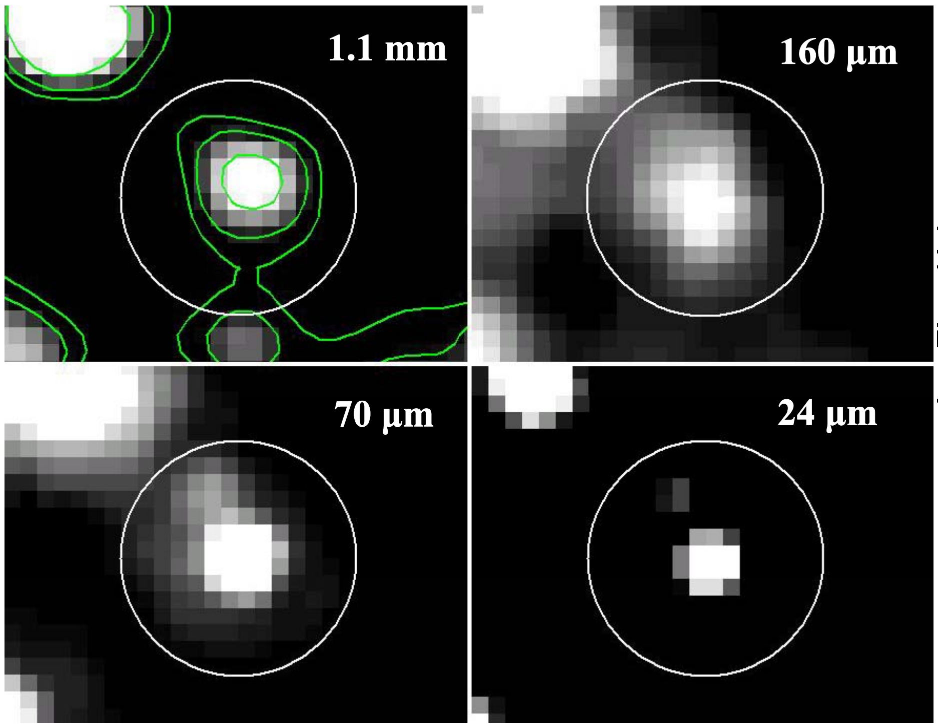
T_{warm} = **51 ±2.5** K

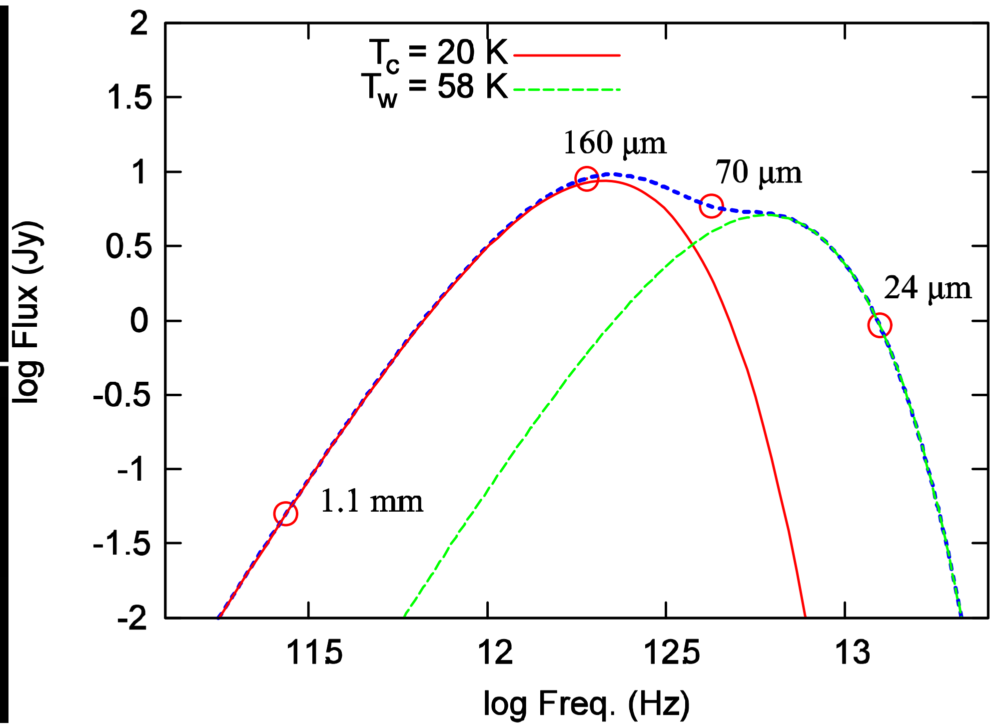
T_{cold} = **17 ±2.7** K

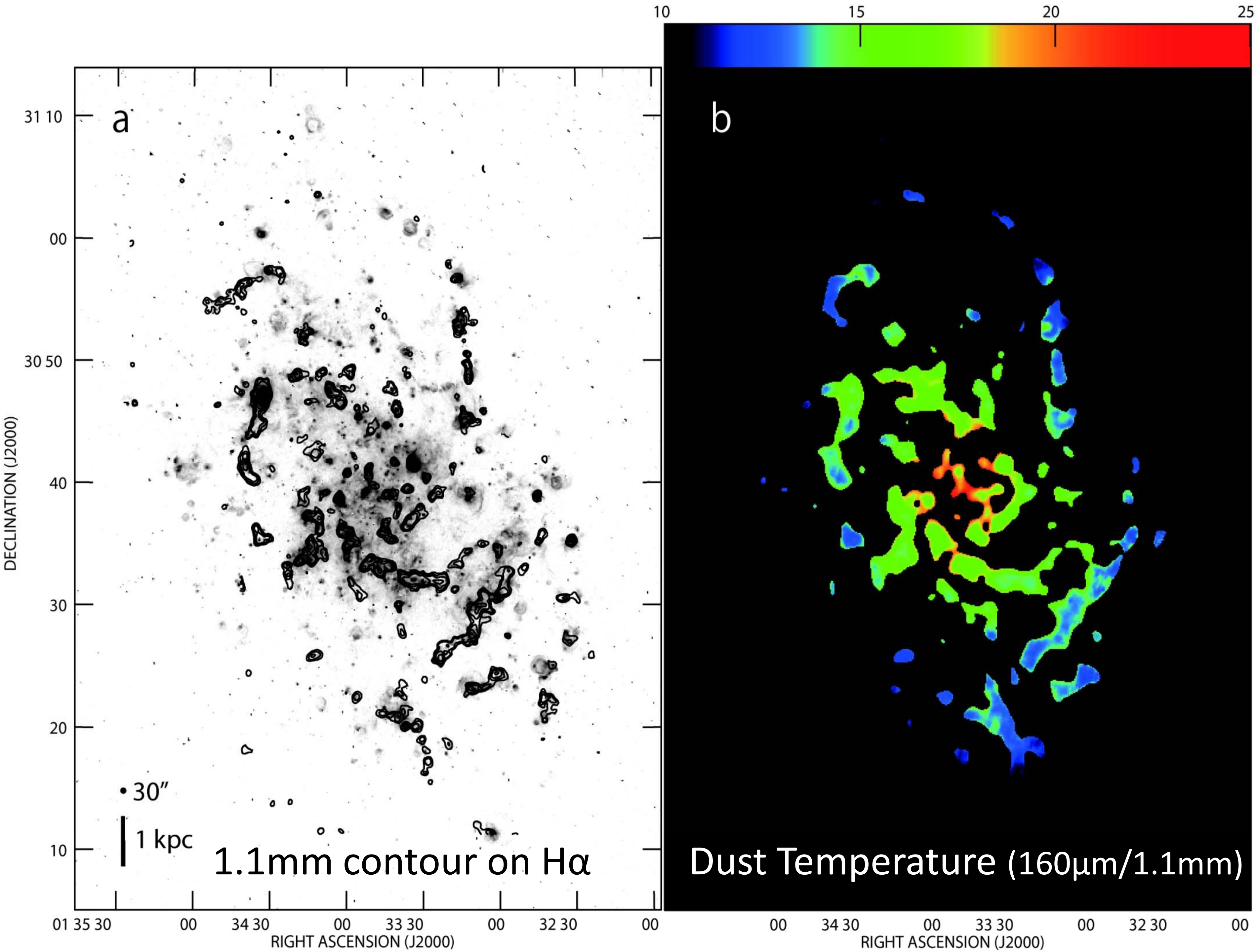


Cold Dust in the vicinity of HII regions

- ”Cold” dust exists even near SF regions, at ~100 pc scales



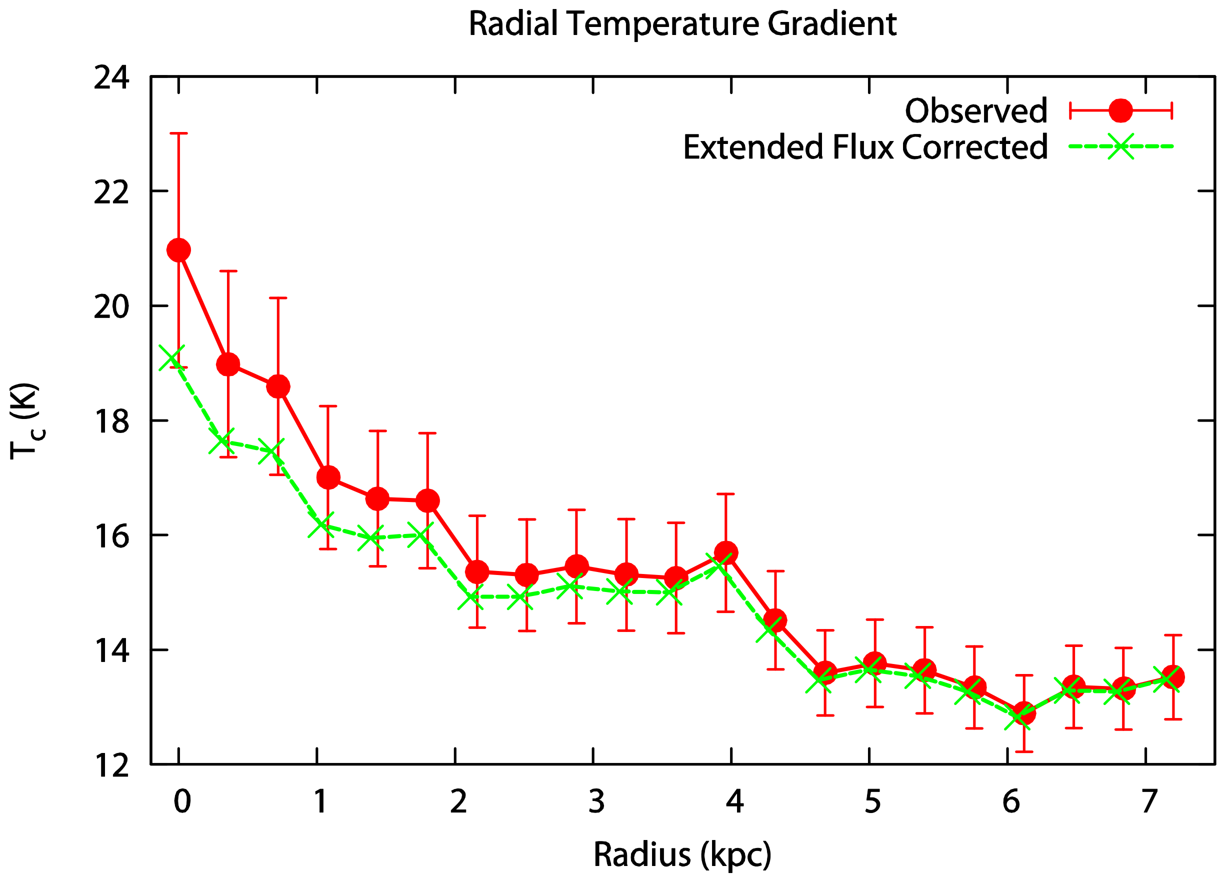




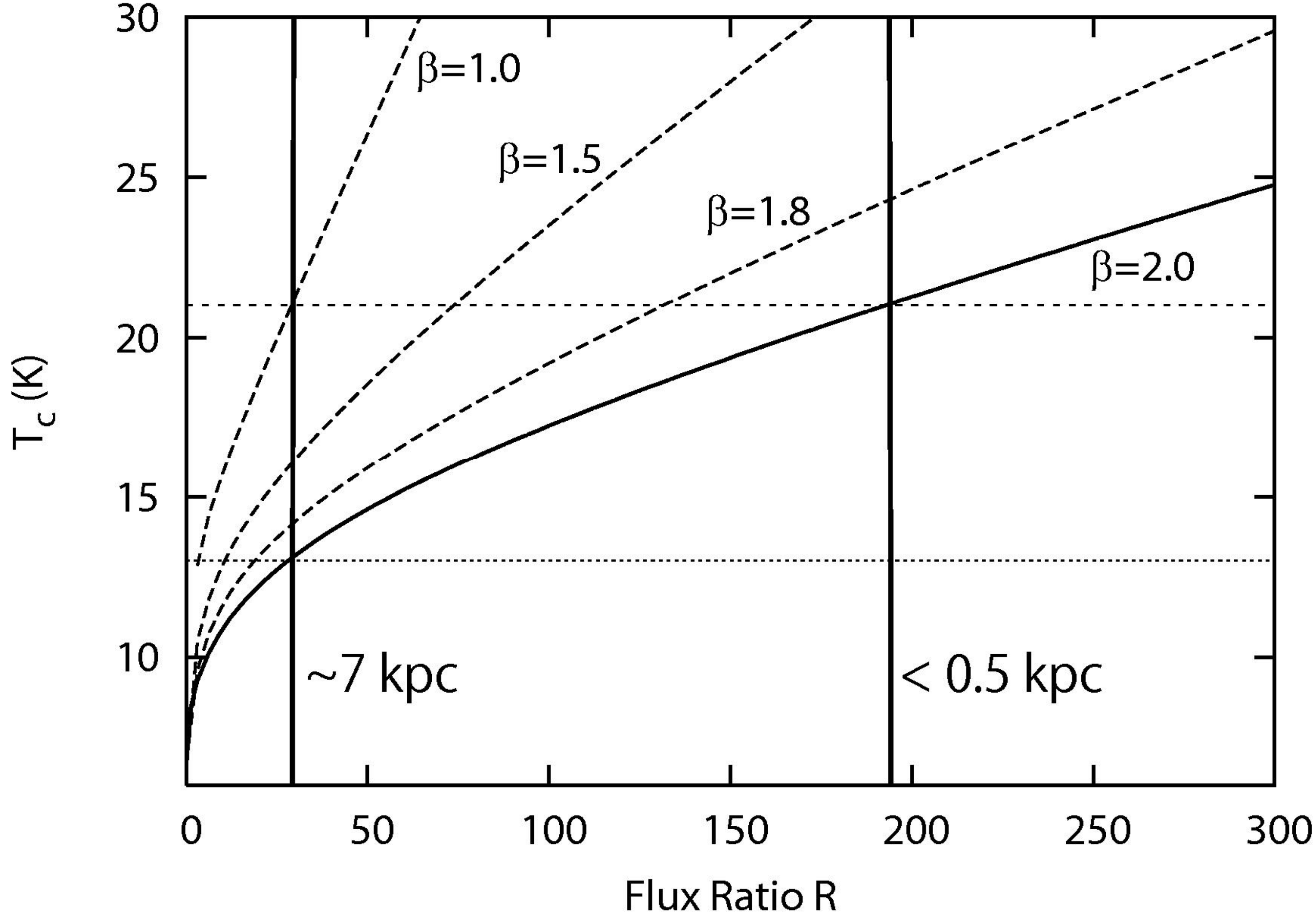
10
15
20
25
31 10
00
30 50
40
30
20
10
DECLINATION (J2000)
a
b
30″
1 kpc
1.1mm contour on Hα
Dust Temperature (160μm/1.1mm)
01 35 30
00
34 30
00
33 30
00
32 30
00
RIGHT ASCENSION (J2000)
00
34 30
00
33 30
00
32 30
00
RIGHT ASCENSION (J2000)

Temperature gradient

- Assume extended flux = half of total flux (observed = 10 Jy)
  (Tabatabaei 08; 11 brightest HII regions account for 50% of 160µm power)
- distribute 10 Jy in exponential disk → re-derive temperature
- consistent with solar vicinity ISRF heating, i.e., small OB contribution
  (e.g., Li & Draine 2005)



Color Temperature

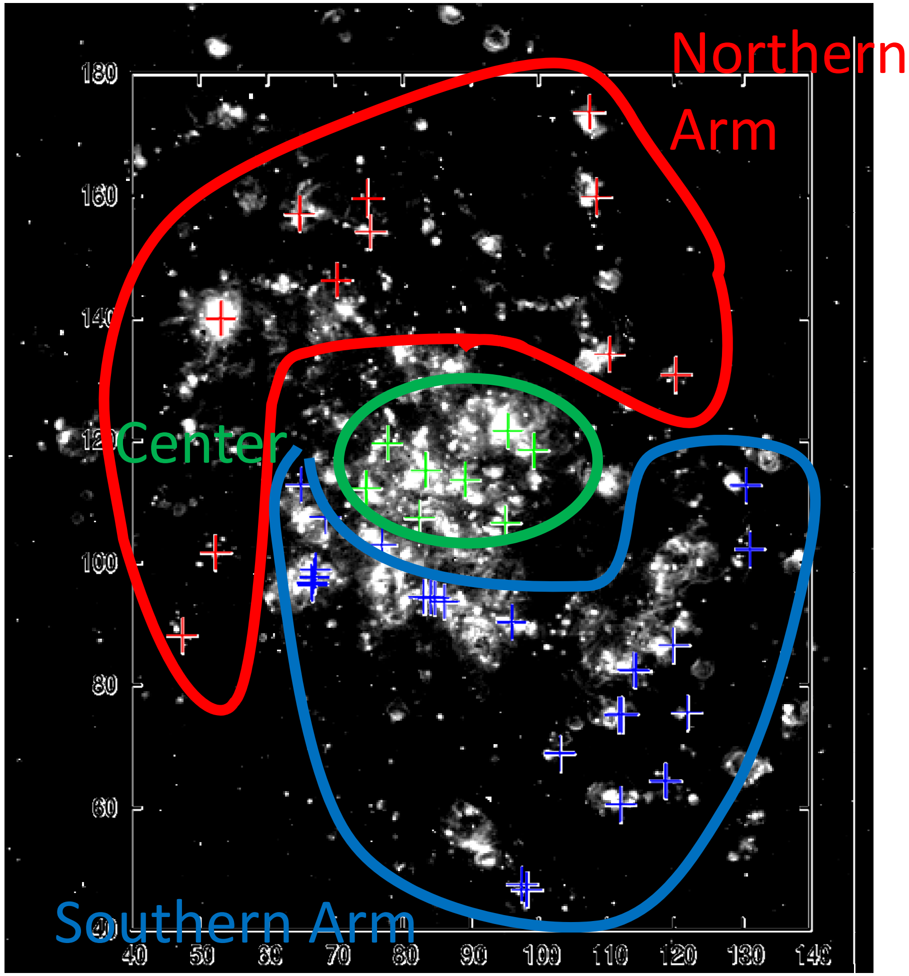


Unlikely to be β variation → T variation

Aperture photometry

HII regions with known
Oxygen abundances (61)

Ks-band (2Mass), Hα, 24µm

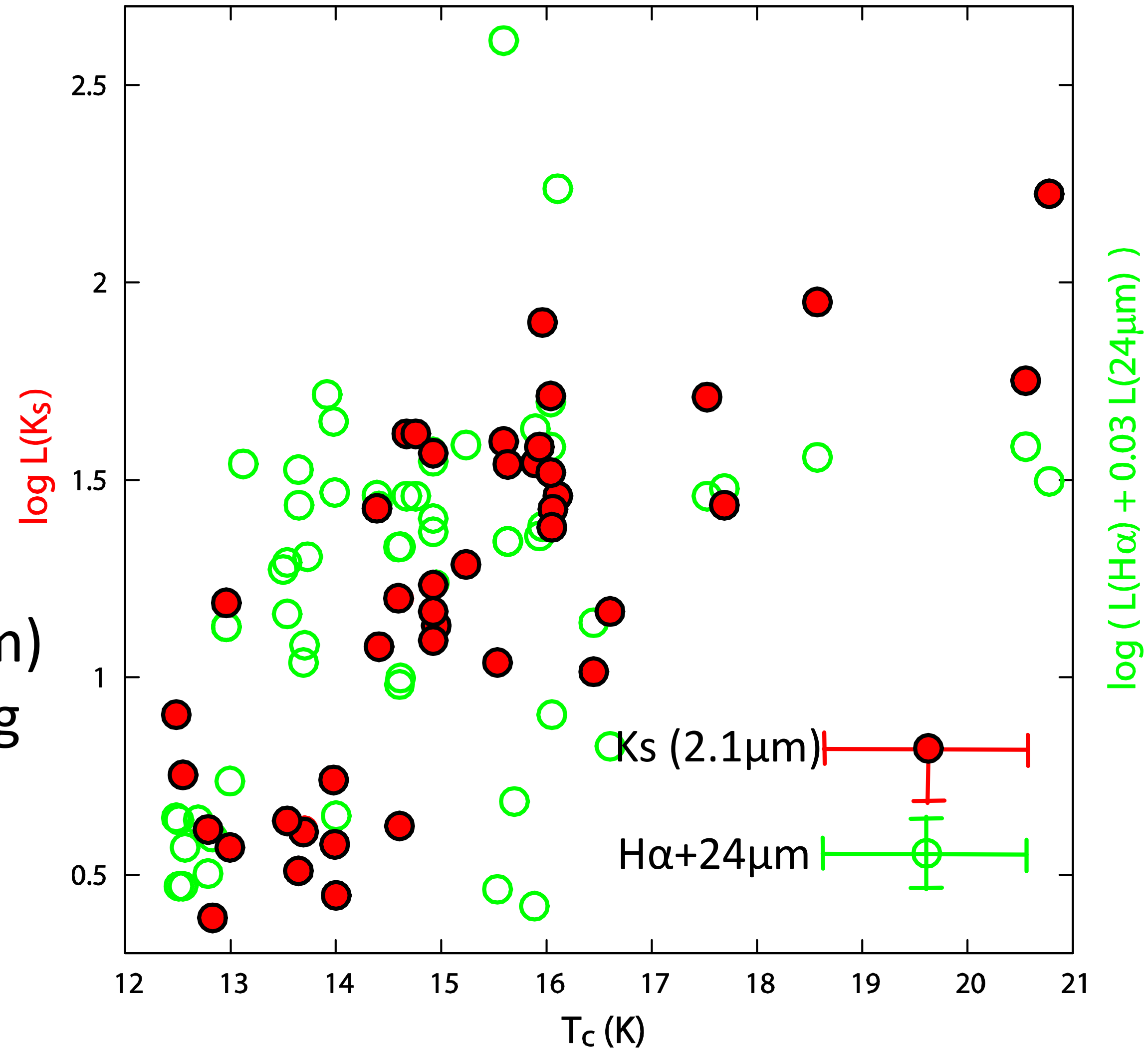


Implication on heating source

- Hα+24μm ∝ UV flux from OB stars （Calzetti+ '07）
  corr. coeff. r^2=0.26

- Temp – Ks relation
  corr. coeff. r^2=0.71

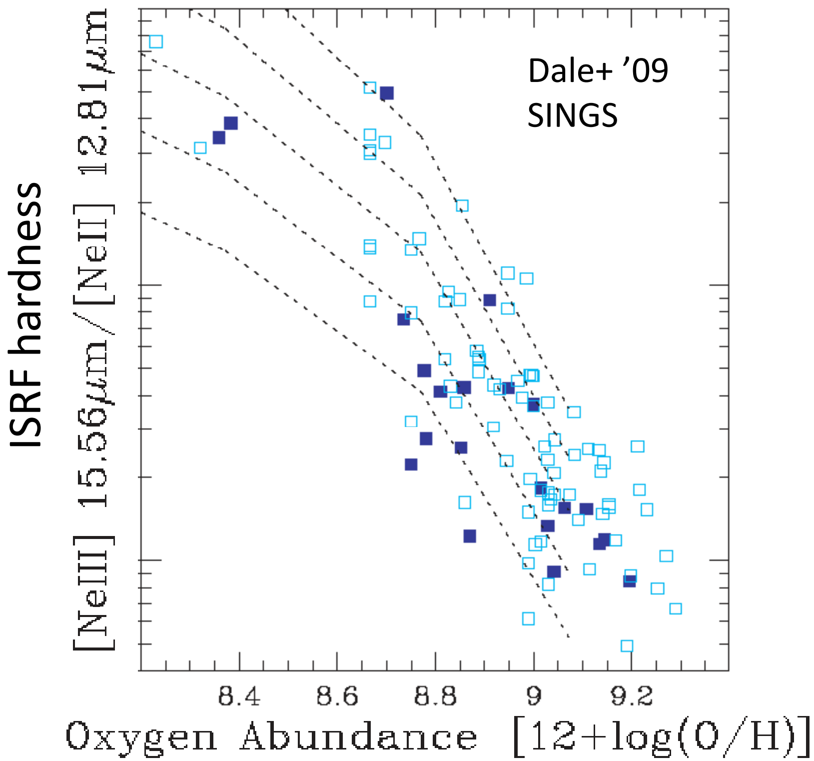
→ stars in Ks band (2.1μm) are more likely to be heating dust than OB stars.

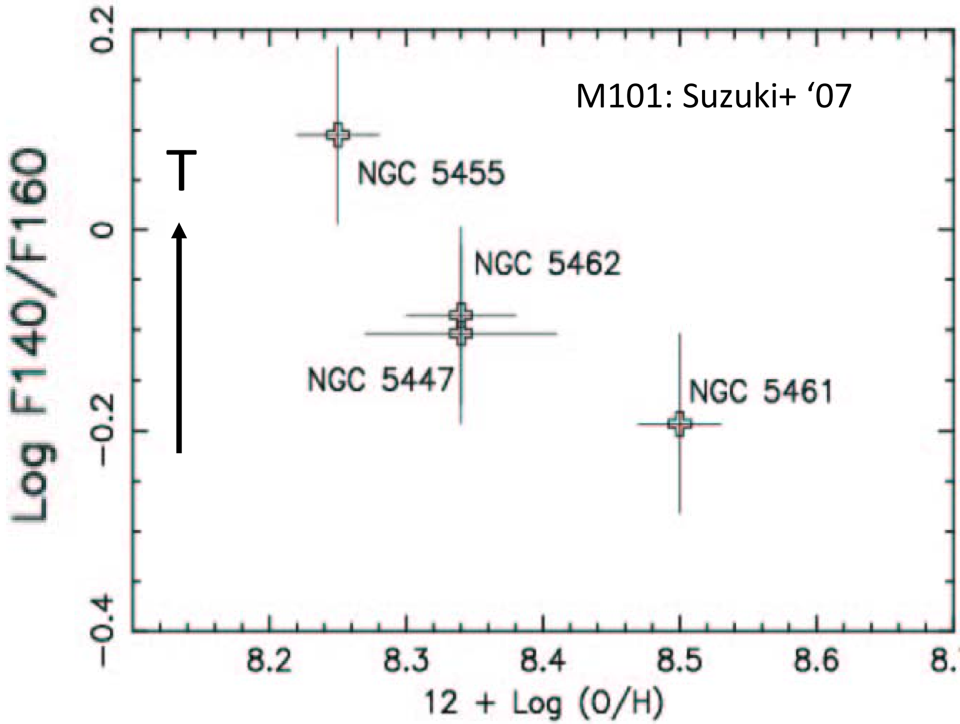


Temperature – Metallicity relation

<u>For UV heated dust,</u> expect an anti-correlation between T_d and 12+log(O/H).

- metal ↑ → dust abundance ↑ → UV photon mean free path ↓
  → UV contribution to ISRF↓ → dust temperature ↓





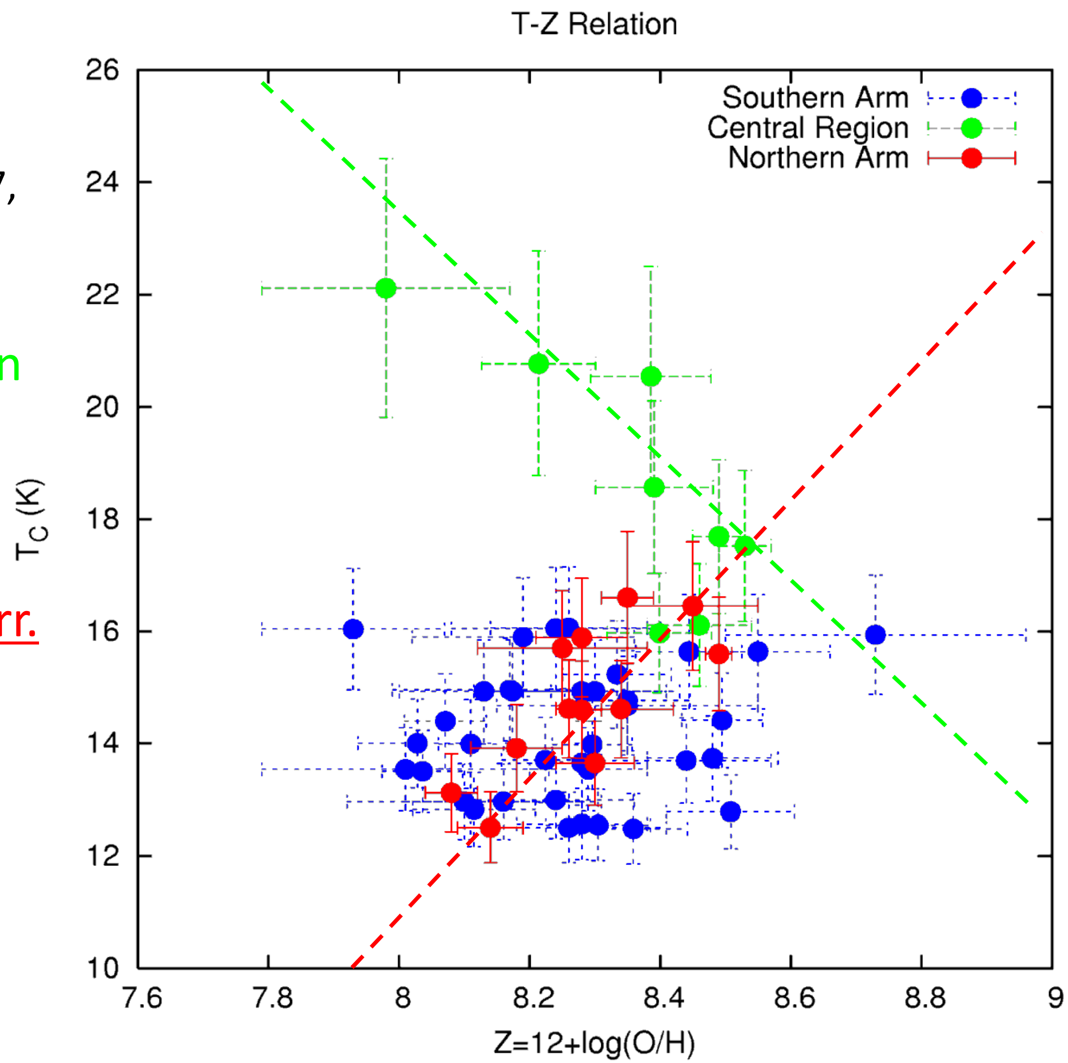
Temperature – Metallicity relation

- Oxygen abundance from optical spectroscopy
(Diaz'87, Vilchez'88, Crockett'06, Magrini'07, Rosolowsky'08) : [OII], [OIII], [NeIII]

- Central regions = anti – correlation
= UV heating (but non-OB)
Consistent with previous studies

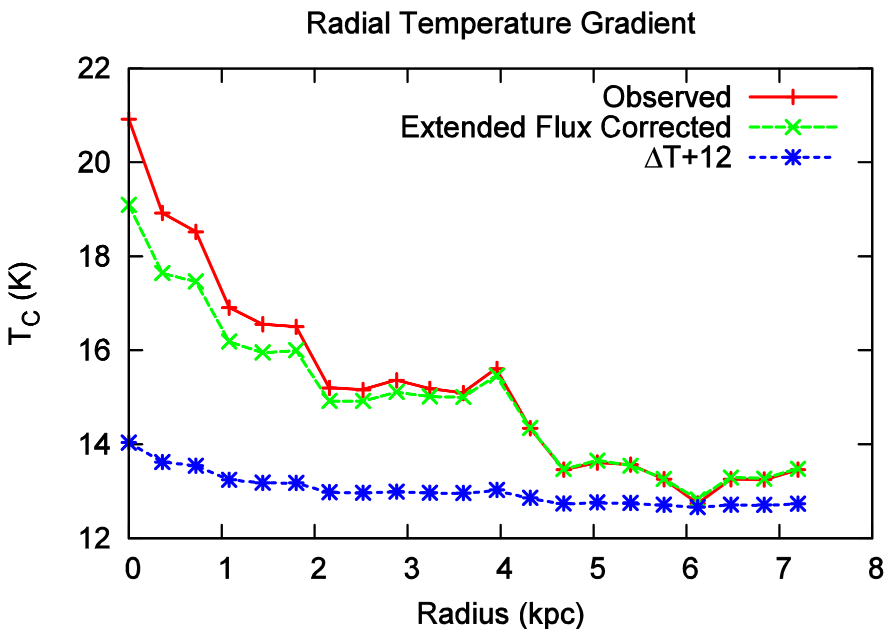
Northern Spiral Arm = <u>positive corr.</u>
= heating cotribution from softer photons ??
(e.g., Bianchi+ '00 :
NGC6946 → optical photons)

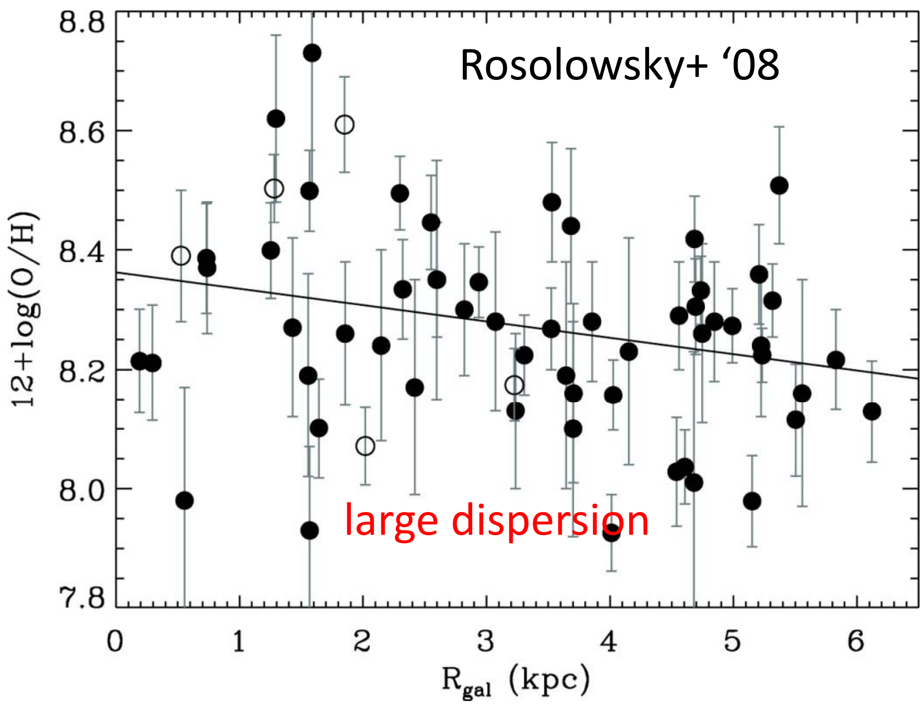
Southern Spiral Arm = no corr.
= large metallicity dispersion:
dynamical, evolutional reason ?



temperature - metallicity

Combination of metallicity gradient and T_d gradient can't reproduce the T_d – log(O/H) relation
→ the relation should be of "local" origin





M33 with ASTE/Spitzer

- 1.1 continuum observations with ASTE / AzTEC
- Cold dust associated mainly with star forming regions
- Comparison with Spitzer MIPS 160um → smooth radial temperature gradient
- Comparison of Tc with SFR and Ks flux in individual regions
  → non-massive stars as the likely heating source of "cold" dust
- relation between dust temperature and metallicity
  → variation within regions
  northern spiral : positive relation
  southern spiral : no correlation
  center : anti-positive relation
  → strong implication on the heating source
- how should we interpret FIR – submm radiation in (unresolved) normal, star-forming galaxies observed by Herschel/ALMA etc... ?