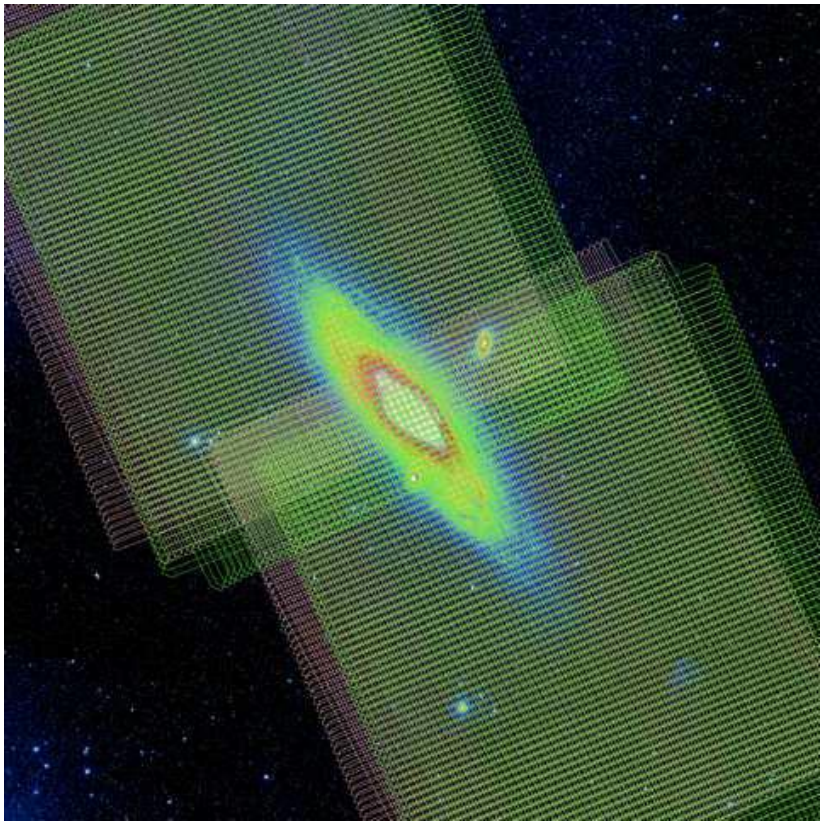
HELGA

Matthew Smith,
SPIRE SAG2,
Ghent PACS team

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

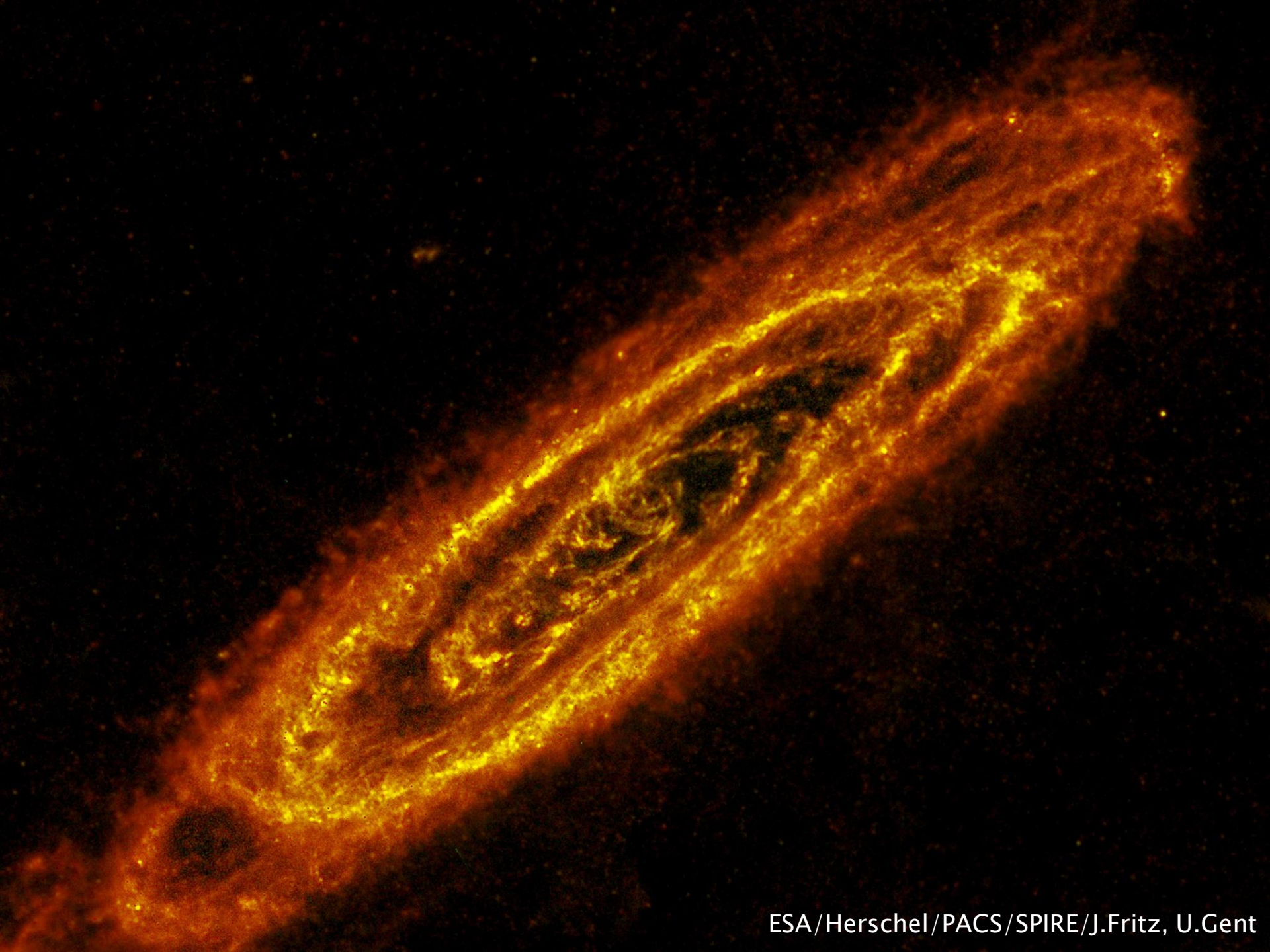
Matthew.Smith@astro.cf.ac.uk

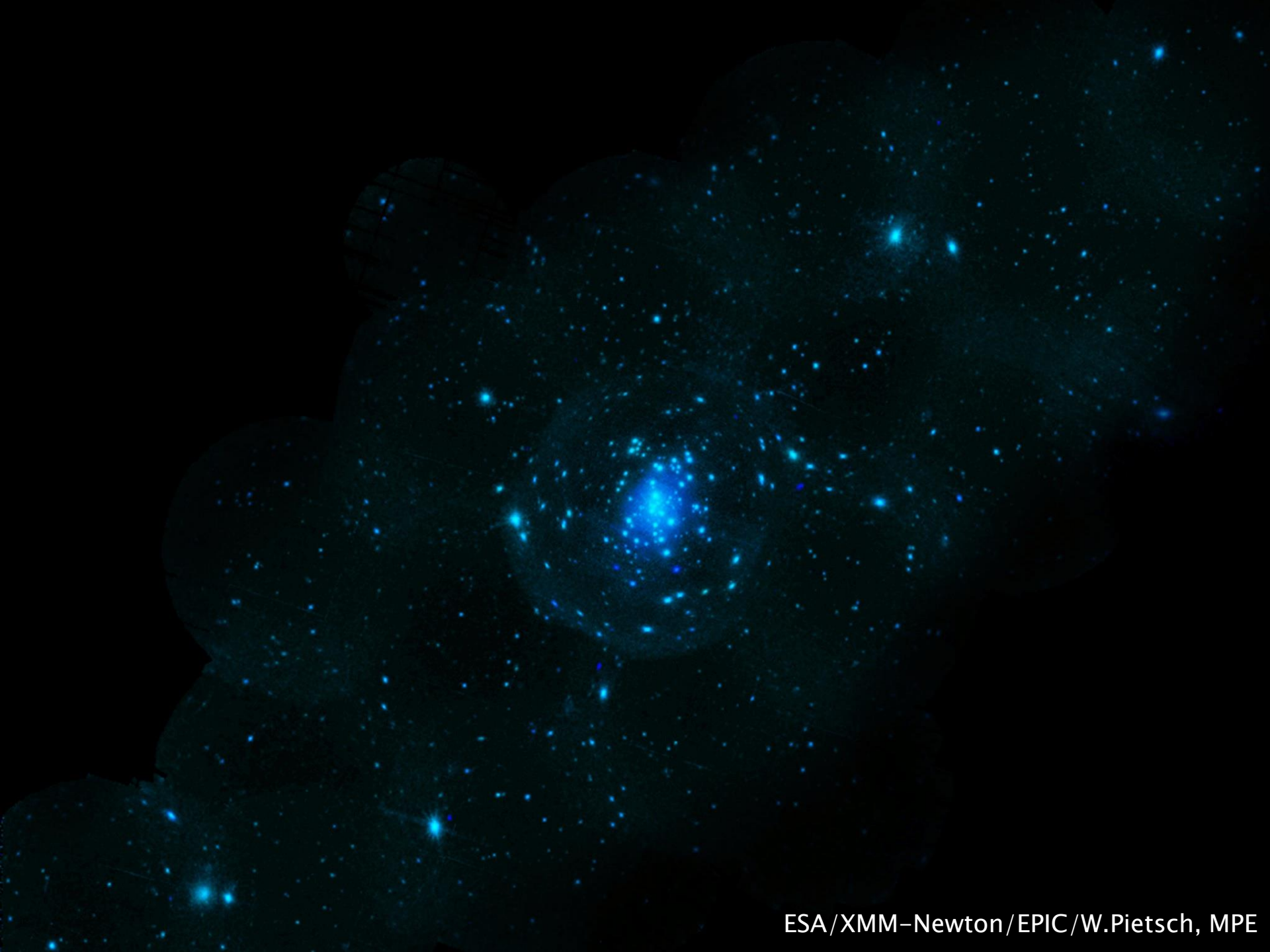
Herschel Exploitation of Local Galaxy Andromeda (HELGA)



- SPIRE/PACS guaranteed time programme.
- Parallel Mode Observations at 100, 160, 250, 350 and 500μm simultaneously.
- Observed whole HI disk ($5.5^\circ \times 2.5^\circ$)
- 18.2 hours
- Complementary XMM
- Results shown on BBC TV


R. Gendler


ESA/Herschel/PACS/SPIRE/J.Fritz, U.Gent

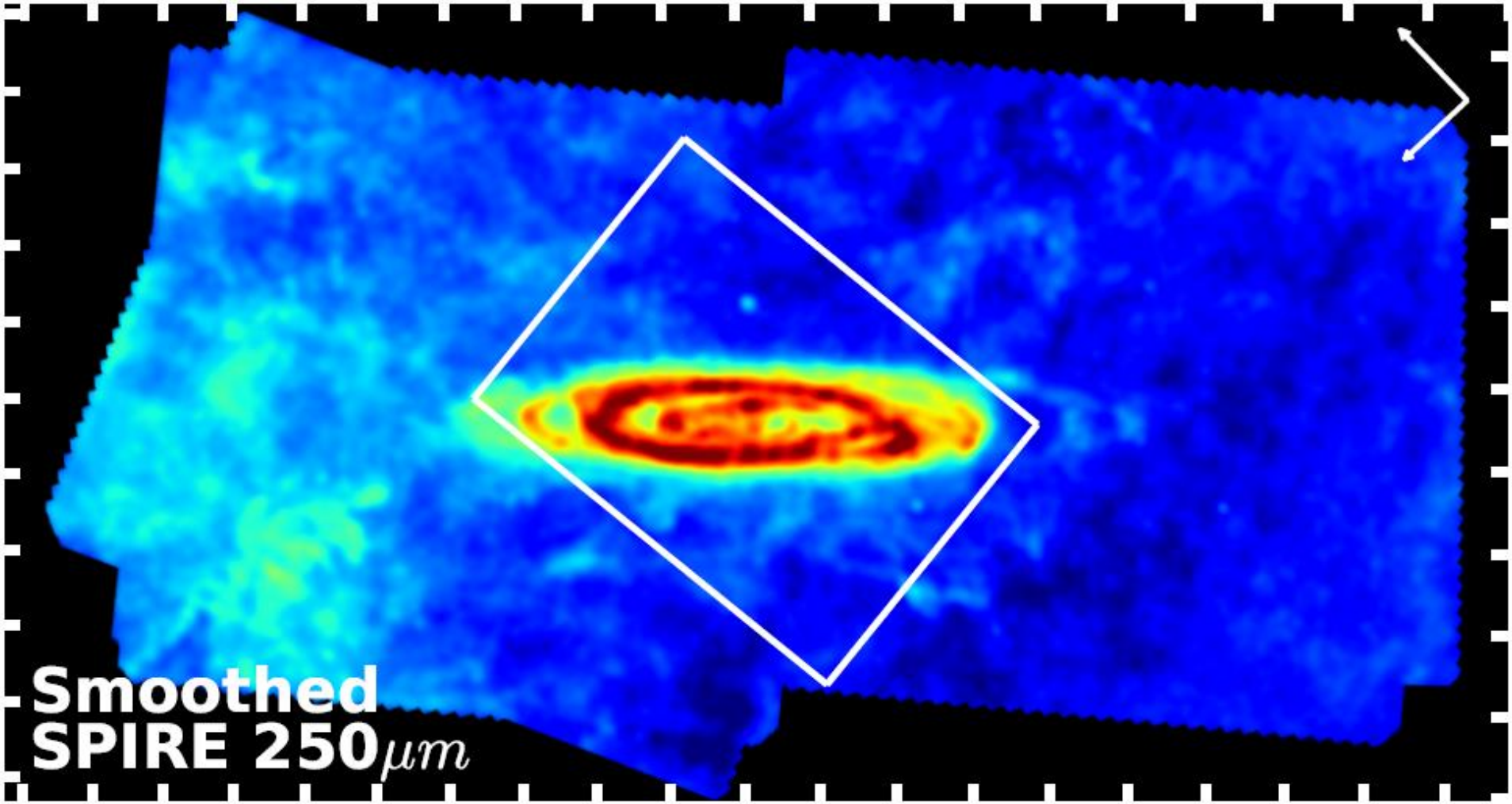

ESA/XMM-Newton/EPIC/W.Pietsch, MPE

Why Andromeda?

- M31 is the closest Milky Way like(?) Giant Spiral Galaxy.
- Can study at high spatial resolutions at all wavelengths.
- Approximately scale of GMC complexes
- So far six HELGA papers (not going to describe in chronological order)

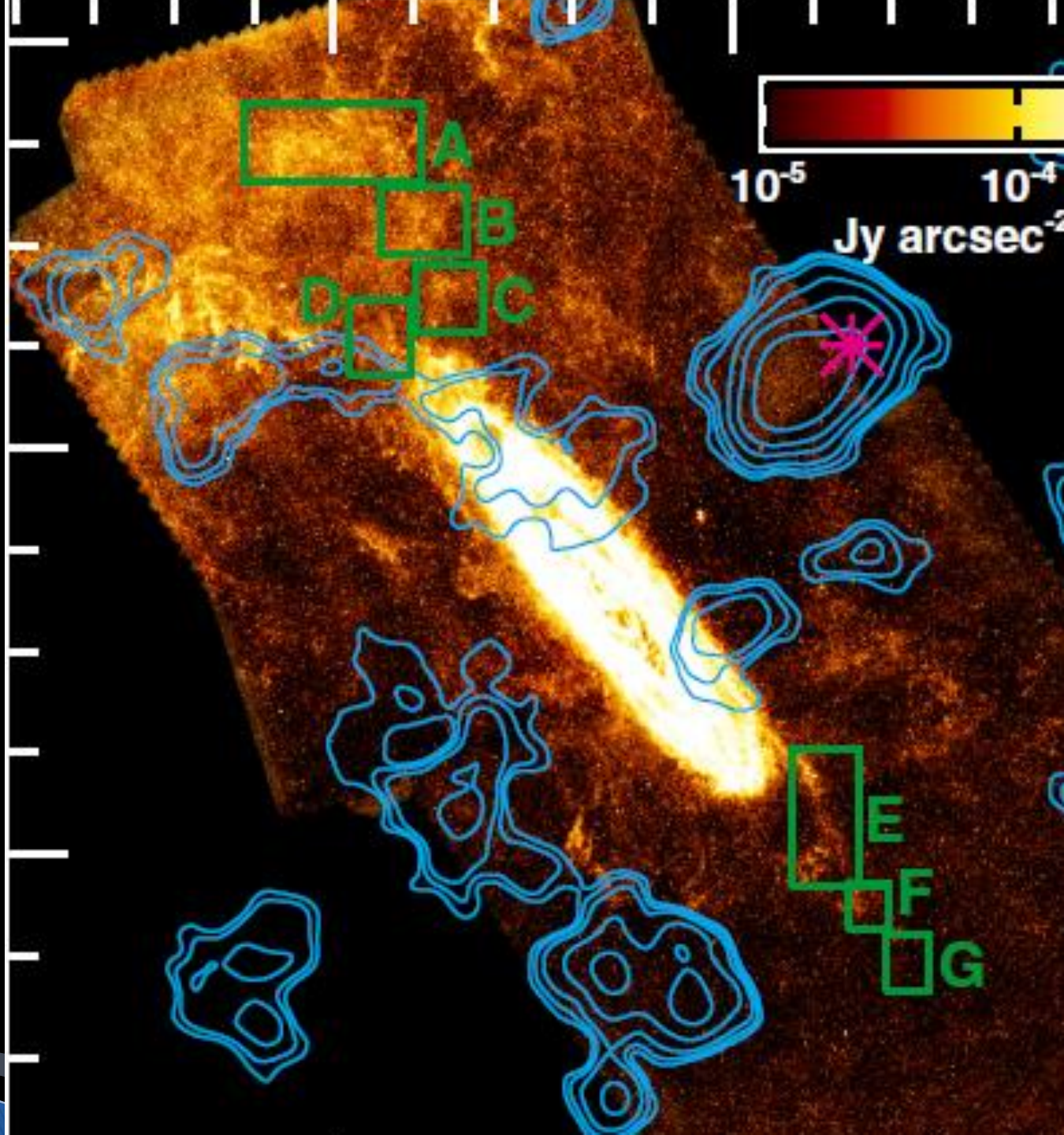
Extended Structure

more info see Fritz et al. 2012



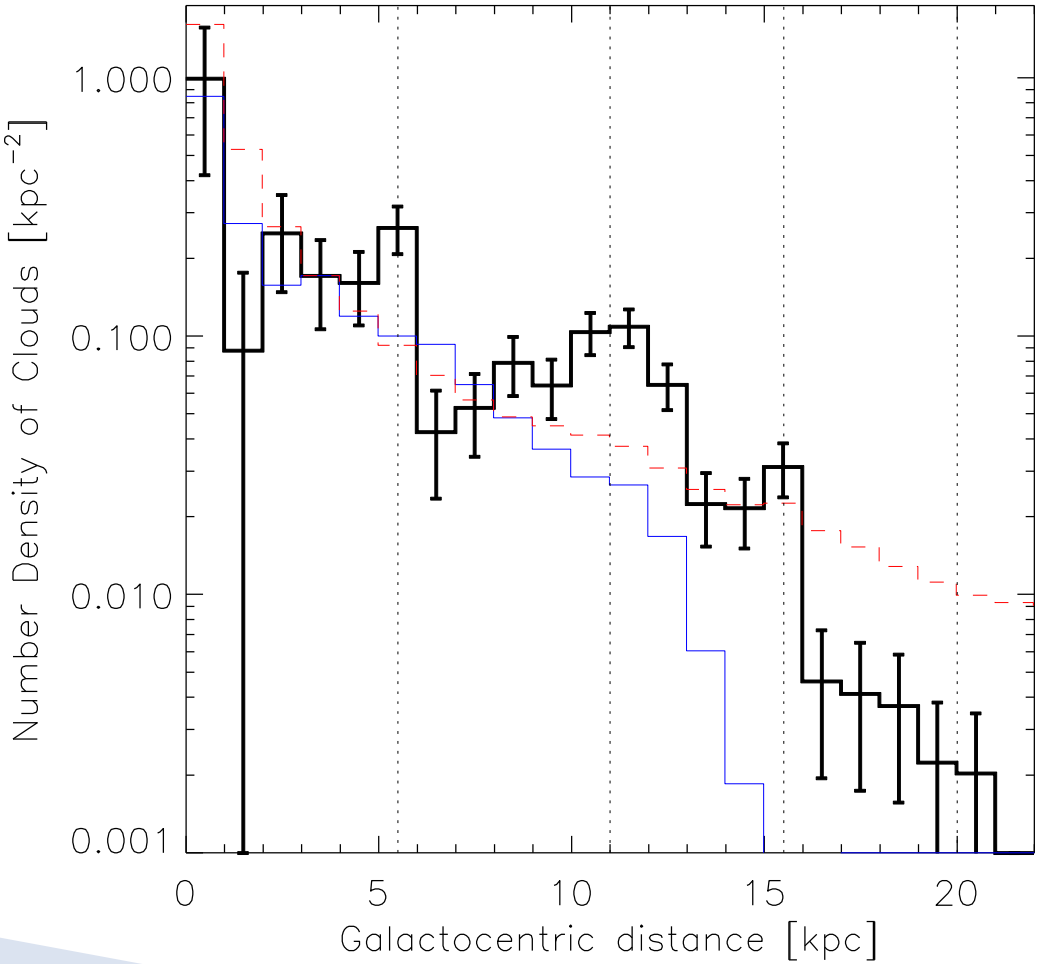
HELGA I

- Fritz et al. 2012
- Survey paper
- E, F, G are at ~21, 26, and 31kpc.
- Gas-to-dust ratio varies from 66-275

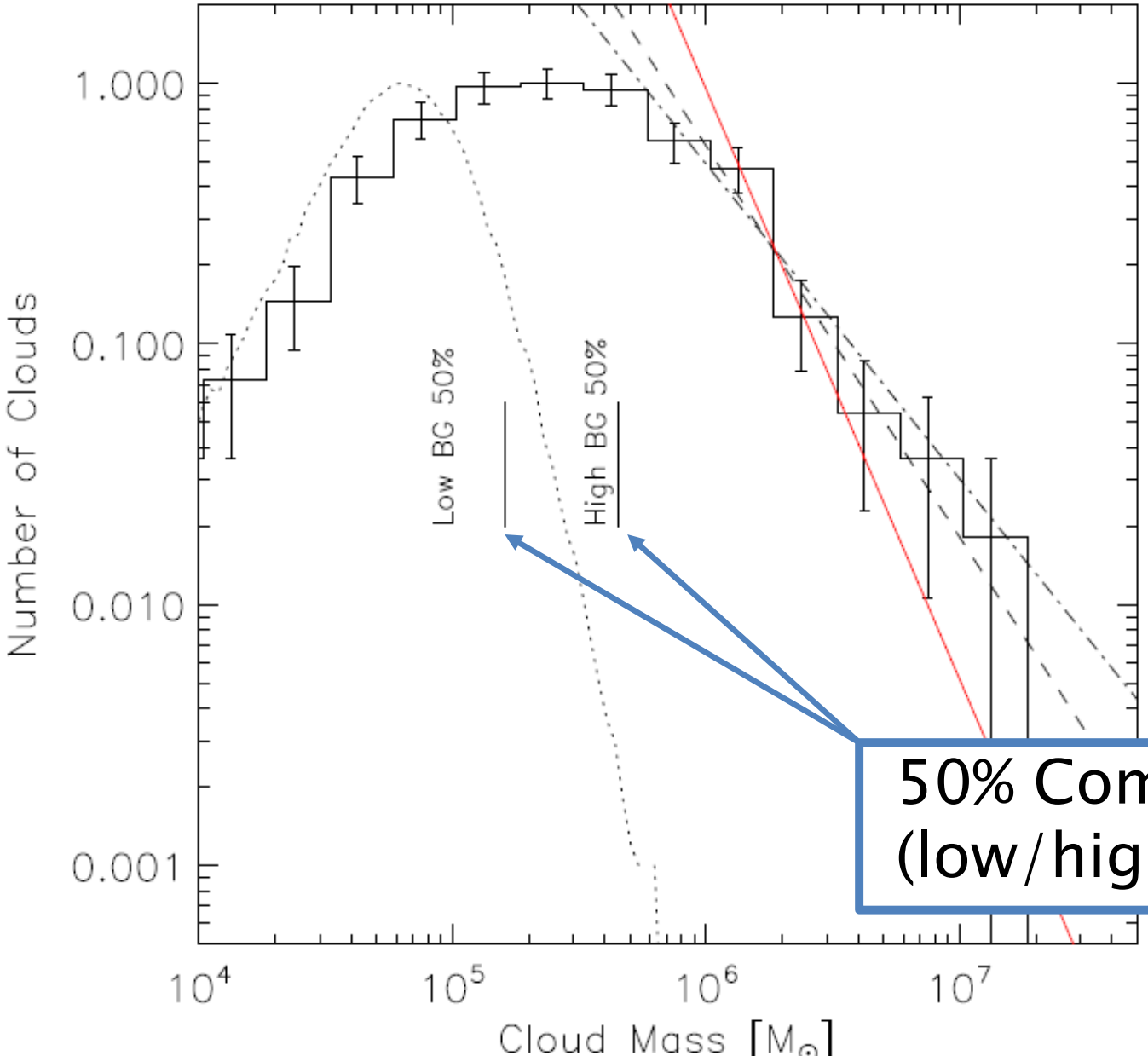


HELGA VI – Kirk et al.

- Run CSAR source extraction to find GMCs or associations of GMCs -> Call both “clouds”
- Most are GMC complexes
- Find 326 clouds (5σ)
- Only 5.8% are within 100pc of IR dark cloud
- Masses 10^4–10^7 $M_\odot$ median 4.1×10^5 $M_\odot$



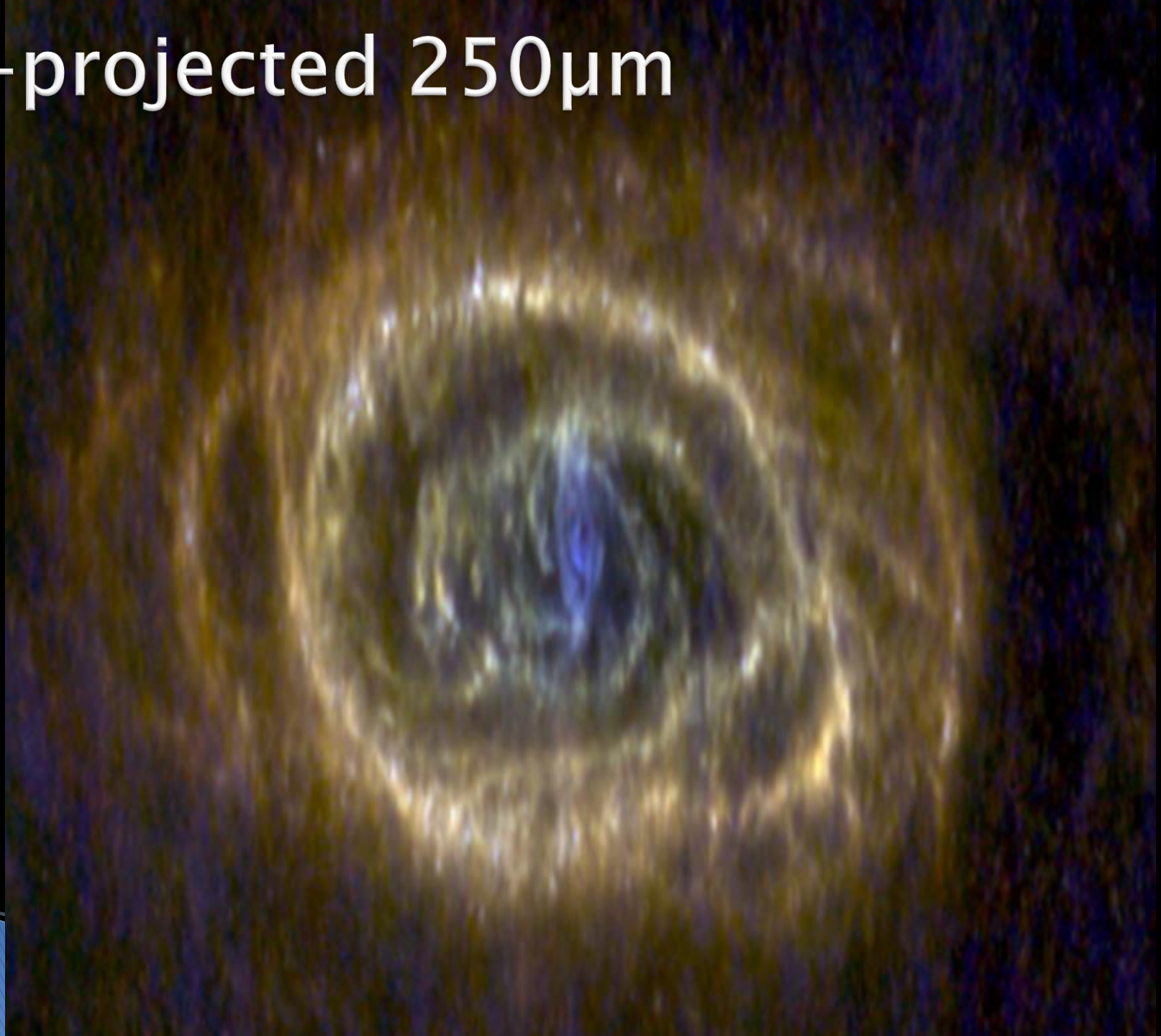
HELGA VI – continued

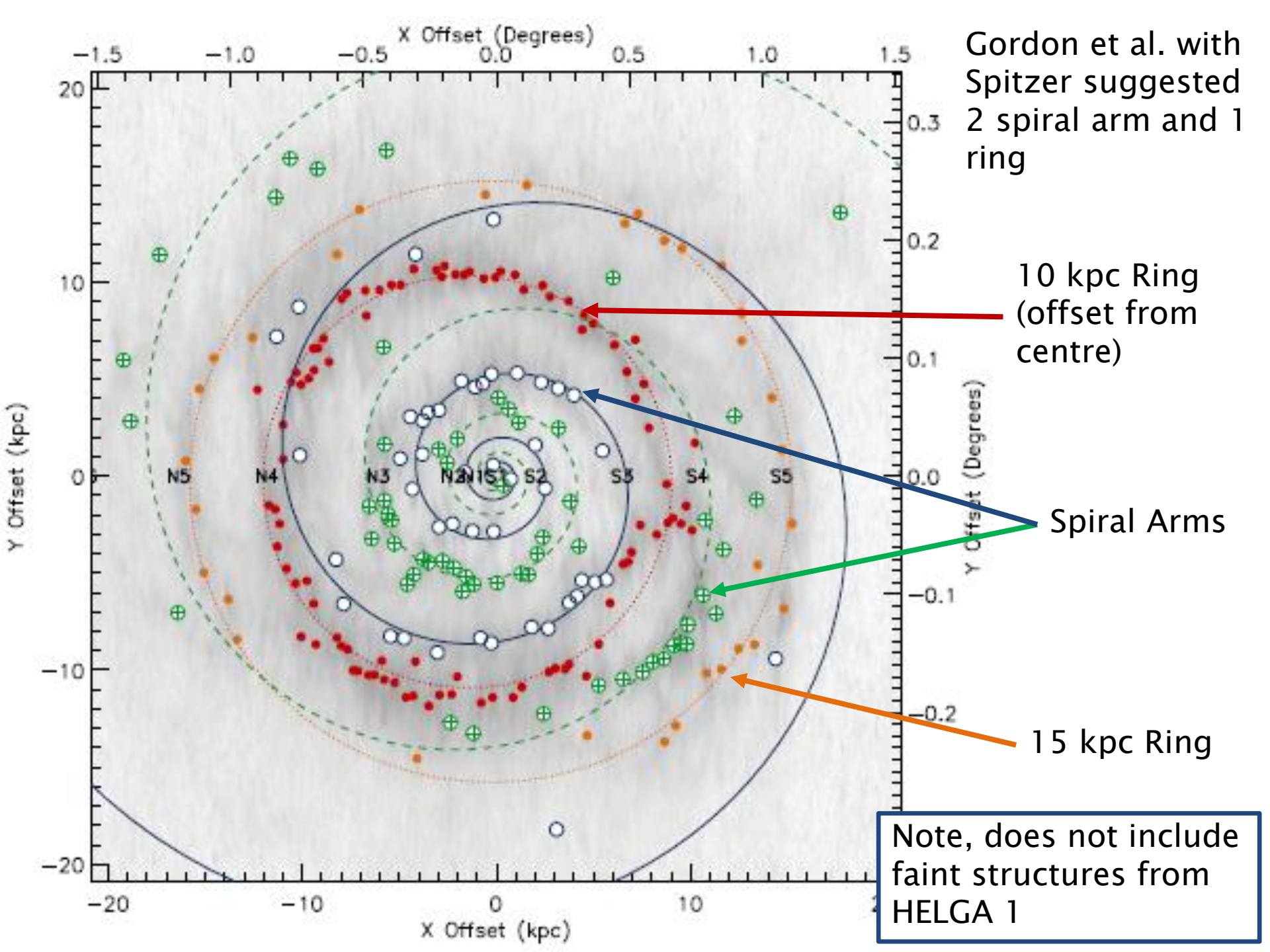


Cloud mass distribution is consistent with the Milky Way (dashed line)

50% Completeness (low/high background)

De-projected 250μm




X Offset (Degrees)
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
Y Offset (kpc)
20
10
0
−10
−20
Y Offset (Degrees)
0.3
0.2
0.1
0.0
−0.1
−0.2
X Offset (kpc)
−20
−10
0
10
N5
N4
N3
N2
N1
S1
S2
S3
S4
S5
Gordon et al. with Spitzer suggested 2 spiral arm and 1 ring
10 kpc Ring (offset from centre)
Spiral Arms
15 kpc Ring
Note, does not include faint structures from HELGA 1

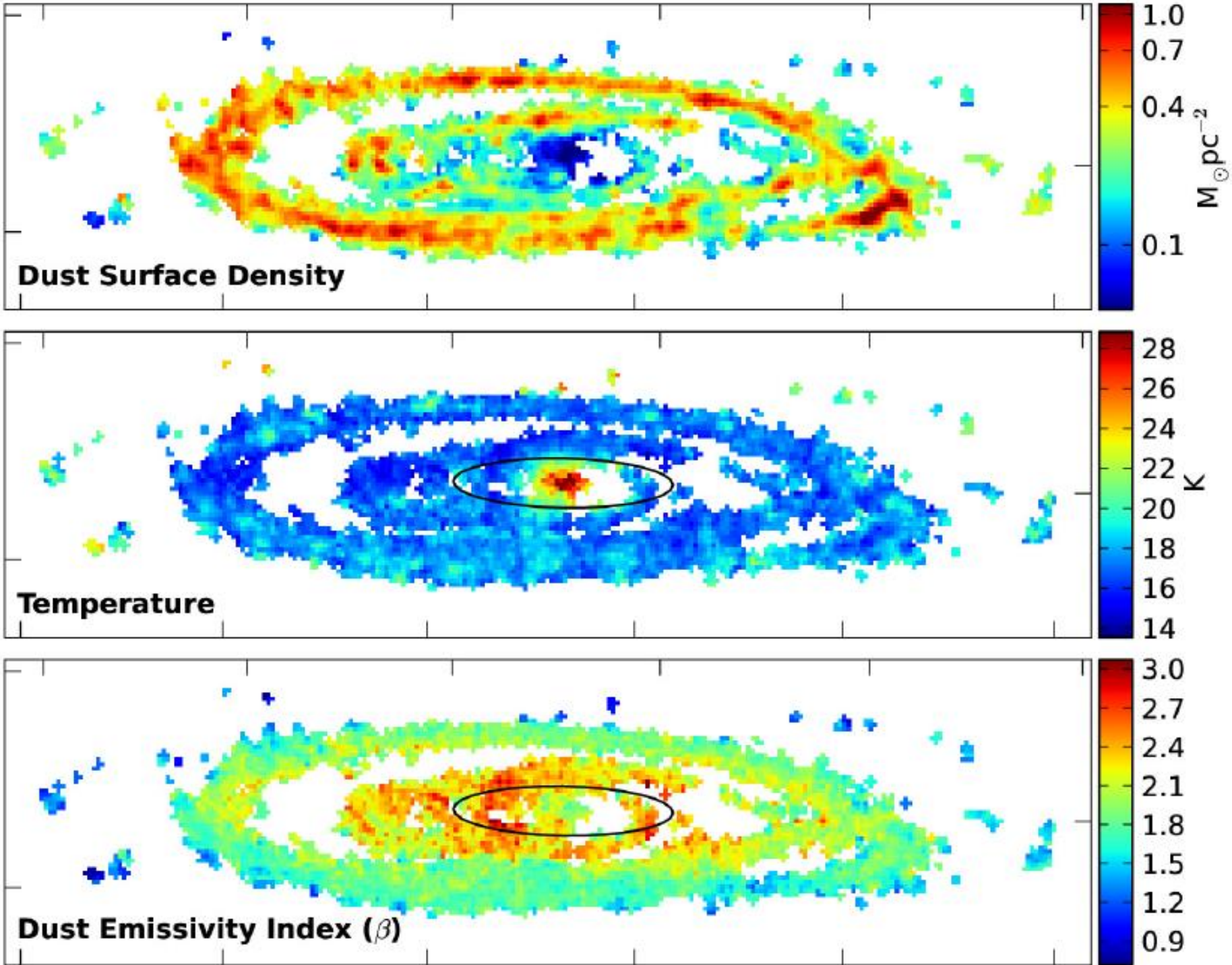
HELGA II – SED Fitting – Smith (2012)

- Only pixels with all 5 fluxes $> 5\sigma$
  $\rightarrow$ 4000 independent pixels!
- Fit modified blackbody:

$$\text{Flux}(\nu) = \text{Mass}_{\text{dust}} \times \kappa_\nu \times B(\nu,T) \,/\, \text{Dist}^2$$

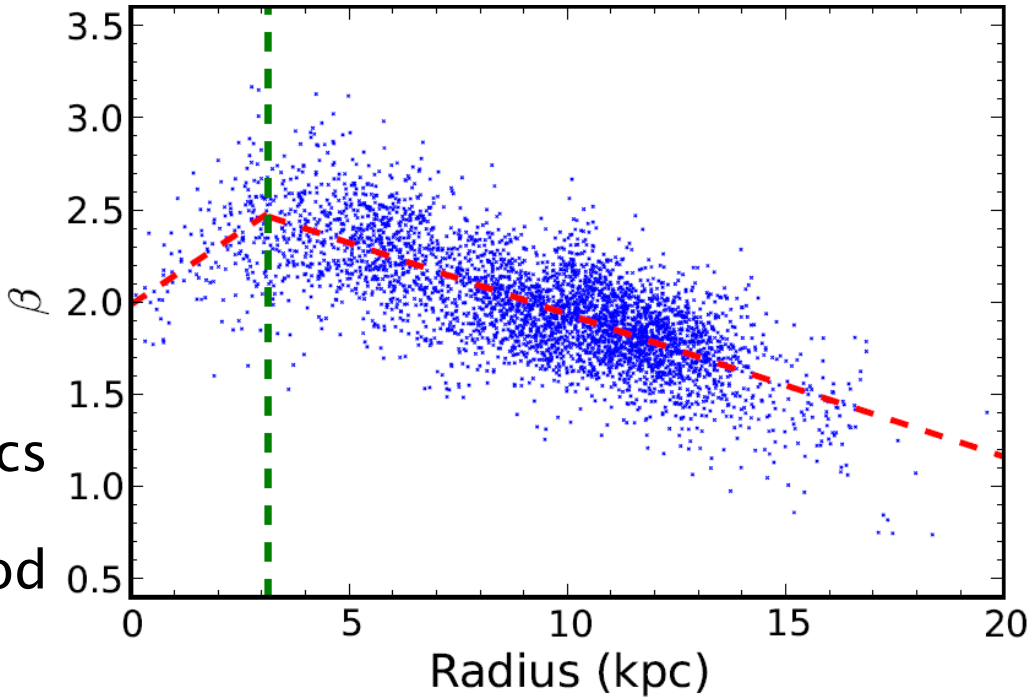
Mass-Opacity Coefficient $\alpha\ \nu^\beta$

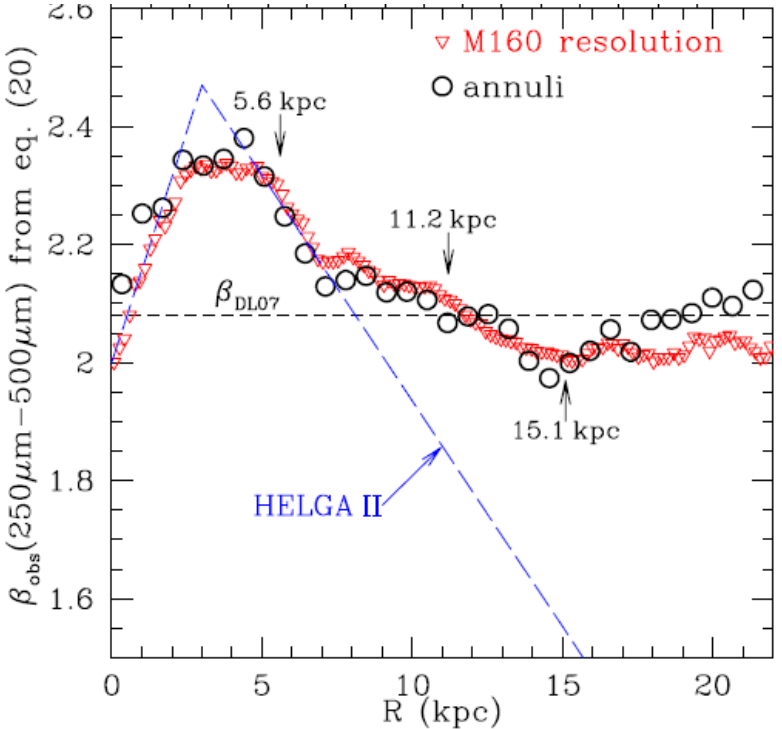
- Find need for a variable β
- Take into account filter profile and correlated uncertainties in SED fitter, bootstrap for uncertainties
- No evidence for any cold-dust component


Dust Surface Density
1.0
0.7
0.4
0.1
$M_\odot pc^{-2}$
Temperature
28
26
24
22
20
18
16
14
K
Dust Emissivity Index (β)
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9

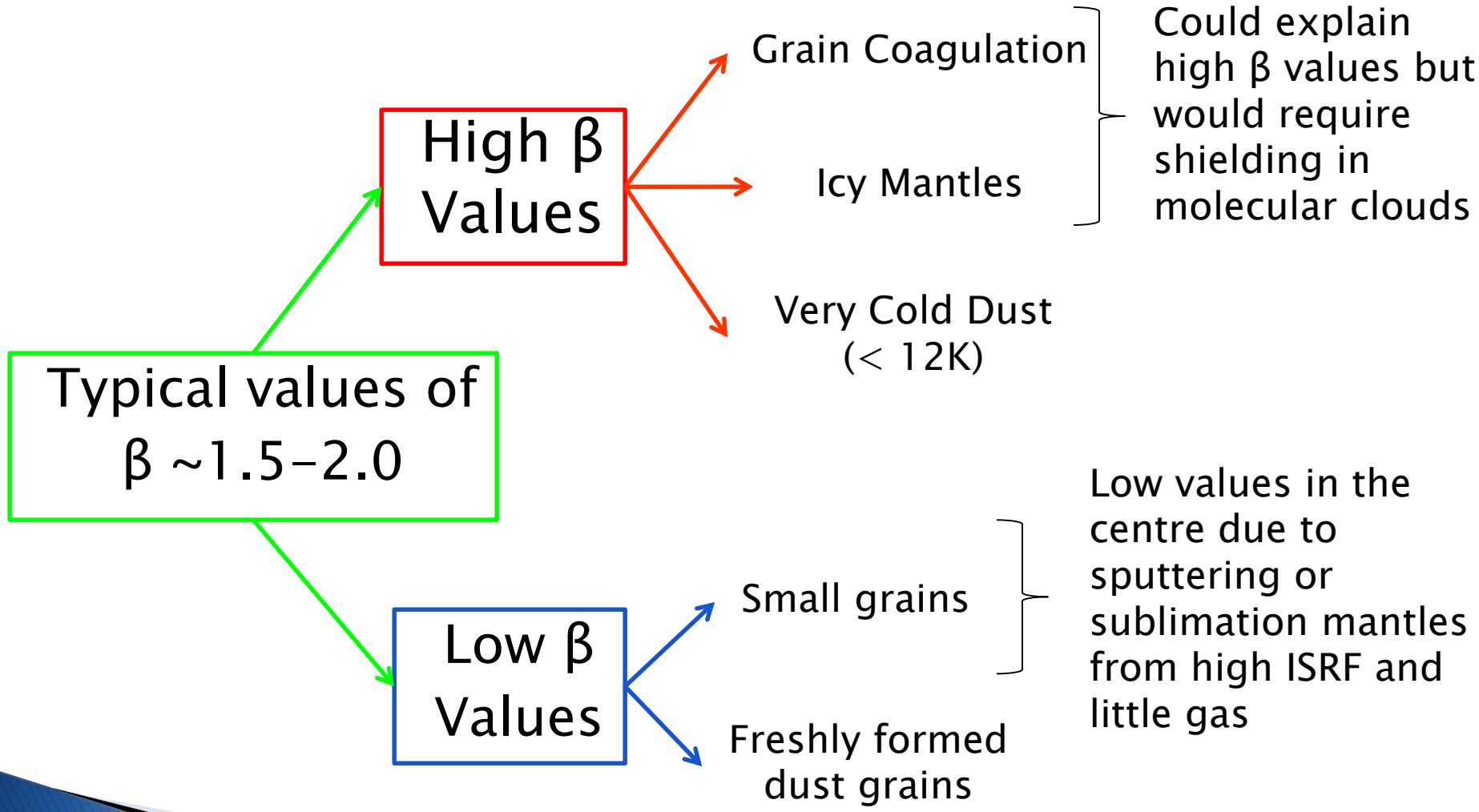
Beta Results

- Change in β around 3.1kpc
- High values not multiple-T
- Not reliant one point – statistics
- β = ~1.8 in main ring is in good agreement with Planck early results.
- Results confirmed with independent Andromeda survey (Draine 2013)
- Similar β variations in M33 found by Tabatabaei 2013 and KINGFISH (e.g., Galametz, Kirkpatrick)





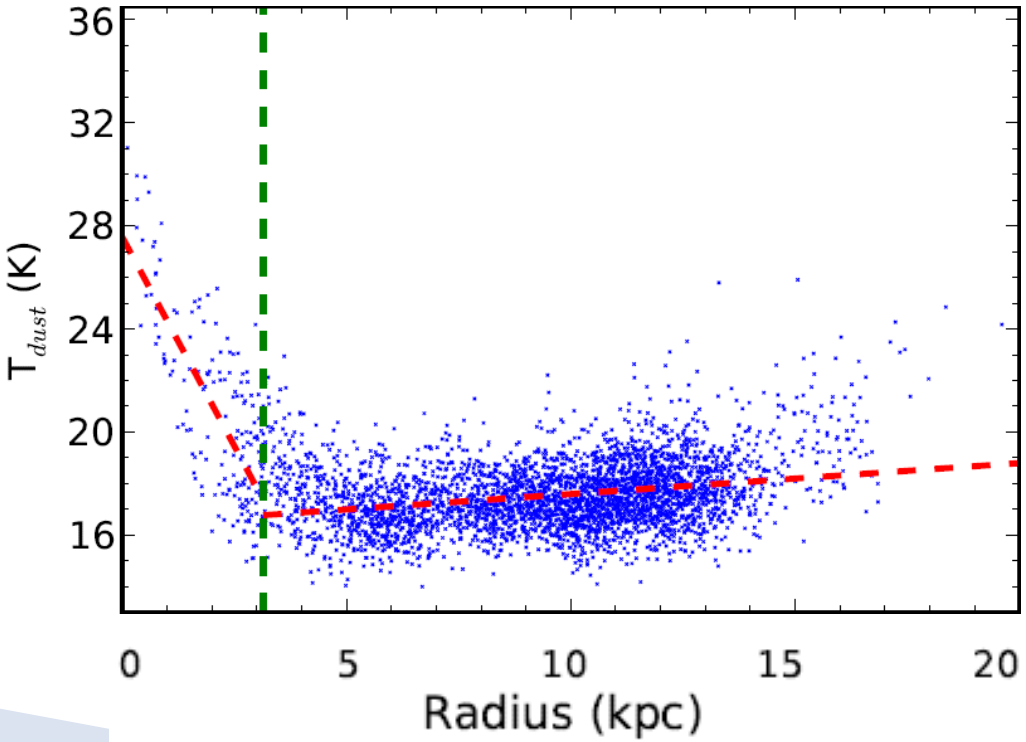
What do Beta Results Mean?



(e.g., Aannestad 1975, see Schnee et al 2010)

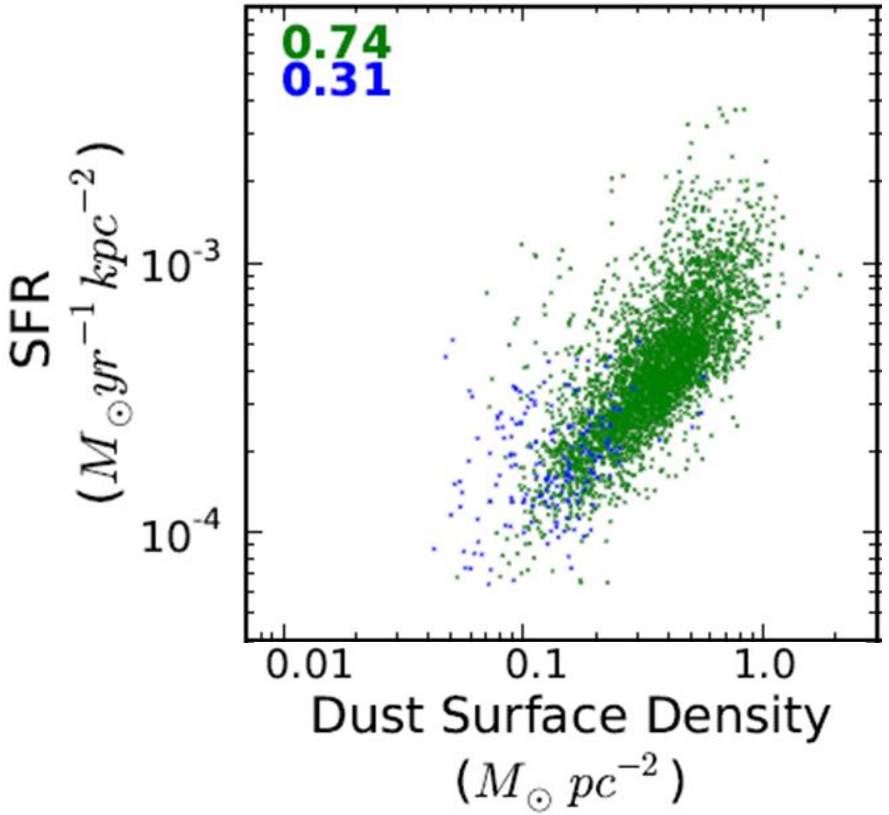
Temperature Results

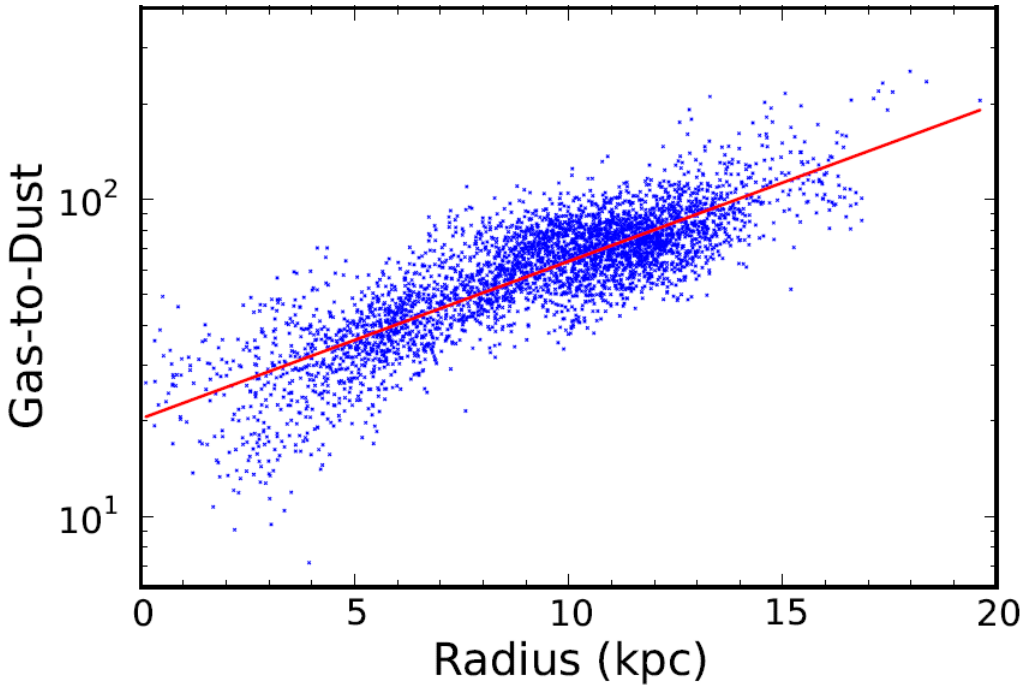
- Andromeda conclusively proved that old-stars can heat the dust (Groves 2012, HELGA II)
- Dust in inner 3kpc are heated by the bulge, although $Flux_{3.6\mu m} \propto T^{4.6}$ bit shallower than 6 predicted.
- Outer parts mixed heating or non-local source
- Fairly flat in ring/spiral structures.
- Be careful if you use a FIR luminosity (100μm+) tracer to purely trace SF



Dust Distribution

- Dust Surface Density is correlated with SFR, not old stellar population.
- Gas-to-dust ratio fits exponential profile (gas from HI and CO)





- HELGA II matches metallicity gradient, expected fixed metals in dust.
- New HELGA V results (later)

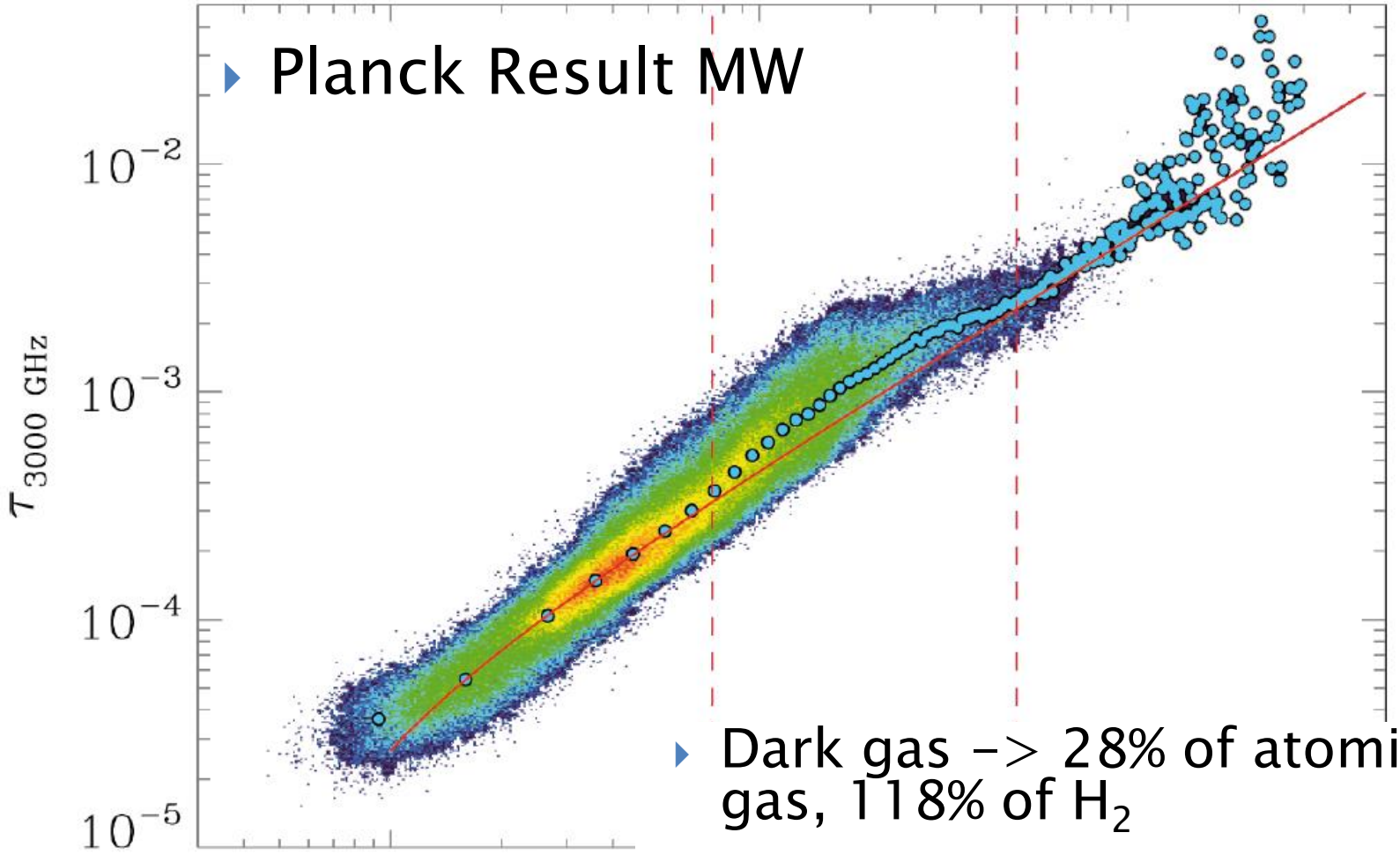
Dust, Gas & Metallicity

- Why do we care about relating Dust, Gas and Metallicity?
  - Dust potentially traces total gas
  - Could calibrate a method to provide gas masses for many high-z objects (more details Eales, Smith, et al. 2012)
- Do global measurements agree with a pixel-by-pixel analysis?

Planck – Dark Gas

$$(\tau = \left(\frac{\tau_D}{N_H}\right)^{ref} * N_H^{obs} + cste).$$

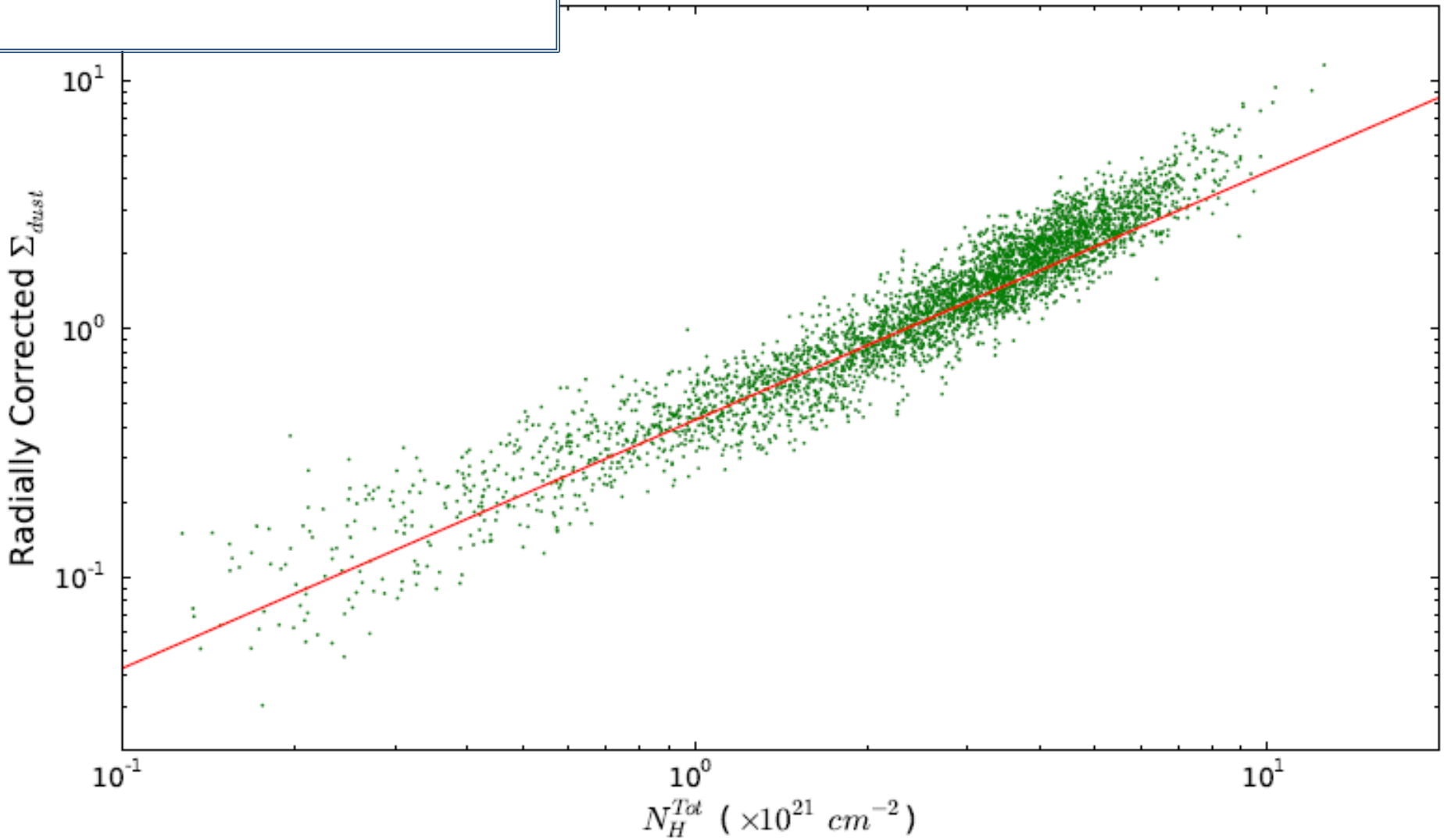
- Planck Result MW



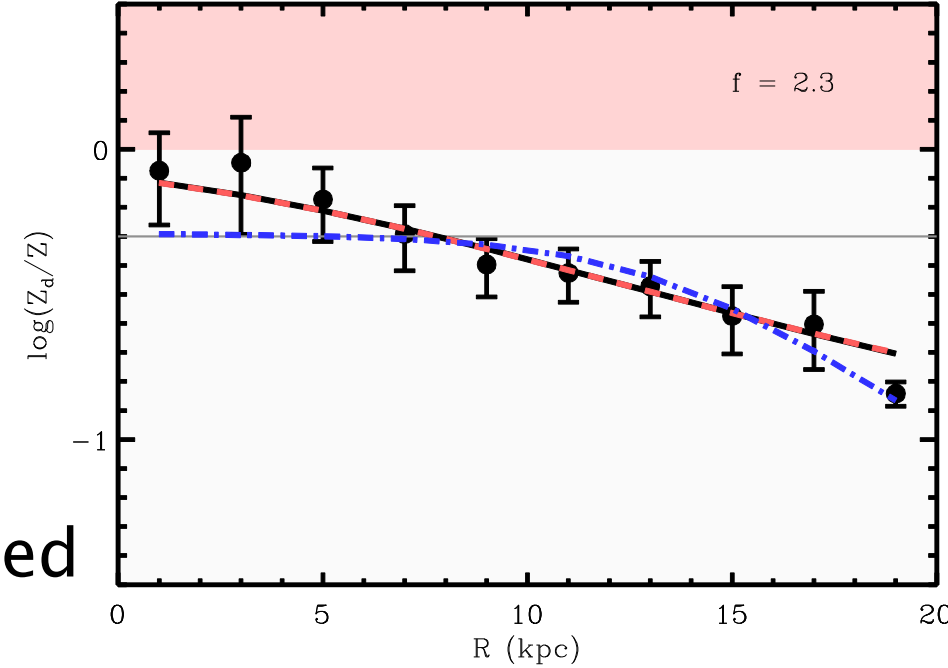
- Dark gas -> 28% of atomic gas, 118% of H_2
- Average X-factor 2.54

Is their Dark Gas in Andromeda?

- Adjusted for radial metallicity gradient
- No region dominated by molecular gas
- Line-of-sight averaging?
- Best fit X-factor $(2.0 \pm 0.4) \times 10^{20}\,\mathrm{cm^{-2}}\,[\mathrm{K\ km/s^{-1}}]^{-1}$



HELGA V – Mattsson (2014)



- After HELGA II new and more reliable metallicity measurements were published
- Closed-box chemical evolution models predict that the difference in the dust-to-gas ratio and metallicity can vary depending on two factors:
  - Destruction rates of dust in the ISM from supernova
  - Grain coagulation/growth in the ISM
- Best fit models suggest growth of the ISM is from substantial interstellar grain growth, while dust production from stars is limited

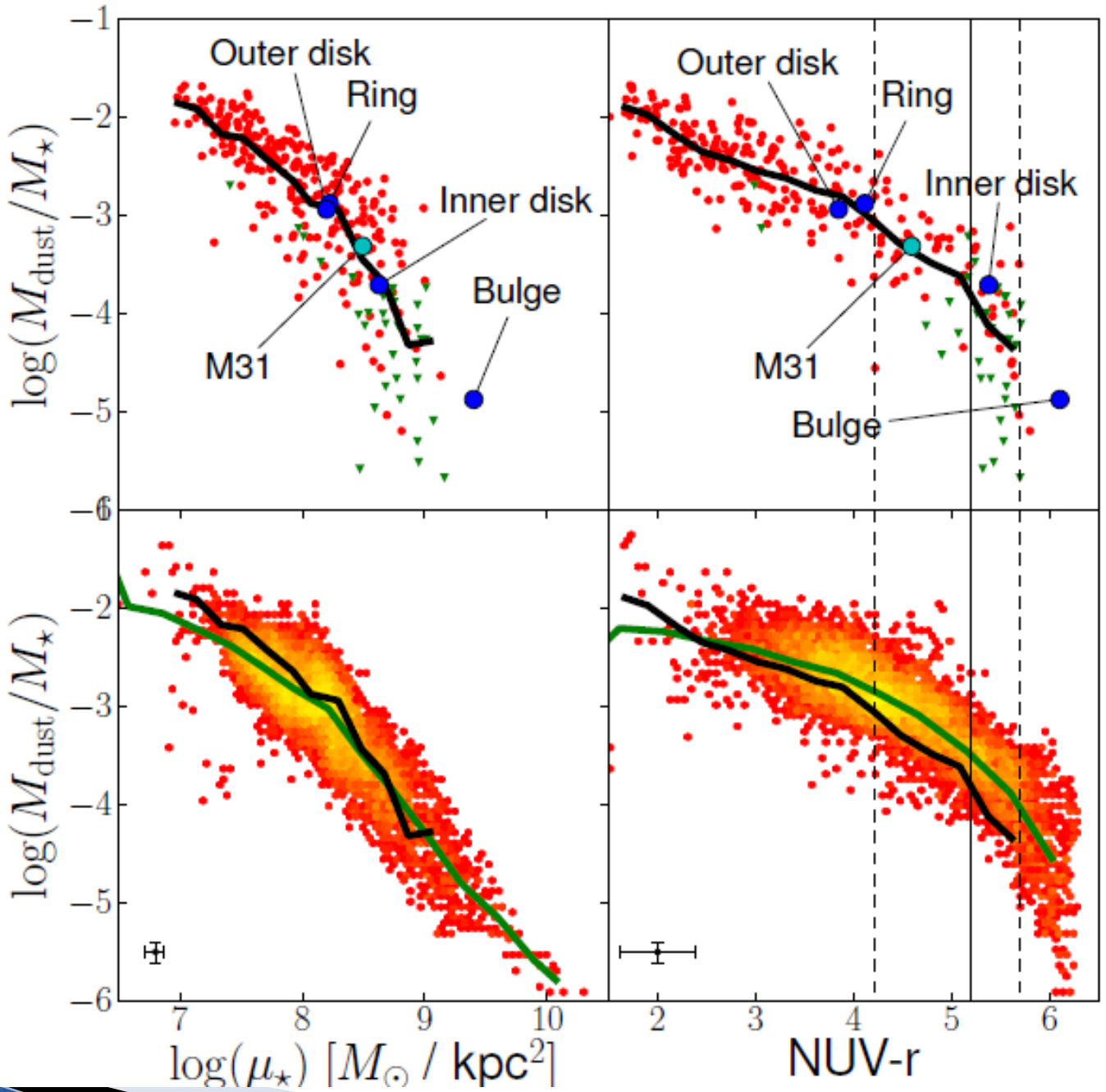
HELGA IV – Viaene et al. (2014)

- Fit panchromatic SEDs using MAGPHYS to every pixel (gridded to 36″ so independent)

- MAGPHYS:
  - Stellar templates and 3 temperature dust
  - employs an energy balance
  - Modified to allow colder temperatures

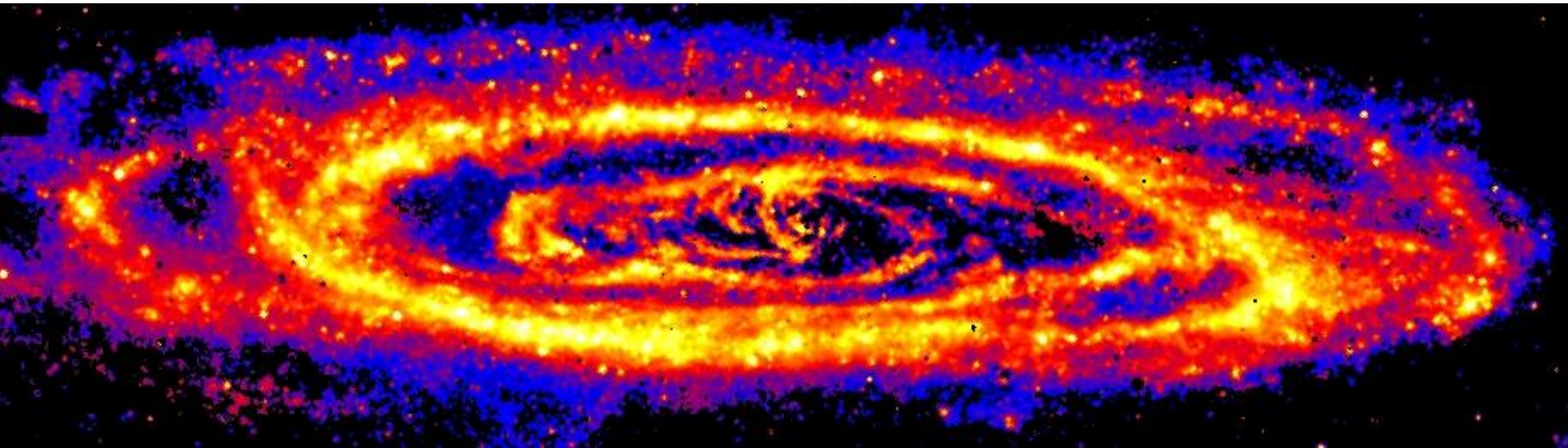
- Combine GALEX, SDSS, WISE, Spitzer-MIPS, Herschel

- Individual regions fit on global dust scaling relations (Cortese et al.)



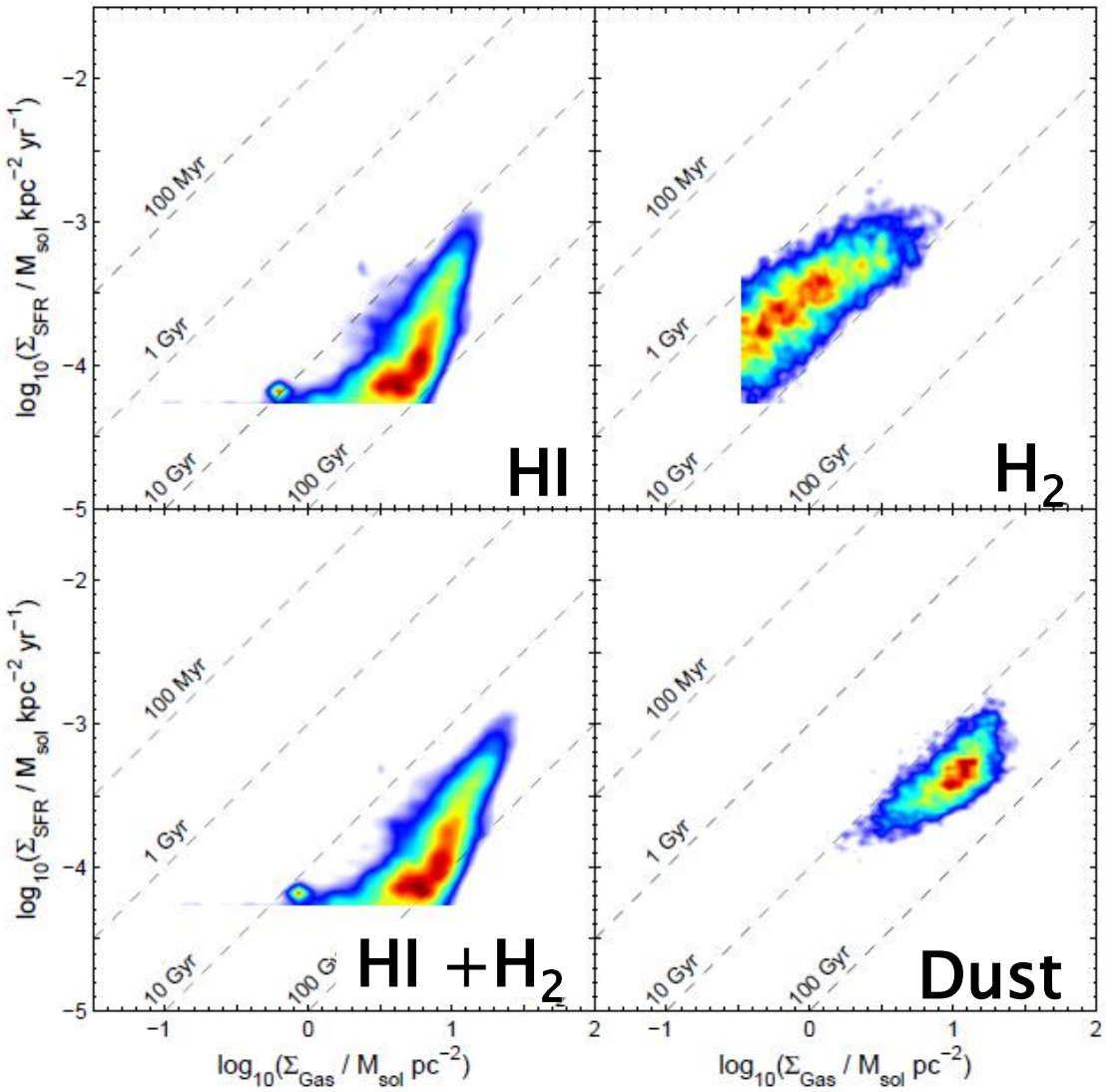
HELGA III – Ford et al. (2013)

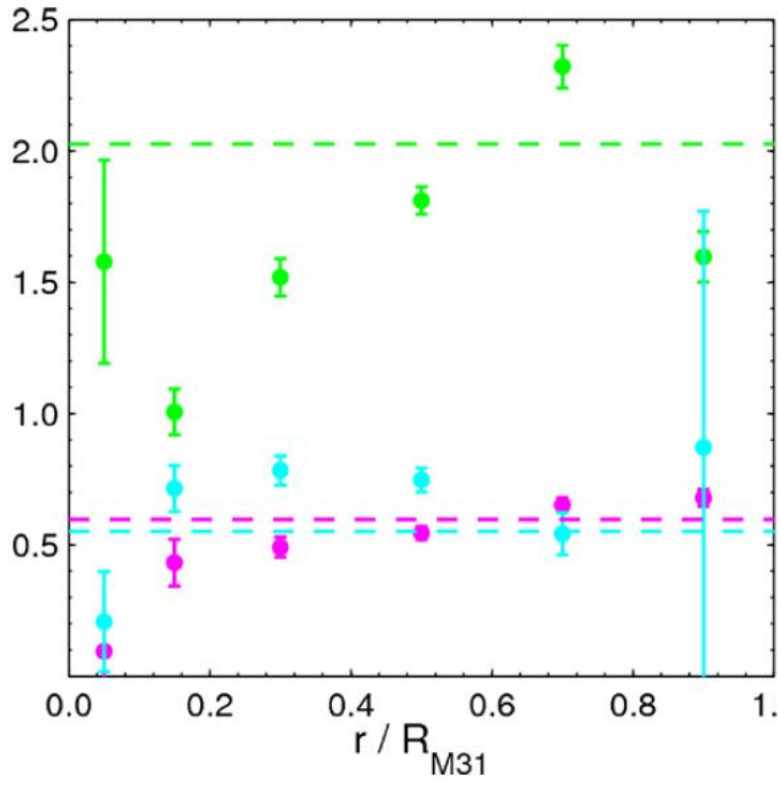
- Investigates the Schmidt-Kennicutt Law in M31
- Creates SFR map from FUV + 24μm (Leroy 2008)
- Foreground stars removed using NUV to FUV ratio
- Removed old-stellar population contribution by using 3.6μm
- SFR = 0.25 ± 0.06 $M_{\odot}$ yr^{-1}



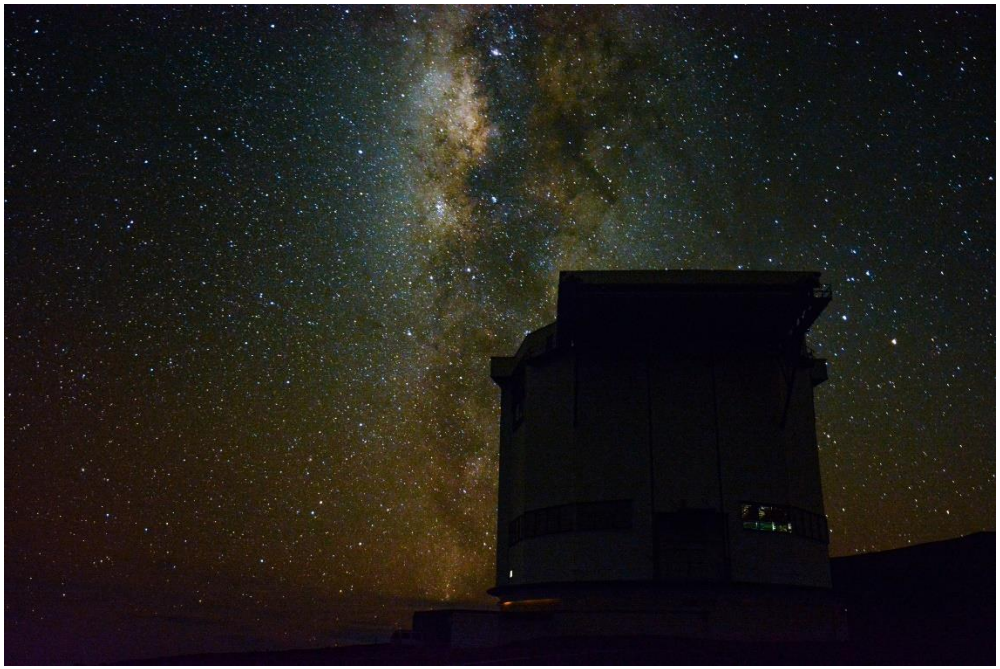
HELGA III

- For HI+H_2 N is ~1.5 to 2.0
- H_2 and dust only both give N ~0.6

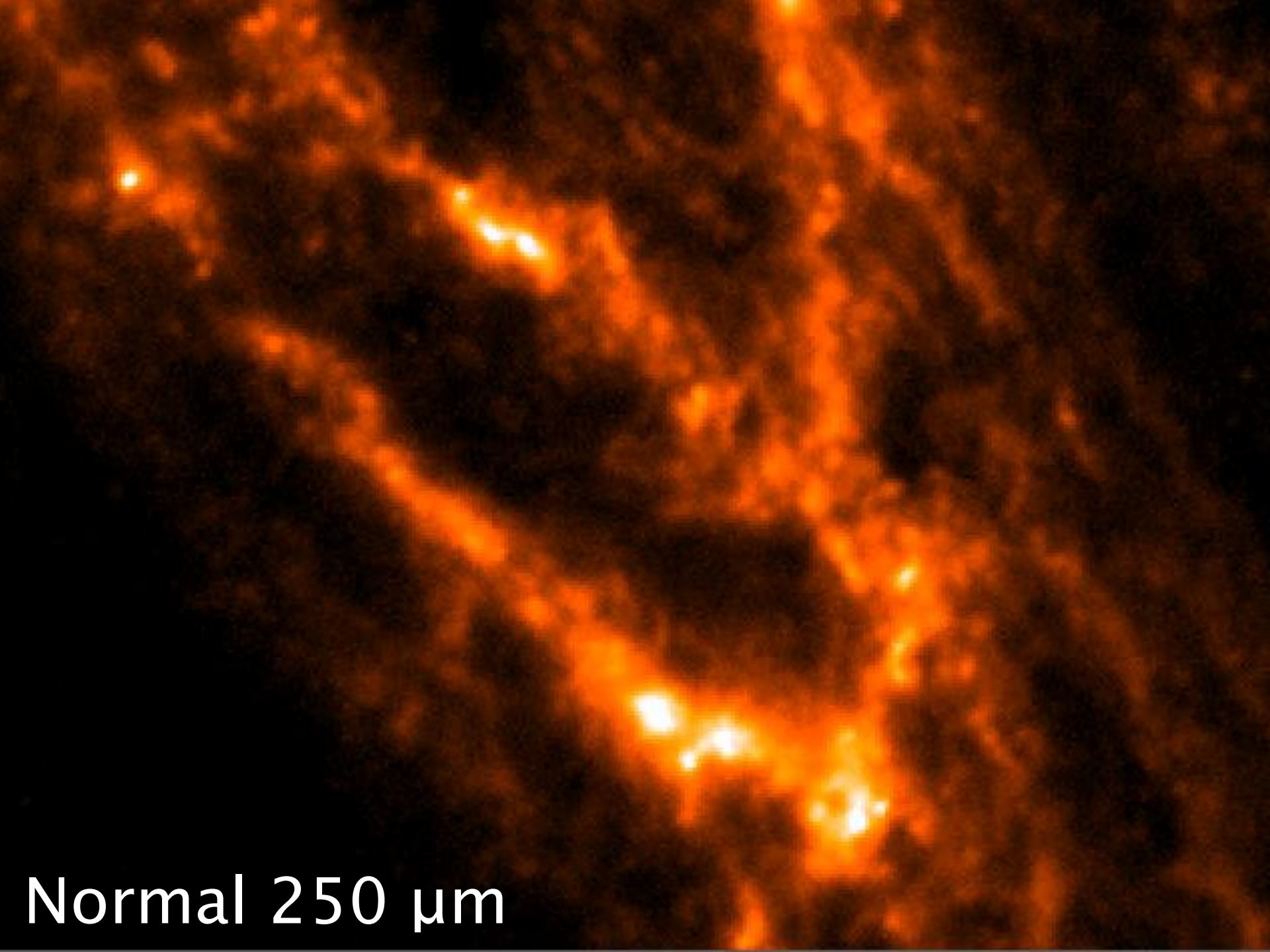


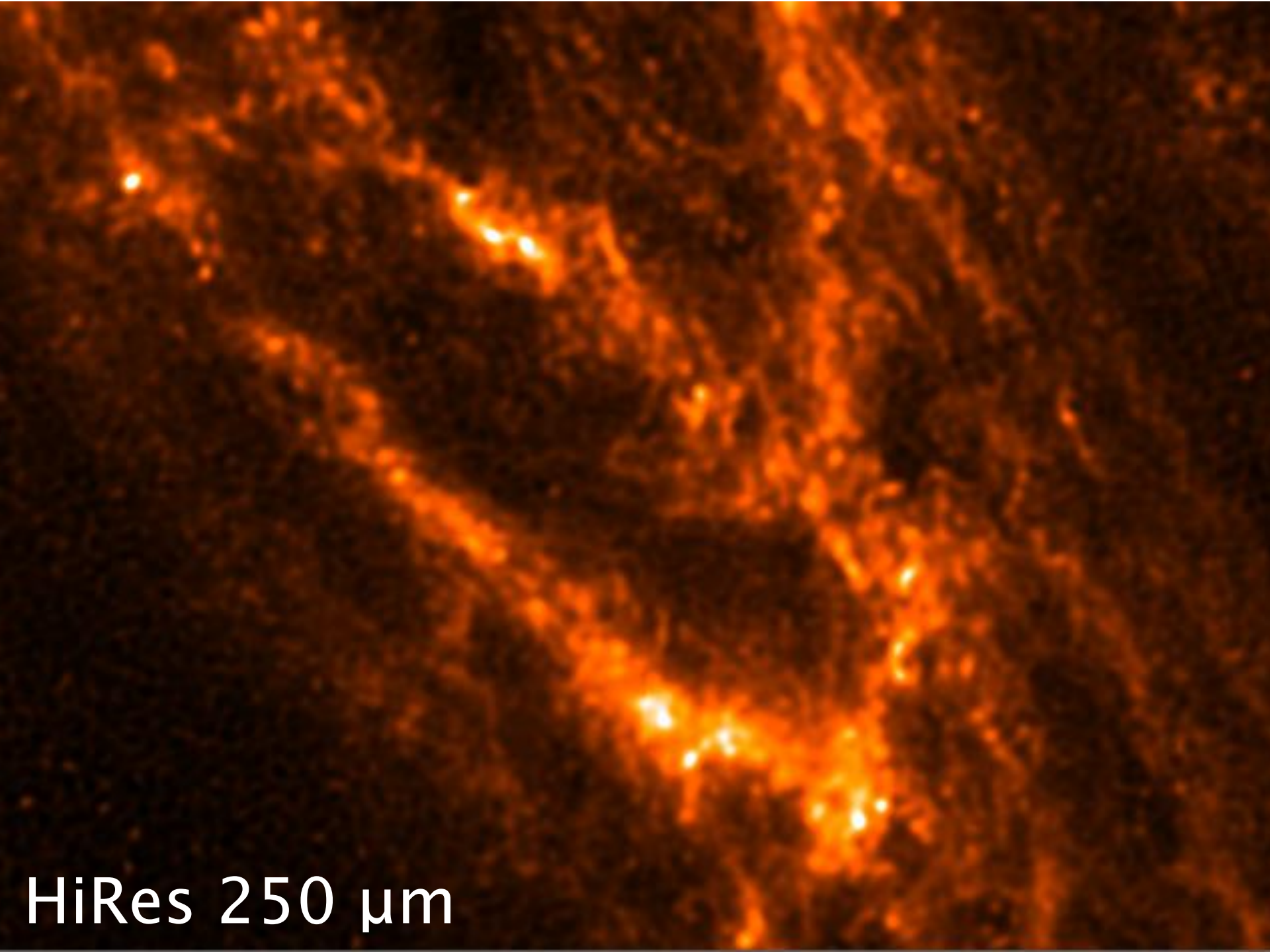


The Future…



- Long wavelength data 850μm to 2mm (e.g., SCUBA2, LMT)
- SPIRE super-resolution mapping
  - Can double resolution
  - Limited to S/N > ~20
  - Need to be careful of systematics
- Consistent analysis across larger samples of nearby galaxies


Normal 250 μm


HiRes 250 µm

Conclusions

- HELGA gives a complete census of dust in our nearest Milky-Way like object.
- Dust, Gas and Metallicity are related, but not always simple
- More to come, hopefully with new observations

Thank You for Listening