Cold Cores and Star Formation in the Spitzer and Gould Belt Surveys

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with

Taurus – Mike Fich, Debbie Padgett,
Alberto Noriega-Crespo & TSS team

GB – Lori Allen, Tracy Huard, Jenny Hatchell & GB team

FCRAO 13 CO Survey
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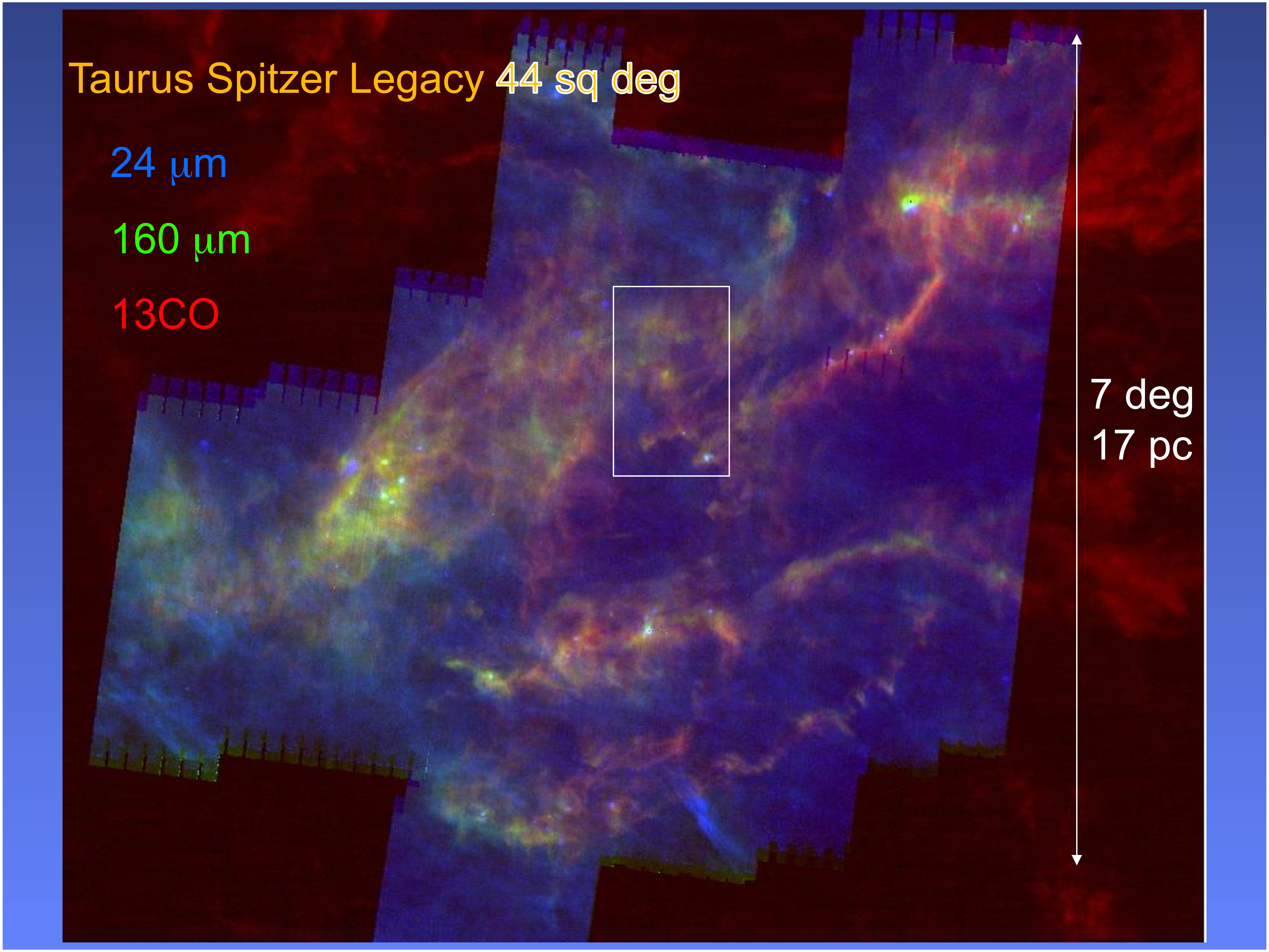
- R. Snell - U Mass
- D. Li – JPL

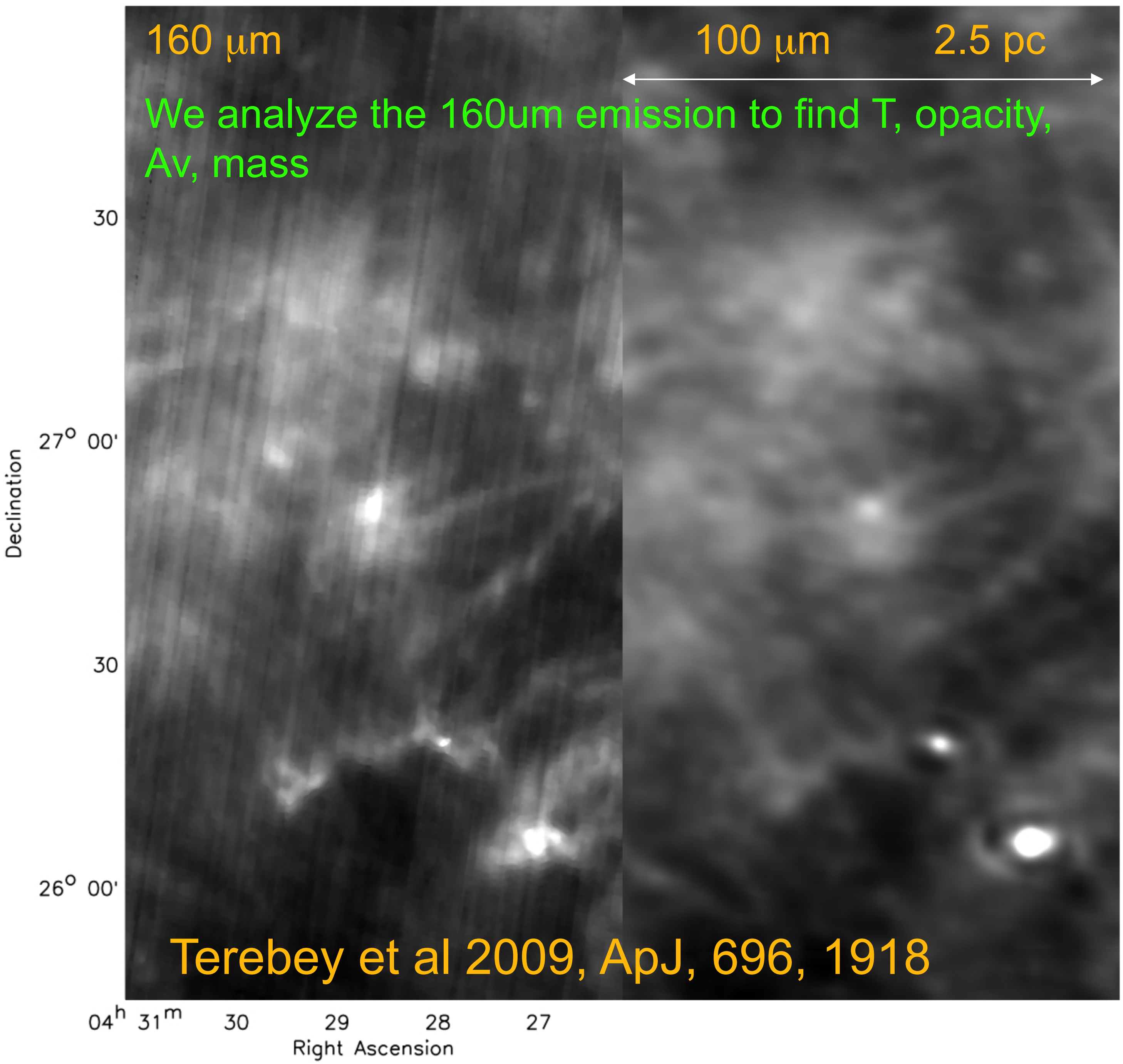
Synergies of Multiple Surveys

- *Spitzer Space Telescope*: MIR/FIR survey determines the state of circumstellar material for all stellar and substellar members including edge-on disks too faint for IRAS.

	IRAC	MIPS			44 deg^2
λ	3.6, 4.5, 5.8, 8.0	24	70	160 μm	
θ	1.7”	6”	18”	40”	

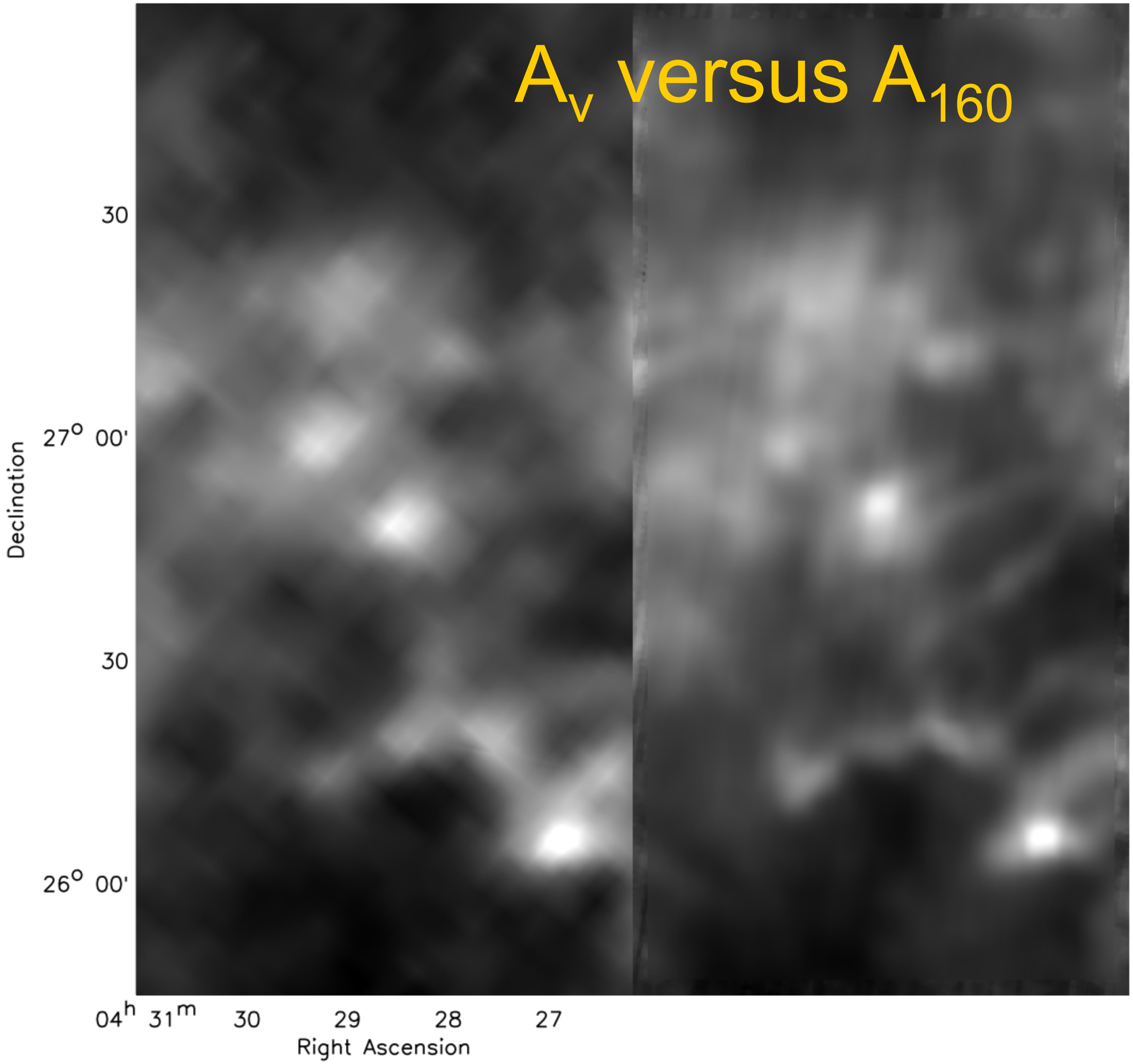
- CFHT and SDSS: Optical surveys identify very low mass stellar members and brown dwarfs and provide accurate griz & I, z band photometry with better than 1“ resolution; SDSS spectral scans as well
- *XMM-Newton*: X-ray survey penetrates tens of magnitudes of visual extinction, identifies potential WTTS, measures effect of stellar activity on circumstellar environment
- FCRAO: Millimeter survey of ^{12}CO and ^{13}CO at resolution of 45” and unsurpassed sensitivity provides molecular cloud context for point sources


Taurus Spitzer Legacy 44 sq deg
24 μm
160 μm
13CO
7 deg
17 pc



160 μm
100 μm
2.5 pc
We analyze the 160um emission to find T, opacity, Av, mass
Terebey et al 2009, ApJ, 696, 1918
30
27° 00'
30
26° 00'
Declination
04h 31m
30
29
28
27
Right Ascension

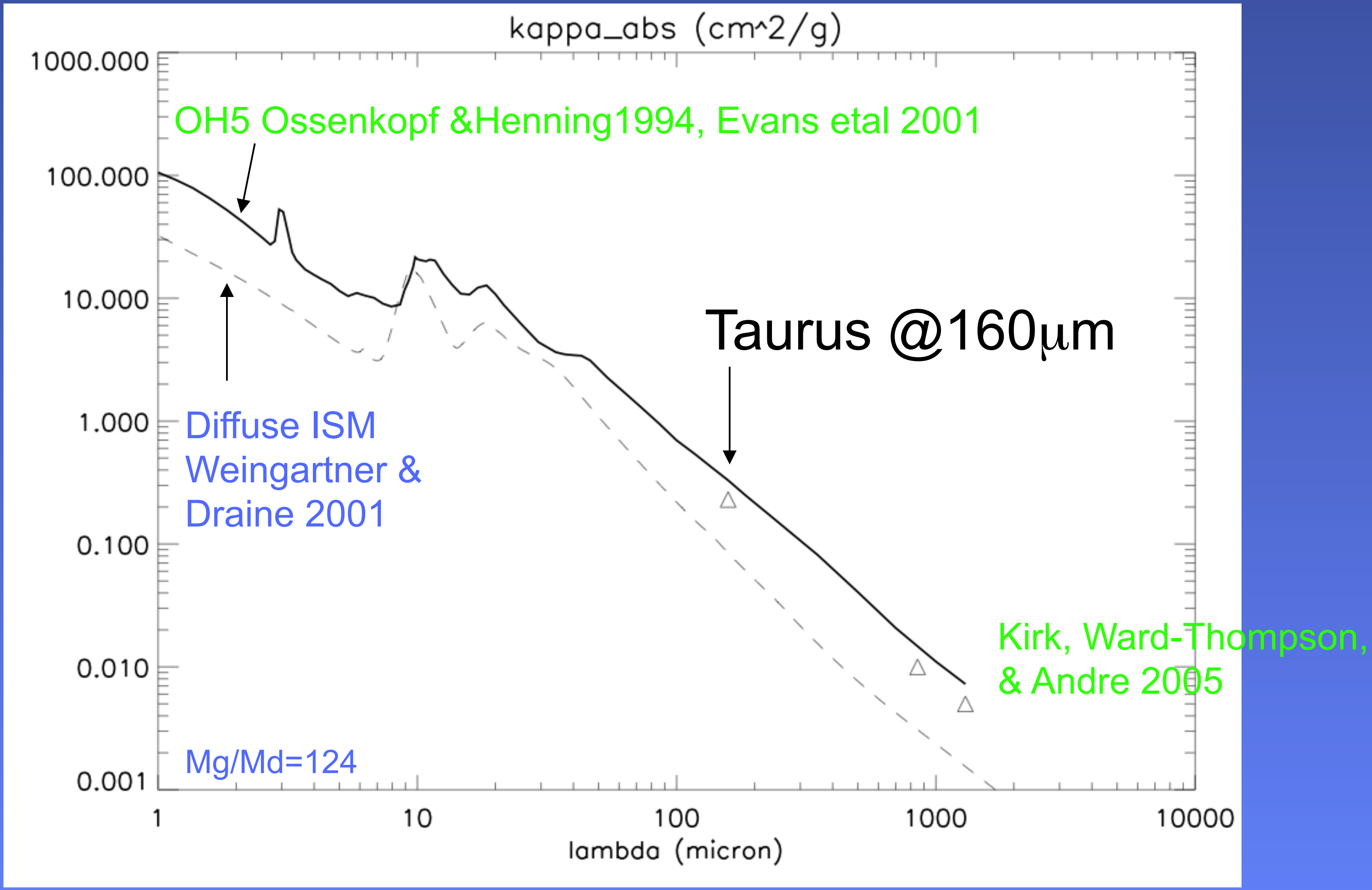
A_V versus A_{160}

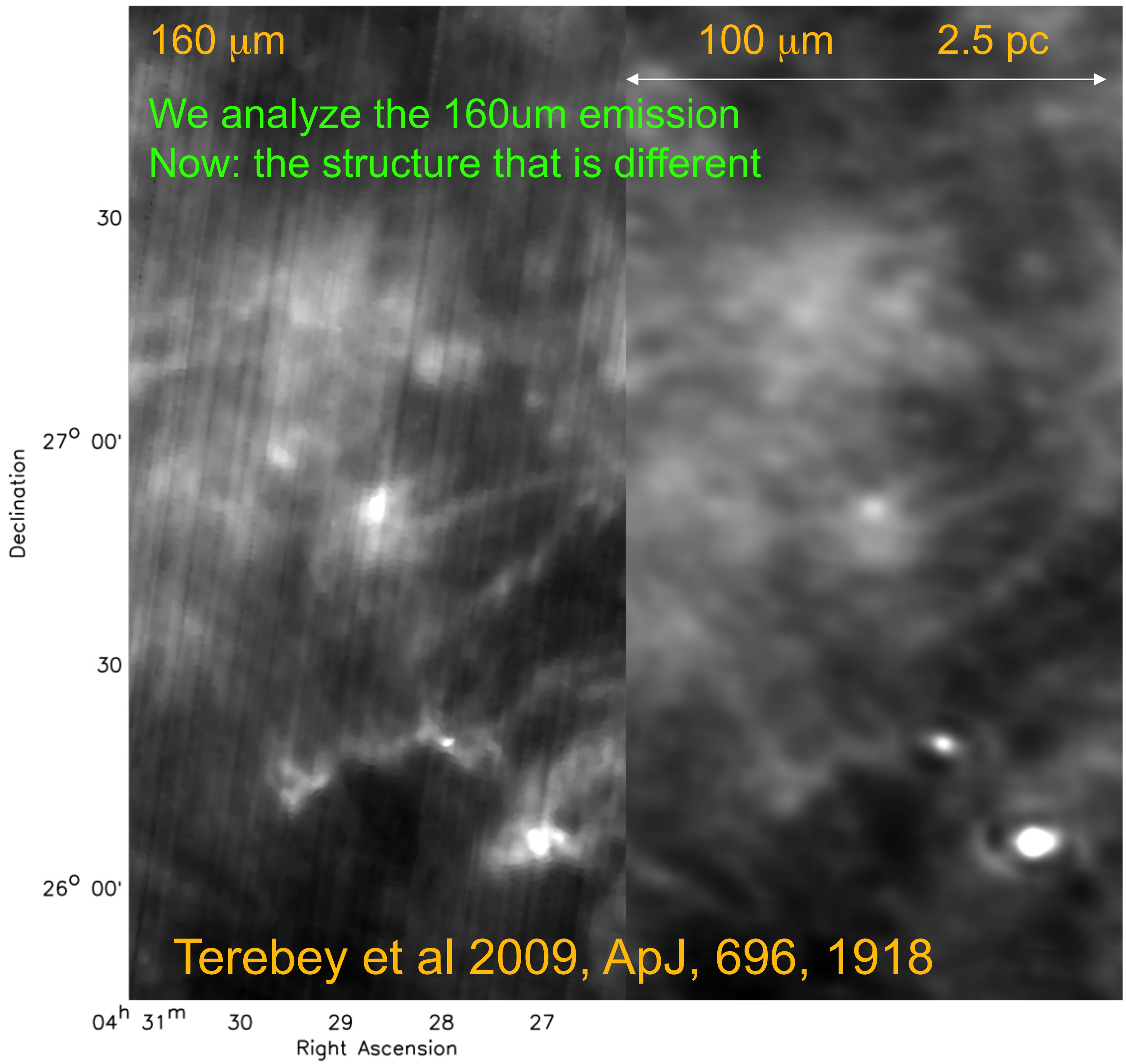


4' matched spatial resolution

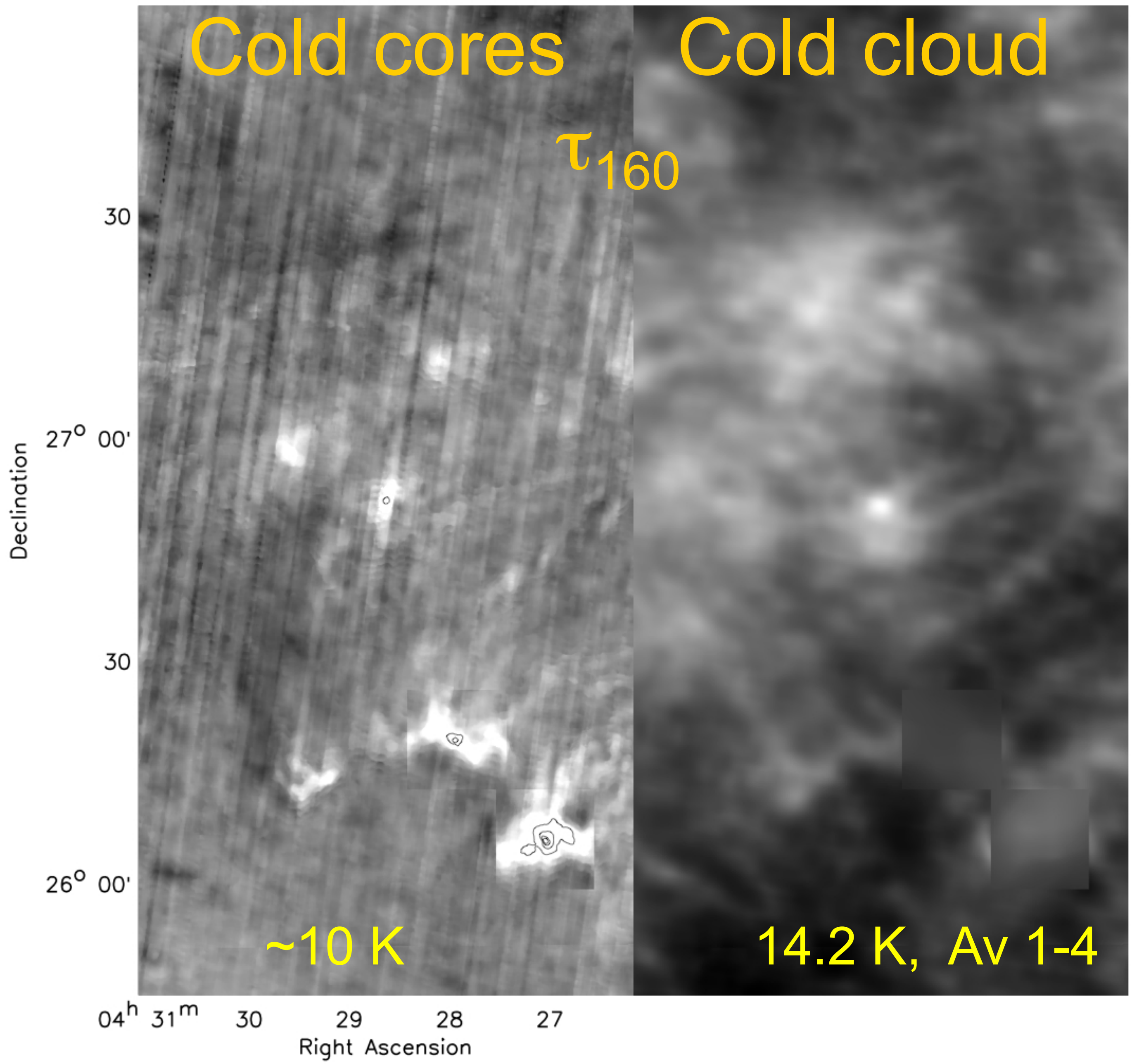
A_V from 2mass Froebrich (2007)

3) Opacity at 160 is
2.6 X higher than Diffuse ISM
Similar to OH94 dense core opacity

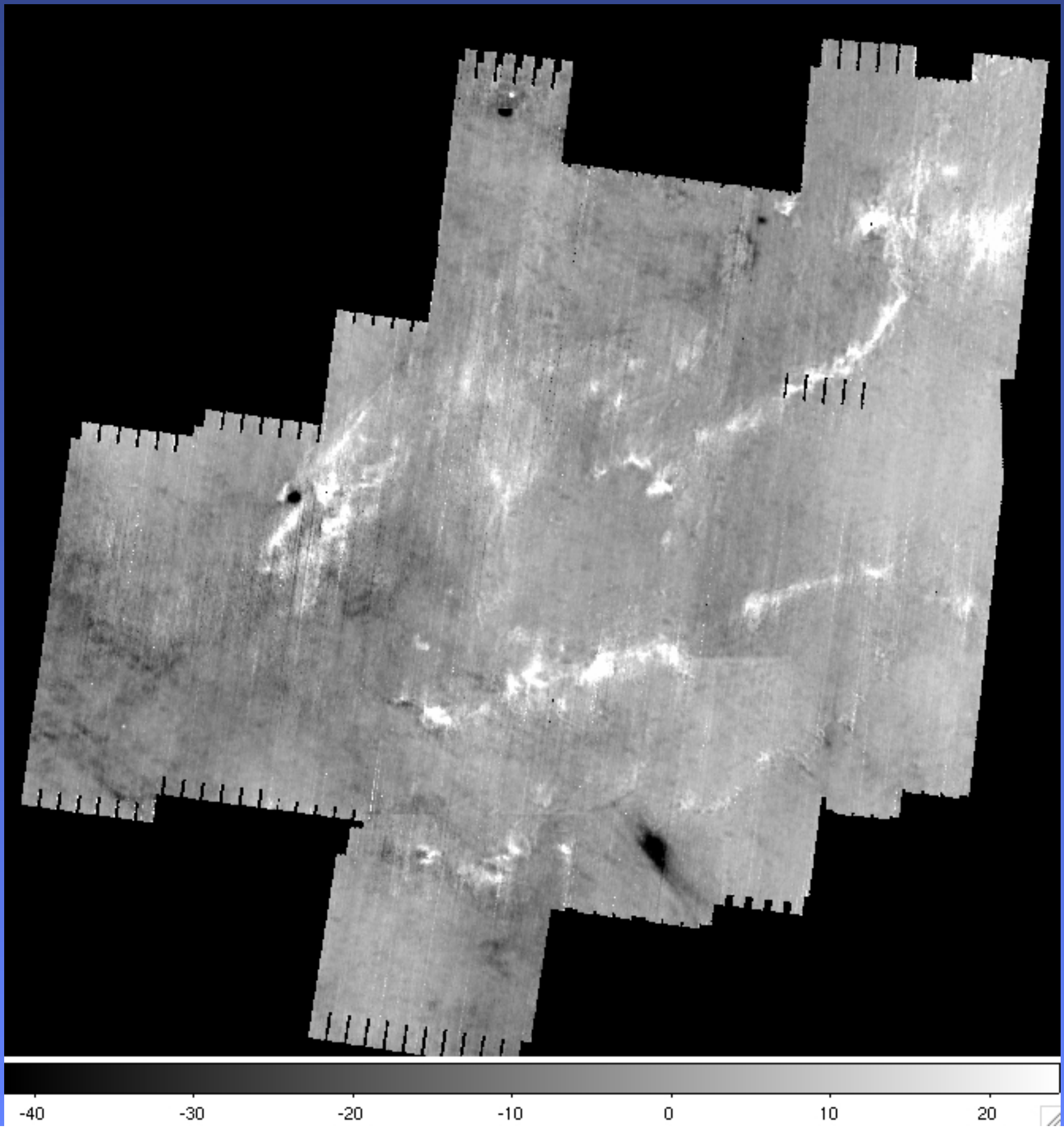




160 μm
100 μm
2.5 pc
We analyze the 160um emission
Now: the structure that is different
30
27° 00'
30
26° 00'
Declination
04h 31m
30
29
28
27
Right Ascension
Terebey et al 2009, ApJ, 696, 1918



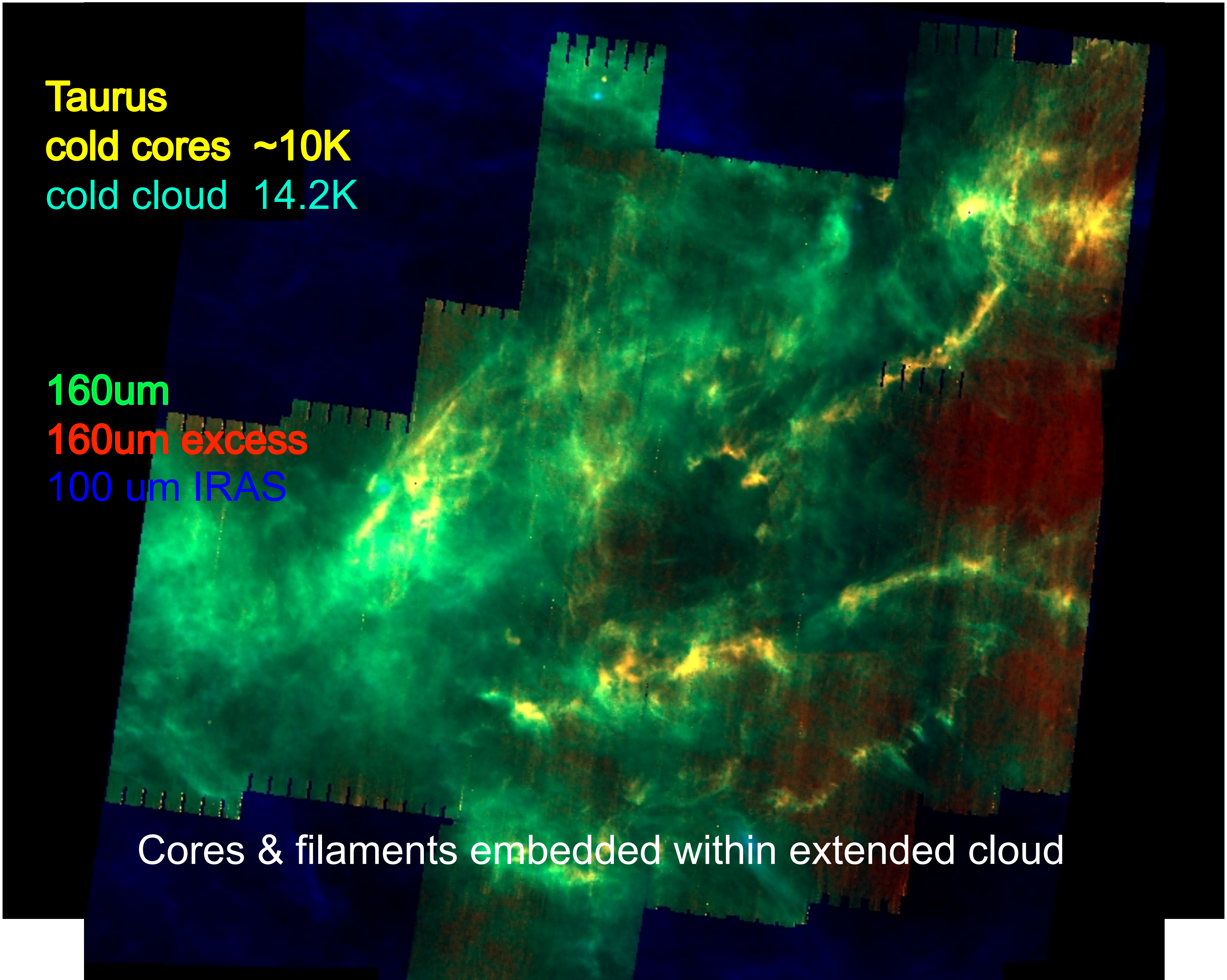
Cold cores
Cold cloud
τ160
30
27° 00'
30
26° 00'
Declination
~10 K
14.2 K, Av 1-4
04h 31m
30
29
28
27
Right Ascension



Taurus
160um
cold cores

white= ~10K
cold dust

183 cores
<R>=0.12 pc


Taurus
cold cores ~10K
cold cloud 14.2K
160um
160um excess
100 um IRAS
Cores & filaments embedded within extended cloud

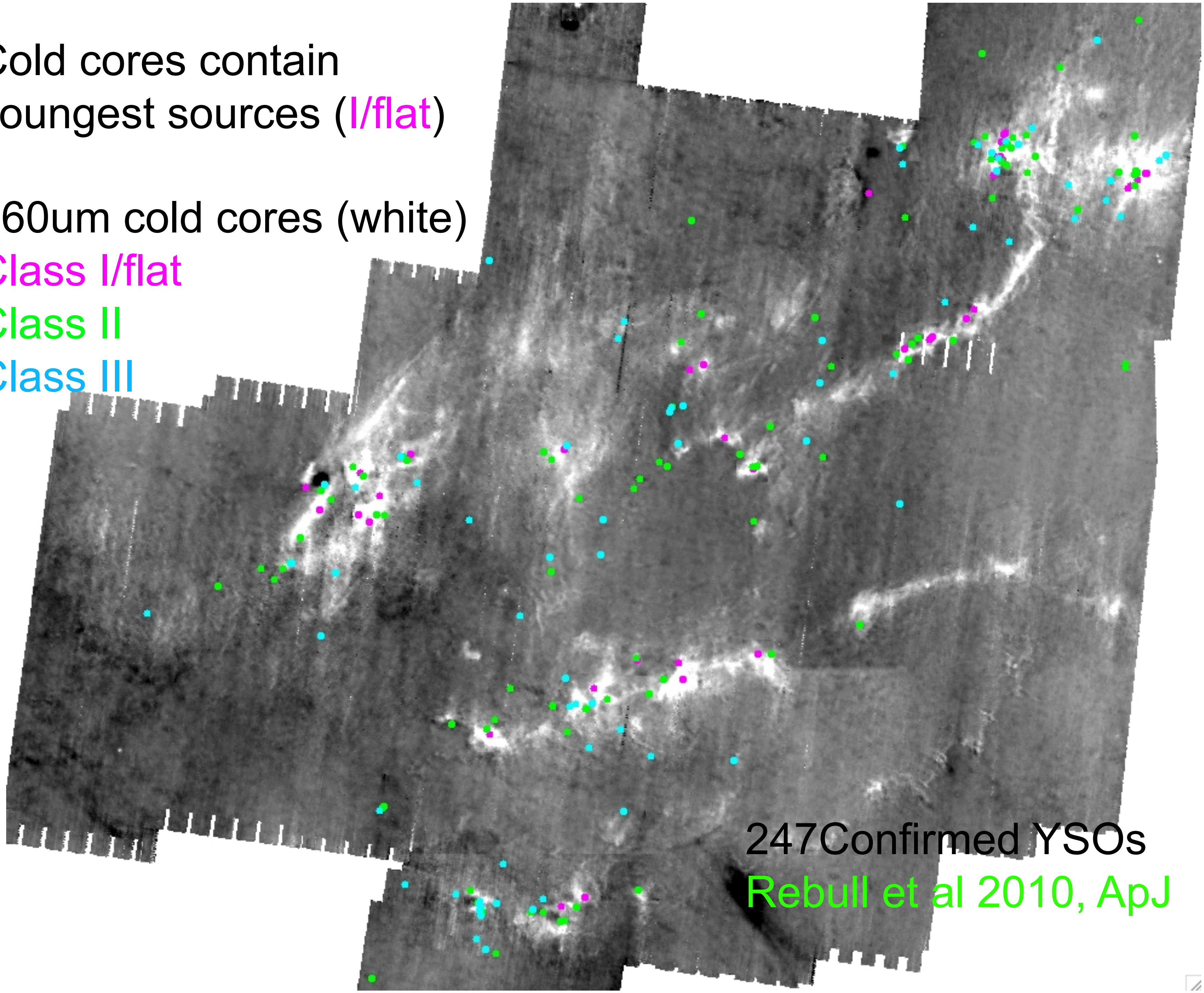
Cold cores contain youngest sources (I/flat)

160um cold cores (white)

Class I/flat

Class II

Class III



Ages from Spatial motions

- Is class II spatial distribution an ‘older’ version of the class I spatial distribution? Do YSOs move or do cloud cores disappear?

- Take class I spatial distribution.
  - Give YSOs 0.2 km/s random space velocity.
  - Move forward in time from 0.3 Myr to 2Myr (c.f.Evans 2009 ApJ 181 321)
- After 0.6 Myr
  - Consistent: Half of Flat spectrum sources leave the natal core
  - relative velocity of core and YSO is ~0.2 km/s
- After 2Myr
  - Statistically Class I -> Class II in terms of cloud background for most of the region
  - But there are regions that cannot be reached by current class I’s

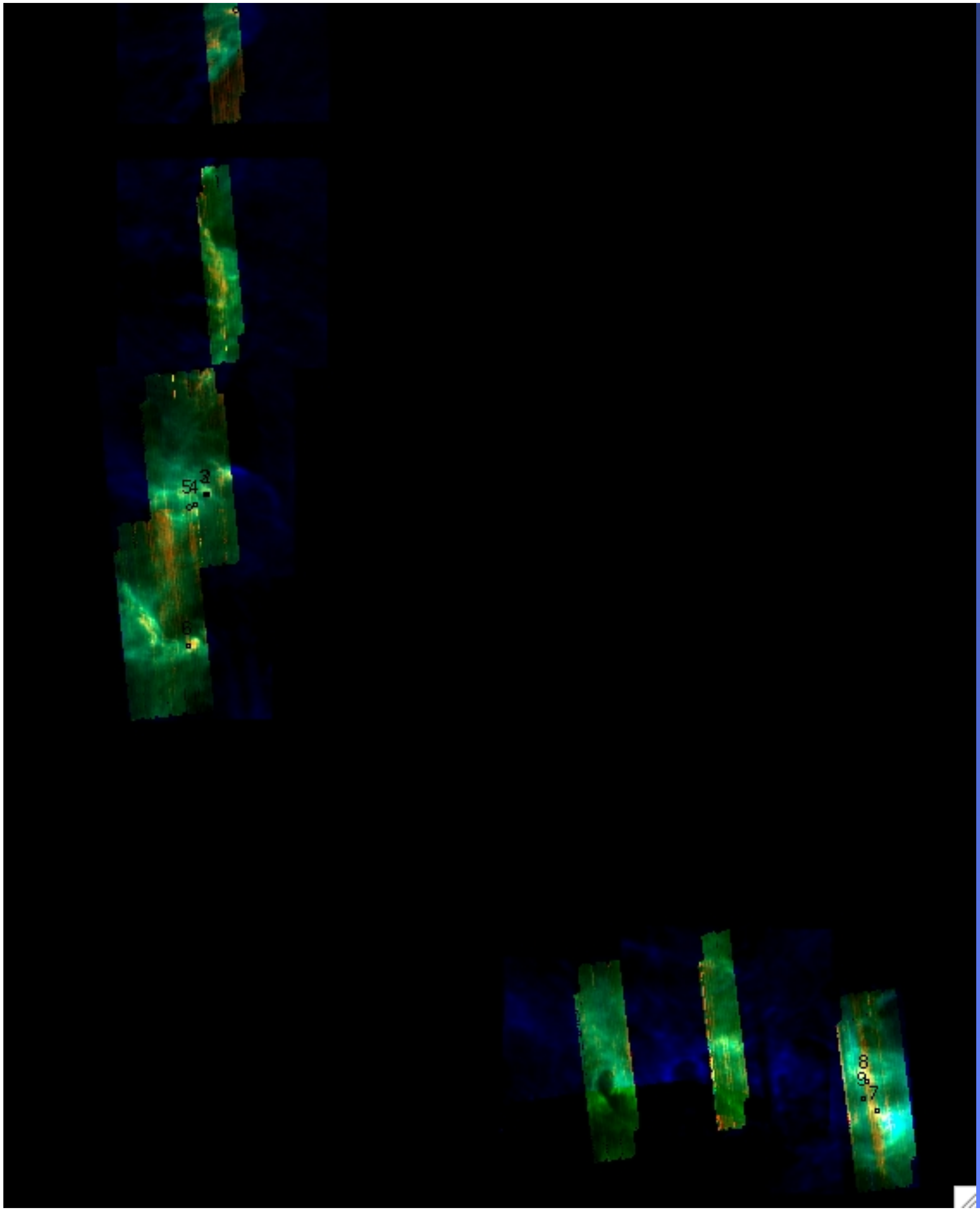
Lifetime of cores

YSO Class		Age relative to class II
I & flat	48	0.6 Myr
II	122	1.5 Myr
III	77 (incomplete)	

Cores 183

Quiescent, if all cores form stars => 2.2 Myr

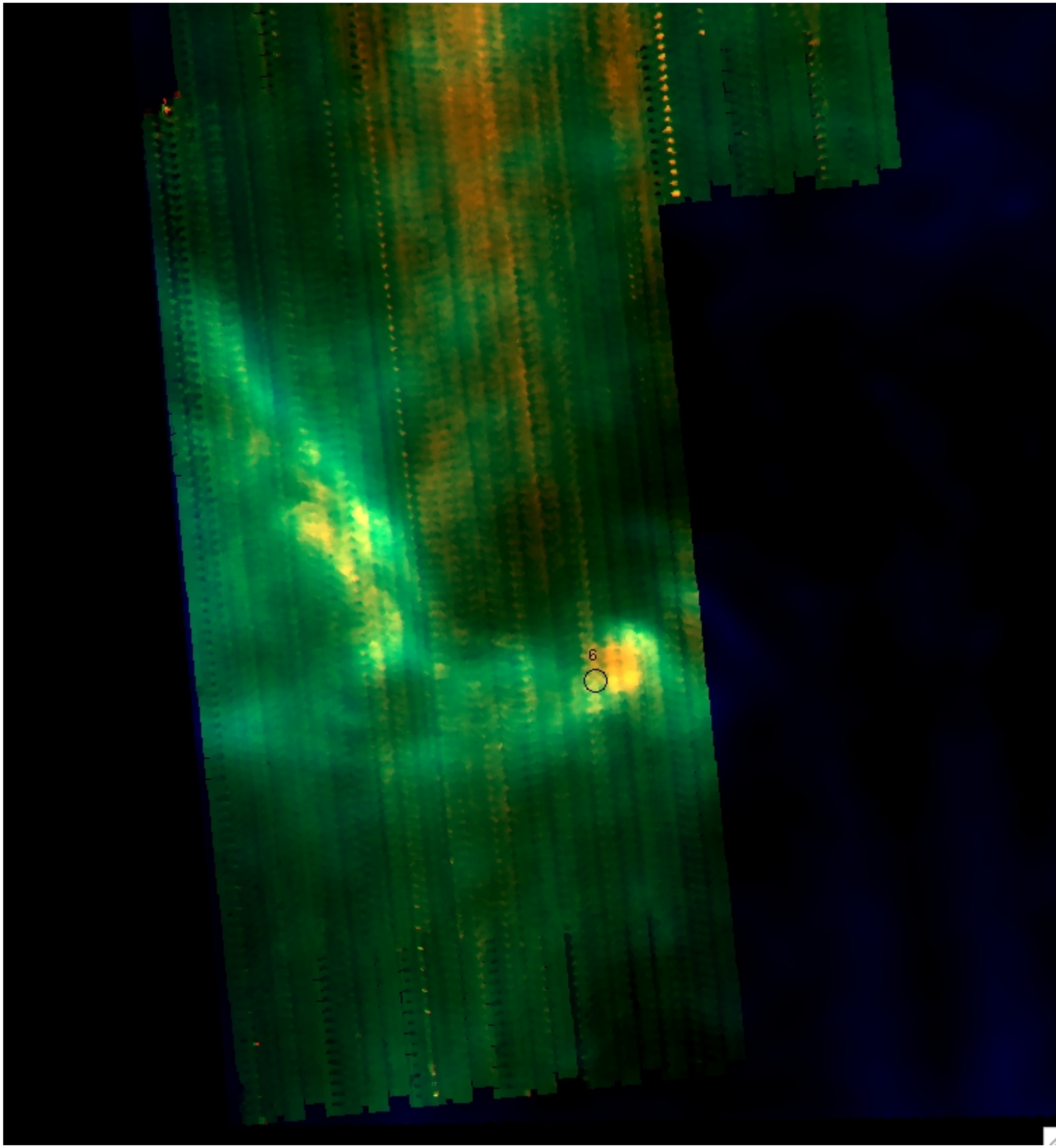
Turbulent, 15% form stars if 0.6 Myr age



Scorpius

Apply technique to GB Survey

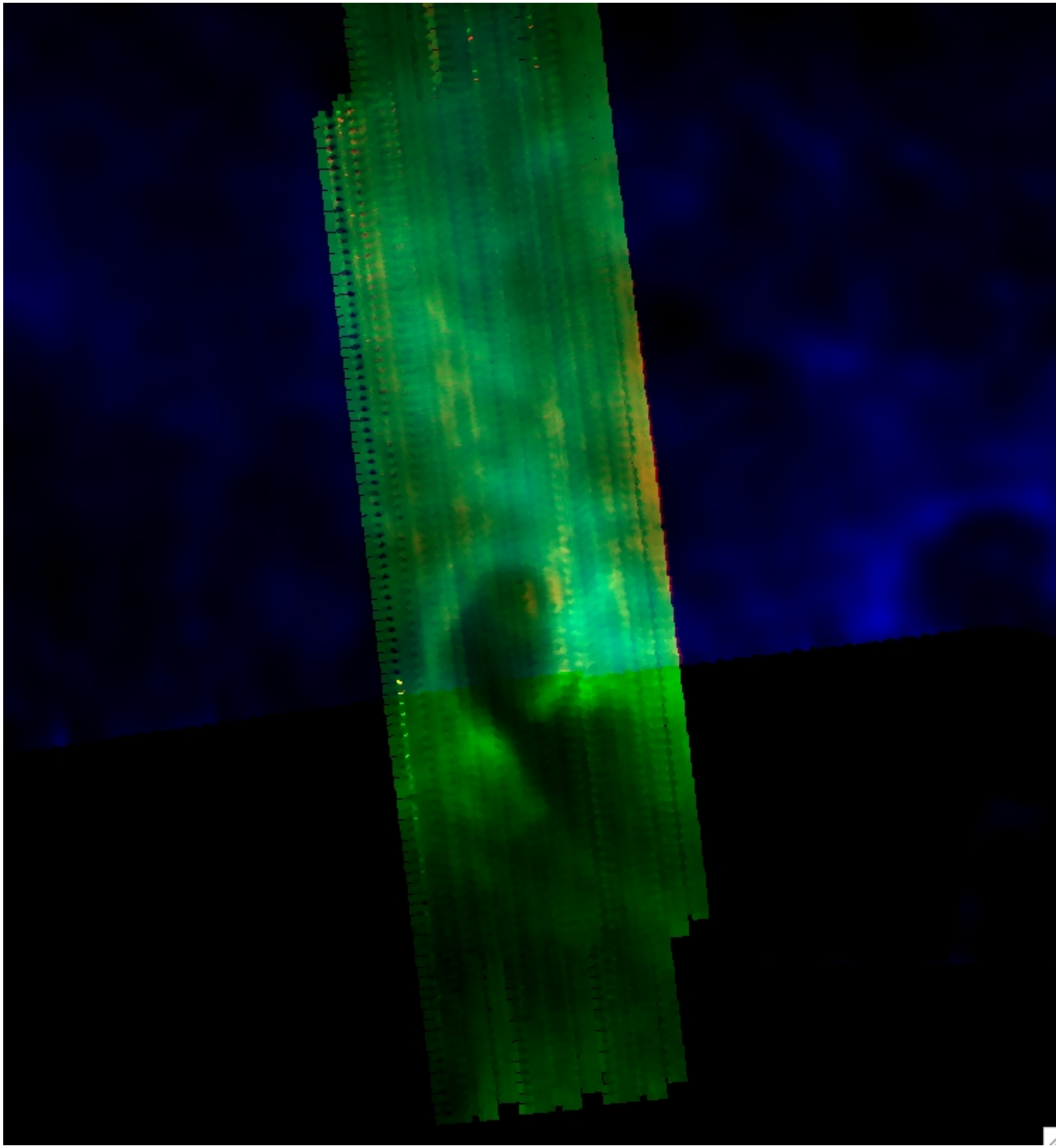
red = 160 excess
green = 160 um
blue = 100 um



Scorpius 3b

cold core=
yellow or orange
1 YSOc

red = 160 excess
green = 160 um
blue = 100 um



Scorpius 4

no cold cores

0 YSOc

red = 160 excess
green = 160 um
blue = 100 um

Gould's Belt

- Cold cores provide mass reservoir for star formation

- No or few cold cores => no class I sources

Scorpius some cold cores, ongoing star formation

Lupus V,VI no cold cores, star formation done

Summary

- Cold dense cores are easily identified by comparison of 160um and 100um images.

- Taurus cloud has Td=14.2 K for Av = 1-4 cloud and
  160μm opacity κ = 0.23 cm^2 /g
  Opacity is 2.6 times higher than diffuse ISM

- Taurus has 183 cold cores, 247 YSOs, 122 class II's
- Class I sources spatially coincident with cold cores
- Class-flat sources imply relative core-YSO velocity is 0.2 km/s
- Ages: Class I -> Class II spatial distribution (mostly)
  assuming random v=0.2km/s for 2Myr

160um Terebey et al 2009, ApJ, 696, 1918
YSO candidates Rebull et al 2010, ApJS, 186, 259
Taurus Survey overview Padgett et al 2010