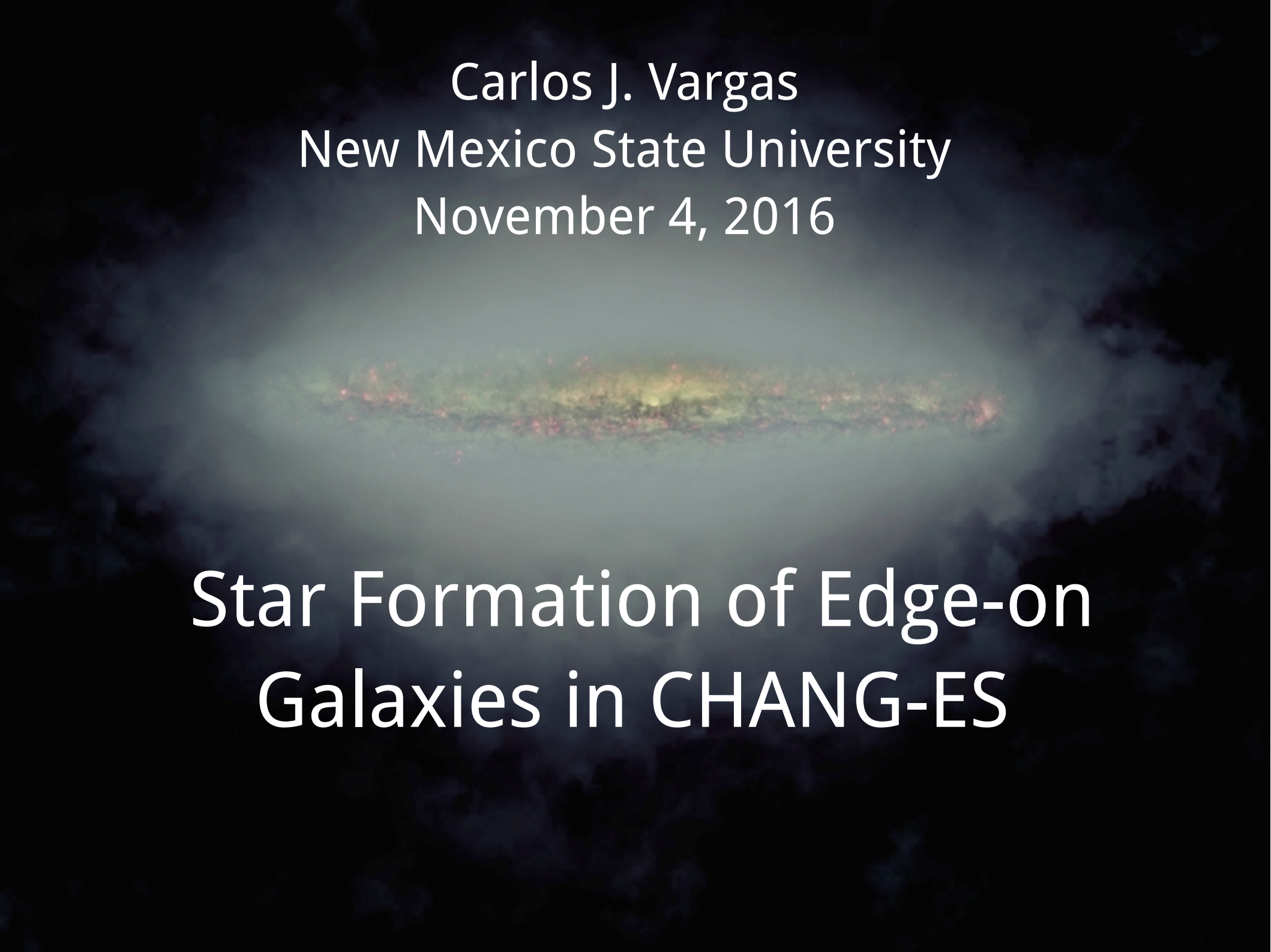
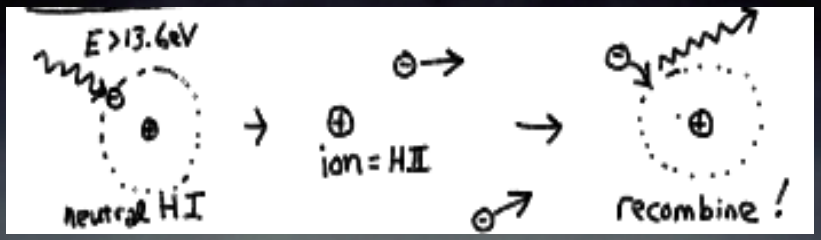
Carlos J. Vargas
New Mexico State University
November 4, 2016



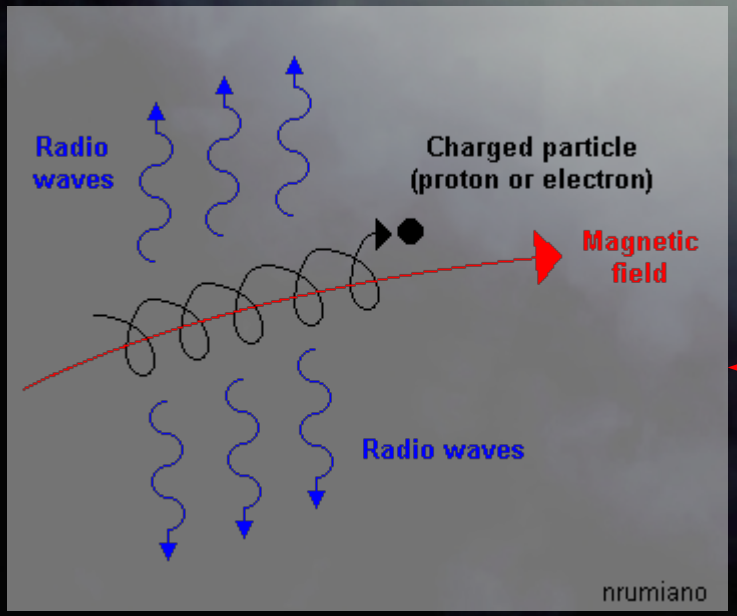
Star Formation of Edge-on Galaxies in CHANG-ES



Recombination Line Emission

Hα → Optical

Synchrotron Radiation



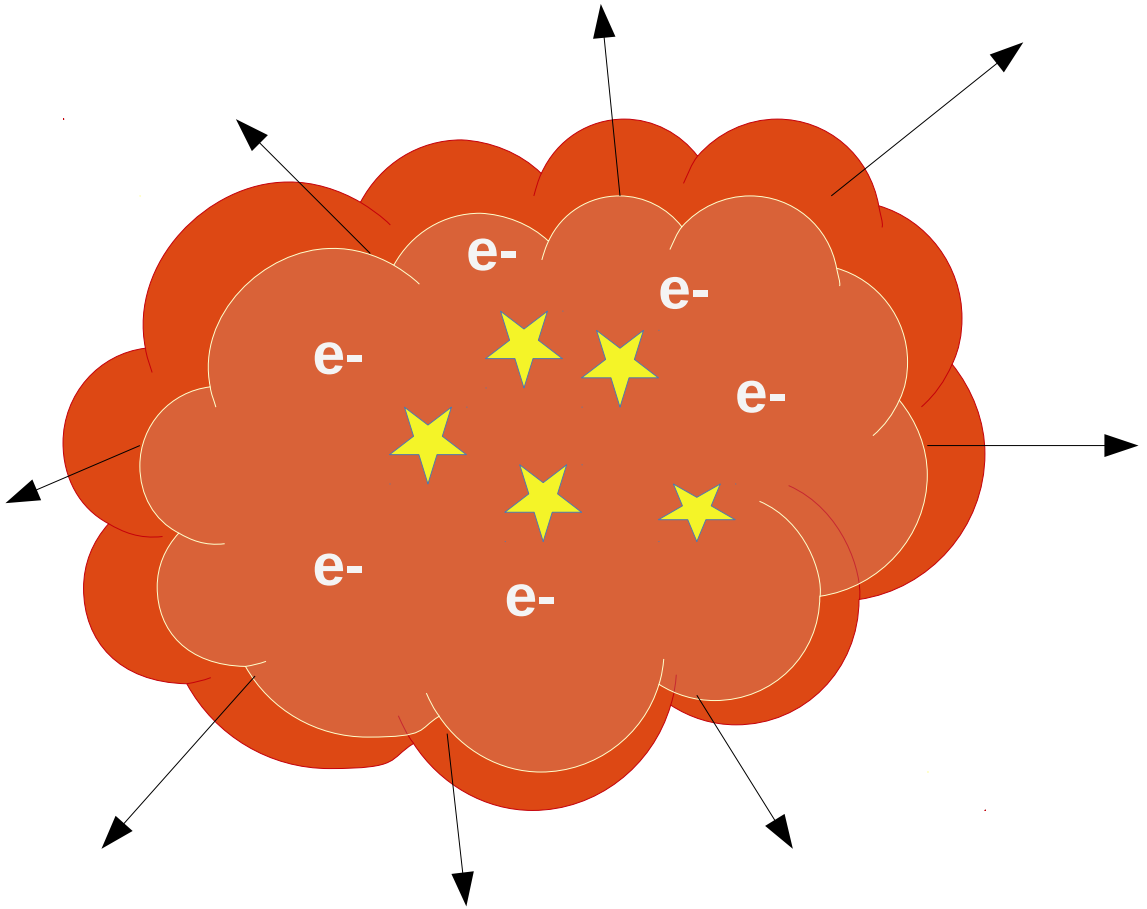
Radio

Bremsstrahlung Radiation

Motivation

- Study relation of SF to continuum halo properties
  - SF maps can be used to predict thermal radio component
- Enables studies of Non-thermal component
  - ie. CR energy spectrum
  - CRs age as they diffuse, which steepens the NTH spectral index
- CHANG-ES Unique Problem: Edge-on Orientation
  - Extinction in Optical
  - How to translate face-on studies of star formation relations between different tracers to edge-ons
- Only have 2 radio frequency bands, we would have to assume constant non-thermal spectral index to separate

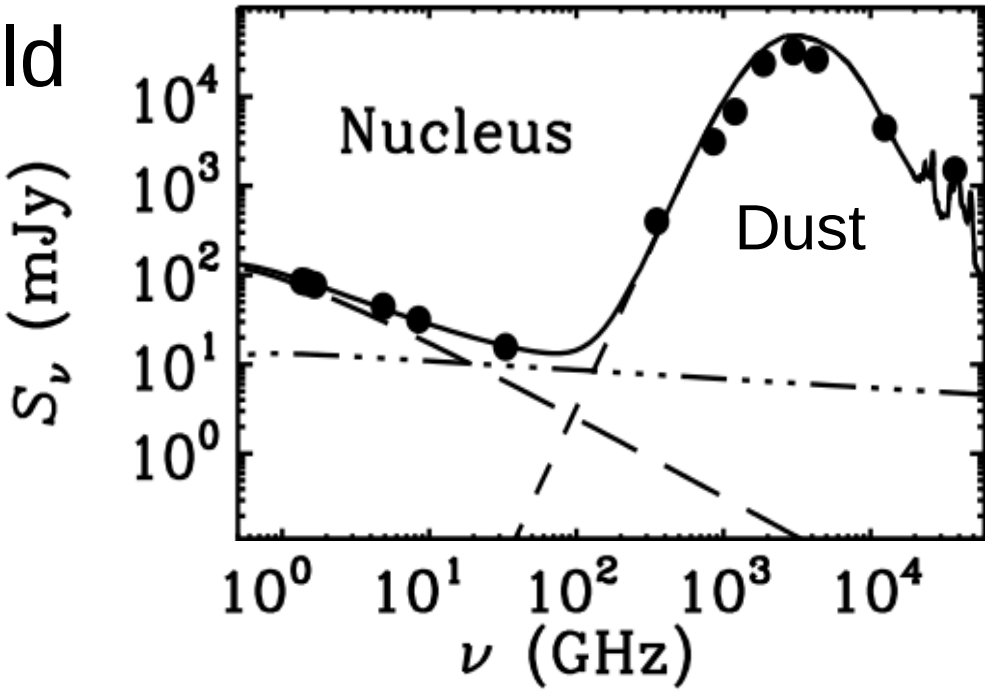
The Nature of Thermal Emission



Dust Obscures Optical Hα
Dust re-emits in infrared

'Ideal' Thermal Indicator – 33 GHz

- Non-thermal spectral index is steep, so thermal fraction increases for higher frequencies
  - Dust emission contaminates eventually, though
- 33 GHz is the 'sweet spot' for thermal emission
- Problem: Small Field

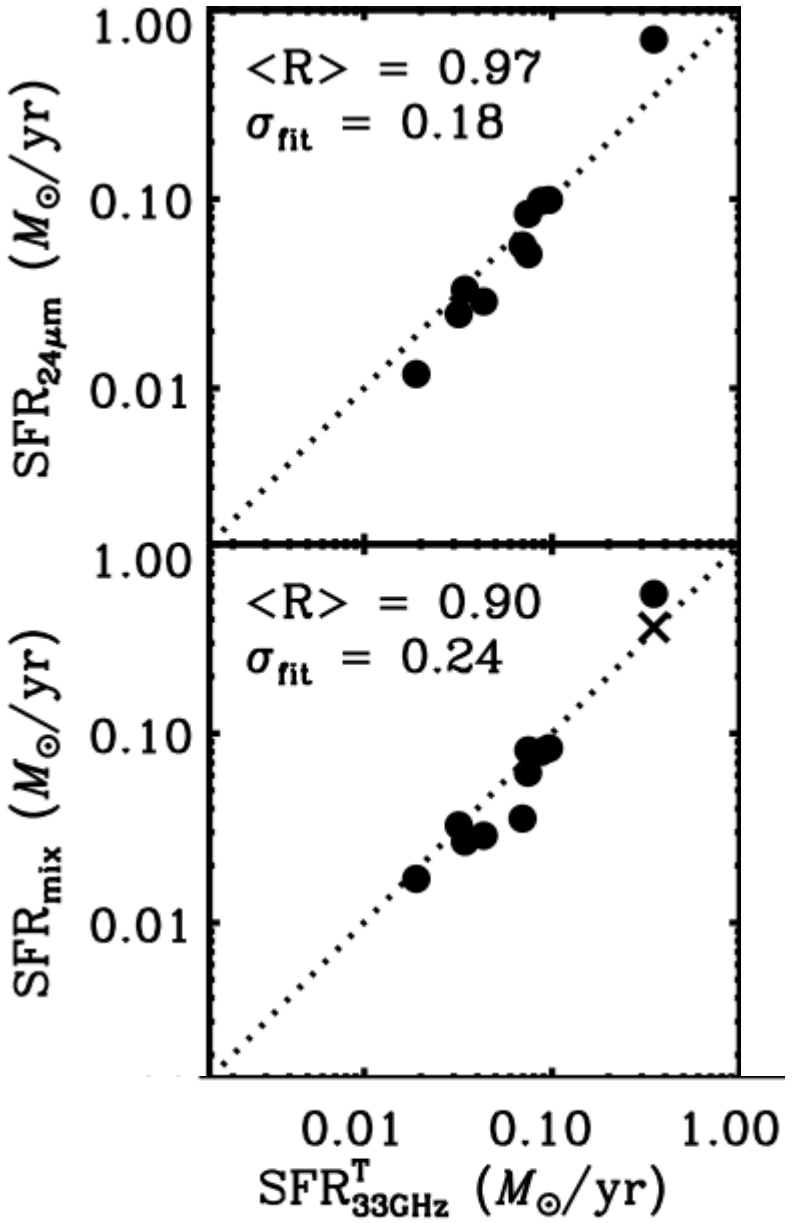


Murphy+2011

Comparison of Thermal Tracers

24μm Only

Hα+24μm



Murphy+2011

The Plan

3 galaxy test sample – NGCs 891, 3044, 4631

From Wiegert+2015 →

	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

- Focus → Use Th radio maps to asses how well SF indicators work

- We compare 3 methods – mixture, 24μm Only, and a new method!
- Derive effect on spectral index after removal of thermal component

Intrinsic Hα Emission

- There is a direct correlation between Hα emission and SFR
- Mixture Method (Calzetti + 07) METHOD ONE

$$\left(\frac{L_{\mathrm{H}\alpha}^{\mathrm{corr}}}{\mathrm{erg\ s^{-1}}}\right) = \left[\frac{L_{\mathrm{H}\alpha}^{\mathrm{obs}} + 0.031\nu L_{\nu}(24\ \mu\mathrm{m})}{\mathrm{erg\ s^{-1}}}\right]$$

  - If $\nu L_{\nu 24} < 4\text{x}10^{42}$; then coefficient is 0.02 (Calzetti+10)

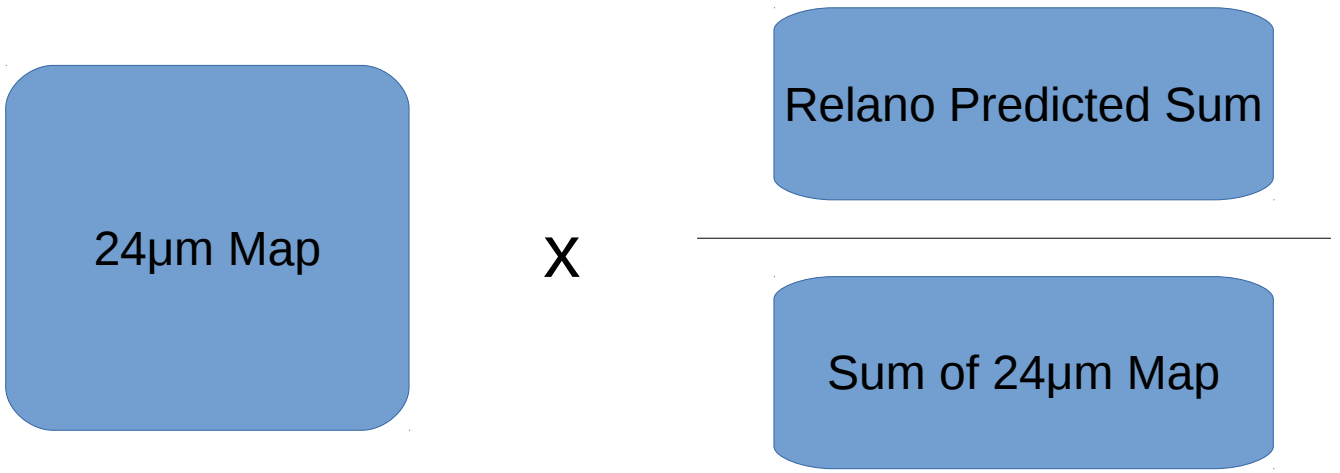
- '24 μm Only' Method (Relano + 07) METHOD TWO:

$$\log(L_{H\alpha}^{corr}) = \frac{\log(\nu L_{\nu}(24\mu m)) + (7.28 \pm 0.52)}{1.21 \pm 0.01}$$

  - Calibrated for regions $1\text{x}10^{38}$ – $3\text{x}10^{44}$ erg/s
    - Typical lowest level in maps ~ $5\text{x}10^{37}$ erg/s/pix
  - Non-linear – application per pixel is incorrect!

Method Two – Linear 24 μm

- Forces 24 μm map to meet the total corrected Hα sum as found with Relano relation



If we knew the intrinsic Hα...

- Relation to Emission Measure (Valls-Gabaud 98):

$$\mathrm{EM}[\mathrm{pc}\cdot\mathrm{cm}^{-6}] = \frac{H\alpha_{corr}\cdot T_{e4}^{1.017}\cdot 10^{0.029/T_{e4}}}{9.41\times 10^{-8}}$$

$$\mathrm{EM} = \int n_e^2 ds$$

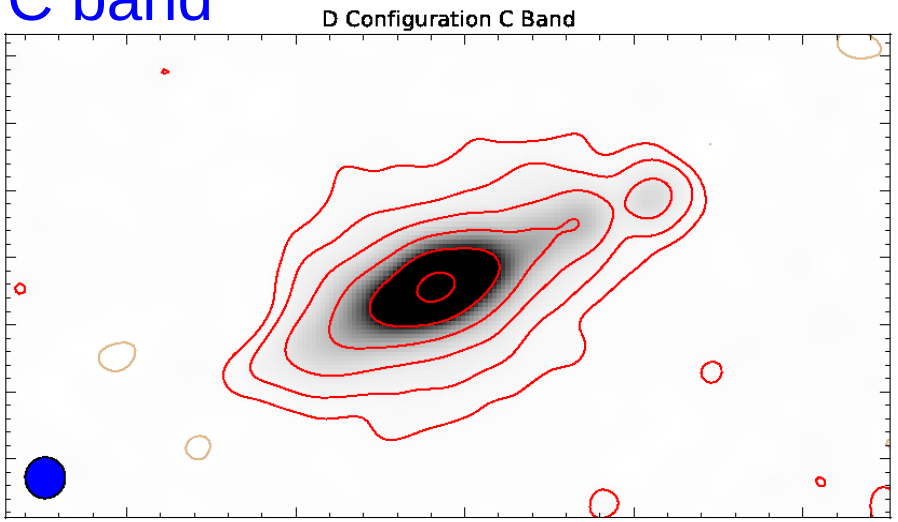
- Can relate EM to tau

$$\boxed{H\alpha_{corr} \rightarrow \mathrm{EM} \rightarrow \tau_c \rightarrow T_b \rightarrow S_{\nu,th}}$$

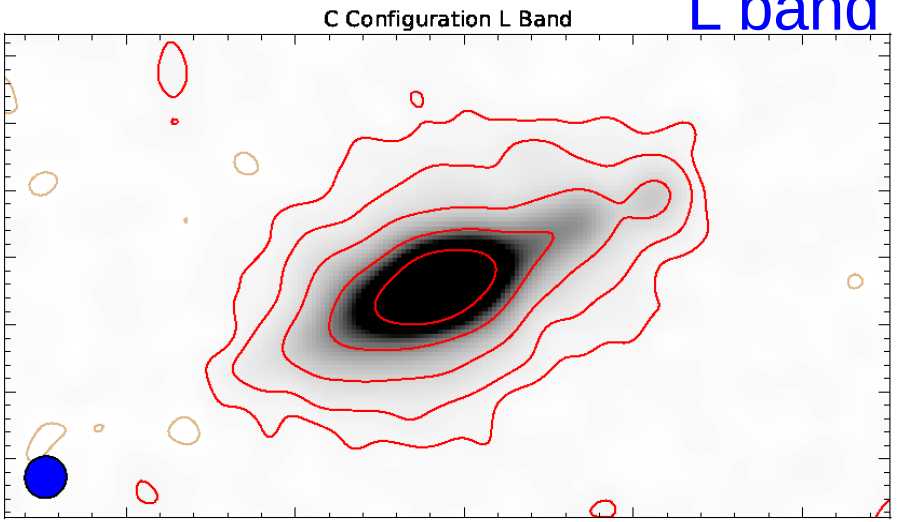
Physics only! But you need to use T_e= 10,000K... valid?

NGC 3044 – Input Data

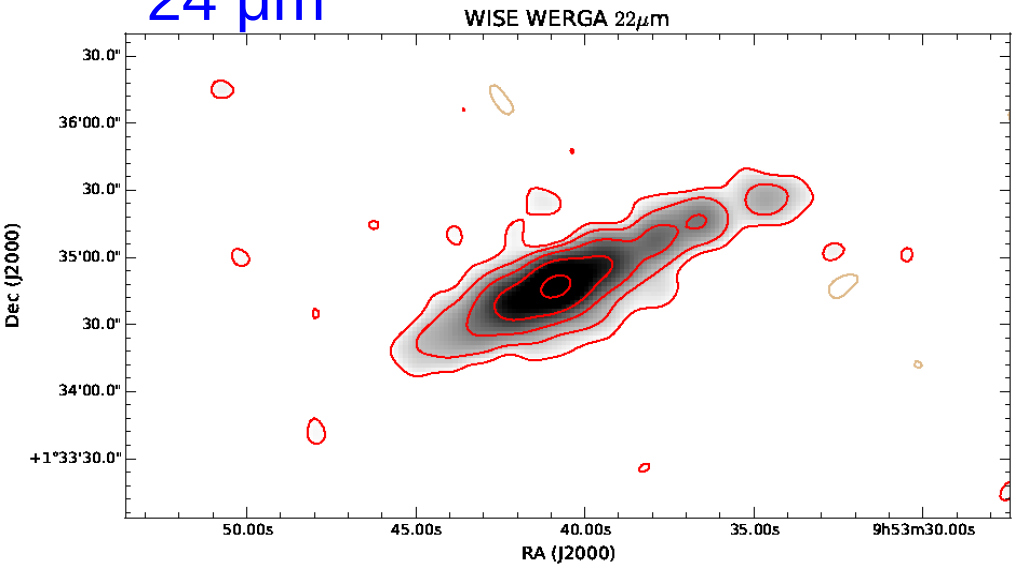
D array
C band



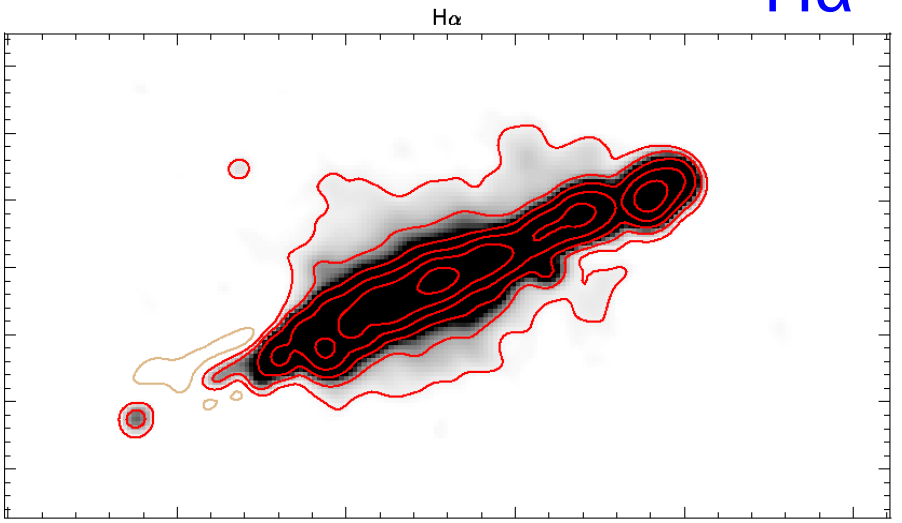
C array
L band



24 μm



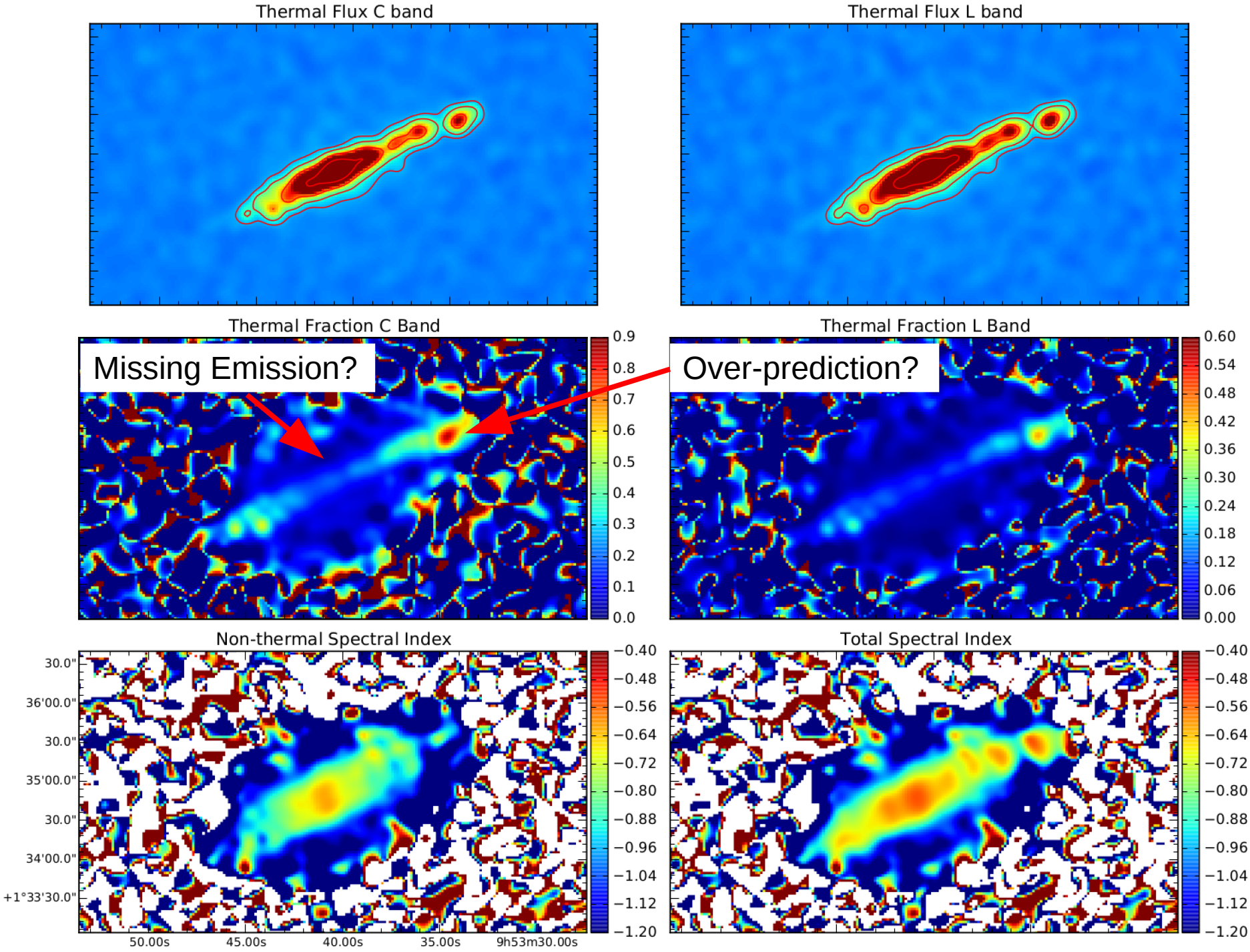
Hα



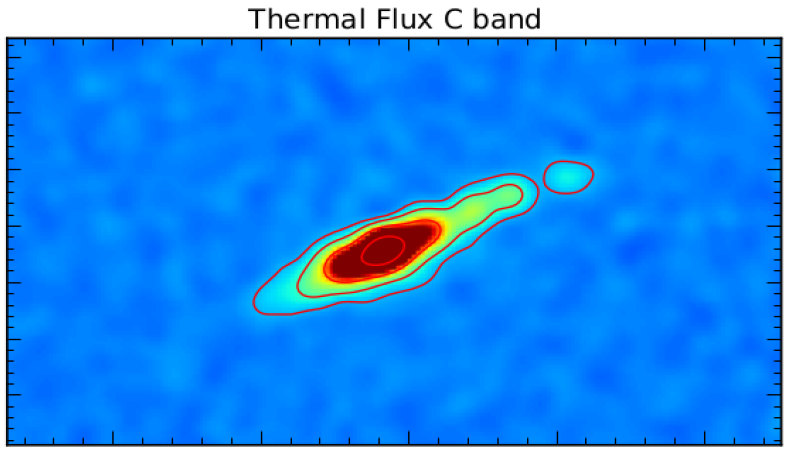
Jarrett

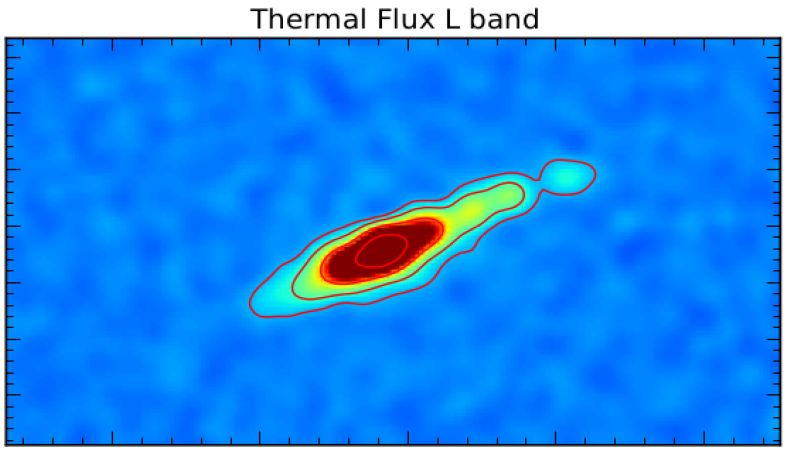
Rand+96

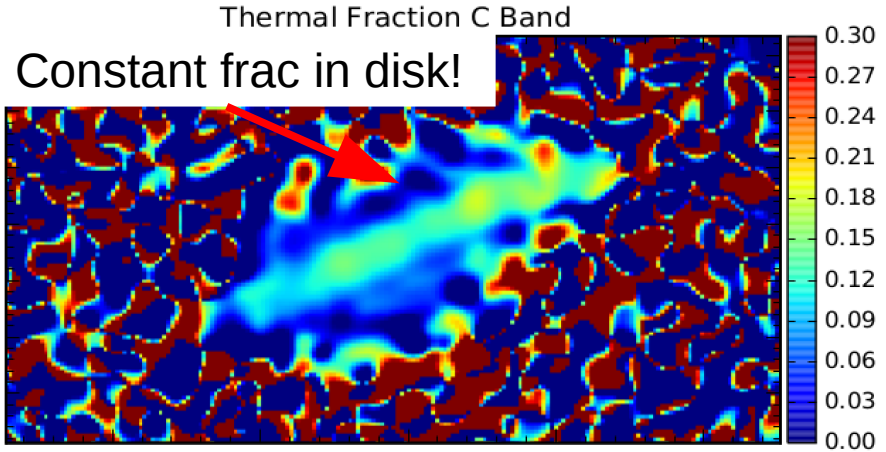
METHOD ONE: Mixture

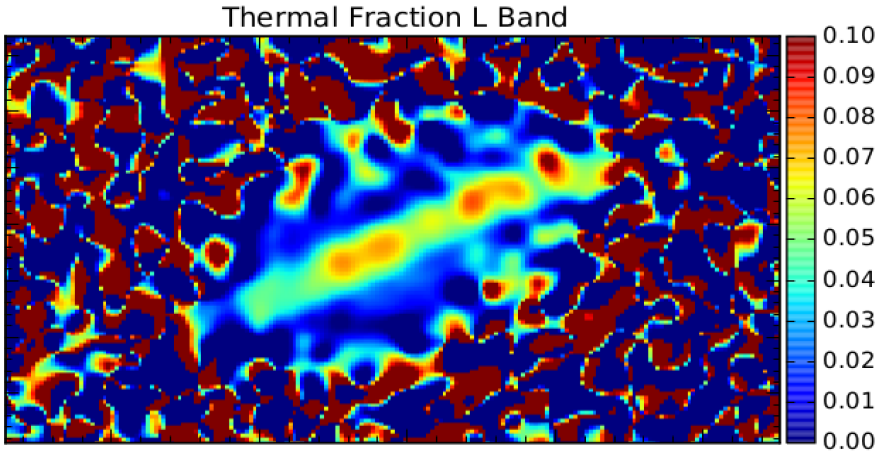


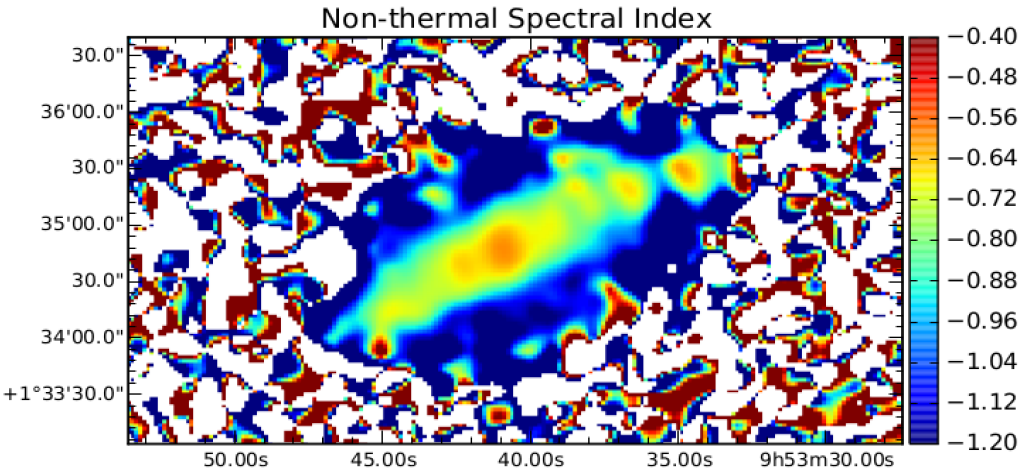
METHOD TWO: 22μm Only

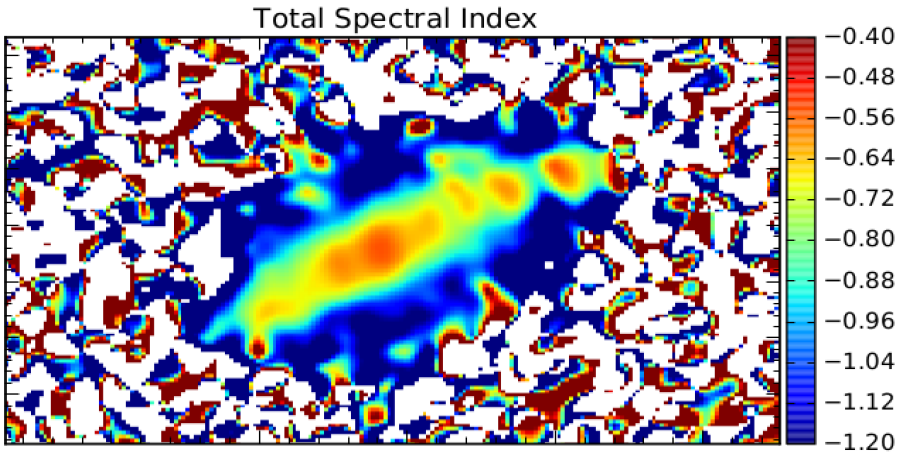






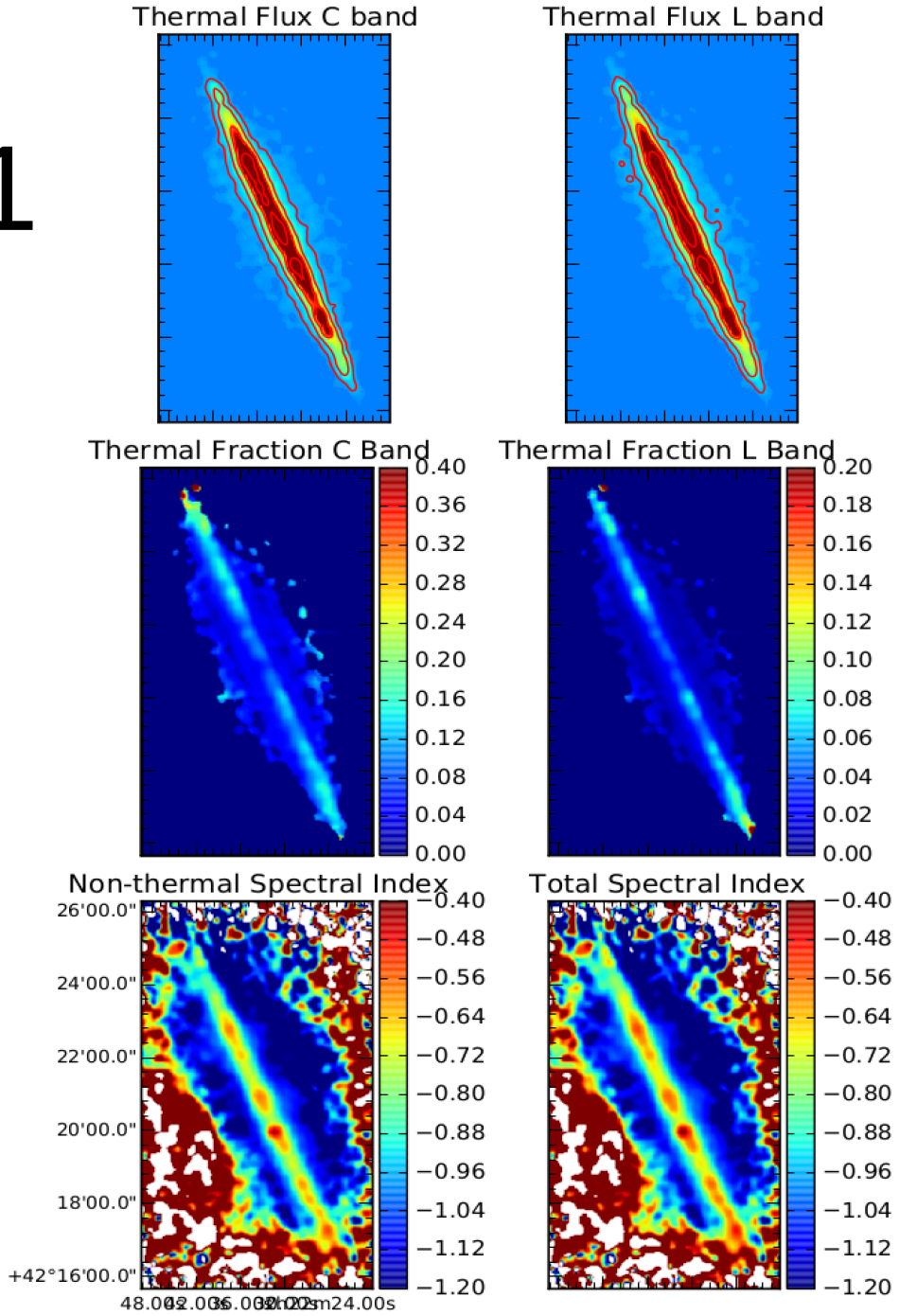






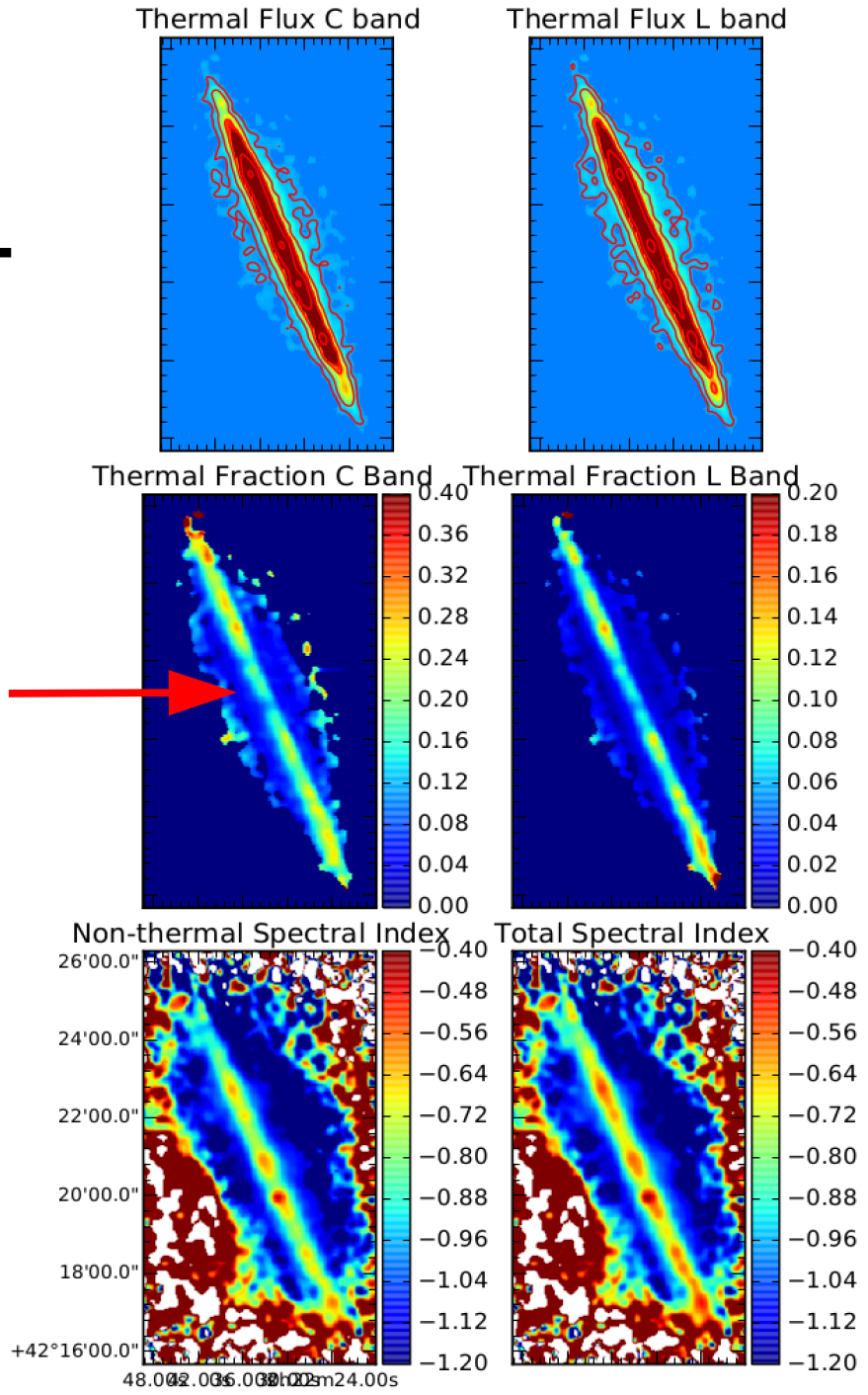
METHOD ONE: Mixture

NGC 891



METHOD TWO: 24 μm Only

NGC 891

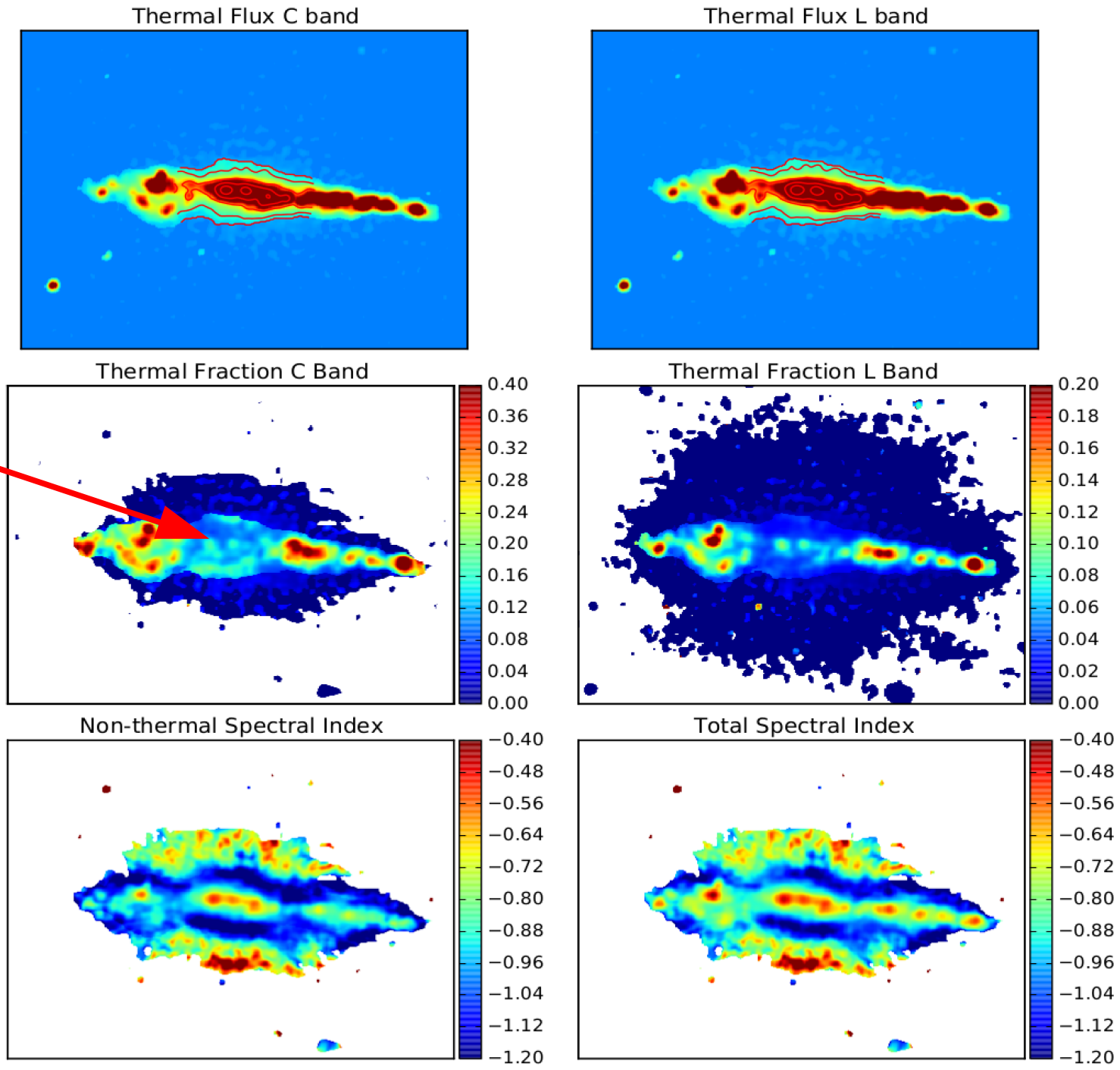


Same Depression in both methods

METHOD ONE: Mixture

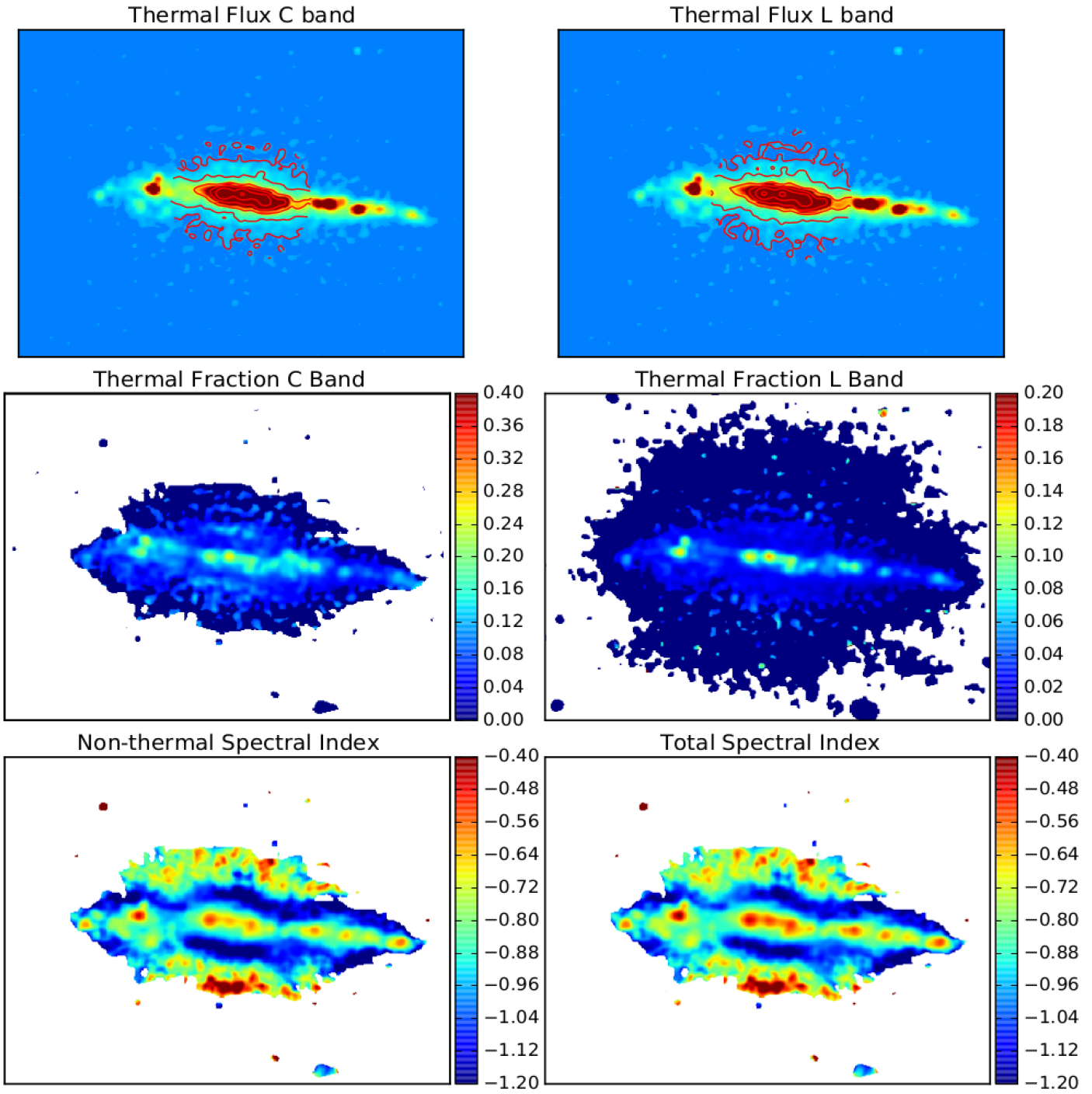
NGC 4631

Clear Depression



METHOD TWO: 24 μm Only

NGC 4631

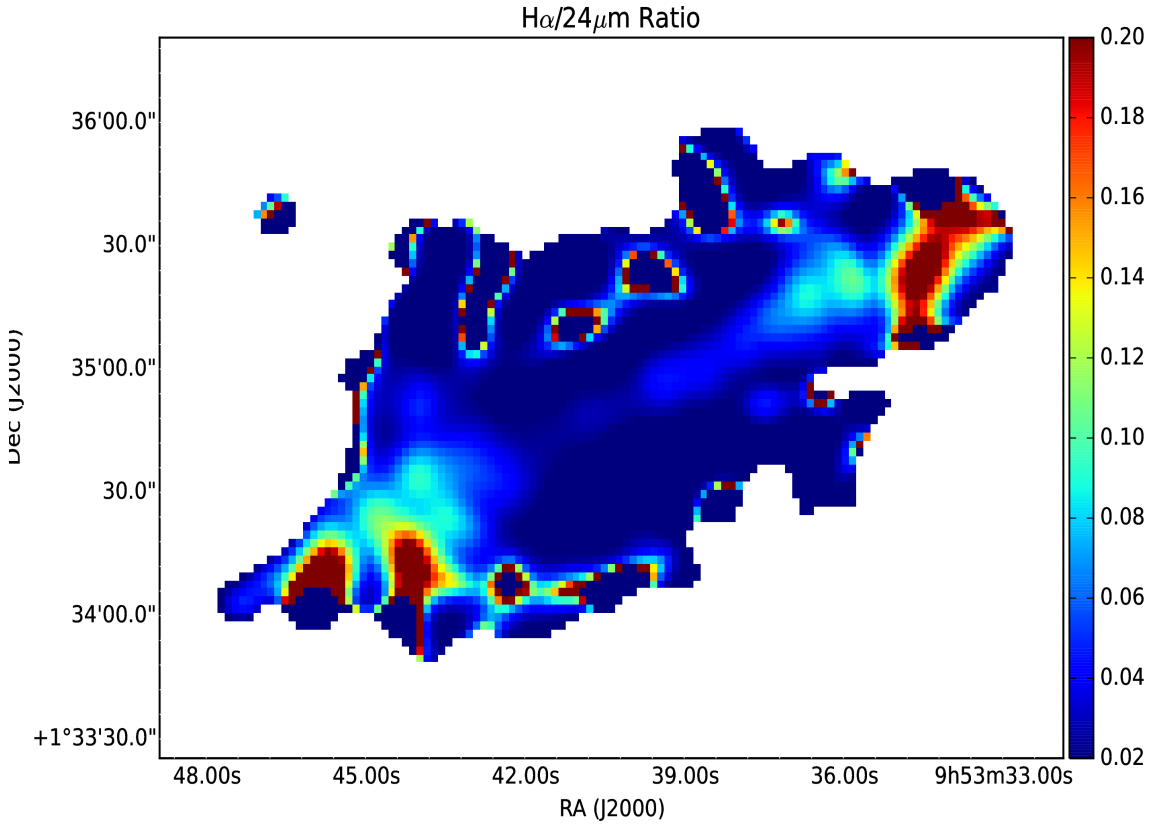


Results/Concerns

- Results: Non-thermal spectral index steepens in vertical direction, as expected
- Concern: are we under-predicting thermal emission in central disk in the mixture method?
  - Spectral index flattest in central disk region, which is where the thermal emission might be under-predicted

Method Three: Modified Mixture

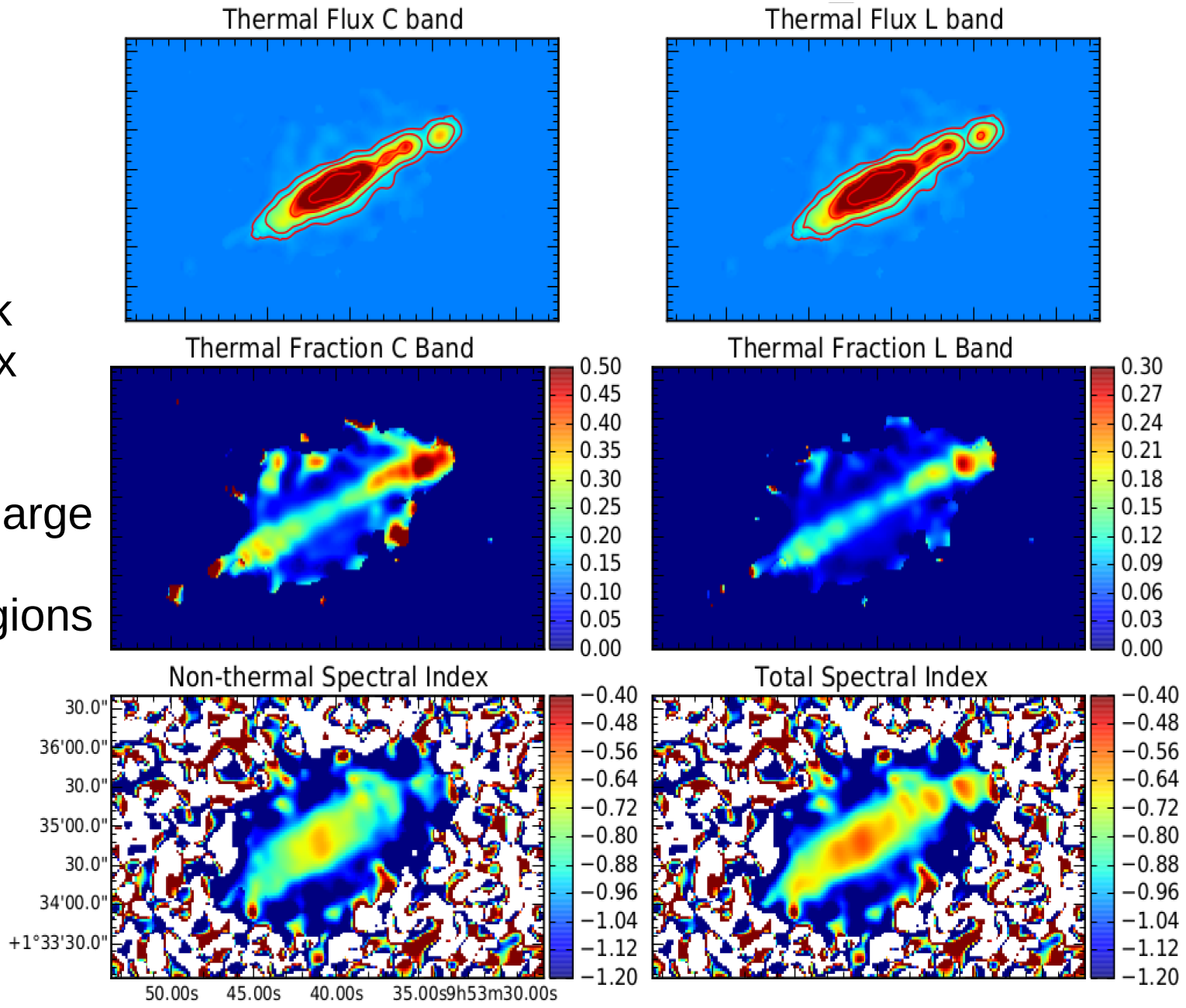
- Vary 'a' in the mixture method as a function of Ha/24um per pixel



METHOD THREE: Modified Mixture

Recovers central disk thermal flux

Lowers extremely large thermal fraction regions



Summary

- Star formation is complicated in edge-on galaxies
  - Mixture may under-predict in the central disk
  - '24um Only' applied linearly may under-predict outer disk and vertical extent
- Method 3 may produce most reasonable results for a sample-wide study
  - Not using Hα at all may be tricky for less dusty galaxies, and salvaging the mixture allows for accurate prediction of outer extent