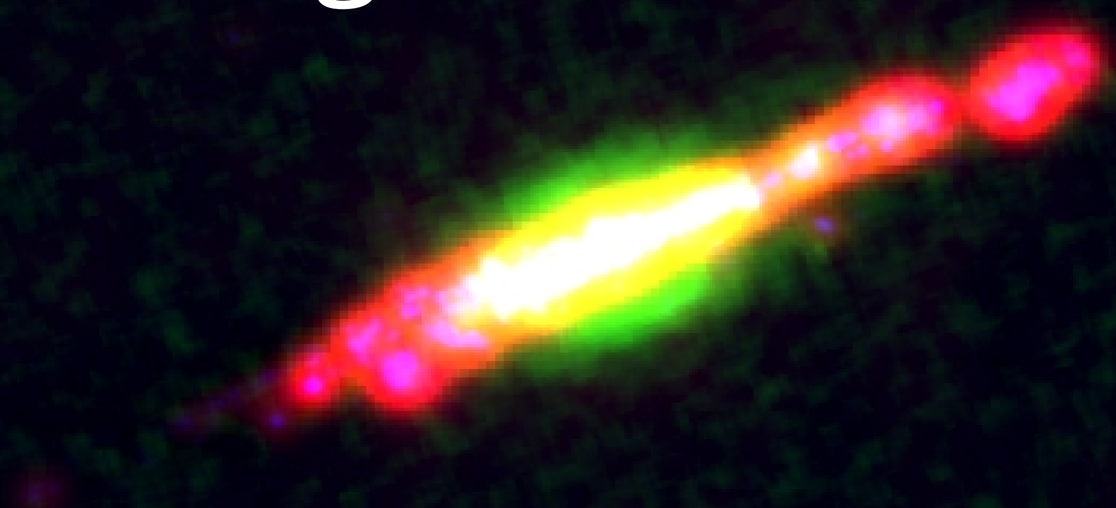
Spatially-Resolved Separation of Thermal Contribution from Radio Continuum Emission in Edge-on Galaxies



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New Mexico State University

November 3, 2017

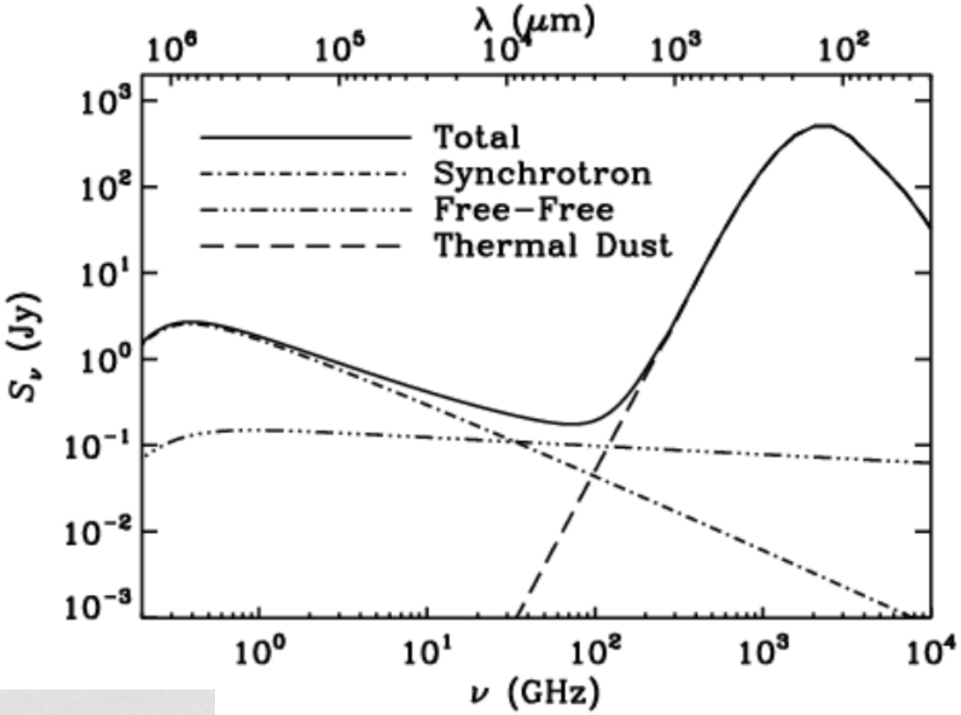
A Joint Effort!

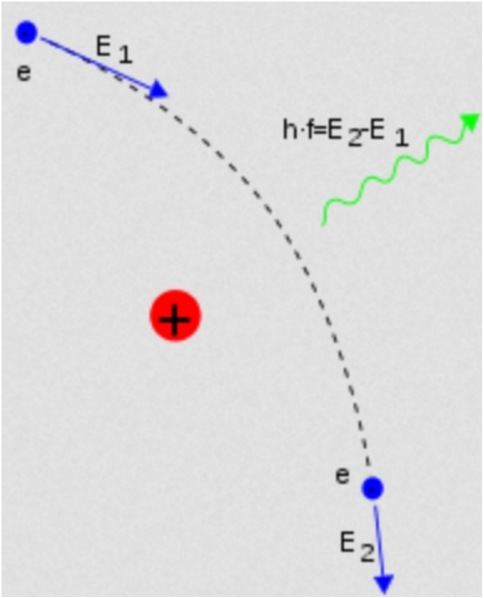
CHANG-ES Thermal Separation Working Group

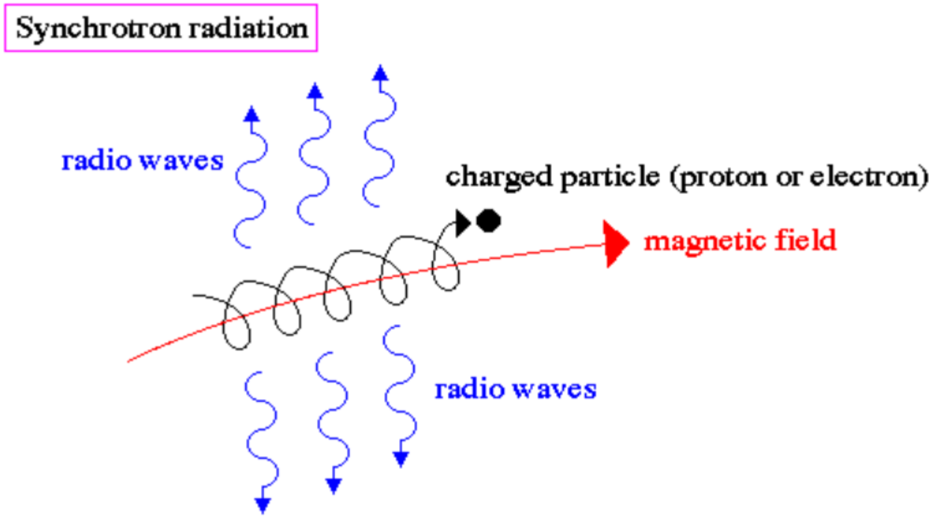
- Rich Rand (UNM)
- Silvia Carolina Mora Partiarroyo (MPIfRA)
- Philip Scmidt (MPIfRA)
- Rene Walterbos (NMSU)
- Daniel Wang (UMass Amherst)

Submitted to ApJ in October

Radio Continuum Emission

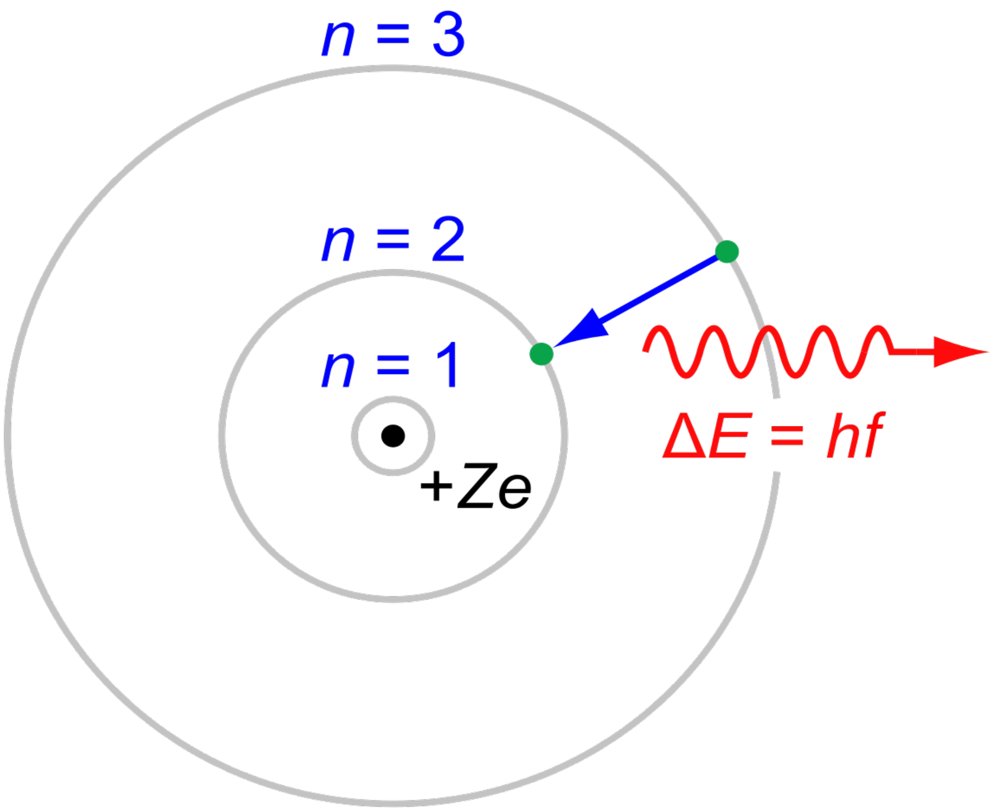






Independent Tracer Of Thermal Emission

- Free-free emission directly linked to recombination, star formation
- Most observable recombination line: Hα



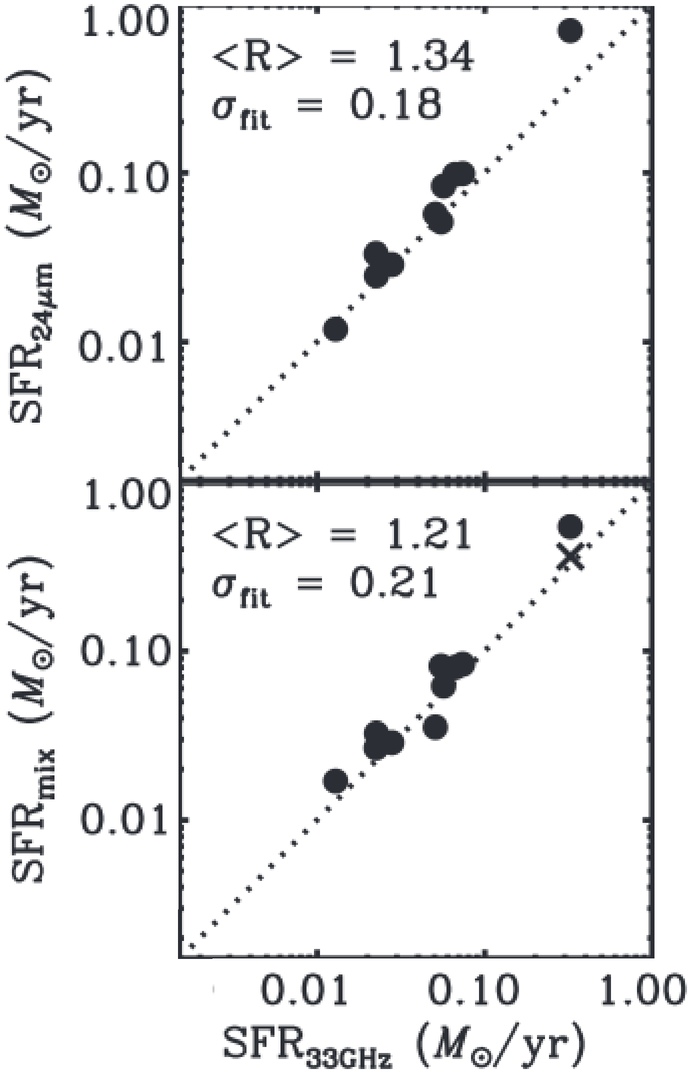
6563 Angstrom – Optical

Hα Extinction Correction

- Hα emission extincted by dust
- 22 μm infrared emission from dust used to correct for extinction

$$\left(\frac{\mathrm{SFR_{mix}}}{M_\odot\,\mathrm{yr}^{-1}}\right) = 5.37\times10^{-42}\left[\frac{L^{\mathrm{obs}}_{\mathrm{H}\alpha}+0.031\,\nu L_\nu(24\,\mu\mathrm{m})}{\mathrm{erg\,s^{-1}}}\right]$$

$$\left(\frac{\mathrm{SFR}_{24\,\mu\mathrm{m}}}{M_\odot\,\mathrm{yr}^{-1}}\right) = 5.58\times10^{-36}\left[\frac{\nu L_\nu(24\,\mu\mathrm{m})}{\mathrm{erg\,s^{-1}}}\right]^{0.826}$$



Murphy+2011, Calzetti+2010

Thermal Prediction

- Mixture – Hα + 22 μm
- 22 μm Only
- Test sample, 3 galaxies: NGCs 891, 3044, 4631

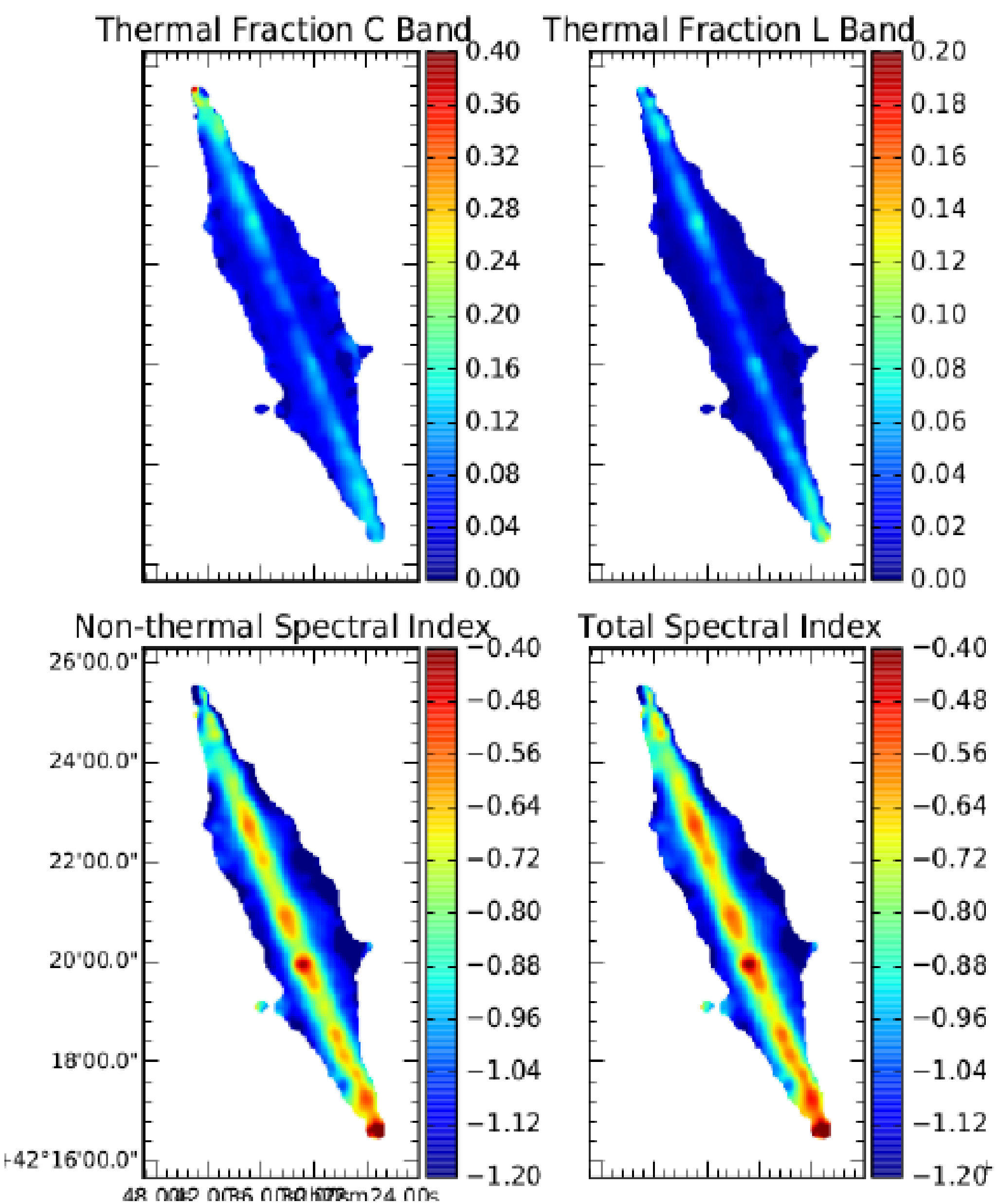
$$\left(\frac{\mathrm{SFR}_{\nu}^{\mathrm{T}}}{\mathrm{M}_{\odot}\mathrm{yr}^{-1}}\right) = 4.6 \times 10^{-28} \left(\frac{\mathrm{T_e}}{10^4\mathrm{K}}\right)^{-0.45} \left(\frac{\nu}{\mathrm{GHz}}\right)^{0.1} \left(\frac{\mathrm{L}_{\nu}^{\mathrm{T}}}{\mathrm{erg}\cdot\mathrm{s}^{-1}\mathrm{Hz}^{-1}}\right)$$

For more on comparison between methods see last year's talk, or talk to me

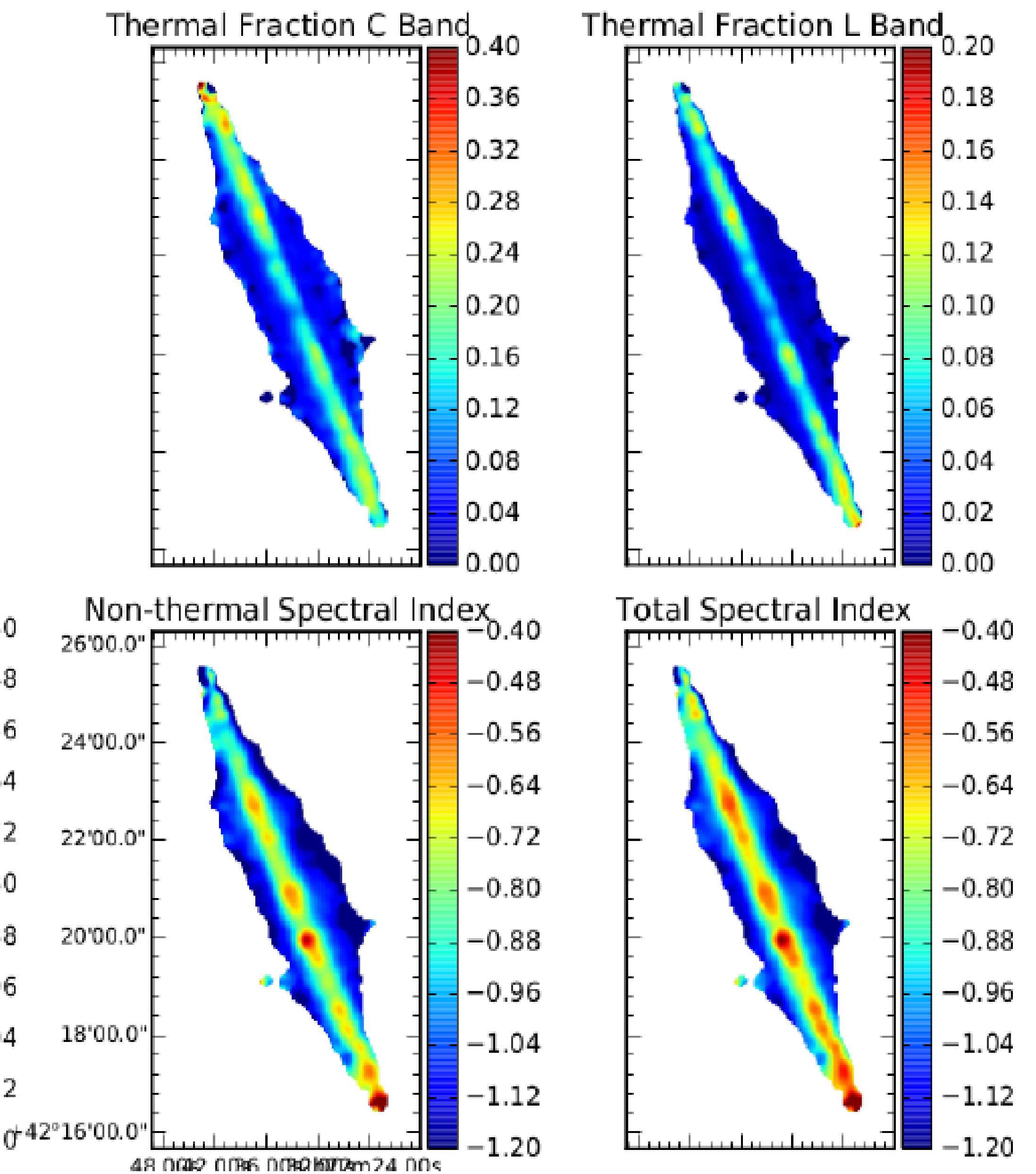
	NGC 891	NGC 3044	NGC 4631
SFR ($M_{\odot}$/yr)	1.55	0.95	1.33
H-Type	Sb	SBc	SBcd
D (kpc)	33.6	26.0	32.3

Results – NGC 891

Mixture

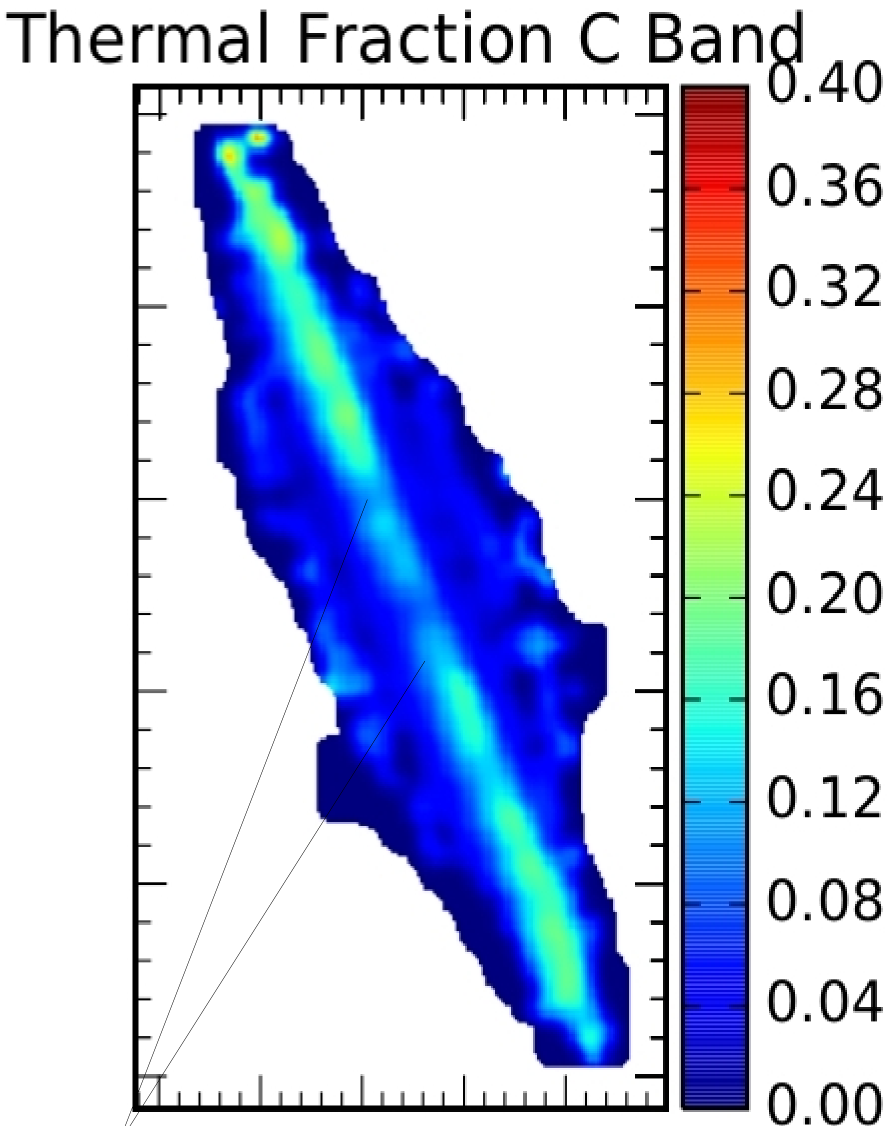


22 μm Only



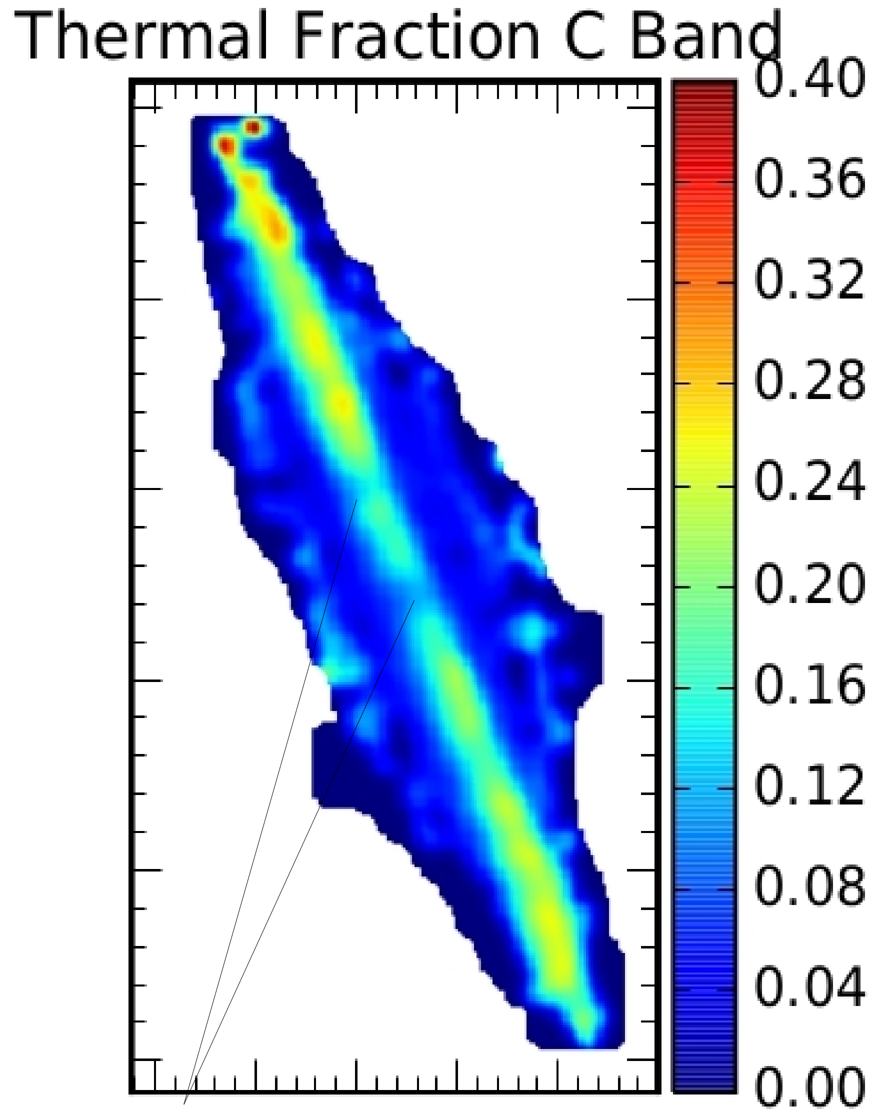
What if we change T_e?

T_e= 7,000 K



~11%

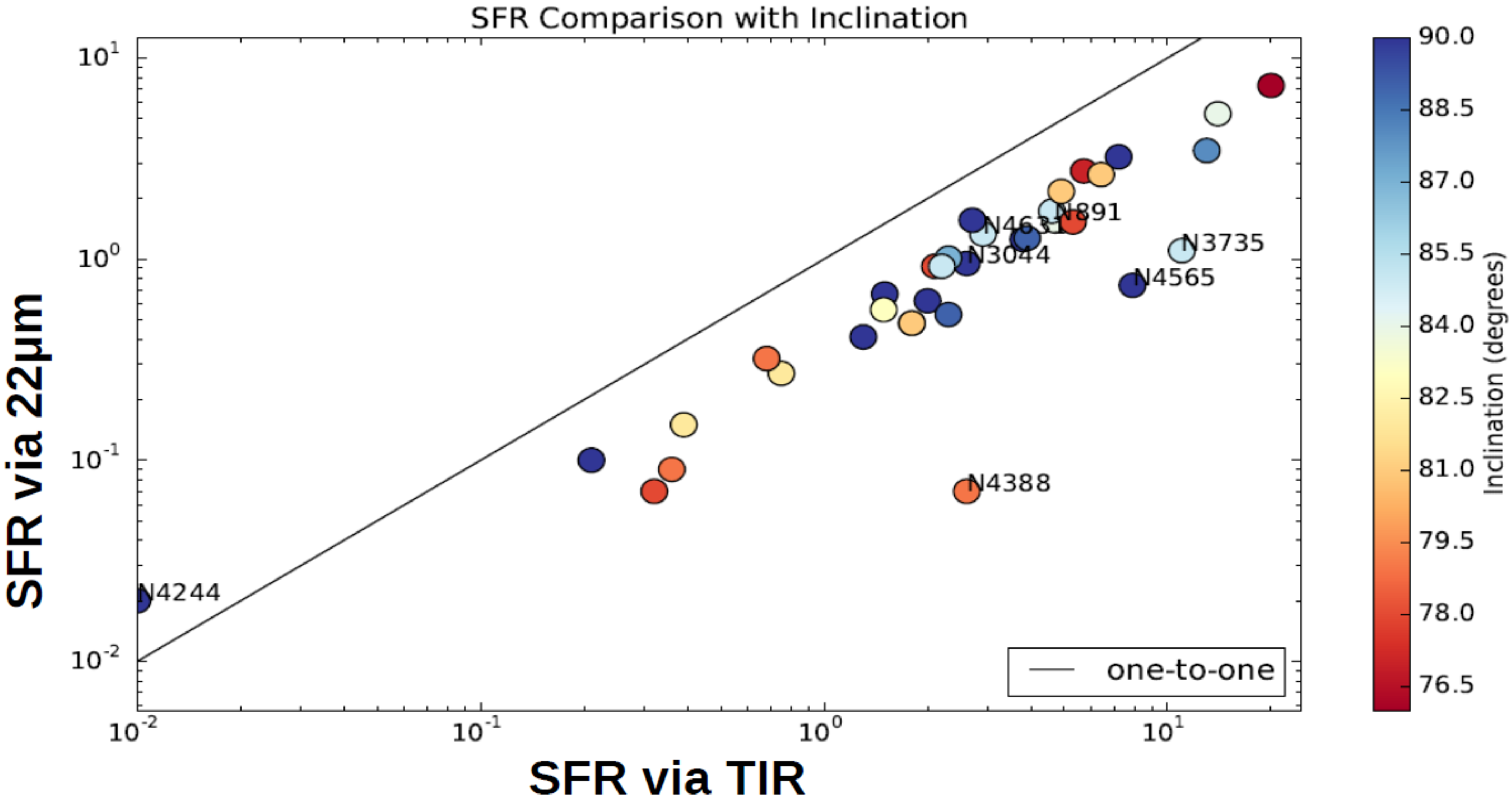
T_e= 13,000K



~21%

Variations in electron temperature can cause variations of ~10% in thermal fraction

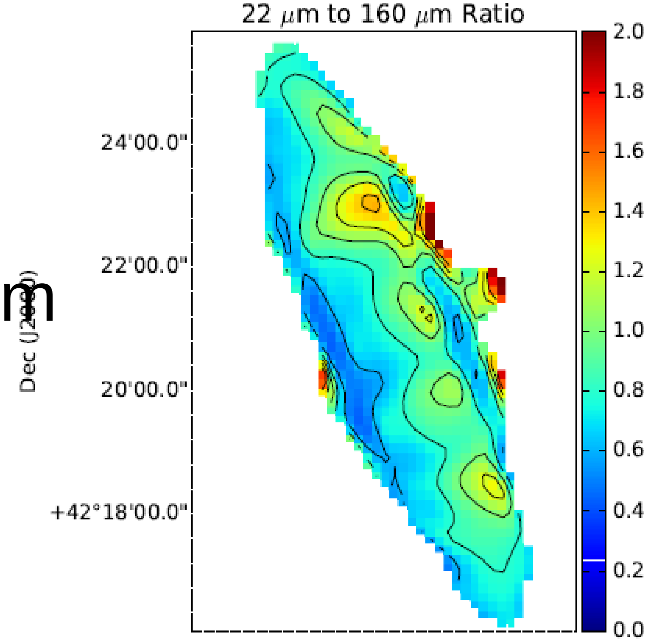
SFR Disparity

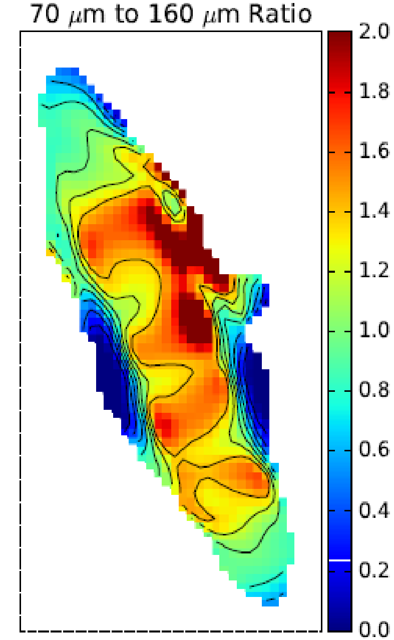


- TIR from IRAS 25, 60, 100 μm, and Dale & Helou 2003 definition plus SFR from Kennicutt 98
- After correcting for difference in IMFs, newer LTIR calibration, and low LTIR/L24 sample, the difference is a factor of ~1.6
- No inclination dependence...?

What if we go further into the IR?

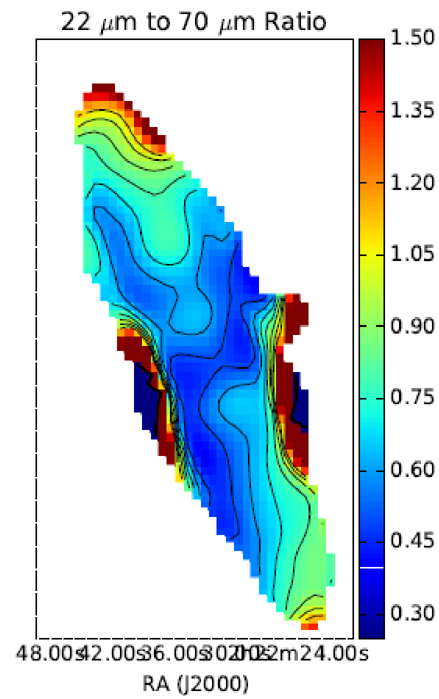
22µm / 160µm





70µm / 160µm

Which do we trust?



22µm / 70µm

Expanded Sample – IRAS RBGS

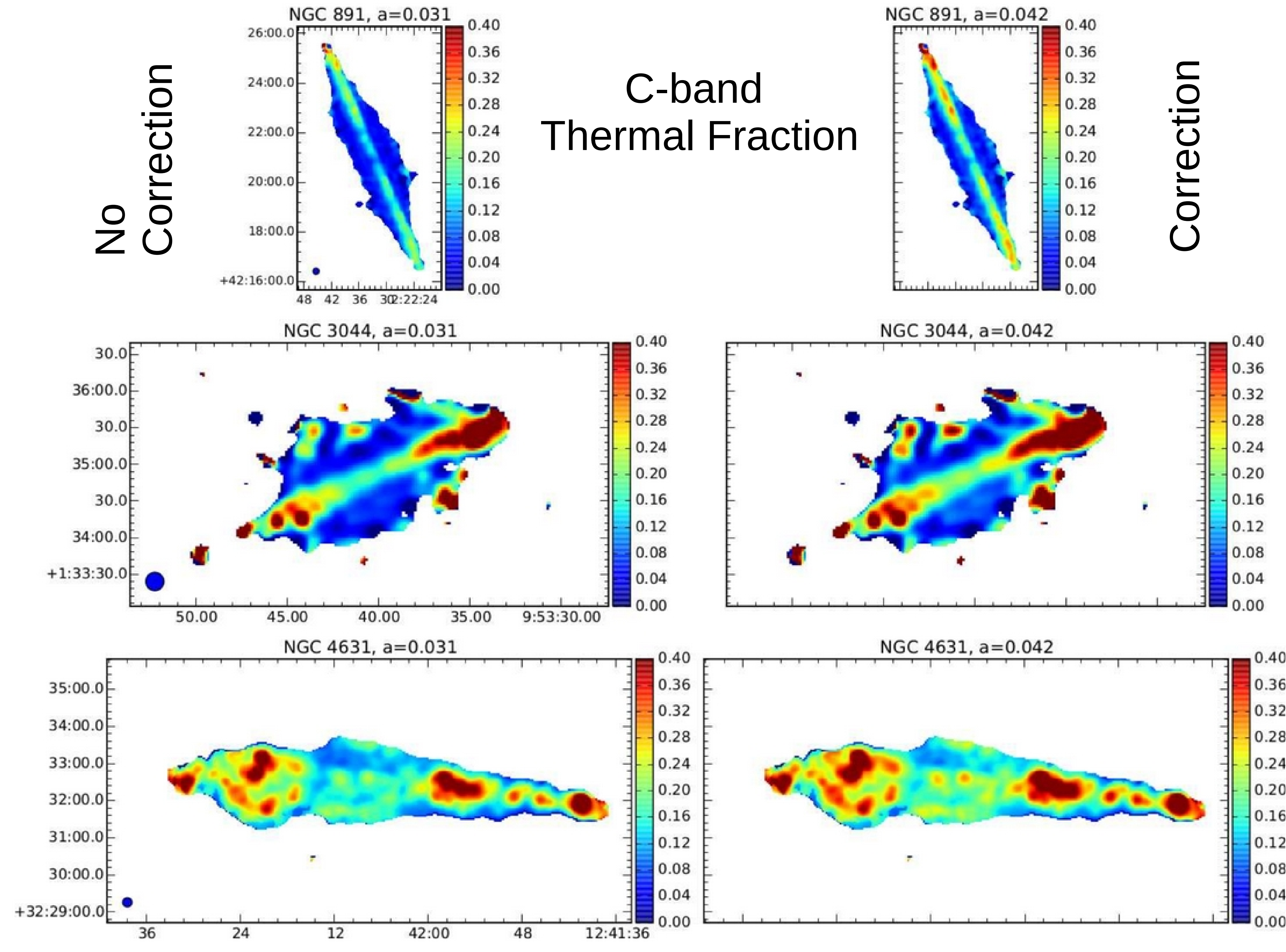
- IRAS Revised Bright Galaxy Survey (Sanders+03)
- Contains 629 galaxies (23 CHANG-ES galaxies)
- 12, 25, 60, 100 μm
- Compared at f25/f100 ratios for edge ons (50) vs. face ons (~150)
- Main result: f25/f100 lower in edge ons by factor of 1.36
- Complex, galaxy dependent morphology
- This is by far the most convincing evidence of extinction

Recommended Method

$$L(H\alpha_{corr}) = L(H\alpha_{obs}) + 0.042 \cdot \nu L_{\nu}(24\mu m)$$

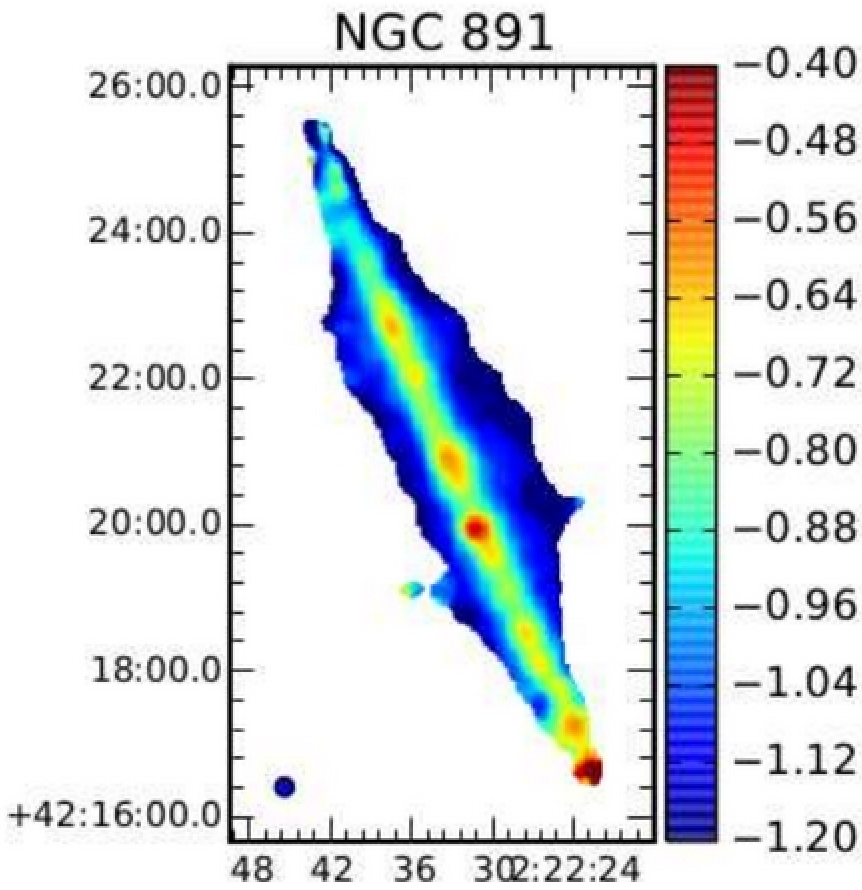
0.031 x 1.36

Extra factor takes into account average global extinction of 22 micron emission in edge-on galaxies

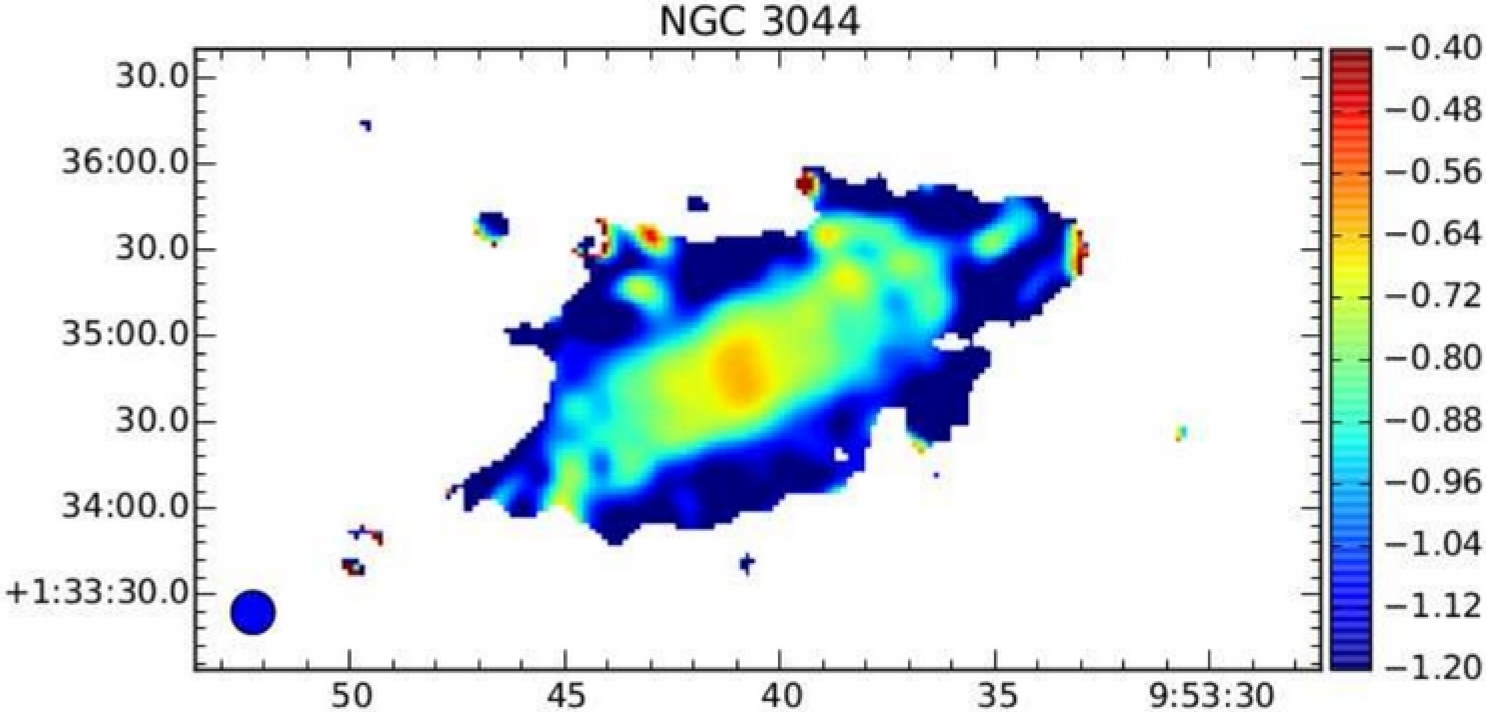


C-band
Thermal Fraction
No Correction
Correction
NGC 891, a=0.031
NGC 891, a=0.042
NGC 3044, a=0.031
NGC 3044, a=0.042
NGC 4631, a=0.031
NGC 4631, a=0.042
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
26:00.0
24:00.0
22:00.0
20:00.0
18:00.0
+42:16:00.0
48 42 36 30 2:22:24
30.0
36:00.0
30.0
35:00.0
30.0
34:00.0
+1:33:30.0
50.00 45.00 40.00 35.00 9:53:30.00
35:00.0
34:00.0
33:00.0
32:00.0
31:00.0
30:00.0
+32:29:00.0
36 24 12 42:00 48 12:41:36

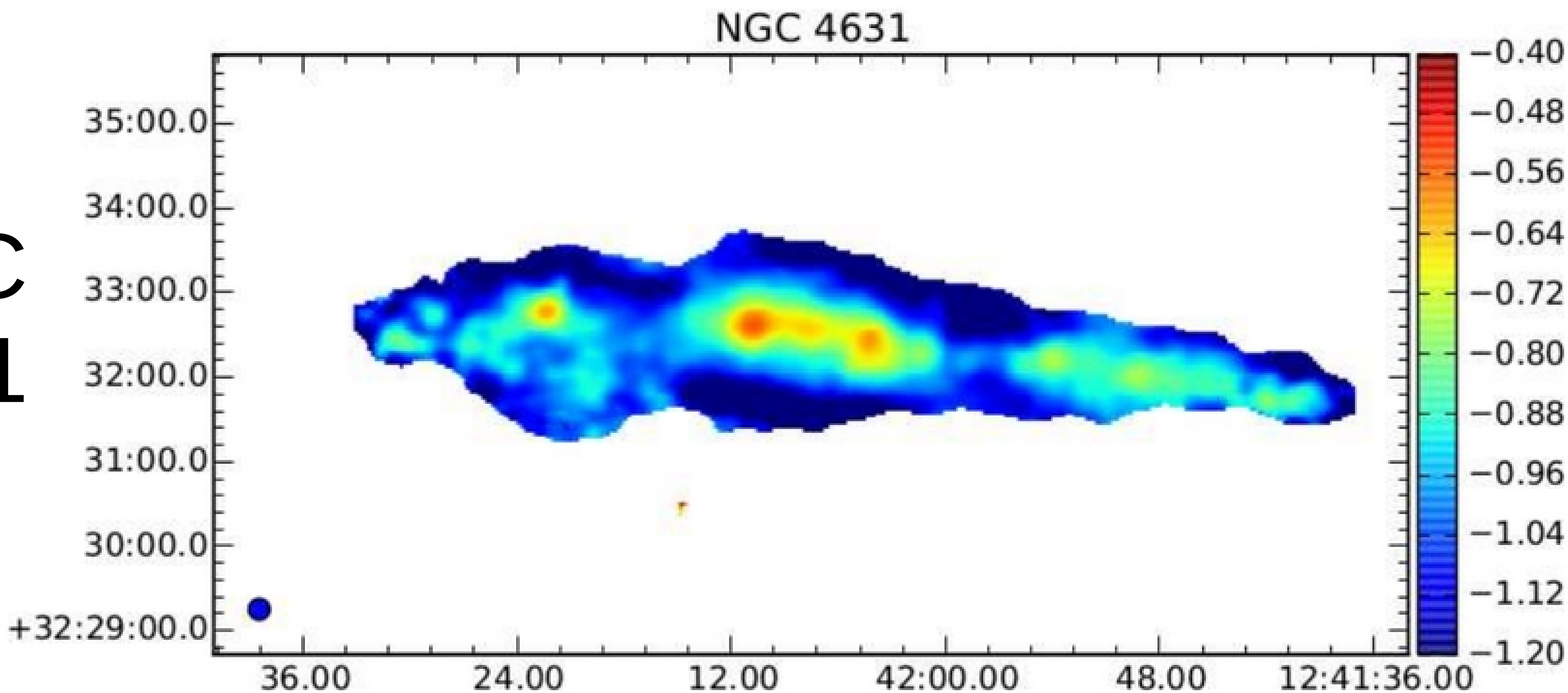
Non-thermal Spectral Index, a=0.042



NGC 3044



NGC 4631



Non-thermal Spectra Index Behavior

Region	NGC 891	NGC 3044	NGC 4631
+2 kpc	-1.16 ± 0.28	-0.82 ± 0.17	-1.18 ± 0.28
+1 kpc	-0.98 ± 0.24	-0.75 ± 0.16	-0.98 ± 0.24
0 kpc	-0.73 ± 0.18	-0.75 ± 0.16	-0.72 ± 0.17
−1 kpc	-1.02 ± 0.25	-0.77 ± 0.16	-0.95 ± 0.23
−2 kpc	-1.17 ± 0.28	-0.89 ± 0.19	-1.24 ± 0.30

α_{nth} steepens with vertical distance from the disk

Conclusions

- Inconsistencies in thermal morphologies of edge-on galaxies likely due to 22 micron extinction
  - Average global 22 micron extinction ~1.36
  - Uncertain electron temperature, metallicity in the central disk may also play a role
- We see clear evidence for steepening non-thermal spectral index with vertical distance
  - Cosmic ray aging