Nearby Galaxies as measures of Feedback

Brent Groves
(MPIA)

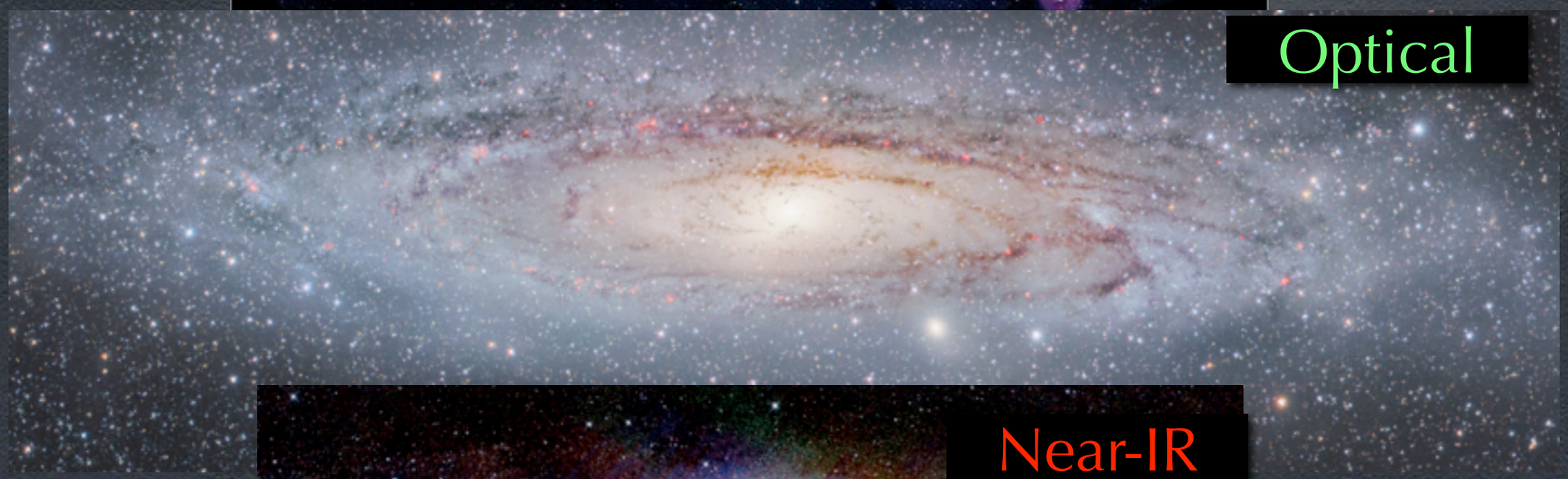
Quenching & Quiescence
MPIA, Heidelberg
July 14-18, 2014

Why Nearby?

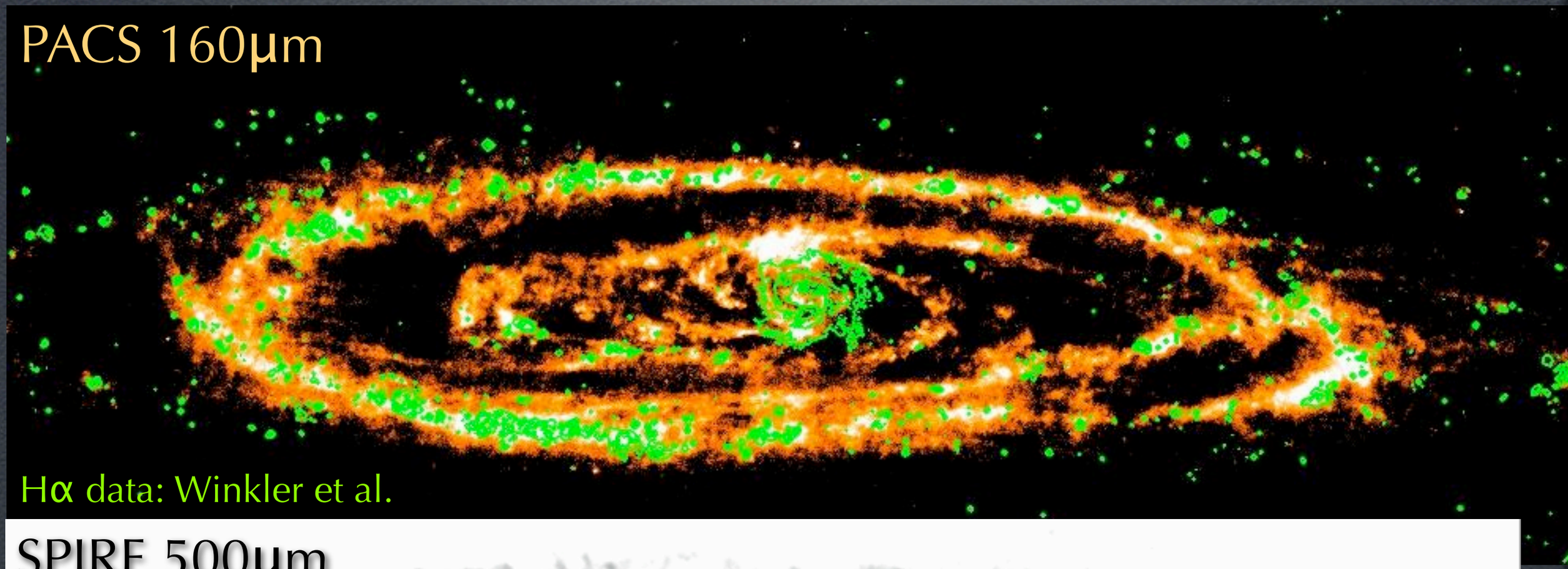
- In nearby galaxies we can resolve the physics of feedback processes (J. Gallagher's talk)
- Proximity means faint structures can be seen (T. Davis' Talk)
- Measure the gas reservoir, stars, star formation, and winds directly

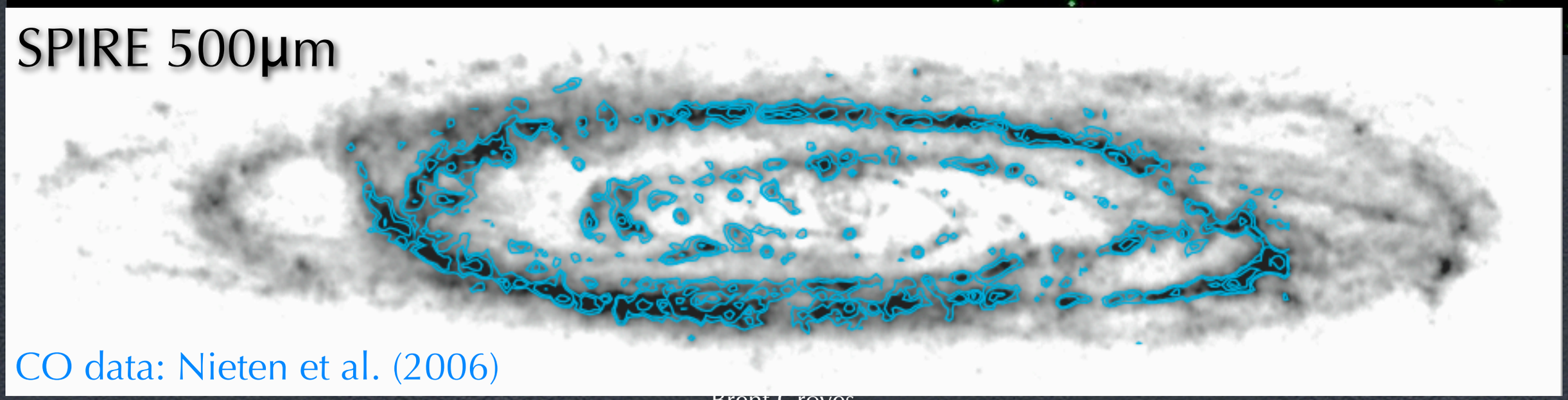
- See Quenching in progress
- See how Quiescence is maintained
- Nearest example: M31!

Stellar View of Andromeda



Dust & Gas!


PACS 160μm
Hα data: Winkler et al.


SPIRE 500μm
CO data: Nieten et al. (2006)

Integrated Andromeda

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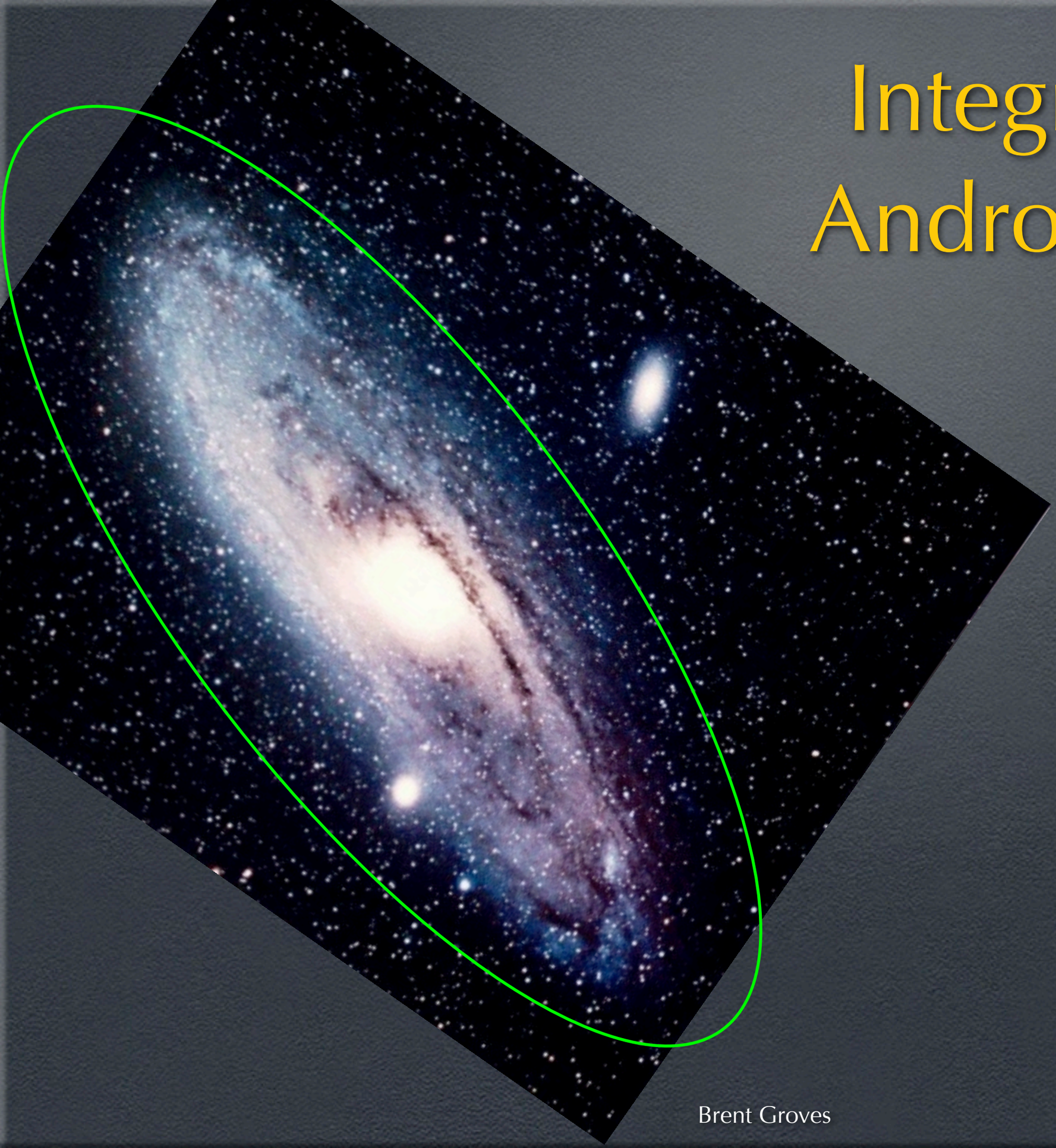
Integrated Andromeda



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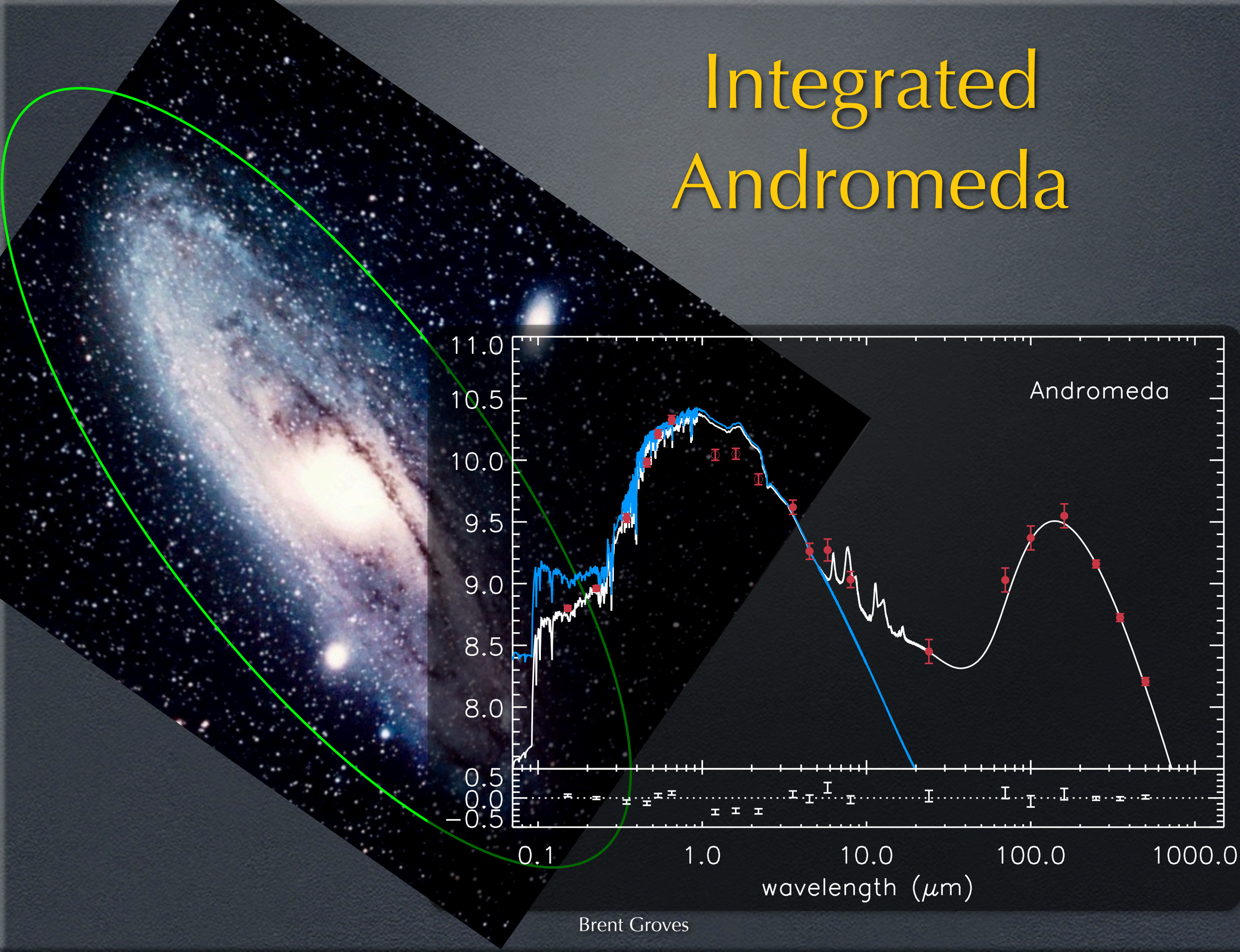

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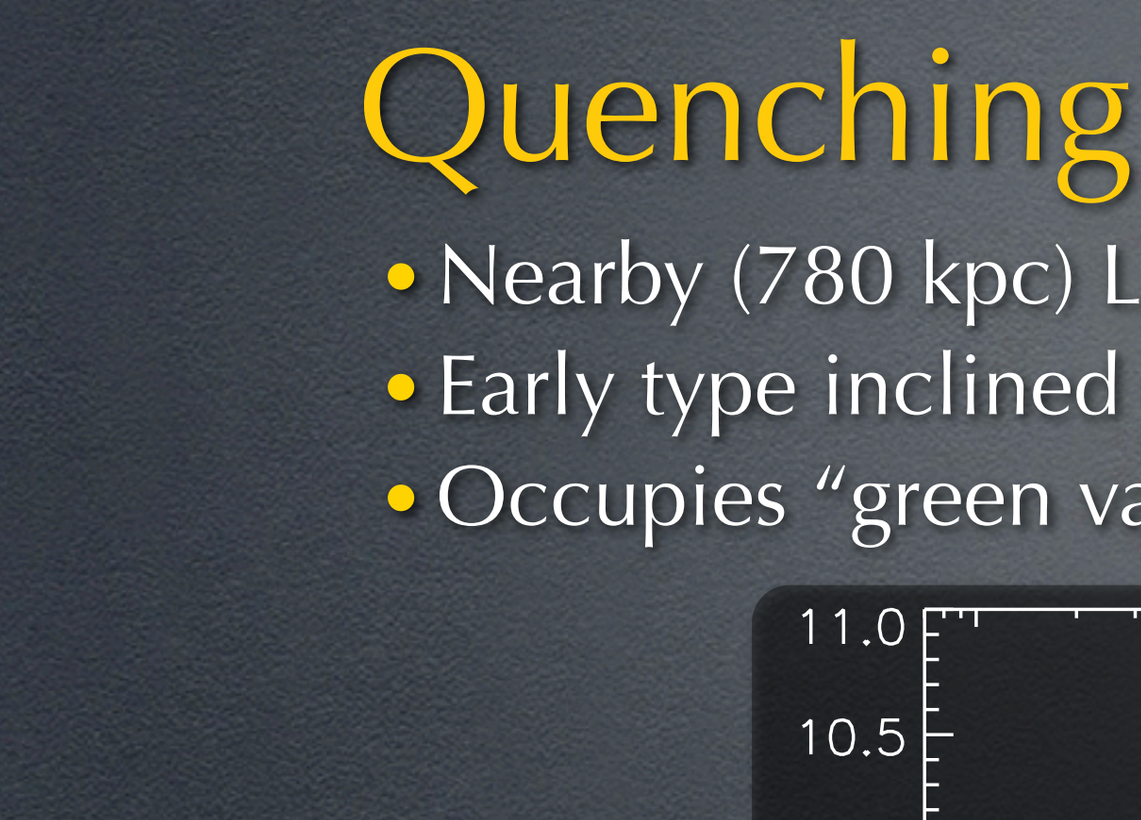
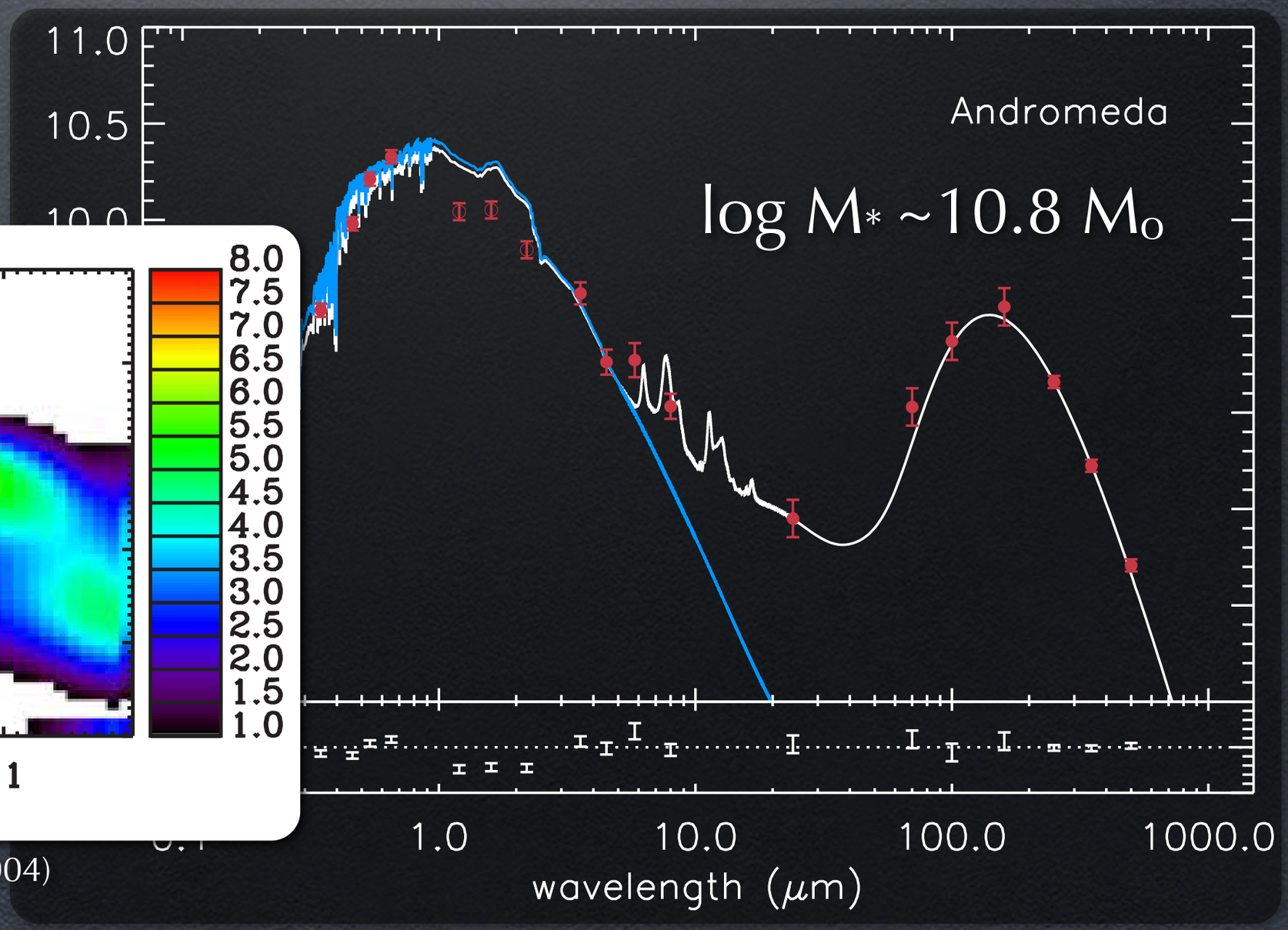
Quenching in Progress?

- Nearby (780 kpc) L* galaxy
- Early type inclined (70°) spiral
- Occupies "green valley"



Brinchmann et al. (2004)



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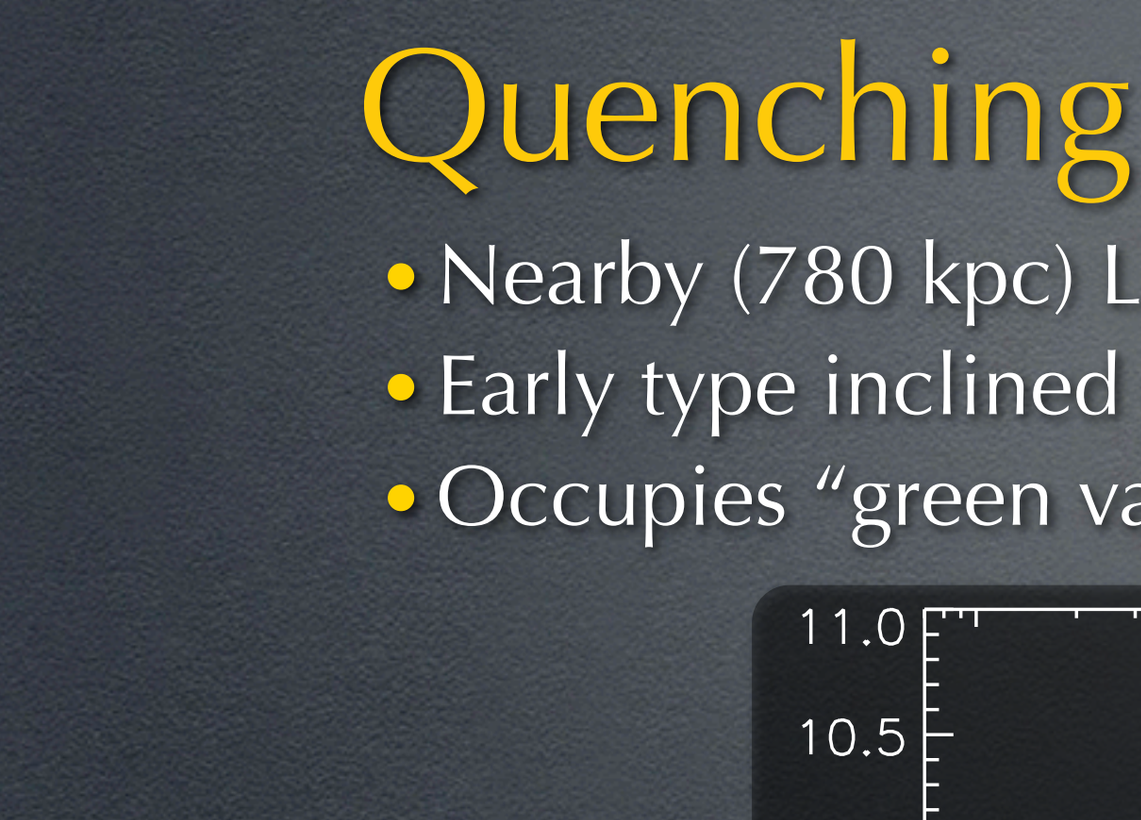

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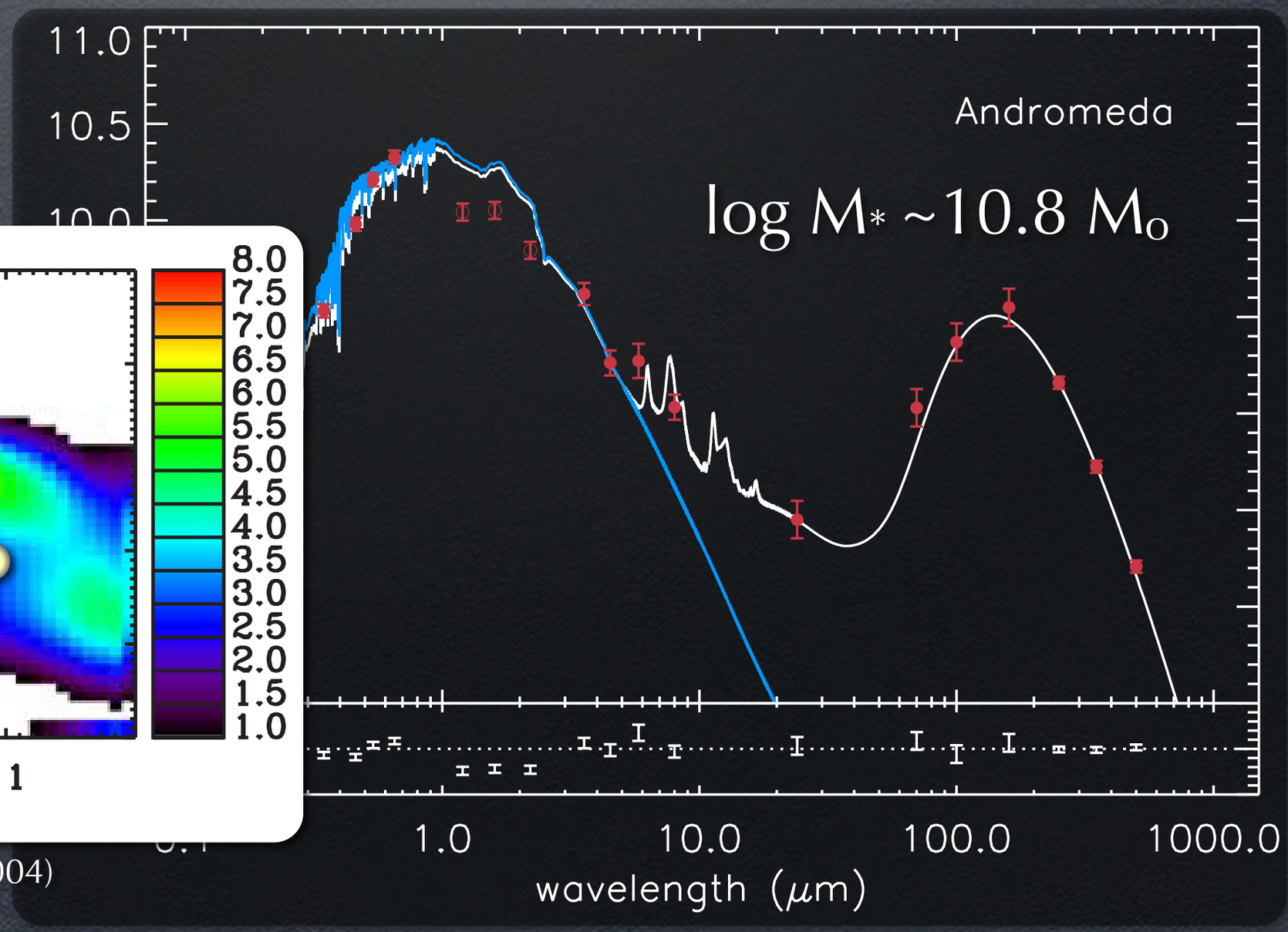
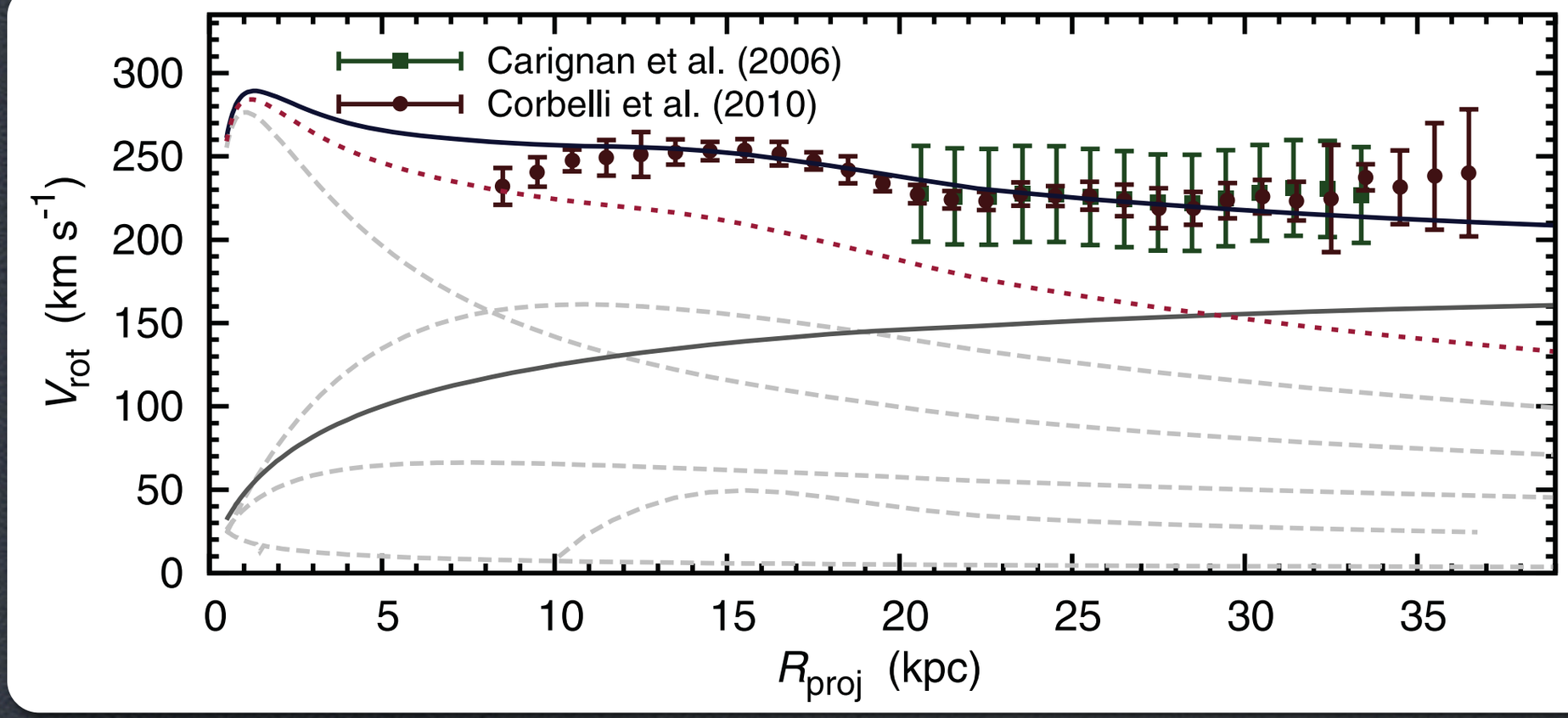


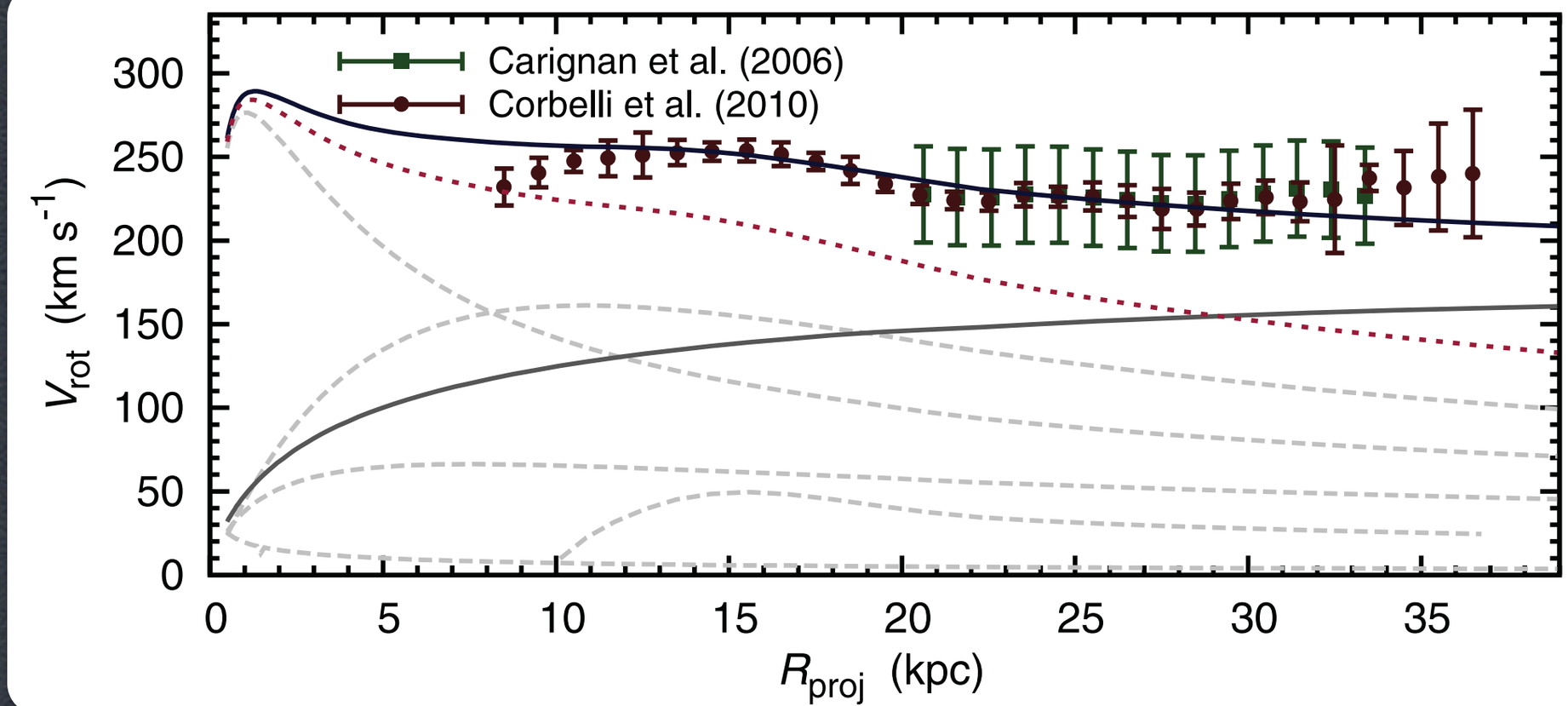
Brent Groves

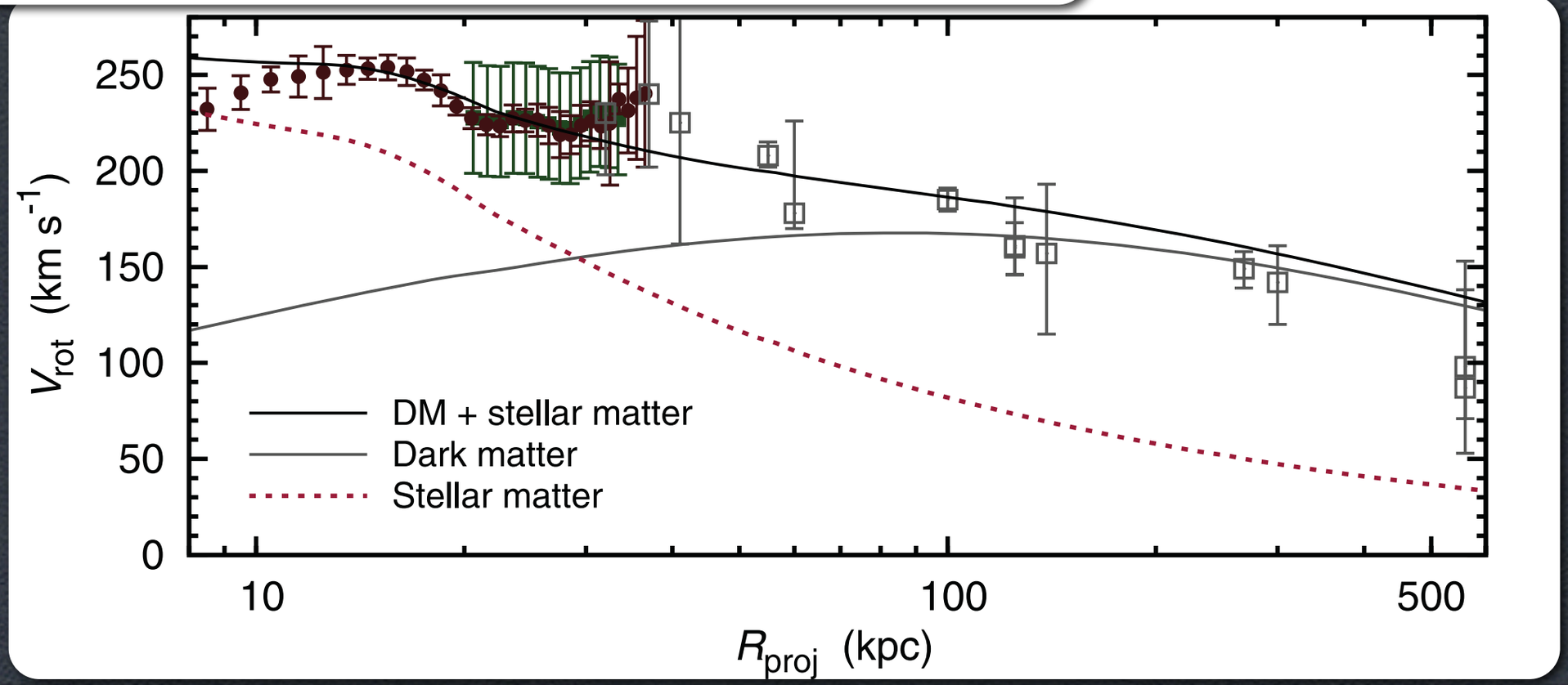
Mass outward



Tamm et al. (2012)

Mass outward





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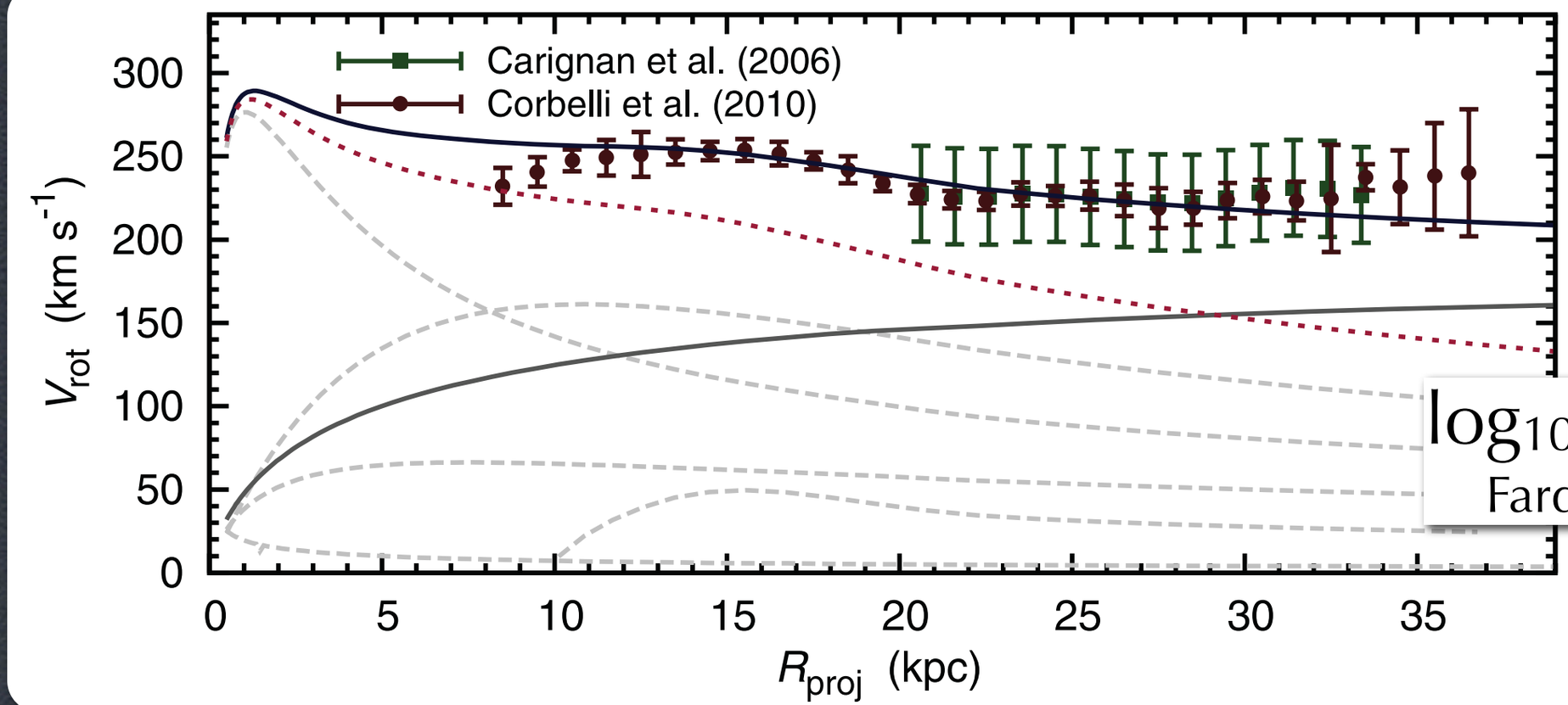
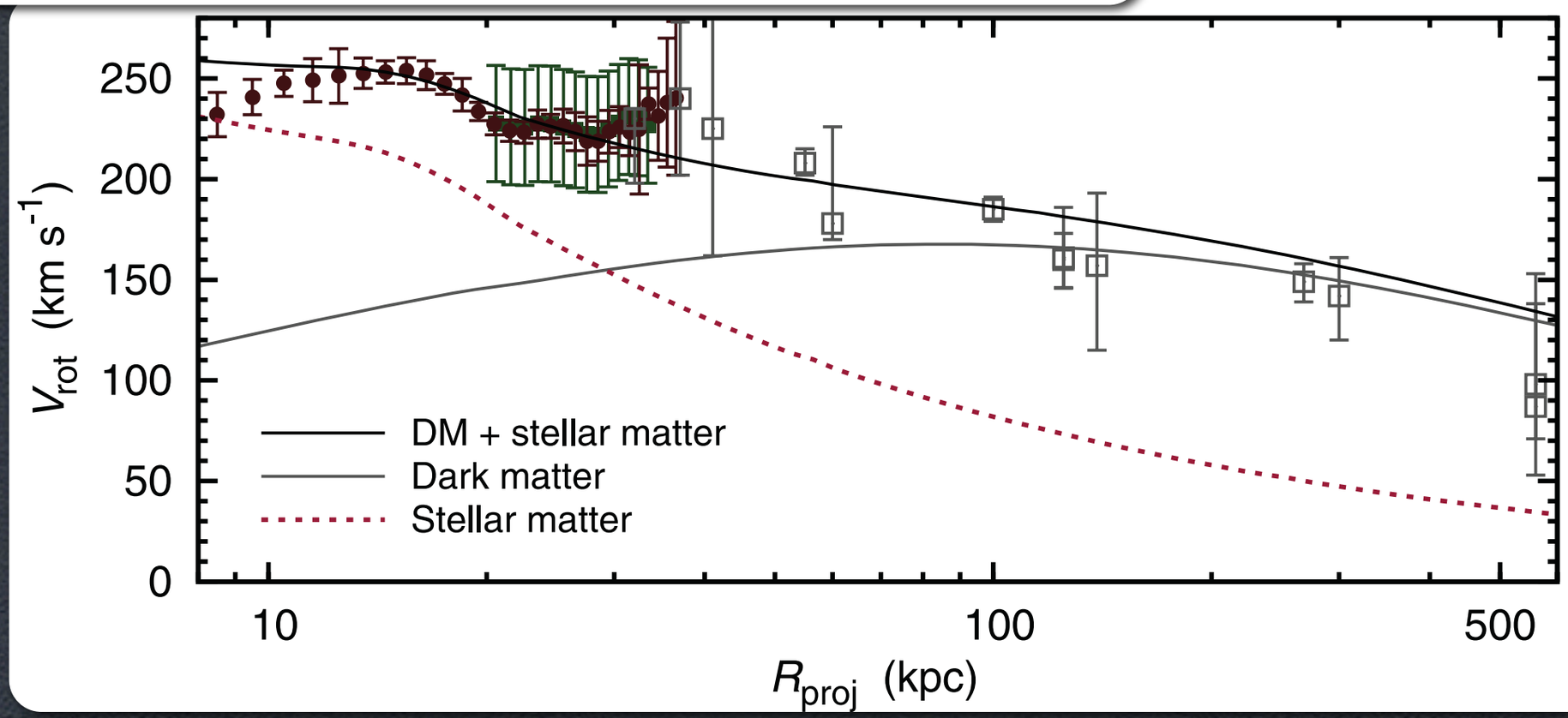
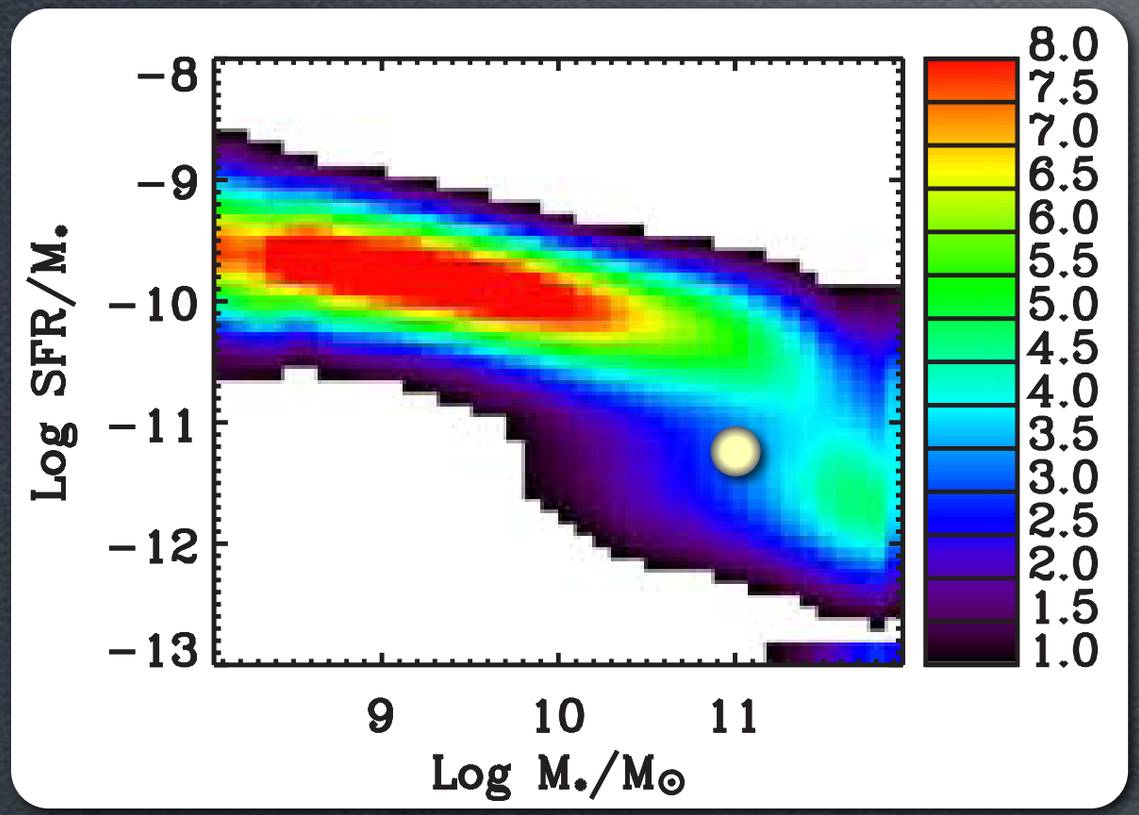


$\log_{10} M_{200} = 12.3$
Fardal et al. (2013)



Tamm et al. (2012)

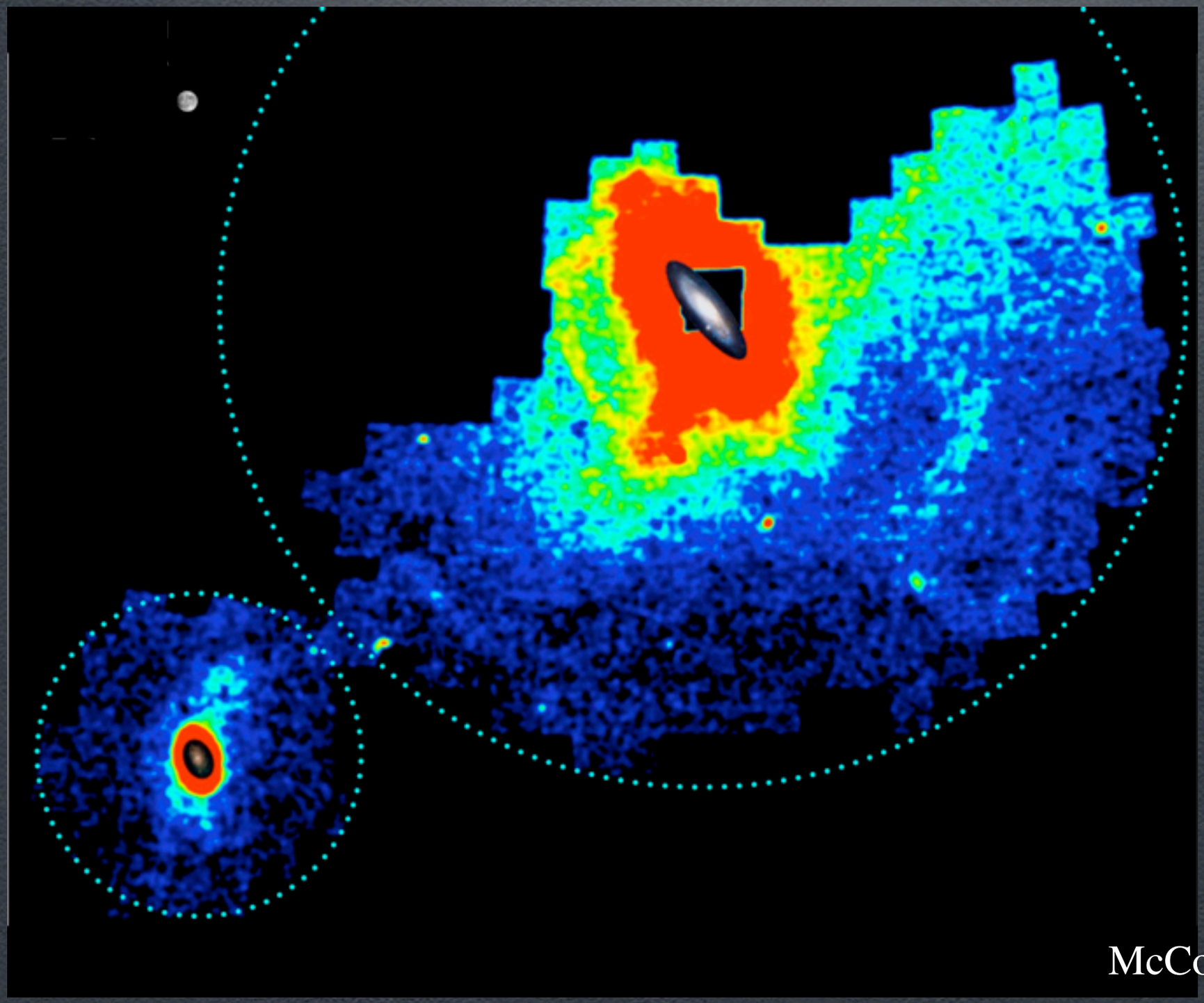
Cause of Quenching?



- M31* hosts a SMBH
- no indication of activity over last ~ Myr
- Suggested major merger ~5 Gyrs ago (Hammer et al. (2013)
- Other indications?

Streams of Stars

The Pan-Andromeda Archaeological Survey



Colour shows stellar surface density

McConnachie et al. (2009)

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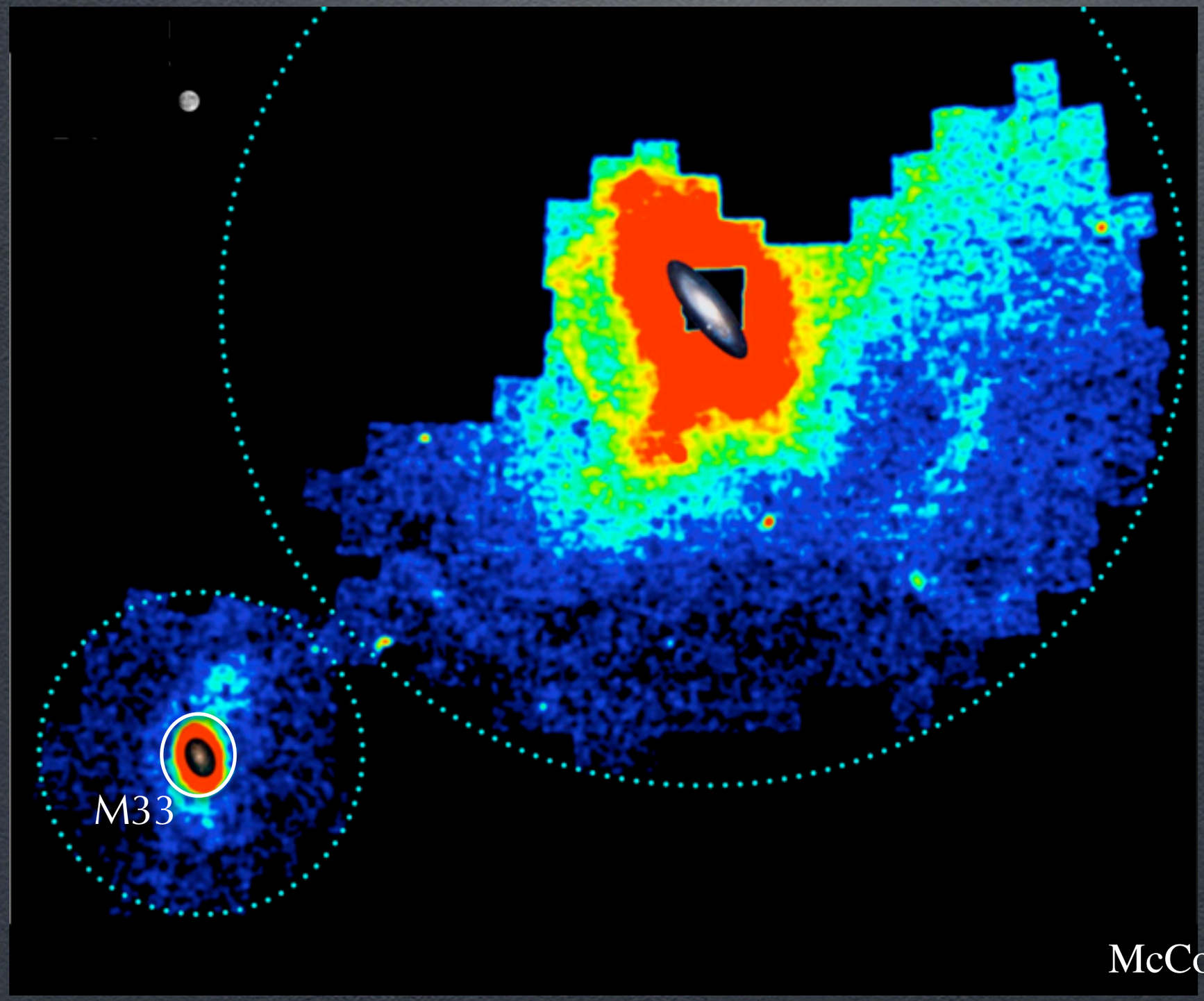

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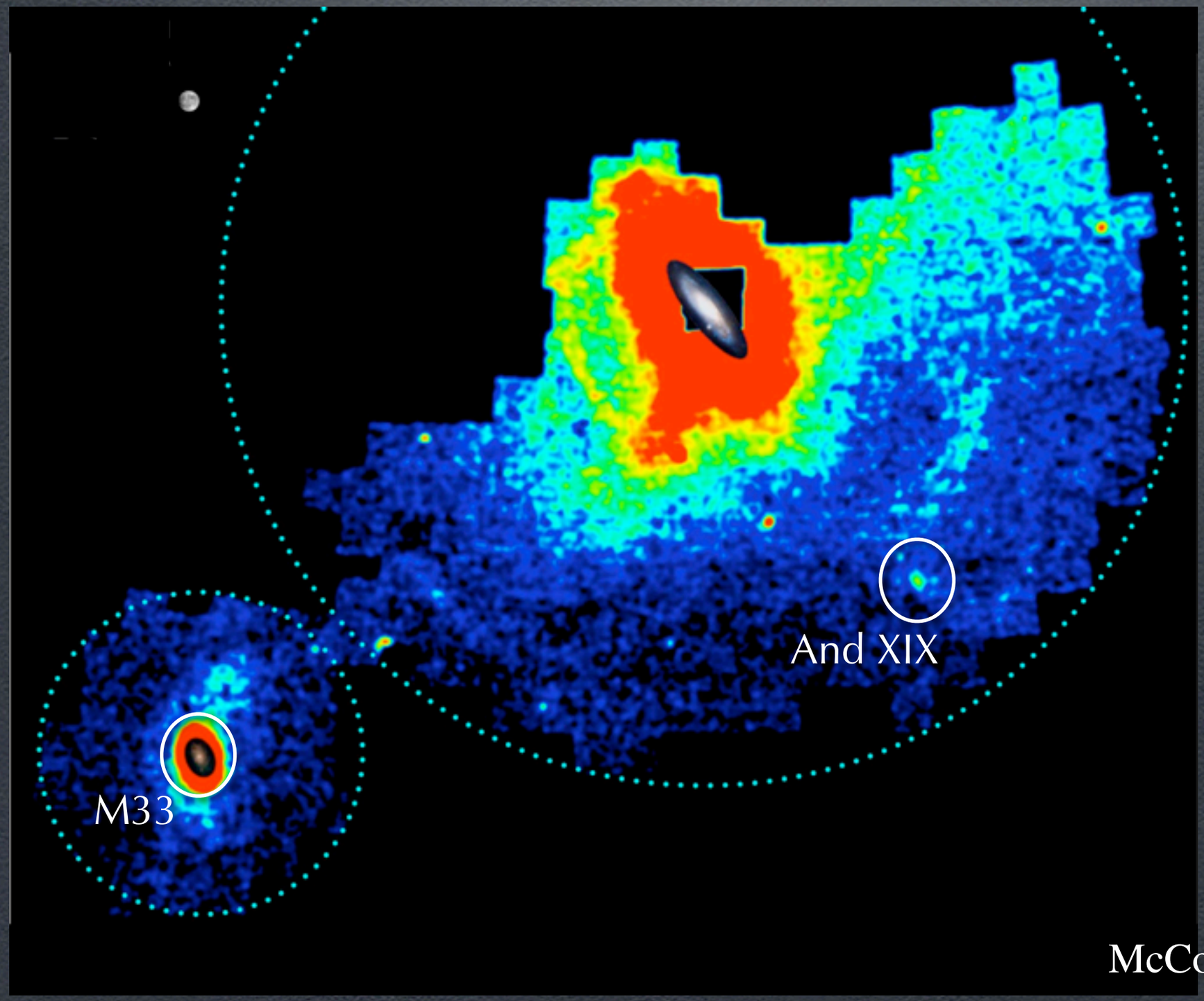

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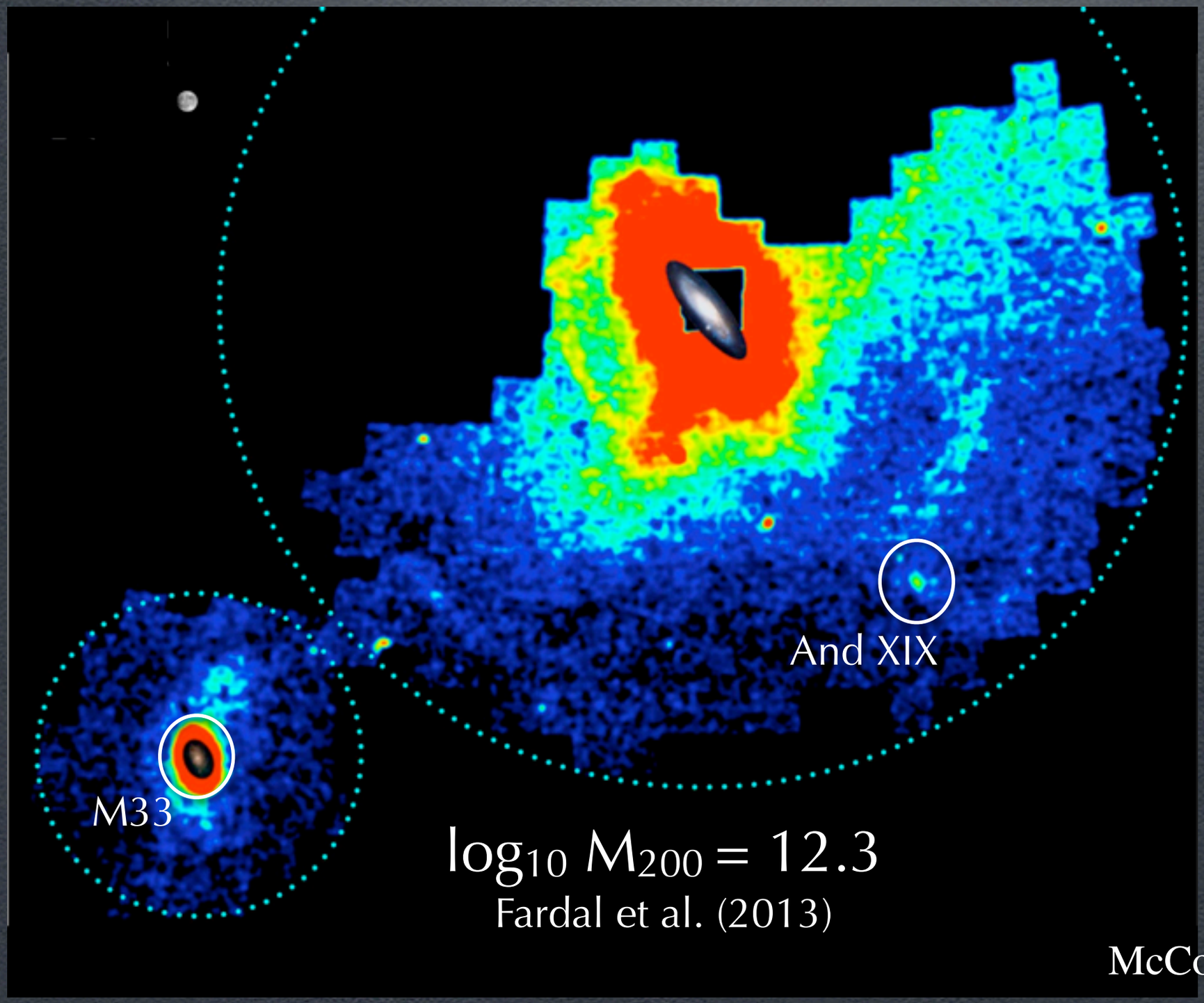

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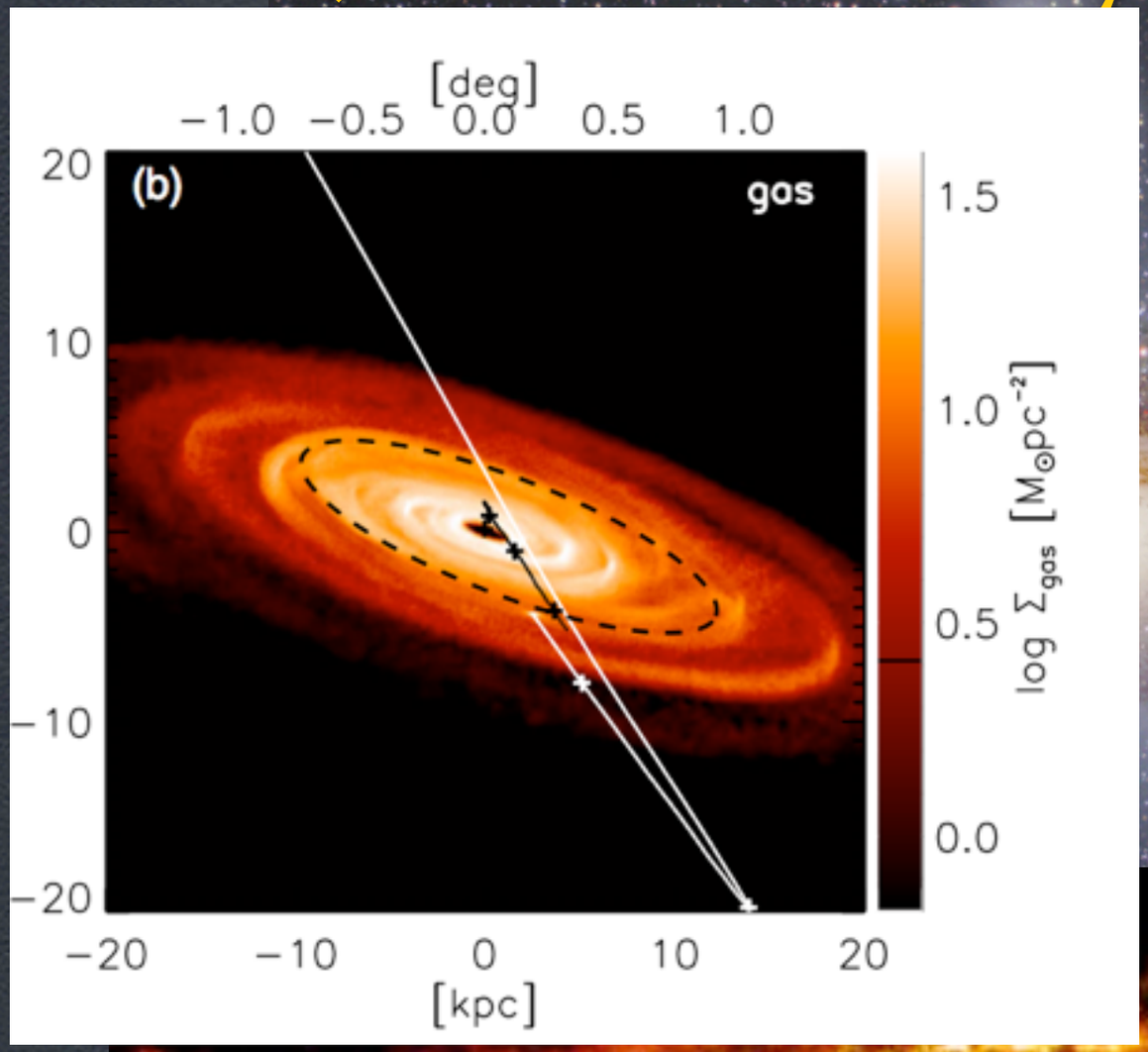

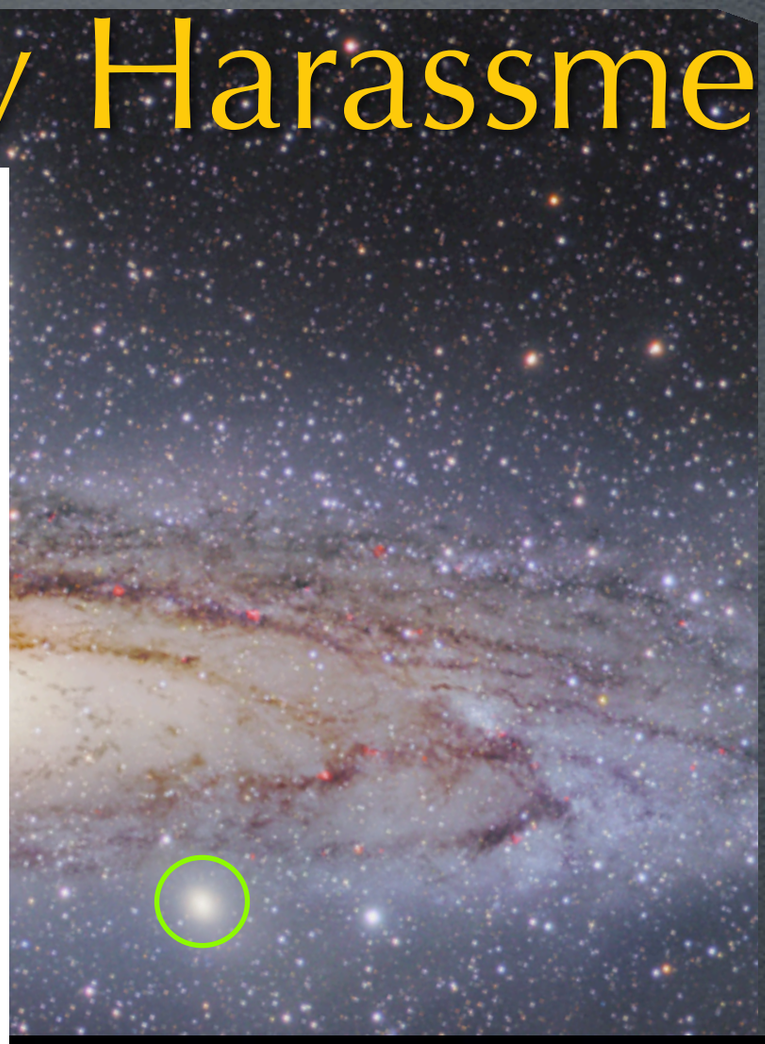

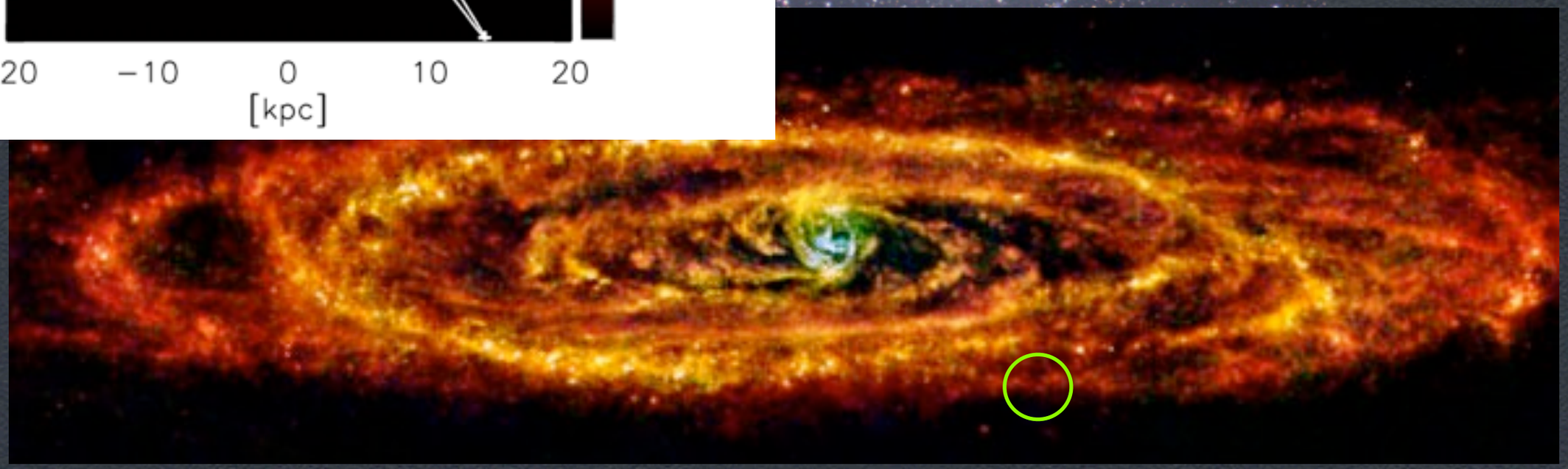

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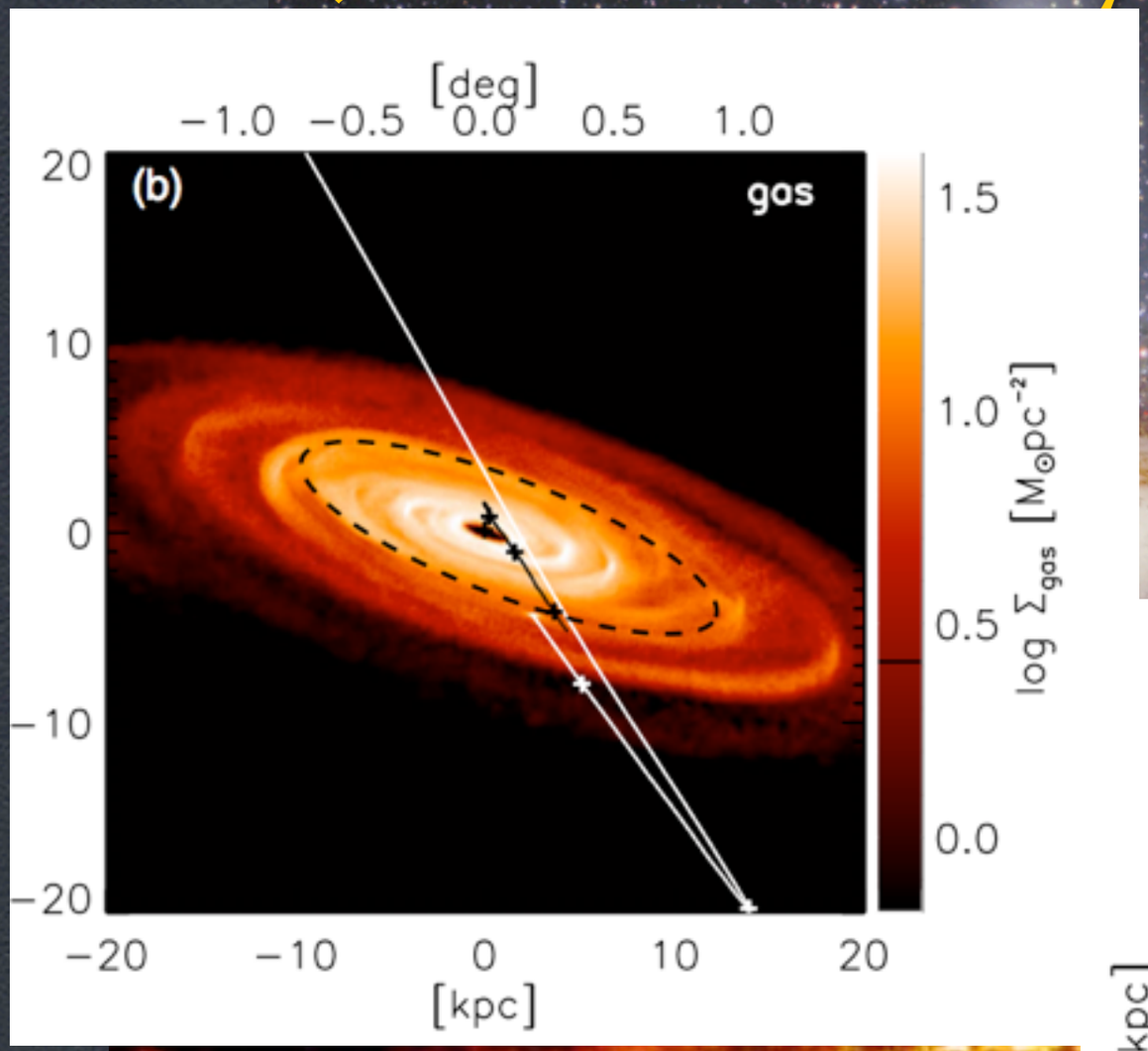
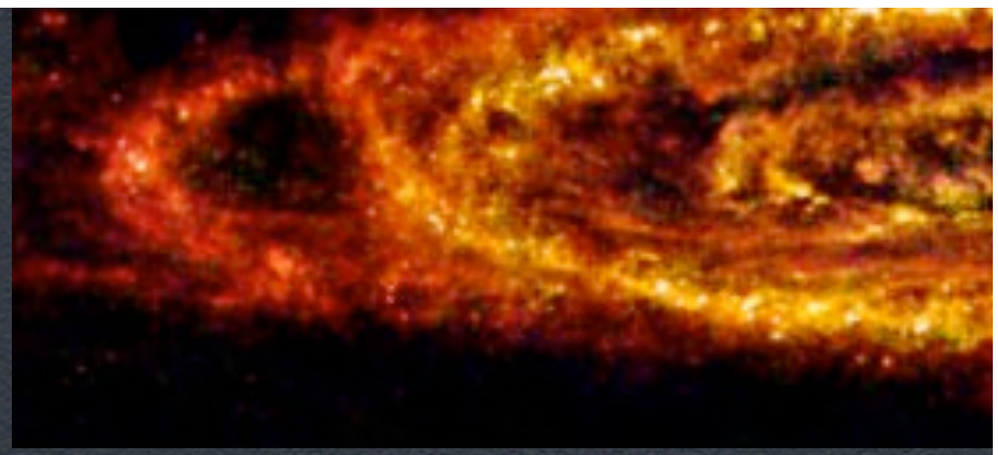
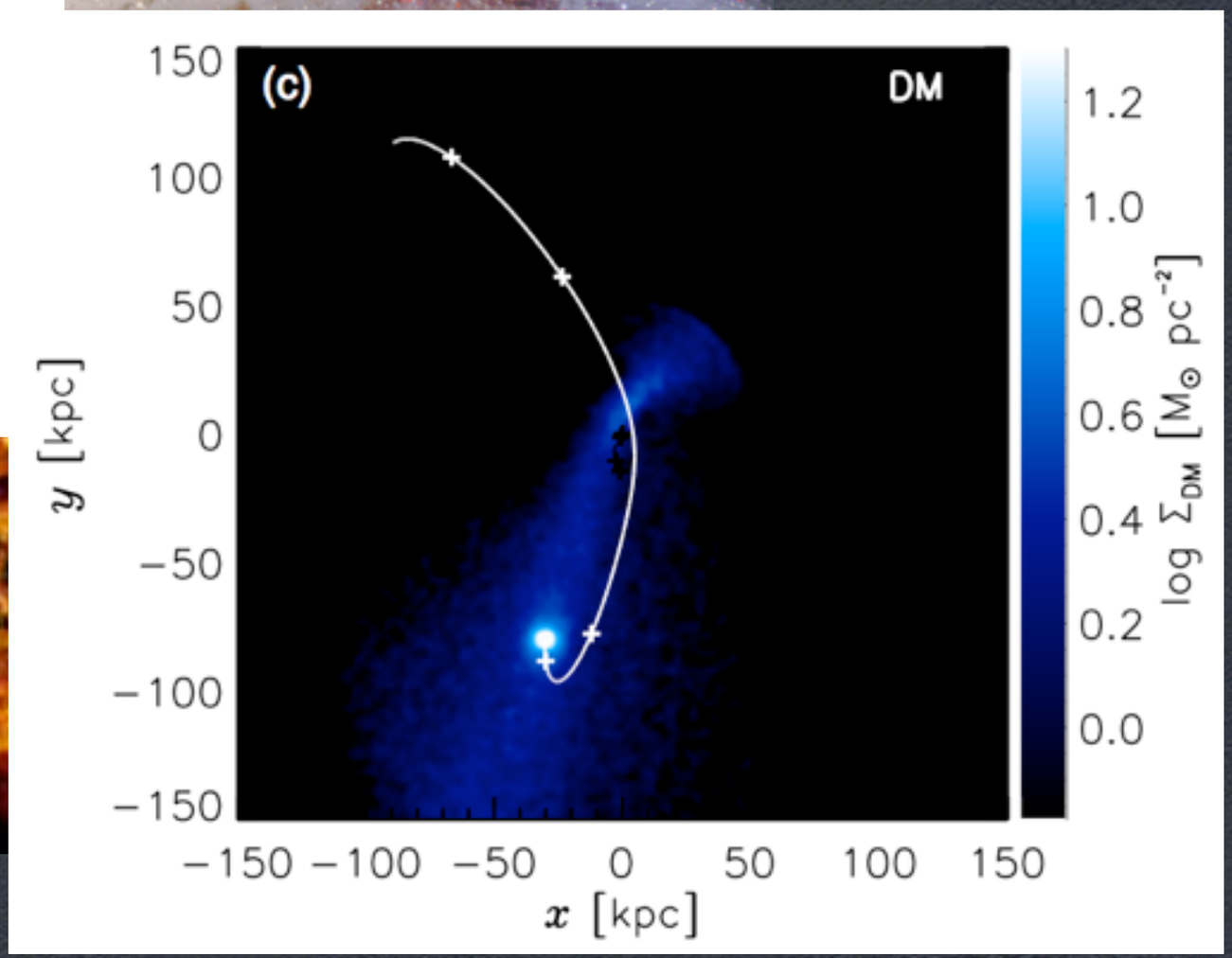
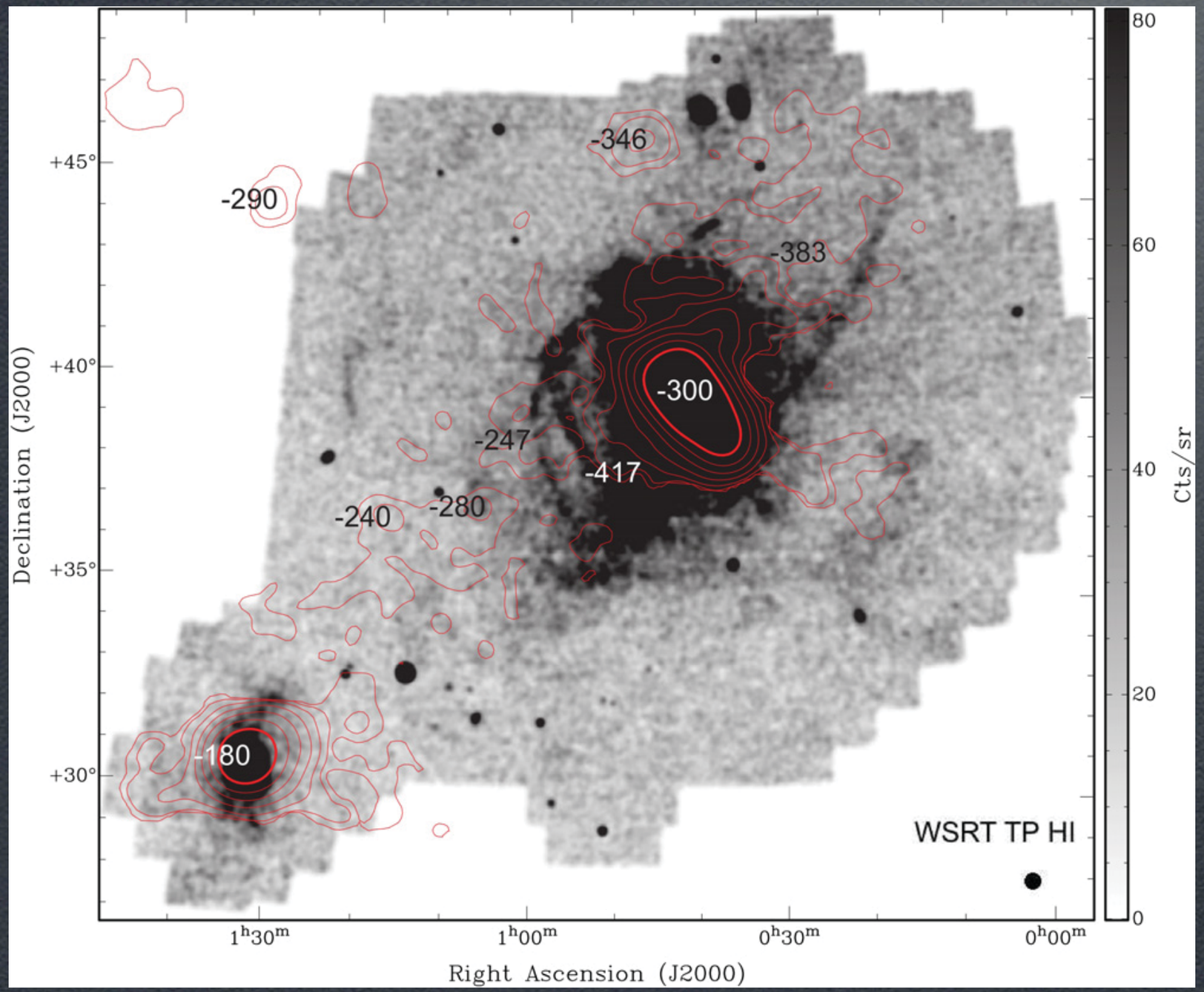






Extended HI - Starvation?



- HI still extended around M31
- but shows interaction with M33

Lewis et al. (2013)

Quiescence

Quiescence

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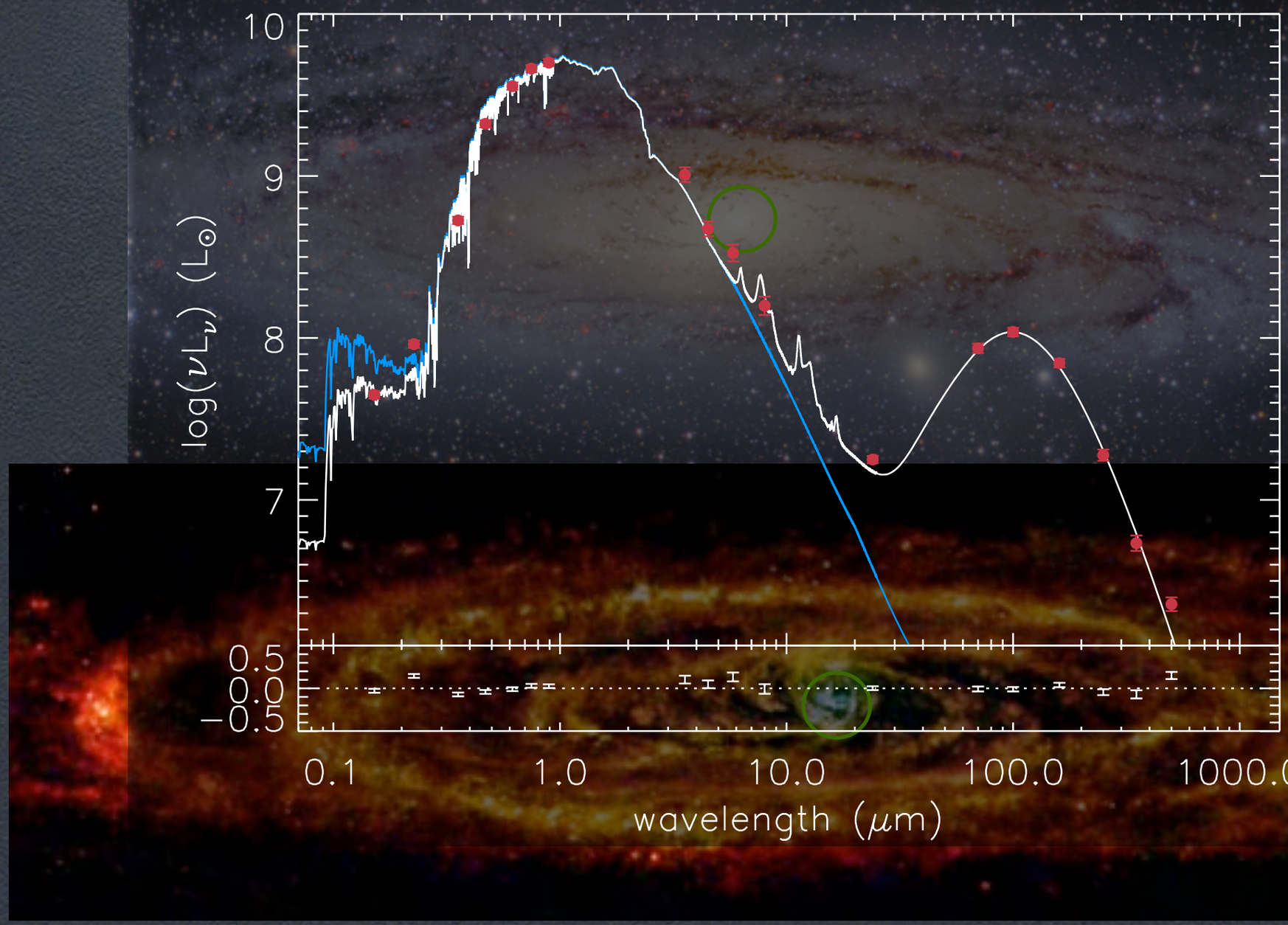

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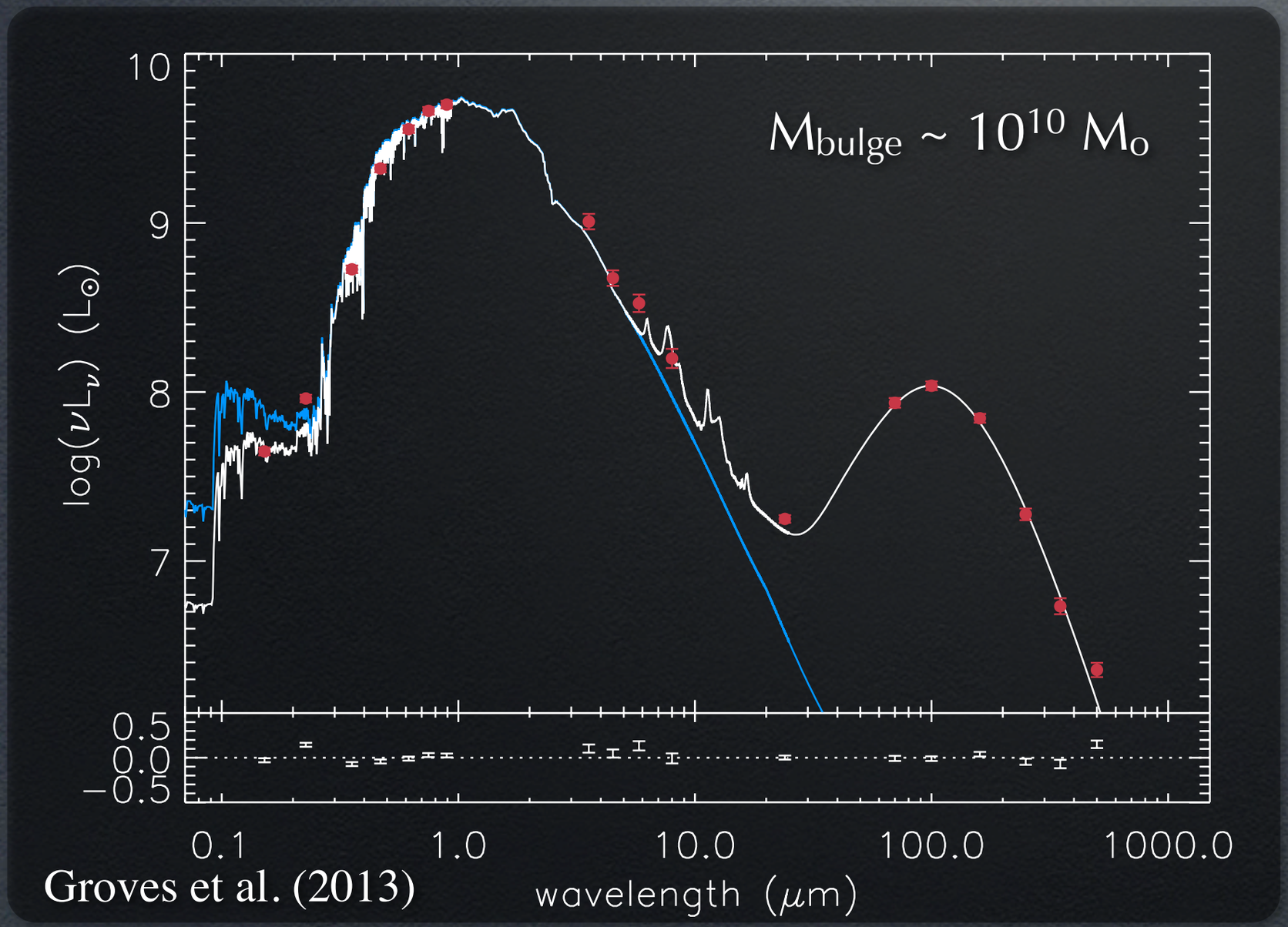
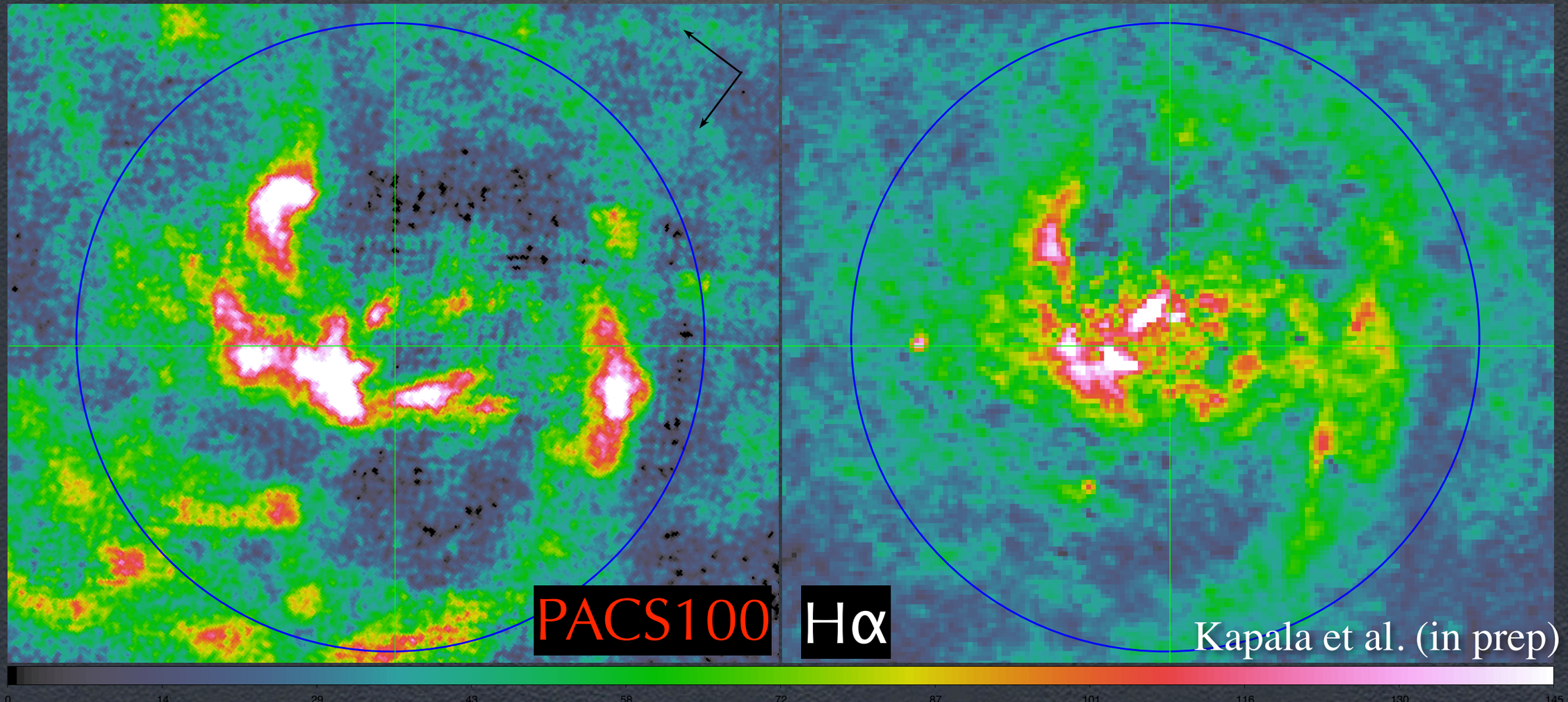


Groves et al. (2013)

- SED suggests no SFR ($< 10^{-2}\ M_\odot$/yr)
- sSFR < 0.01 Gyr^{-1}
- Extremely old (>6 Gyr)
- Dust heated predominantly by old stars!

There is gas…

- $M_{dust} \sim 10^5\ M_o$
- $M_{gas} \sim 10^{6.8}\ M_o$
- most of this in cool phase



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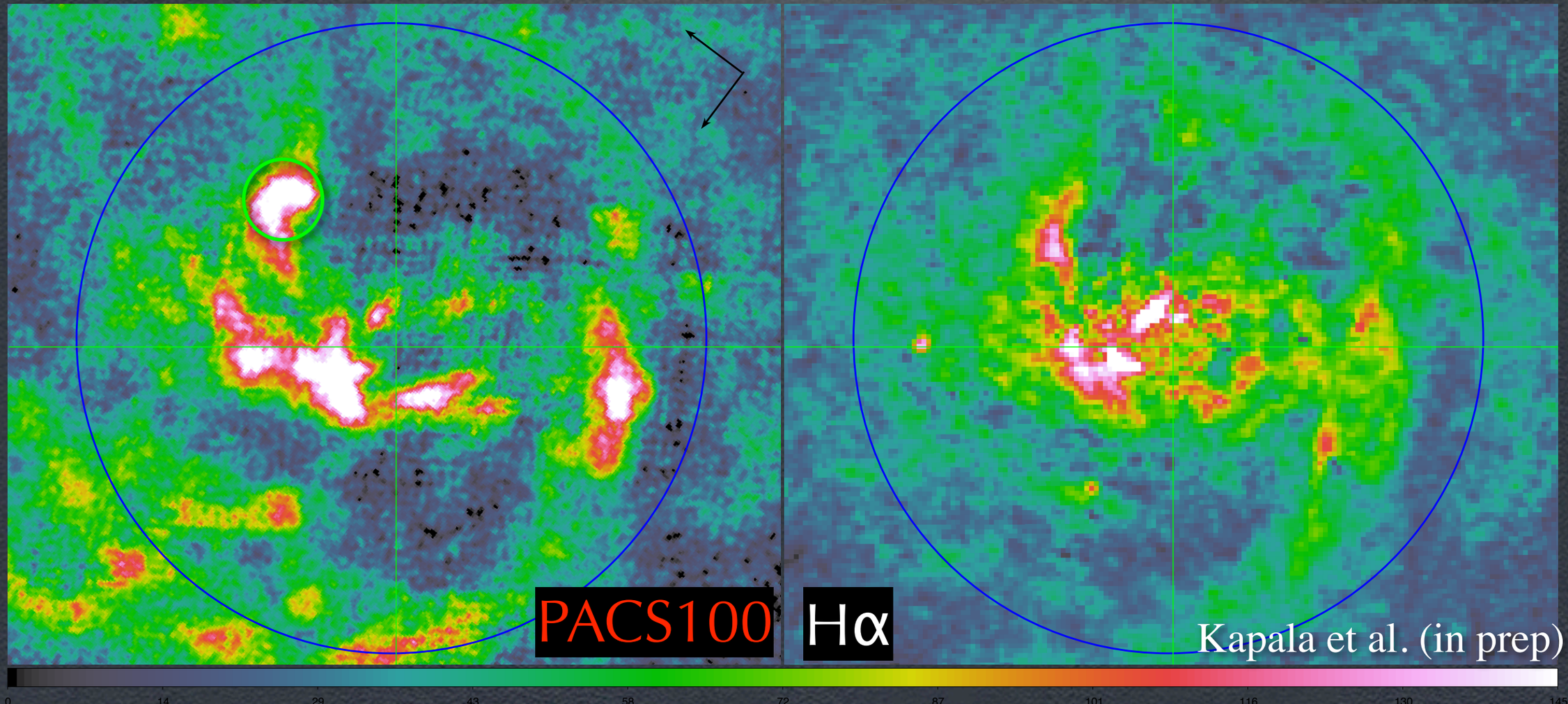

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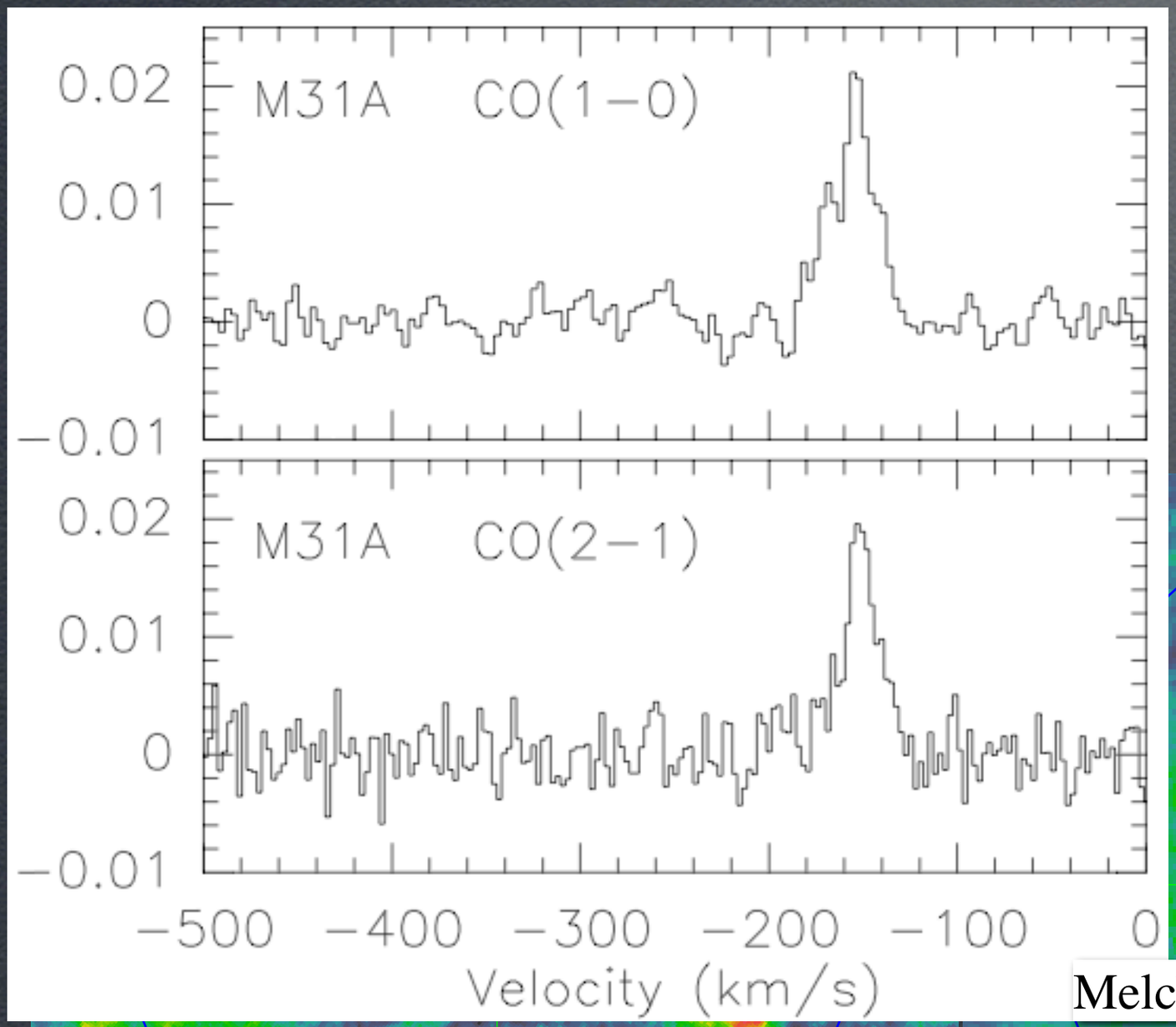

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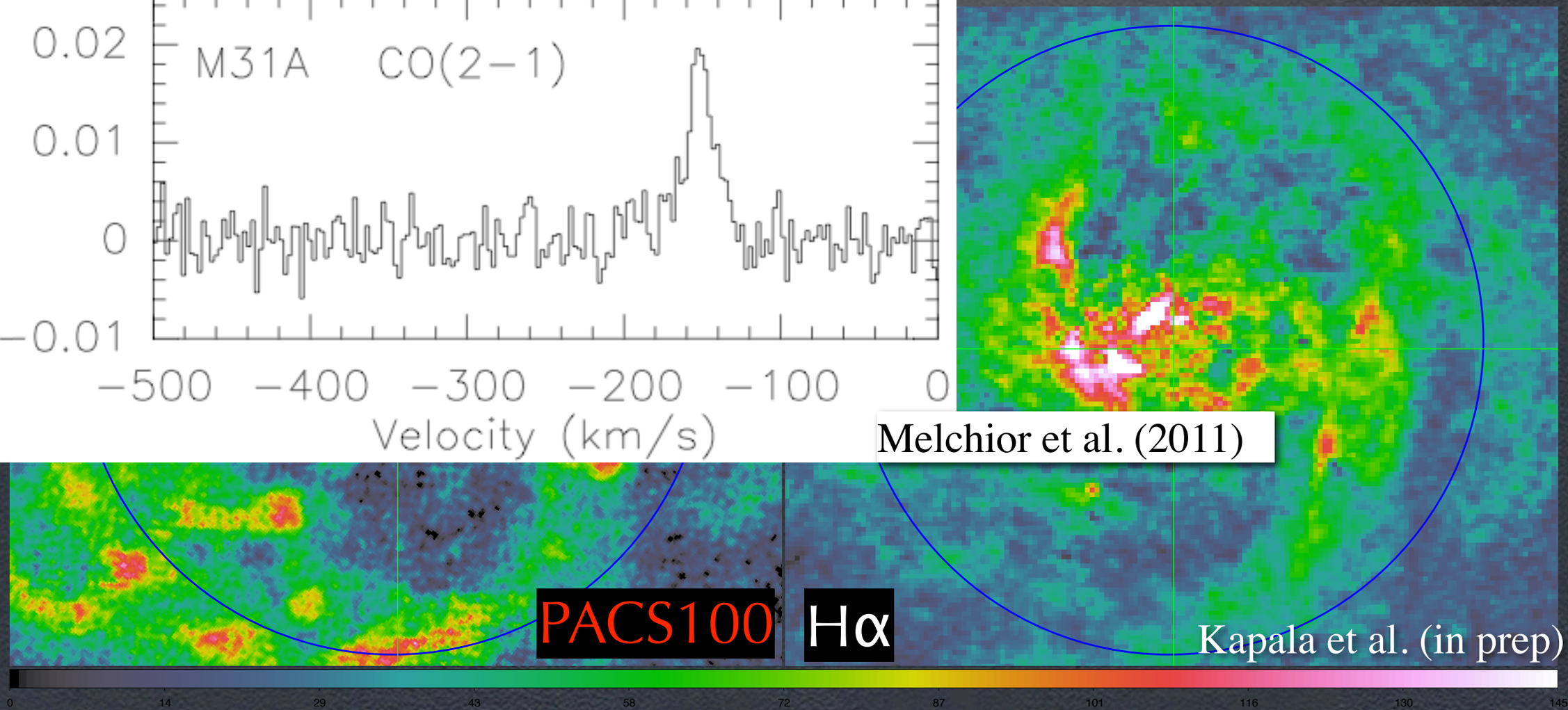
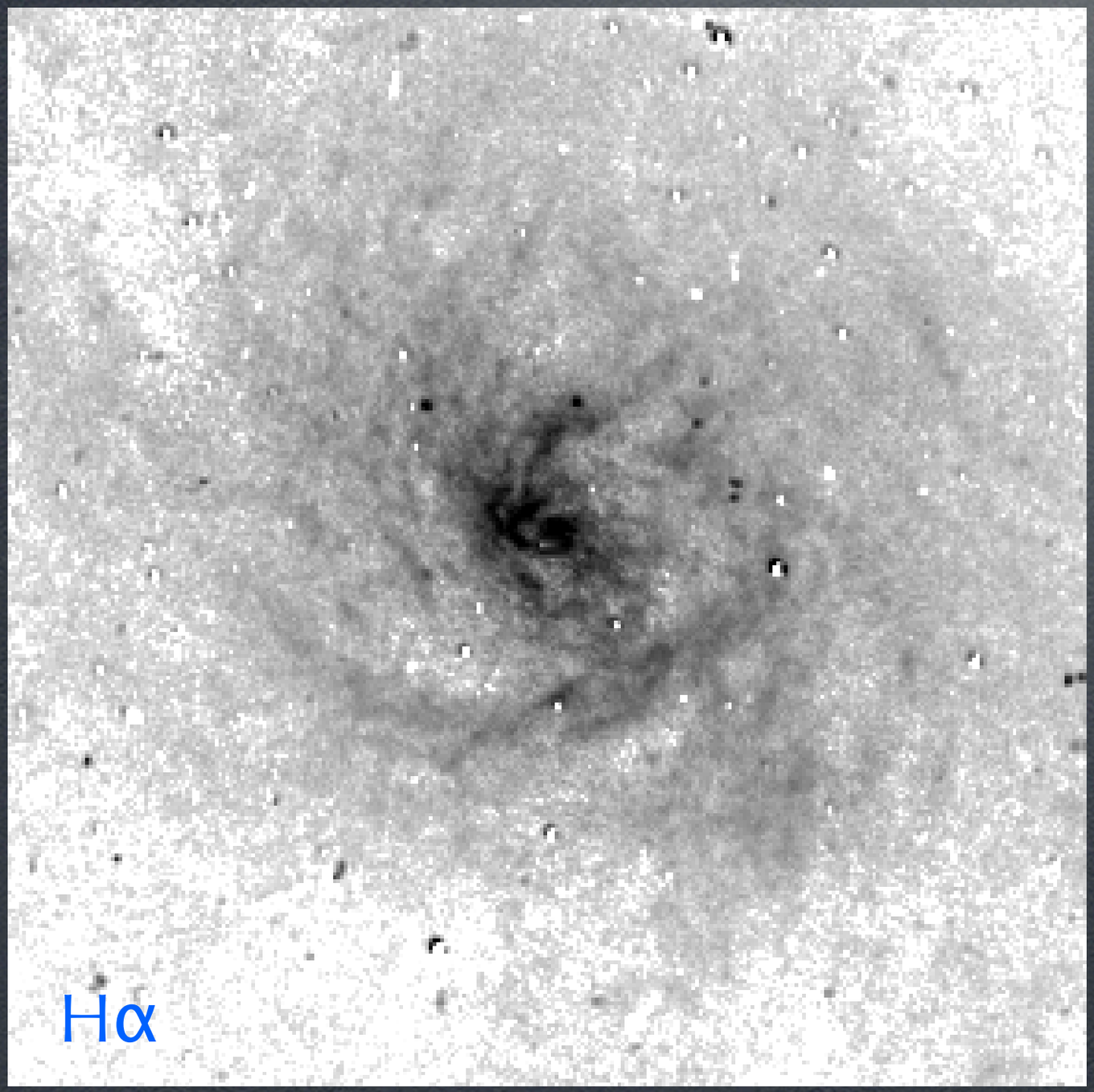


Melchior et al. (2011)

Kapala et al. (in prep)

Gas heating



- Ionized gas follows dust
- but shows LINER-like ratios (R. Singh's talk)
- Shocks may be present, but not dominant based on line widths

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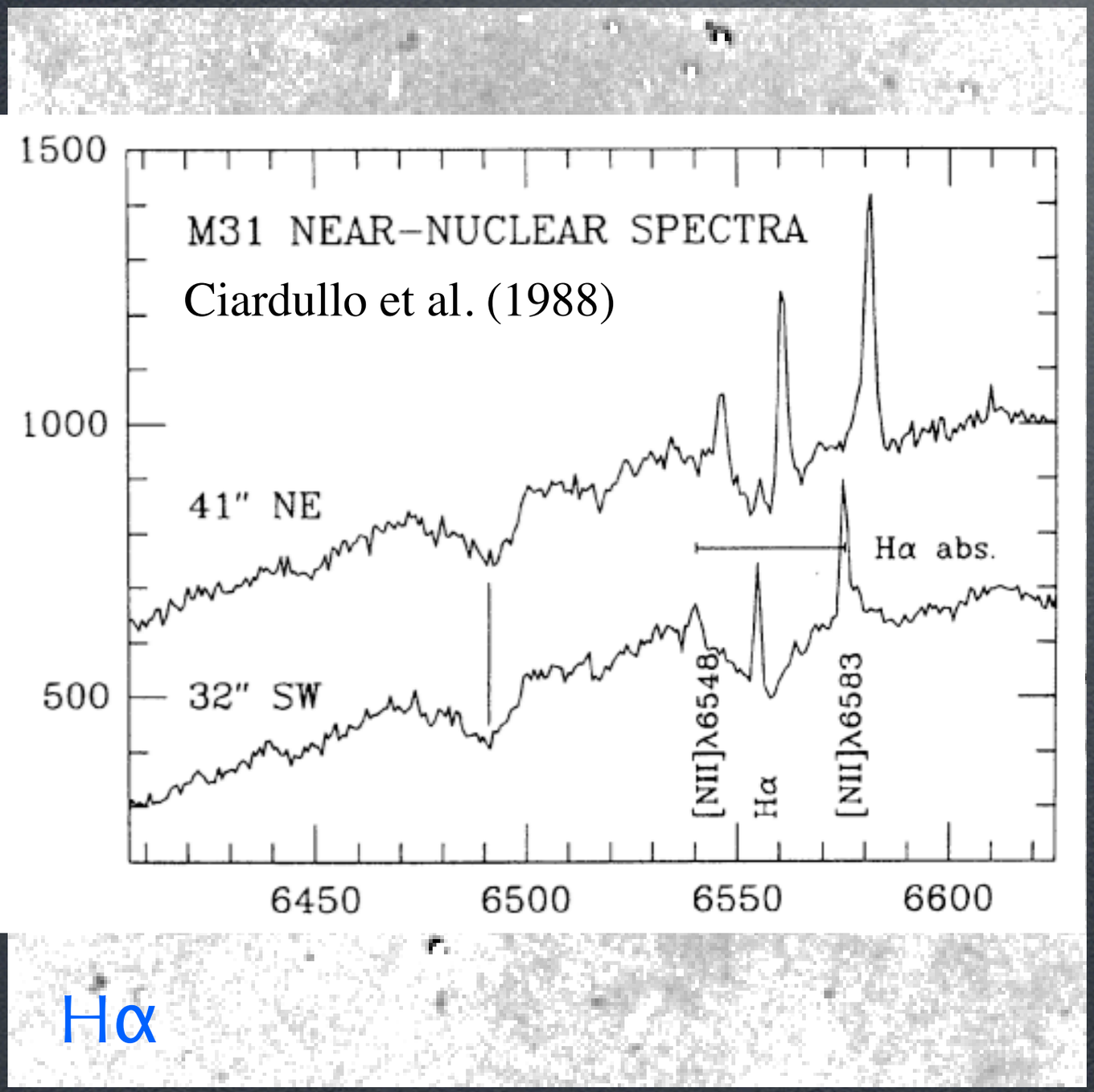

Hα

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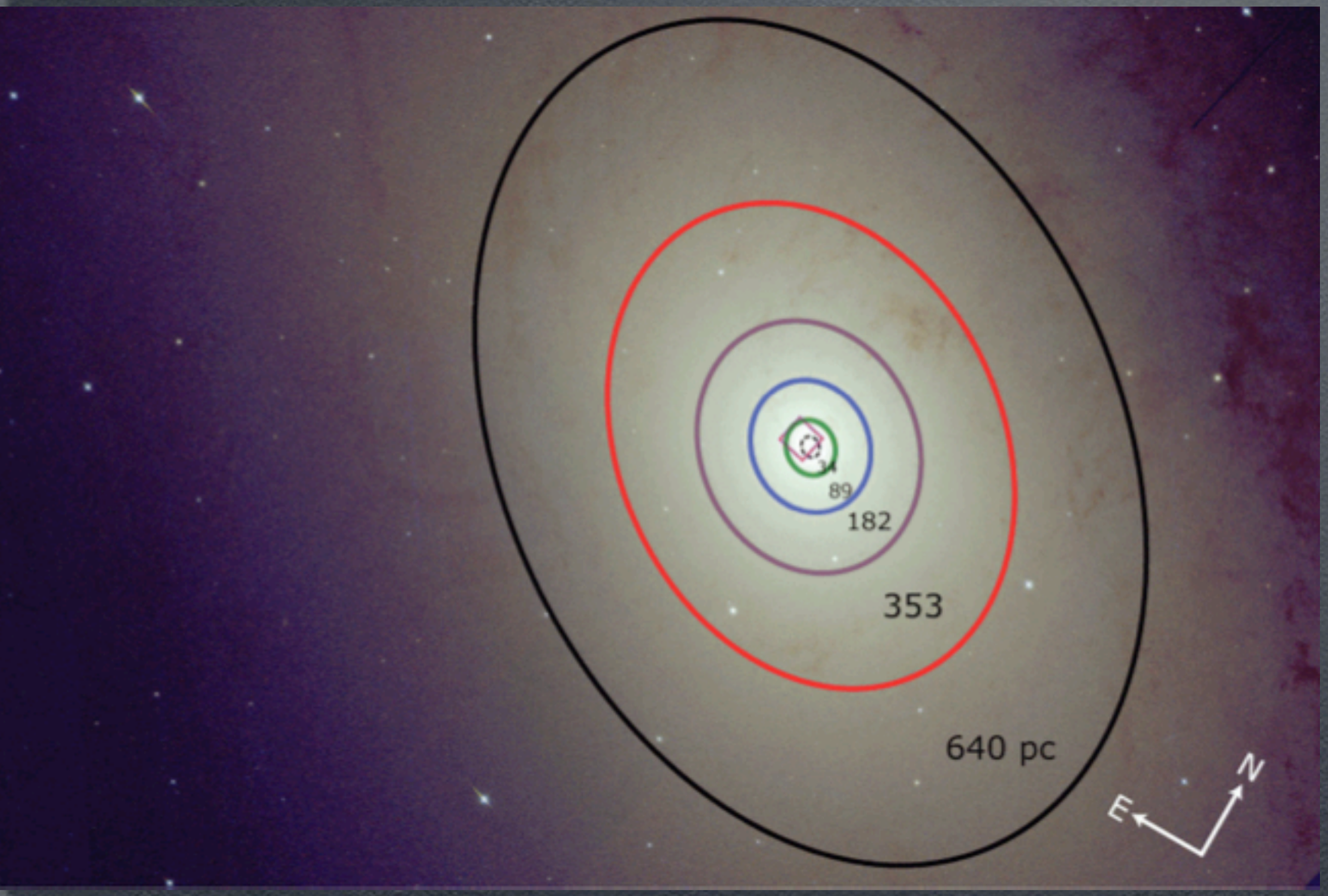
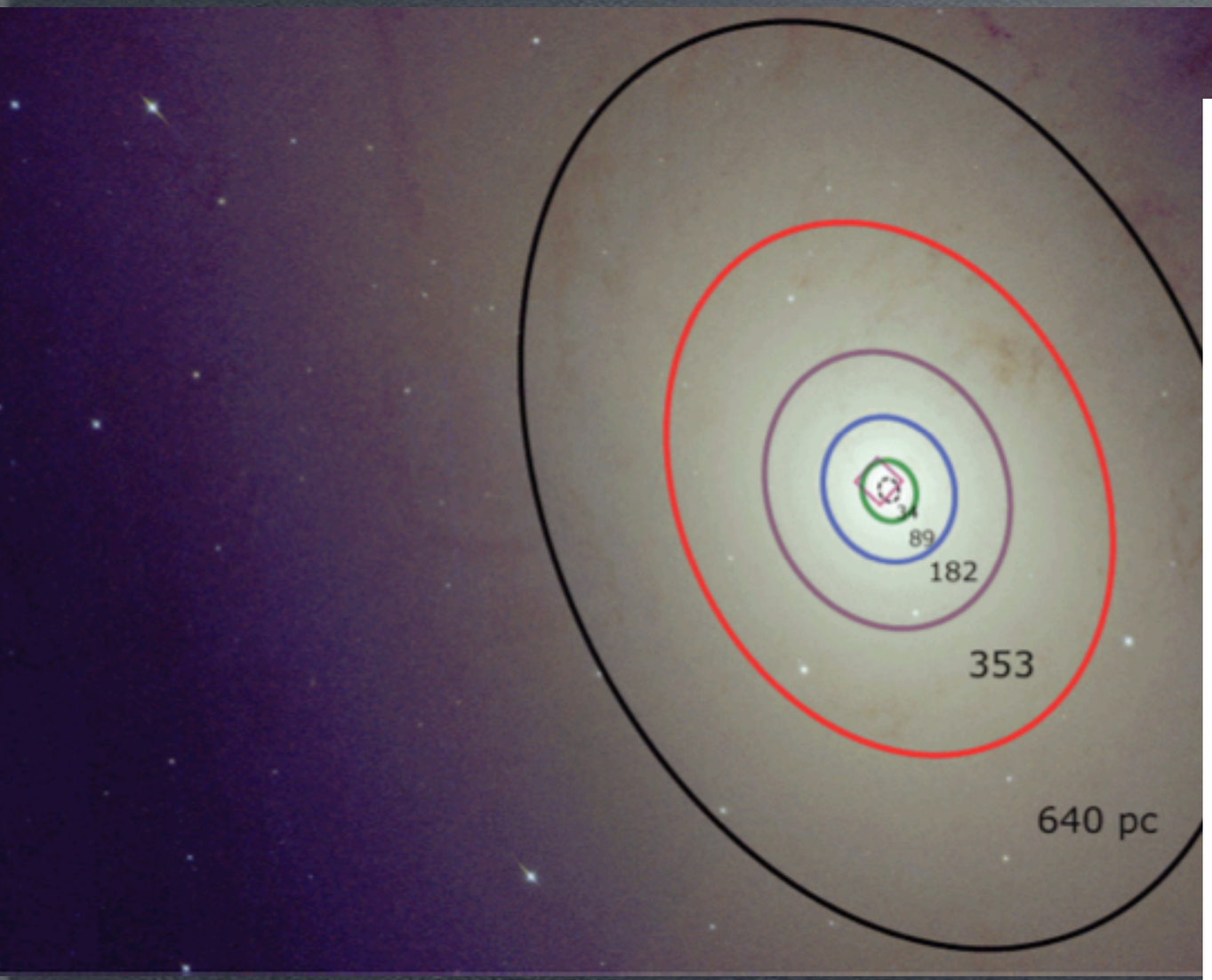
UV heating?



Rosenfield et al. (2012)

- Resolved stars (& UV light) dominated by extreme horizontal branch

UV heating?



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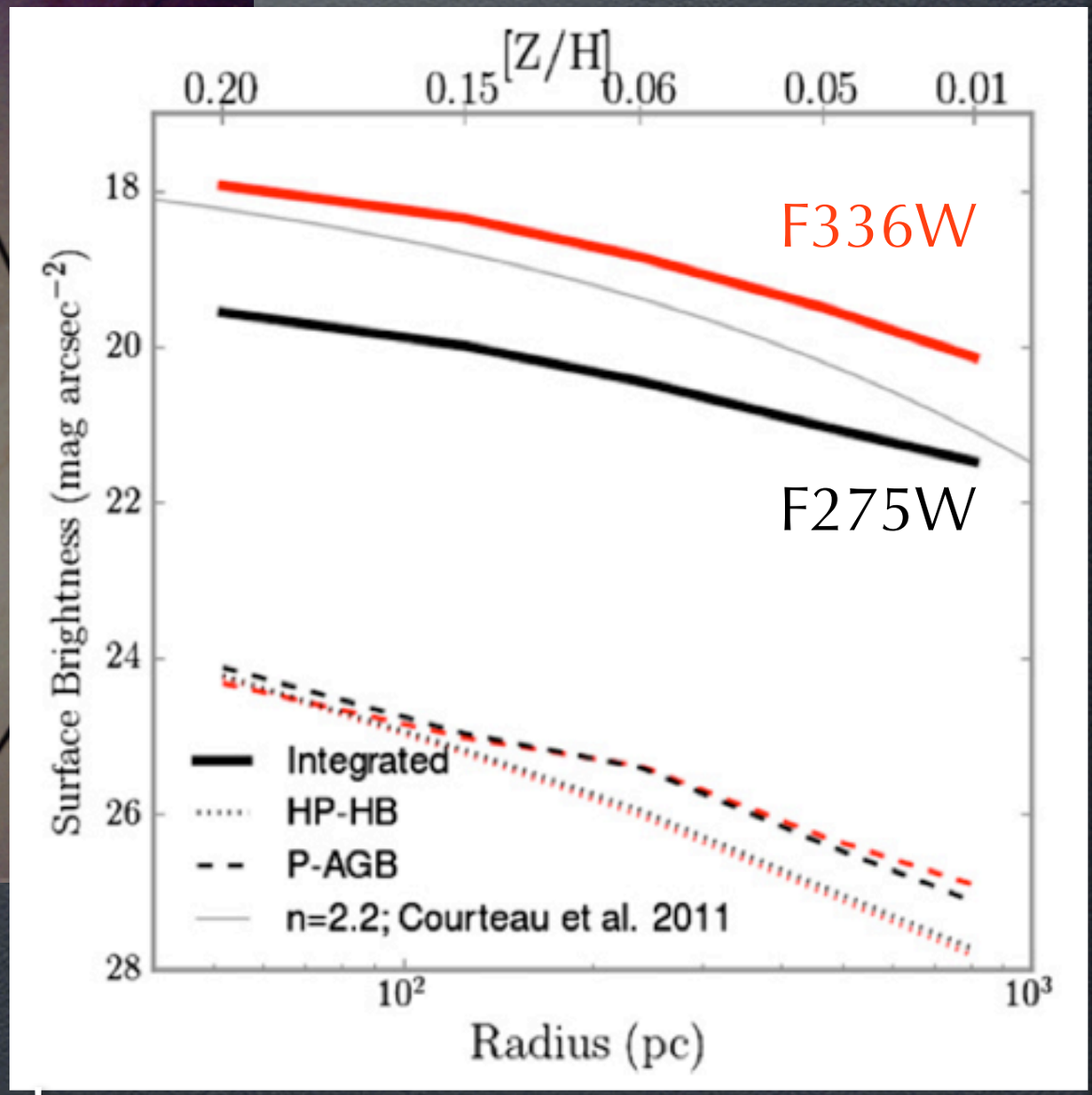

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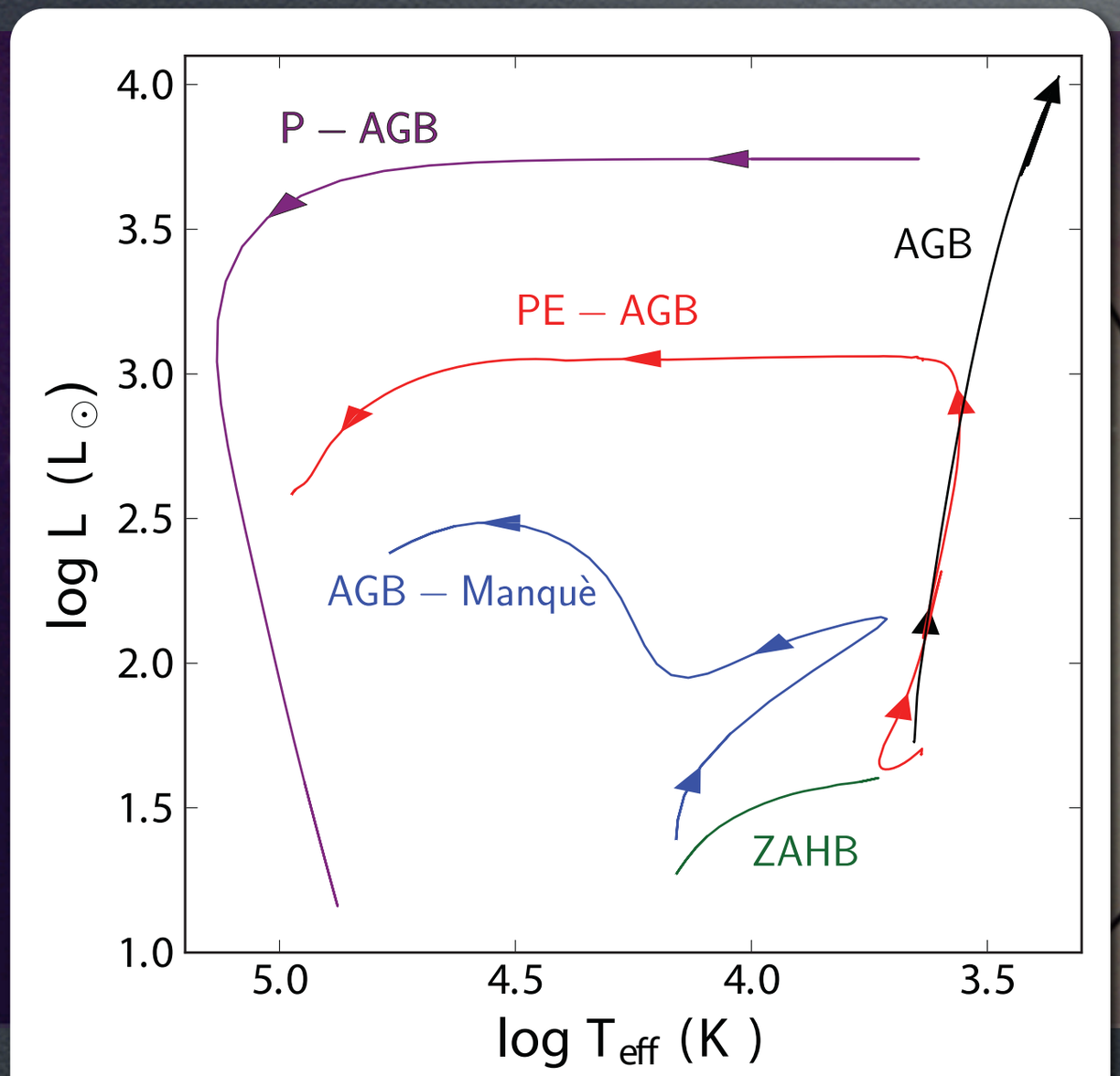

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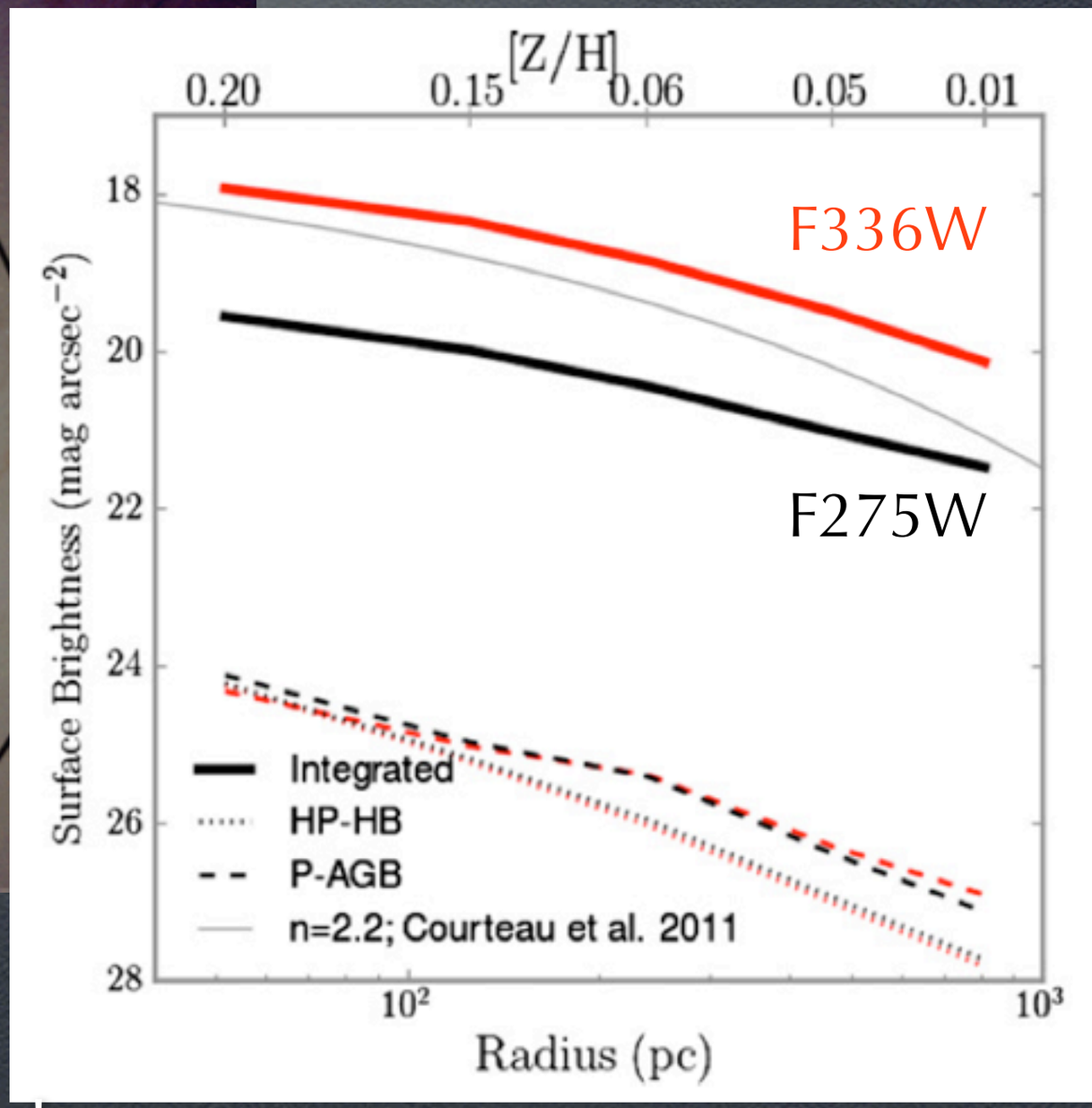

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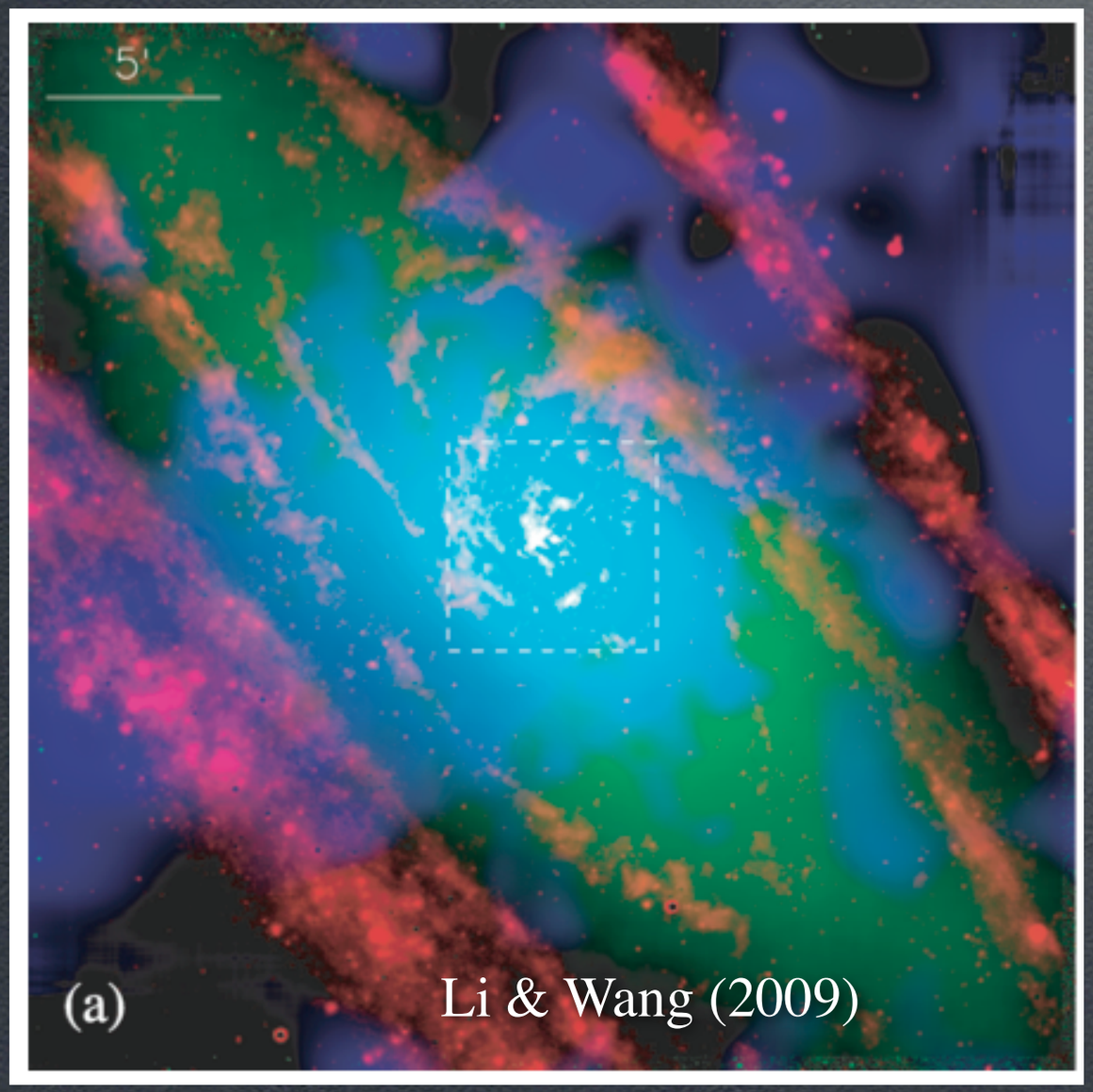
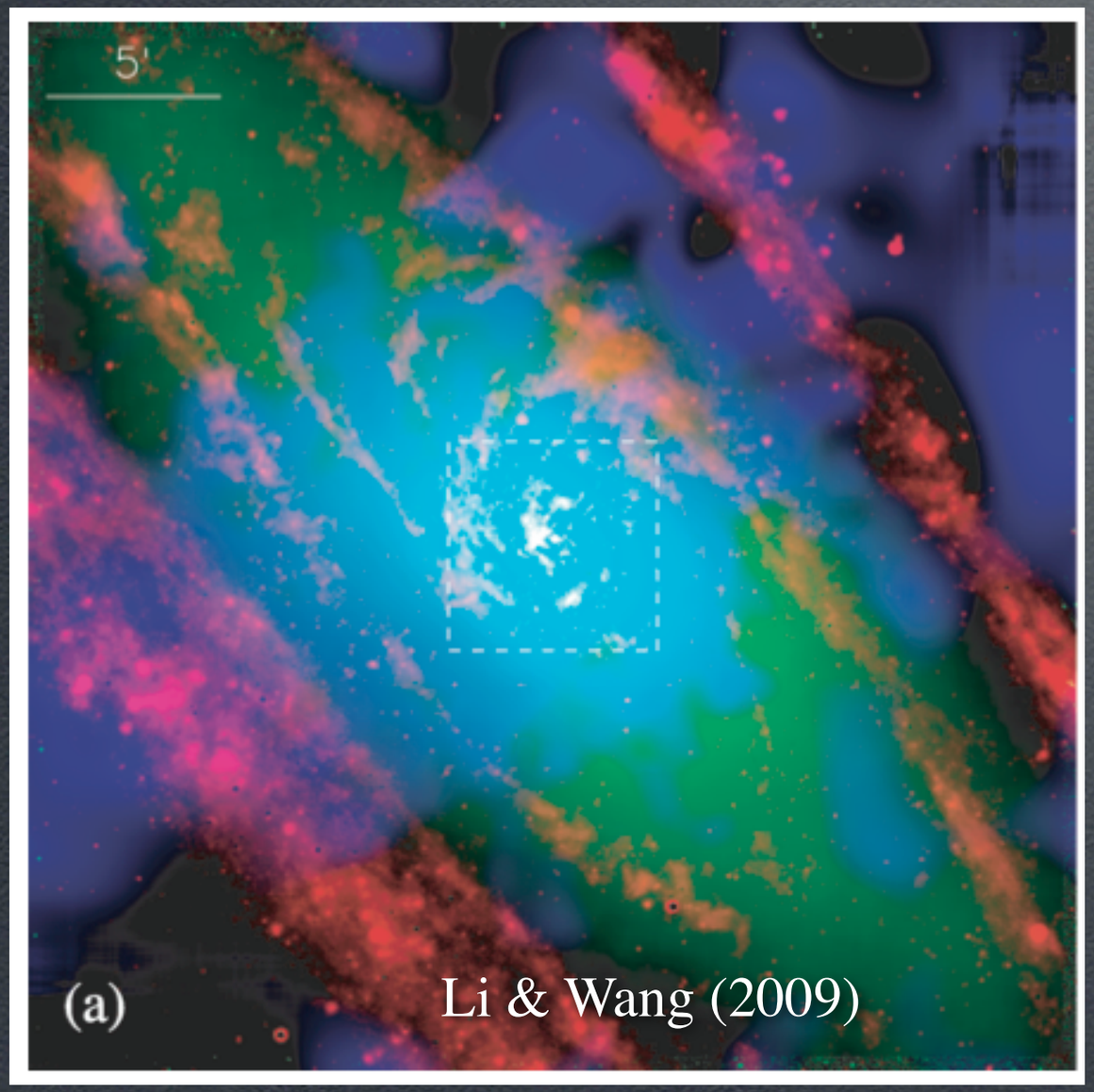
X-ray heating



- Large number of low mass X-ray binaries
- Diffuse X-ray gas heated by SNI

X-ray heating



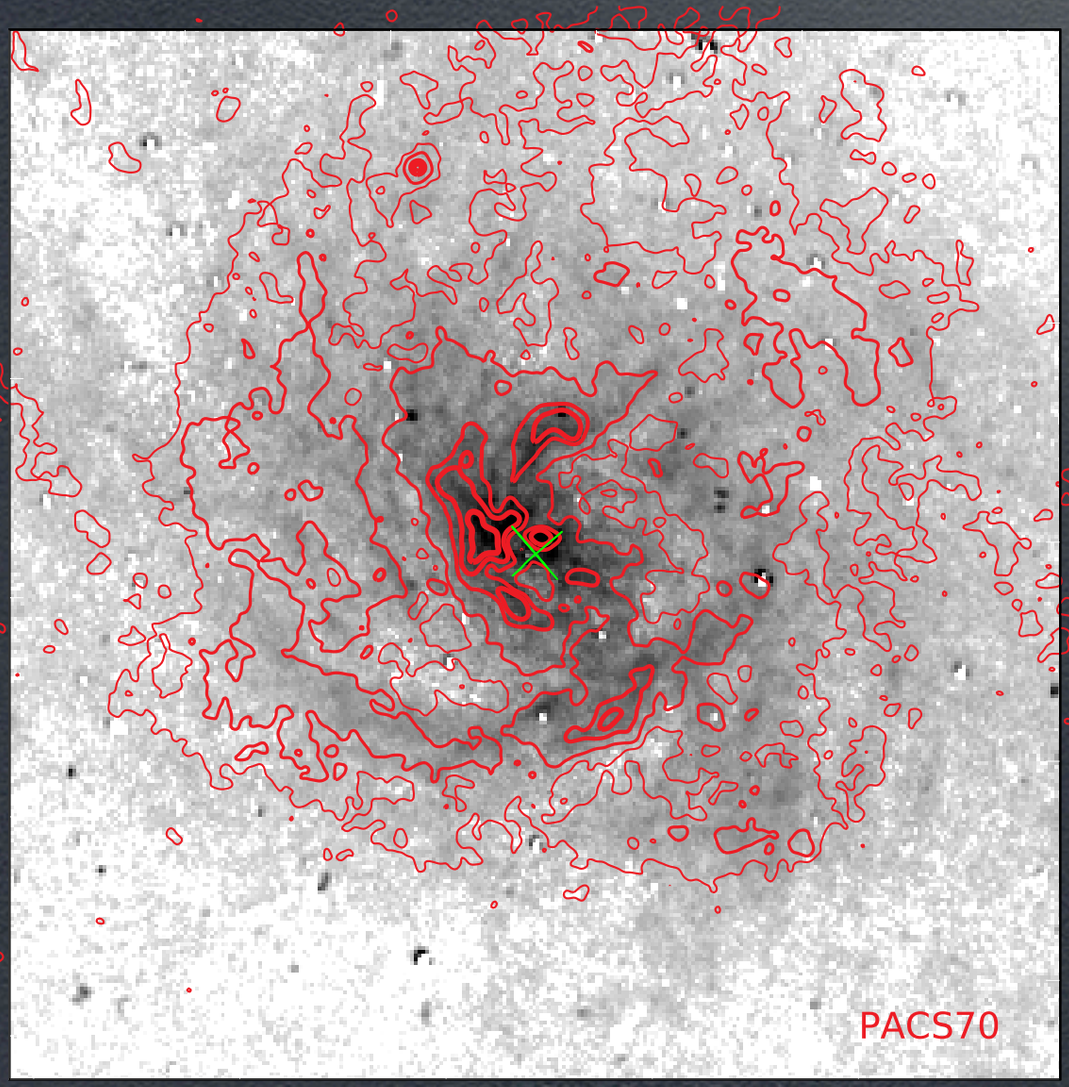
Li & Wang (2009)

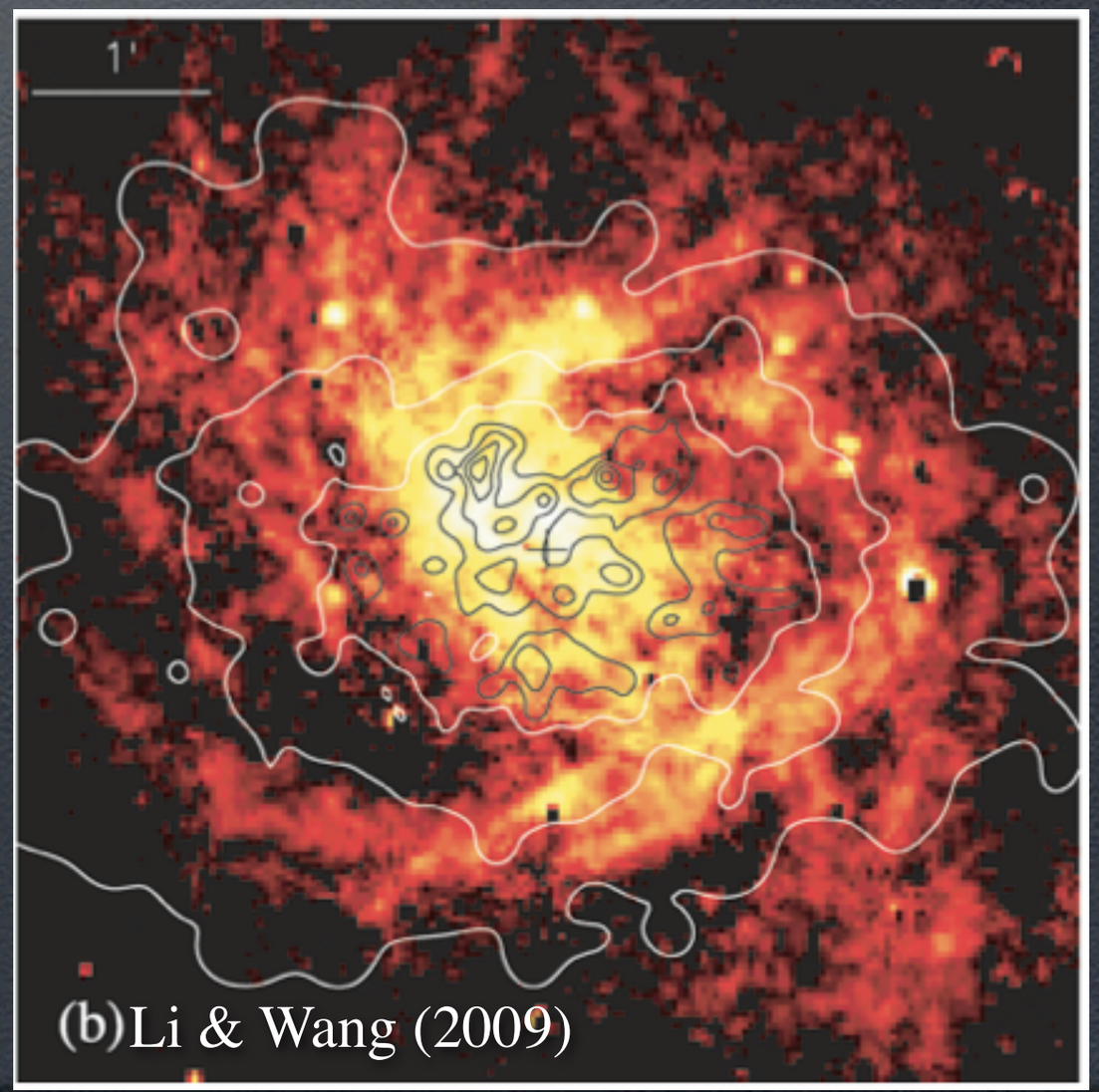
Bogdán & Gilfanov(2008) (& A. Bogdan, and M. Gilfanov's talk)

- Large number of low mass X-ray binaries
- Diffuse X-ray gas heated by SNI

Keeping it hot?

- X-rays will provide diffuse heating deep in the gas (X-ray ionization)
- P-AGB and EHB provide a low level EUV field to also ionize (P. Marigo & winds.. J. Bregman's talk)
- CO line widths suggest dynamically hot...





QnQ in M31

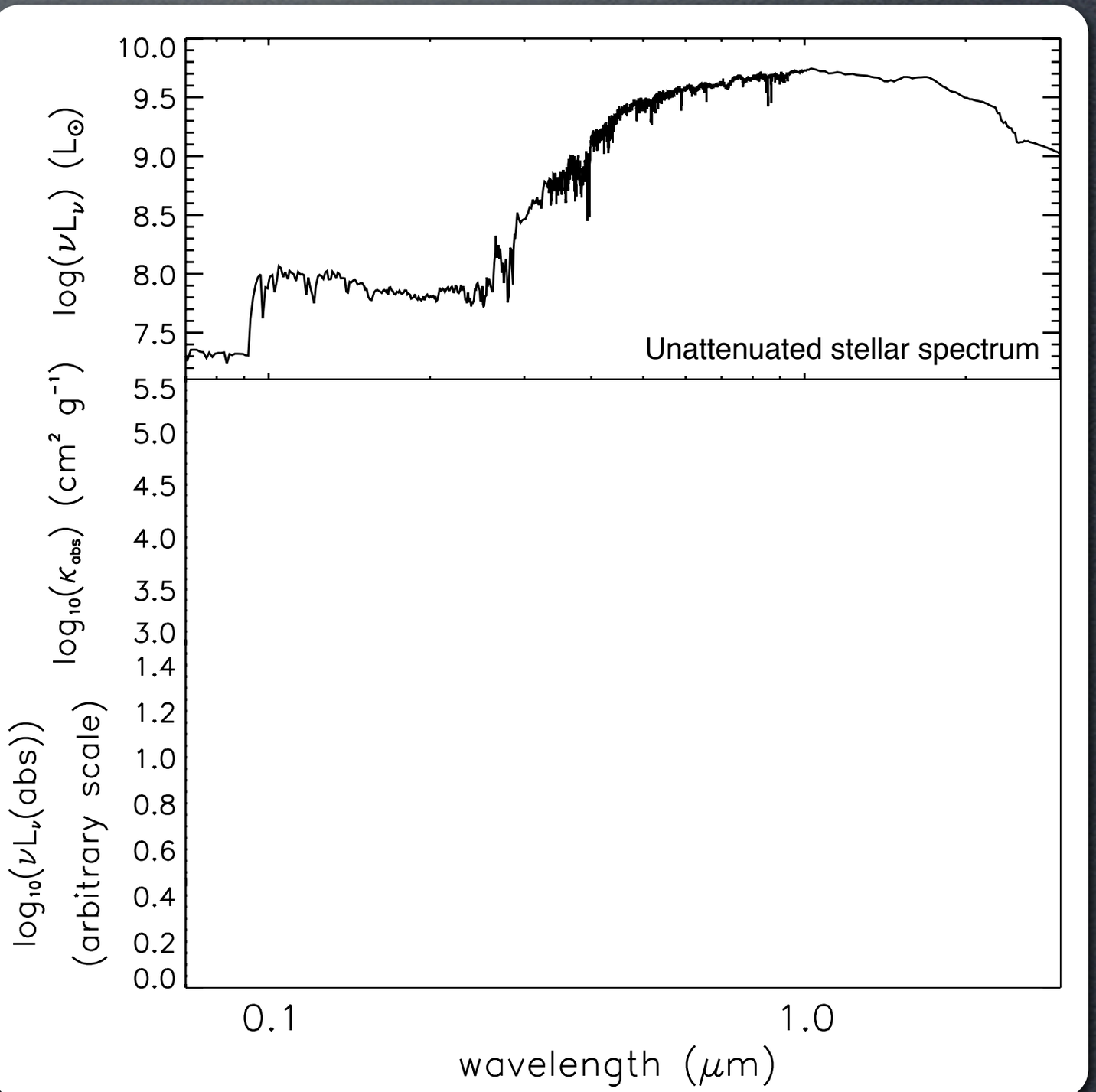
- Nearby galaxies can give insight into the physical processes proposed for quenching galaxies and keeping them quiescent

- M31 appears to be in the process of being quenched

- The bulge of M31 is a perfect test bed for some of the processes of keeping galaxies dead

- Bulge stars so old (red)

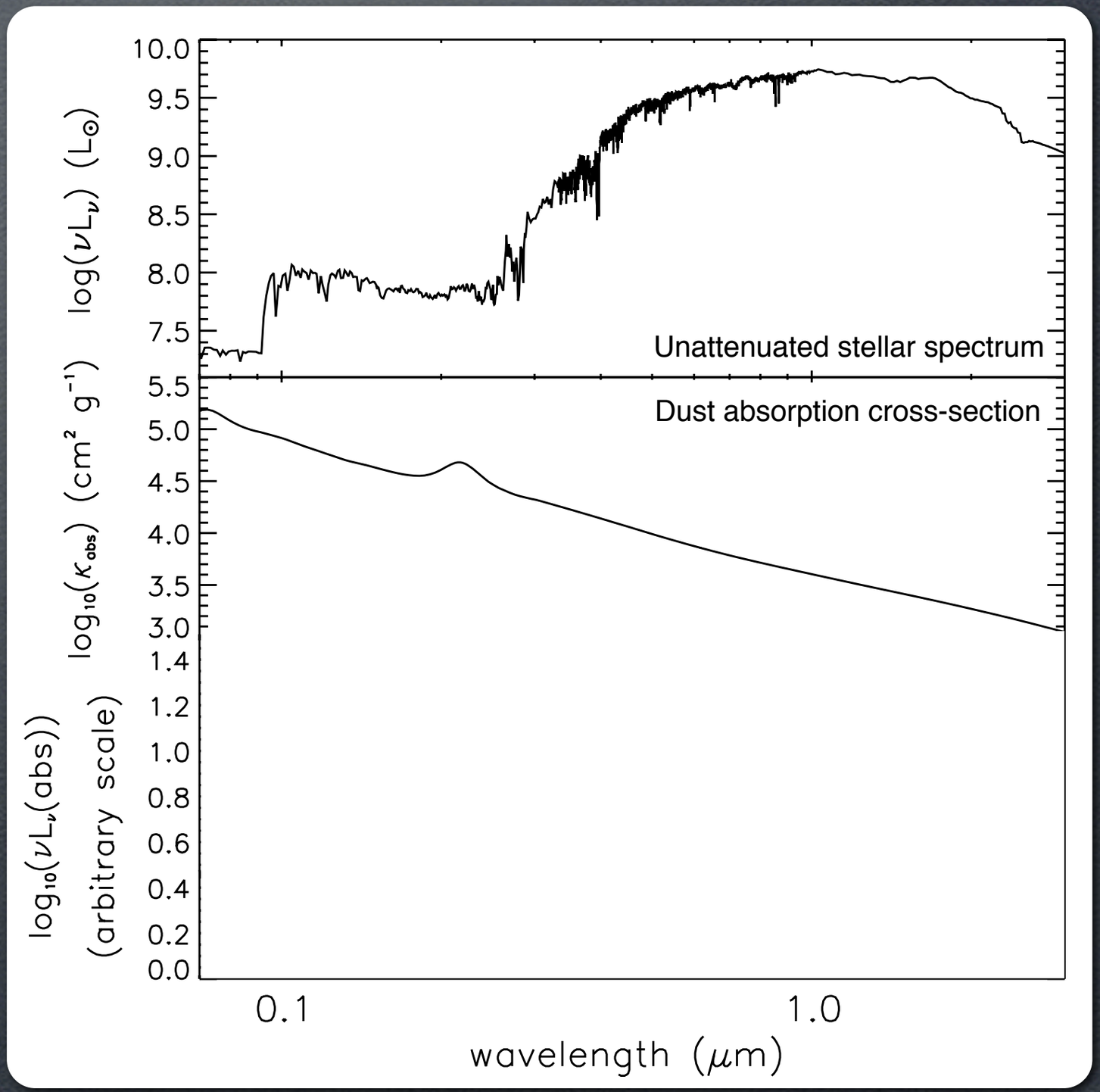
Stars



- Bulge stars so old (red)
- Even with Steep dust opacity

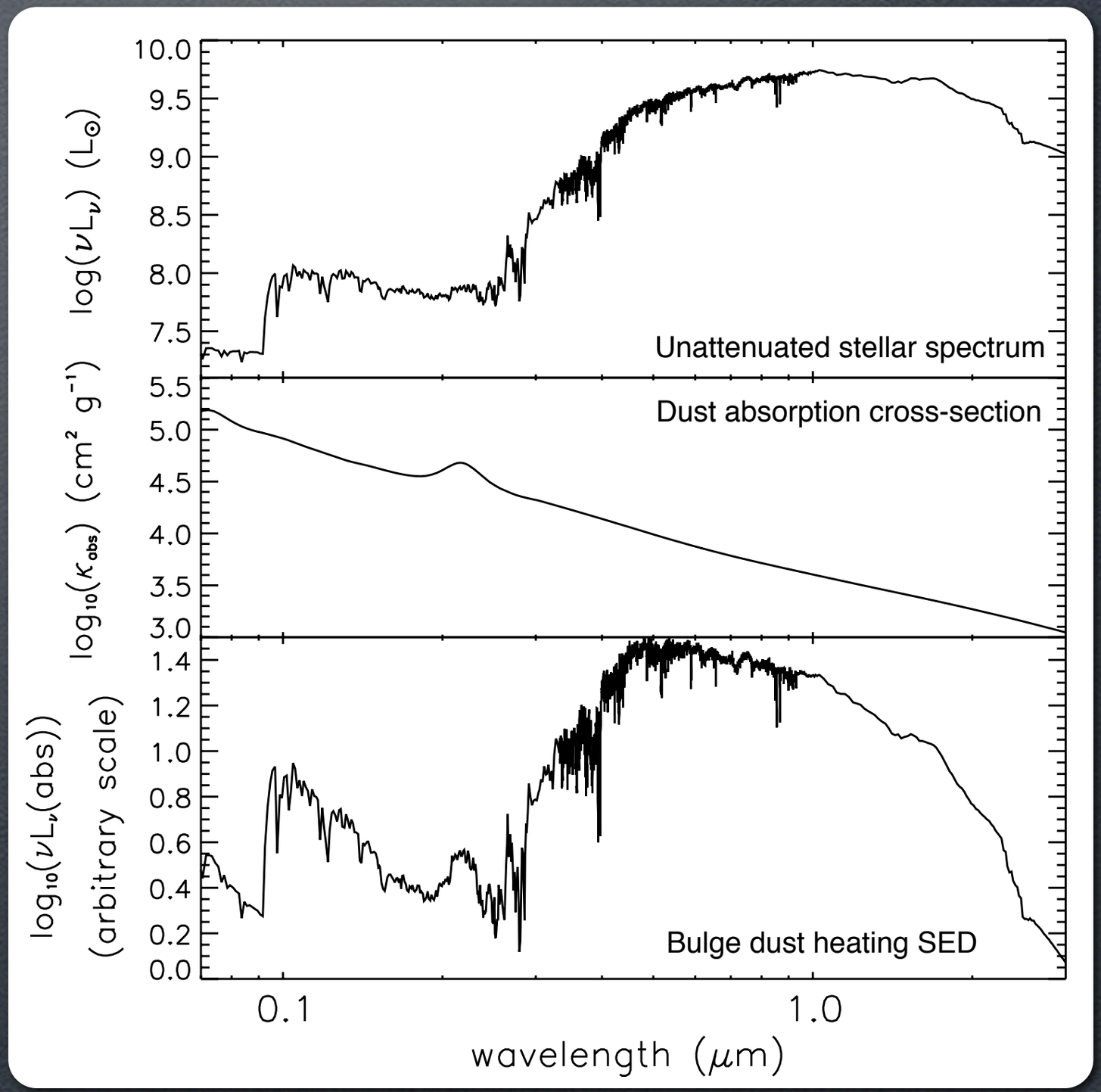
Stars

Dust



- Bulge stars so old (red)
- Even with Steep dust opacity
- Optical light dominates dust heating

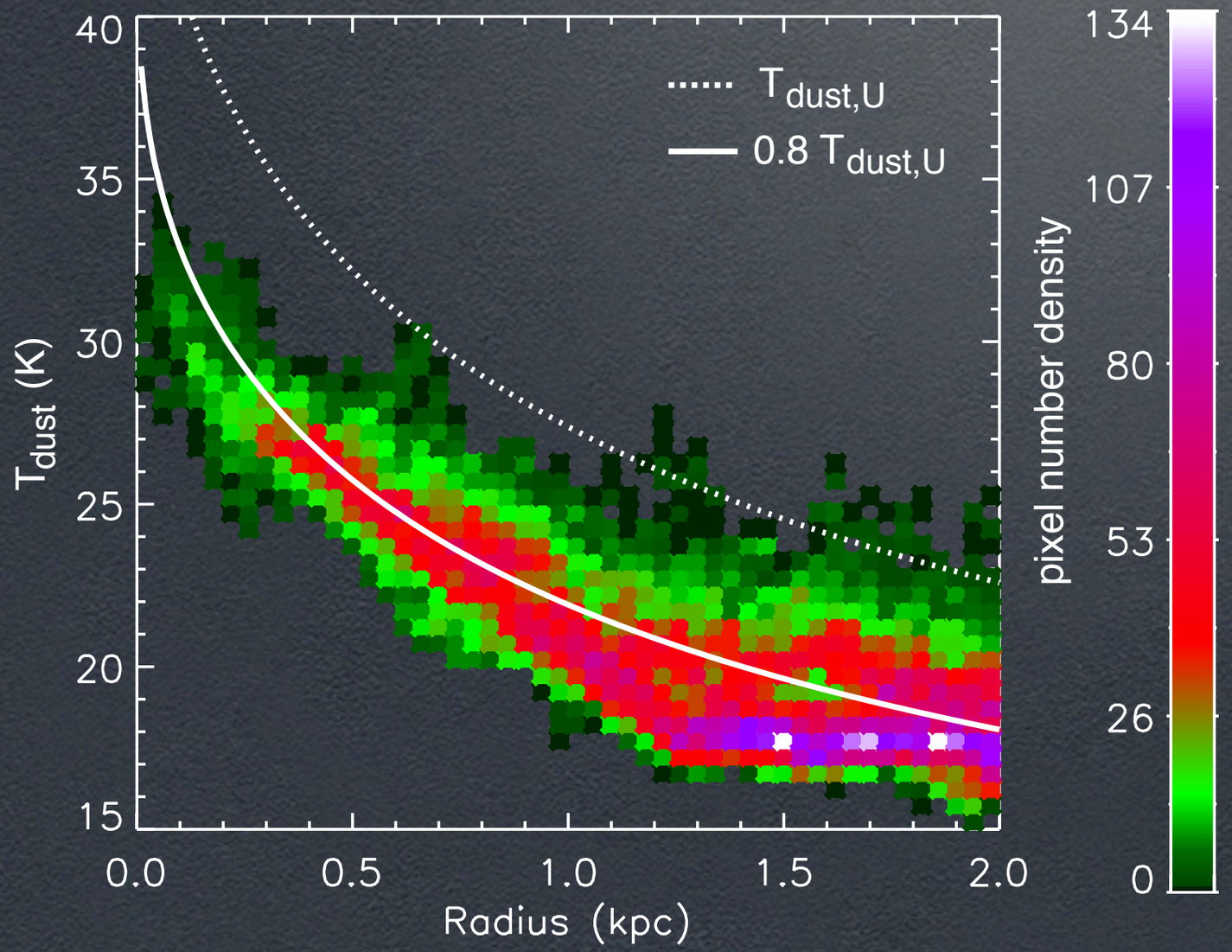
Stars X Dust



Bulge Heating?

$$\nu_{\rm bulge} \propto \frac{1}{(r/r_b)(1+r/r_b)^3}$$

$$U_* = \nu_{\rm bulge} \otimes 1/r^2$$

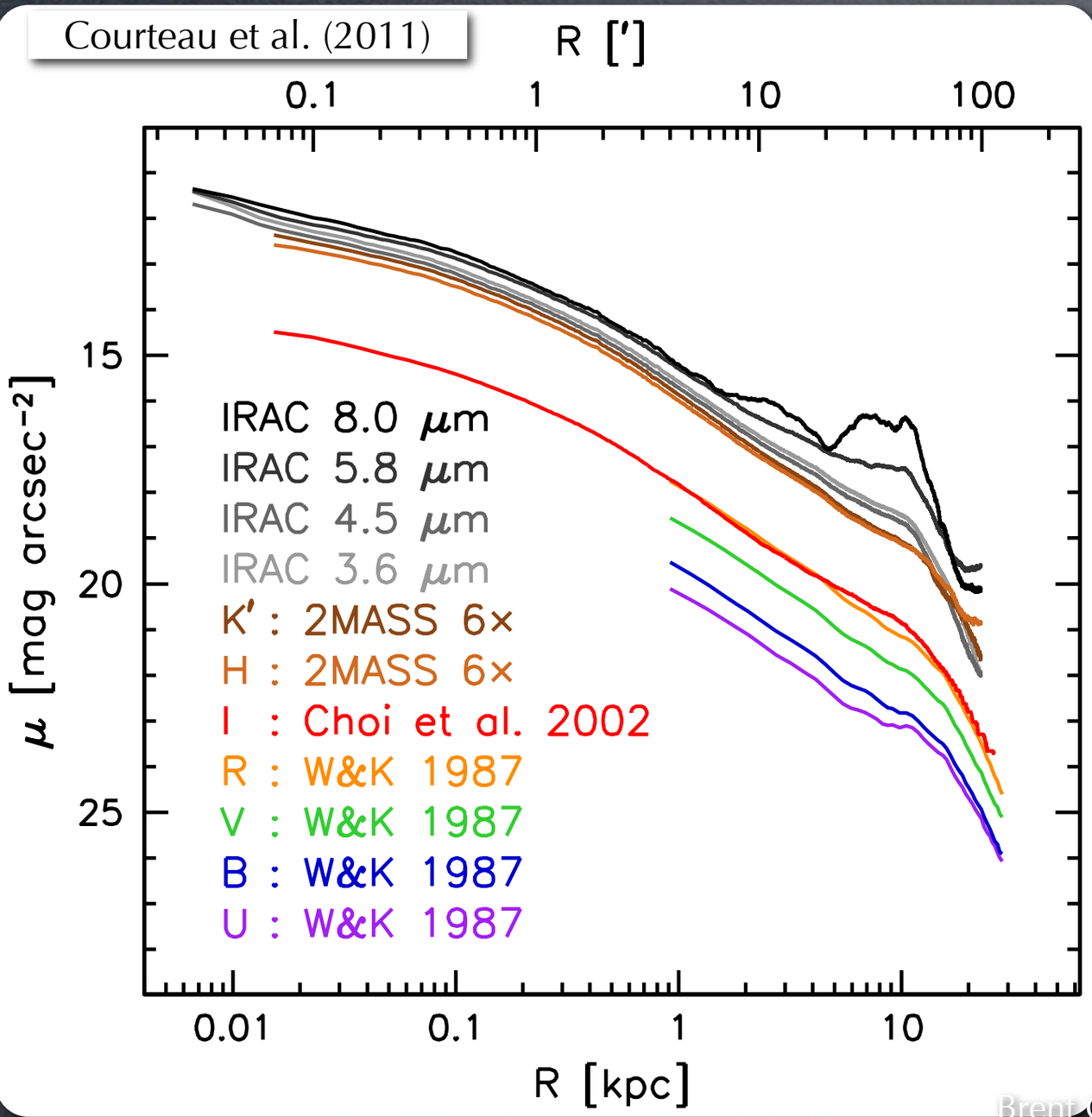


- Steep inner T_{dust} slope suggests bulge dominated heating
- Optical-UV colours suggest old pop. and little dust (as shown by IR)
- Assume
  - optically thin
  - constant M/L
  - diffuse dust
  - $T_d \propto U_*^{1/6}$

Central Stars and Outer Disk

- M31 bulge dominated in inner ~2kpc
- Only at blue-UV and 8m (dust) is outer ring clearly visible

Courteau et al. (2011)



Geehan et al. (2006)