HERschel Inventory of The Agents of Galaxy Evolution (HERITAGE) in the Magellanic Clouds: The Large Magellanic Cloud SDP

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And HERITAGE team

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HERITAGE/SAGE Team members: sage.stsci.edu

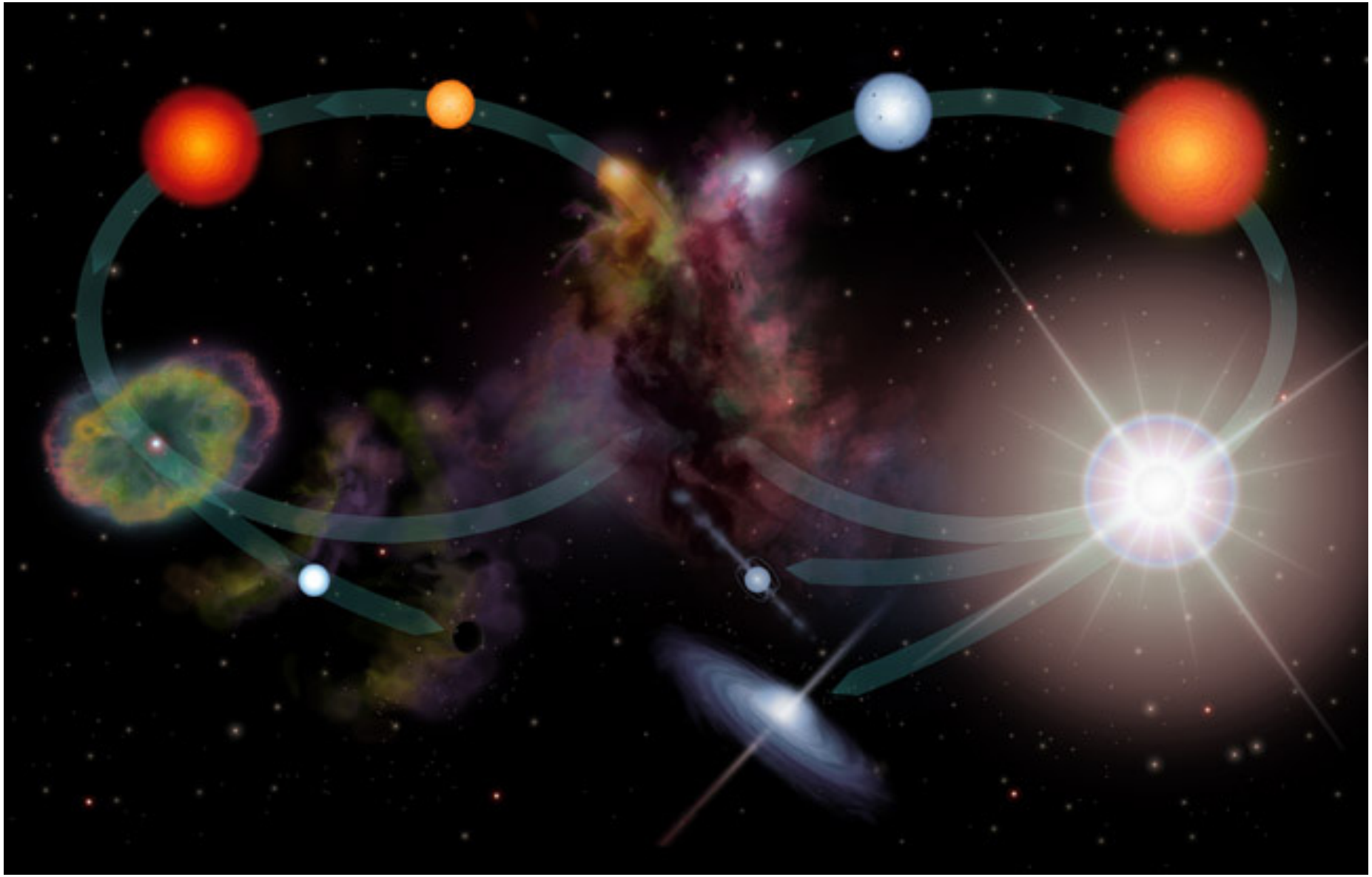
Goals of HERITAGE

- HERITAGE is a 238 hour Herschel Open Time Key Program.
- Study of Galaxy Evolution by studying the processes that cause it: Interstellar medium, star formation and stellar feedback. Follow onto Spitzer SAGE surveys.
- Mass census of all (esp. coldest) ISM dust
- Probe the most massive embedded young stellar objects
- Quantify the dust return from most massive evolved stars
- How? SPIRE and PACs parallel mapping of Large Magellanic Cloud and Small Magellanic Cloud
- Provides critical long wavelengths missed by Spitzer SAGE surveys of LMC and SMC.
  - PACS 100 and 160 microns
  - SPIRE: 250, 350 and 500 microns

HERITAGE: Tracing the Lifecycle of Baryonic Matter:

Intermediate mass stars

High mass stars

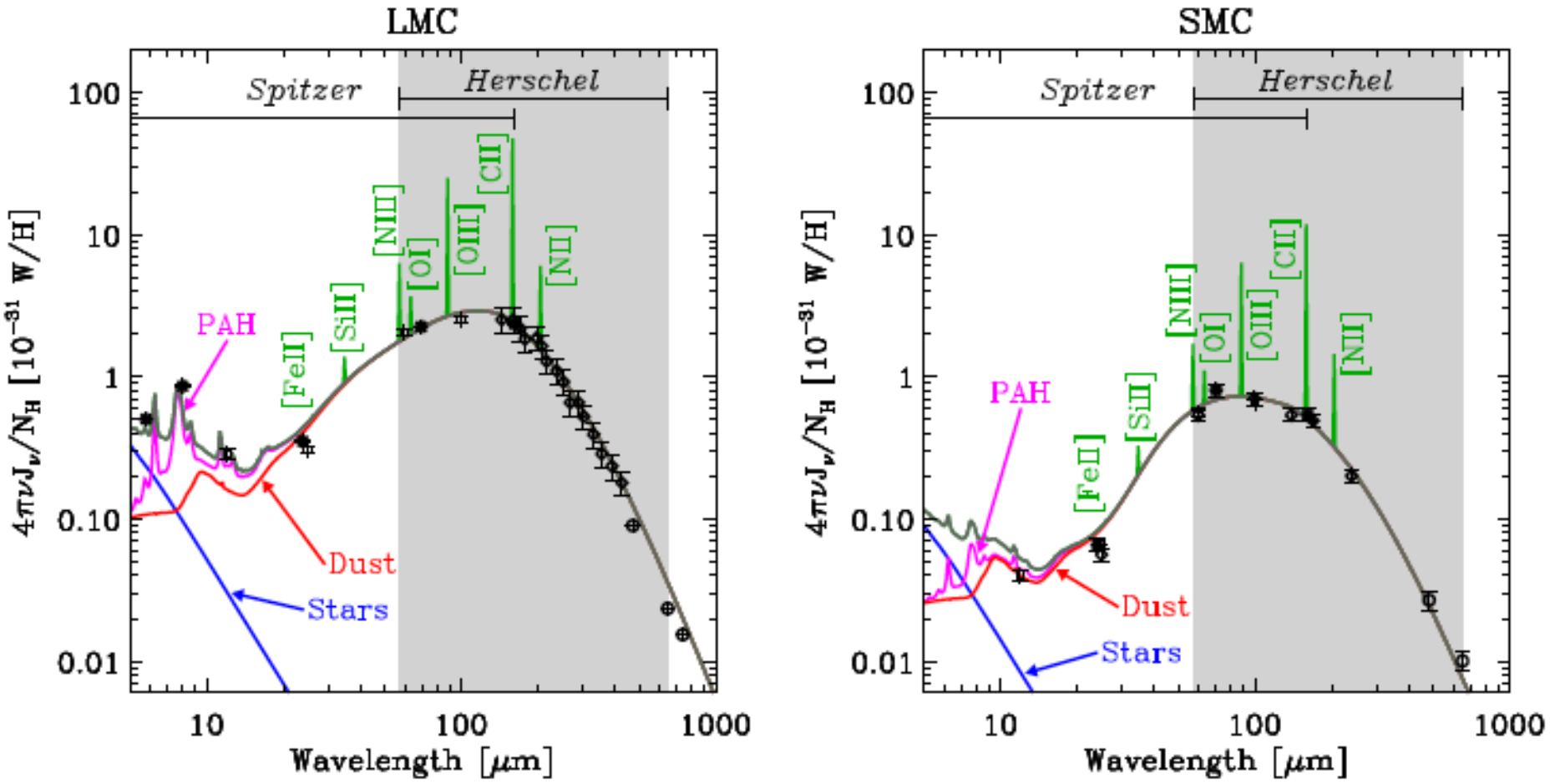


credit: http://hea-www.cfa.harvard.edu/CHAMP/EDUCATION/PUBLIC/ICONS/

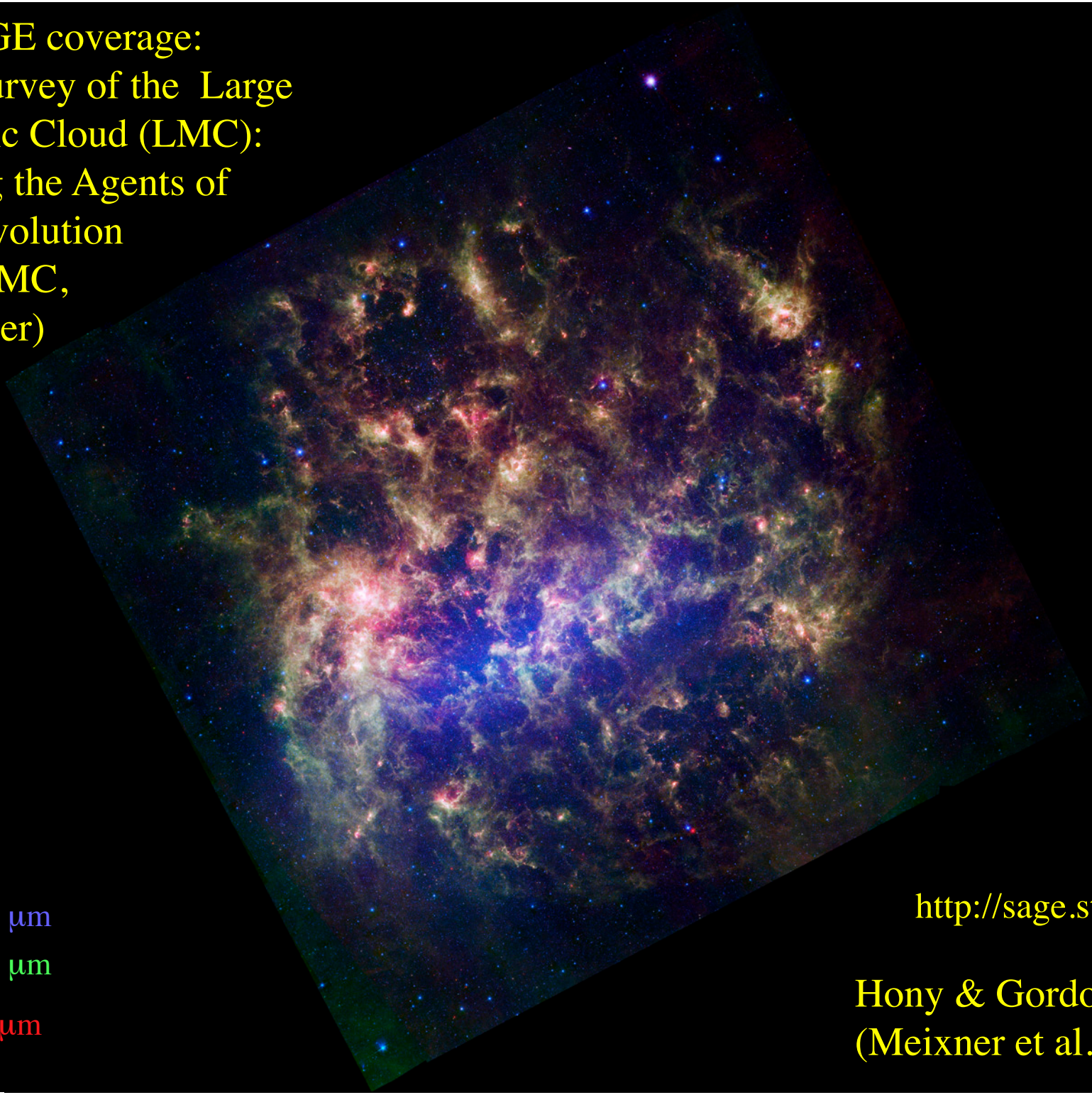
Why the Magellanic Clouds?

- Proximity: ~50 kpc (LMC) and ~60 kpc (SMC) (Schaefer 2008; Szewczyk et al. 2009)
- Mean metallicity: (Dufour et al. 1982; Asplund et al. 2004)
  - LMC: Z~0.5 x $Z_{\odot}$
  - SMC: Z~0.2 x $Z_{\odot}$
  - ISM during Universe's peak star formation epoch (z~1.5 Pei et al 1999)
- Known tidal interactions between LMC and SMC, possibly the Milky Way.
- Long History of Studies & used as a proving ground:
  - Ideal Case study for a galaxy evolution (Bekki & Chiba 2005)

Herschel provides critical wavelengths, completing picture started with Spitzer SAGE survey of LMC and SMC



HERITAGE coverage:
Spitzer Survey of the Large Magellanic Cloud (LMC): Surveying the Agents of Galaxy Evolution (SAGE-LMC, PI: Meixner)

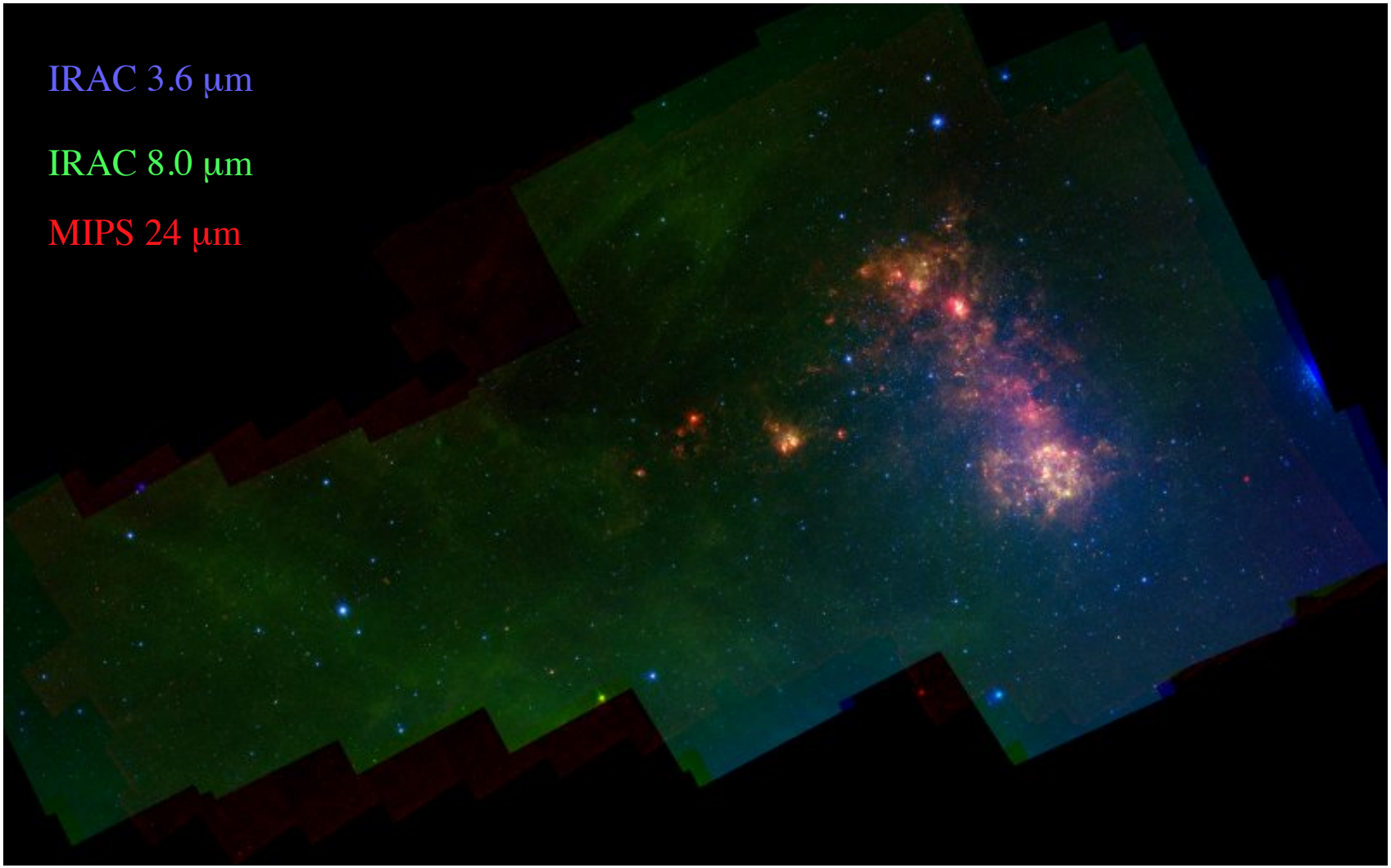


IRAC 3.6 μm
IRAC 8.0 μm
MIPS 24 μm

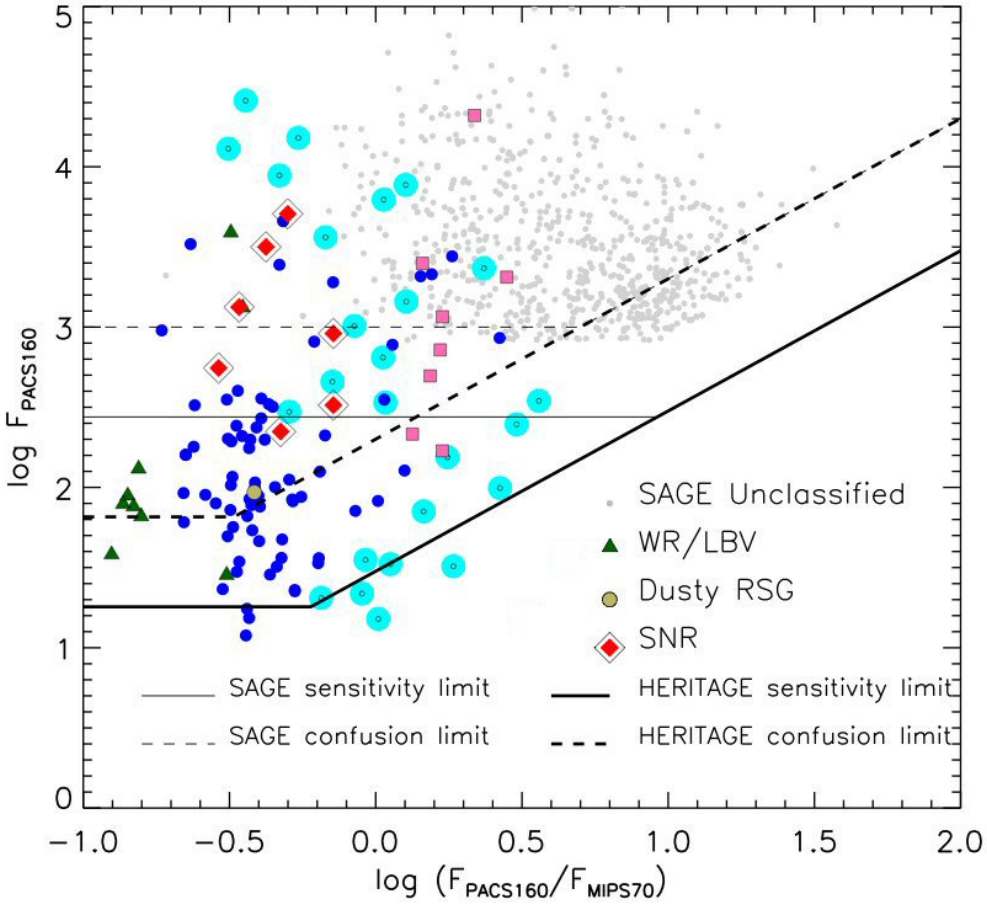
http://sage.stsci.edu/

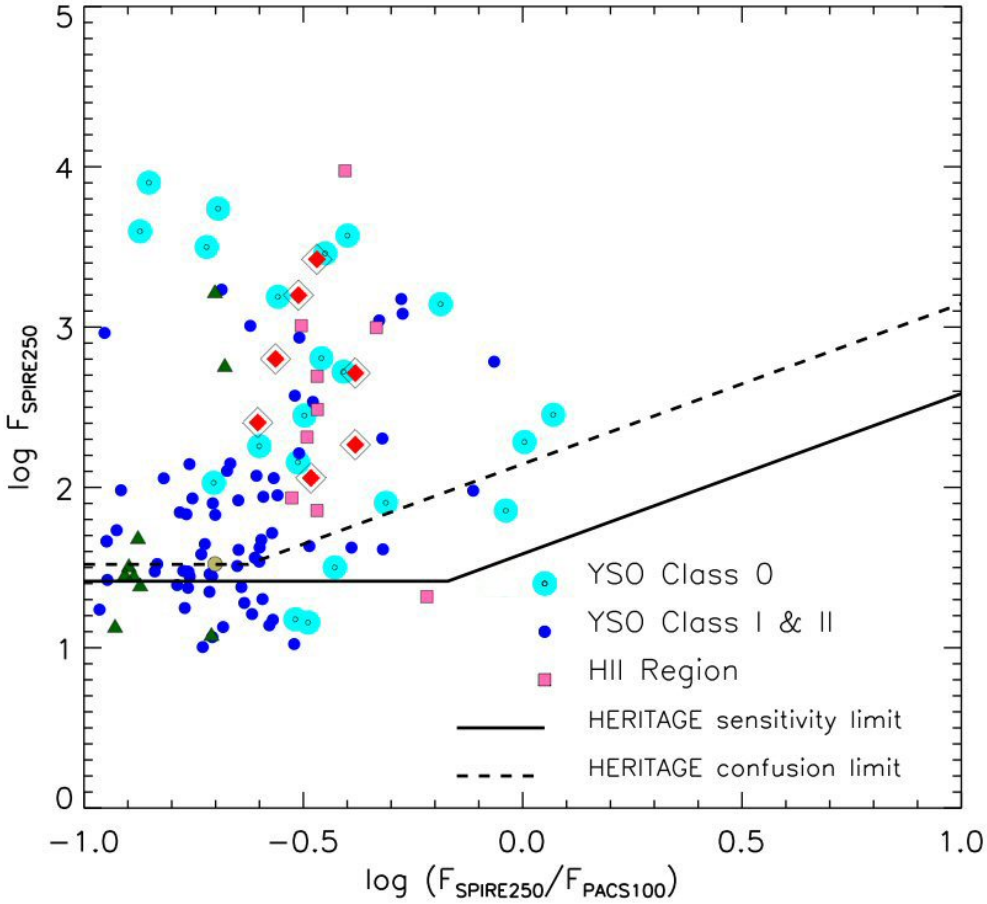
Hony & Gordon
(Meixner et al. 2006)

HERITAGE Coverage similar to
SAGE-SMC : PI Karl Gordon (STScI)



HERITAGE will detect the circumstellar dust from the most massive stars at all stages of their evolution.





Srinivasan & Sewilo

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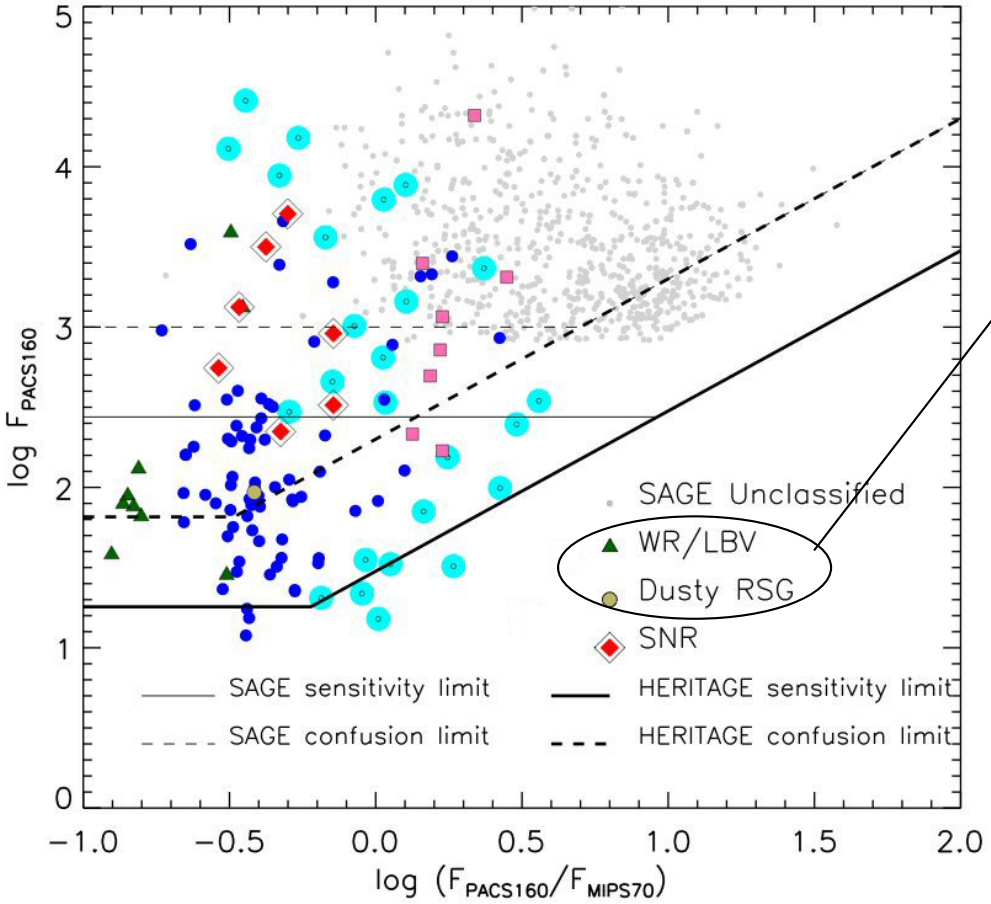
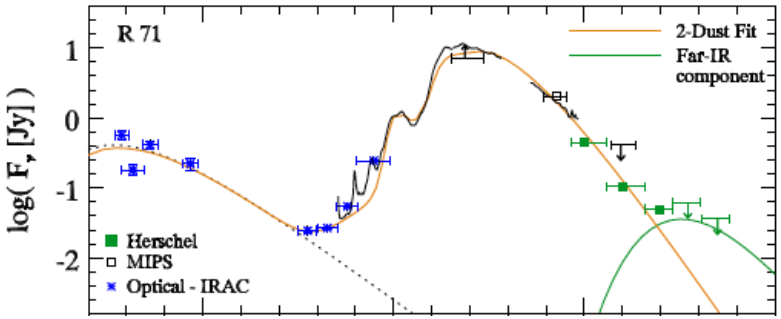
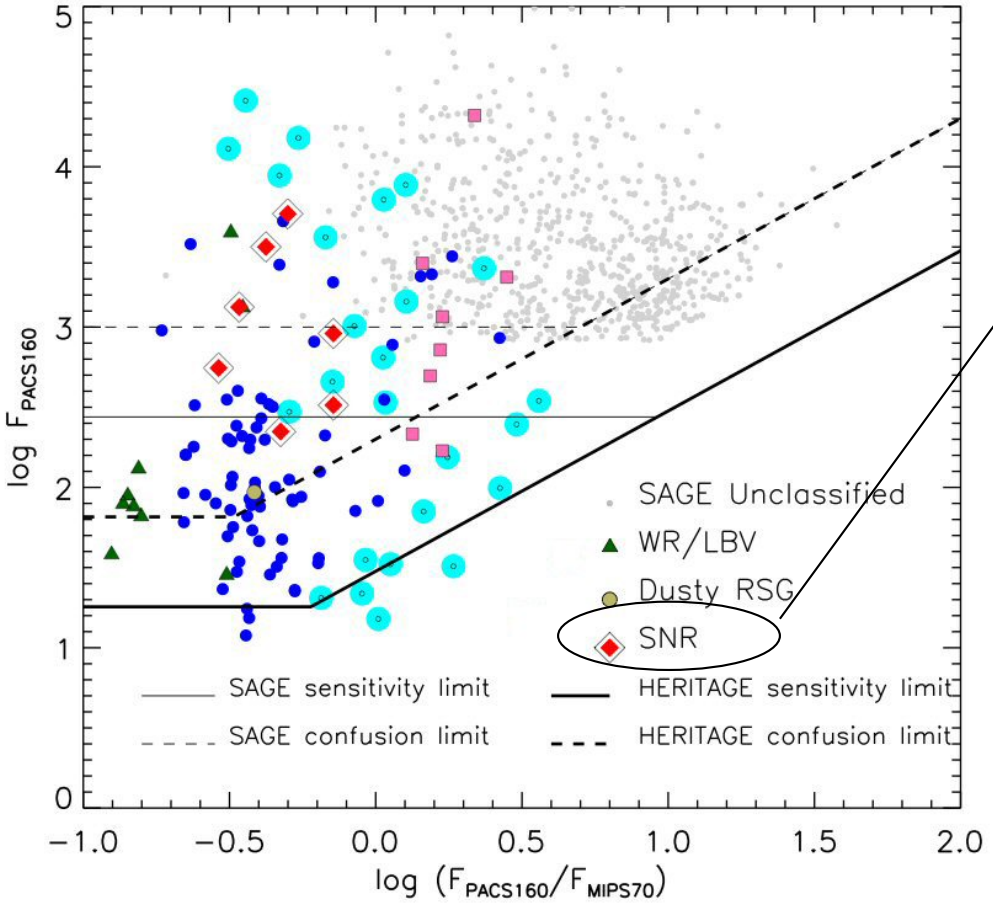


See talk by Boyer et al.
Session B4

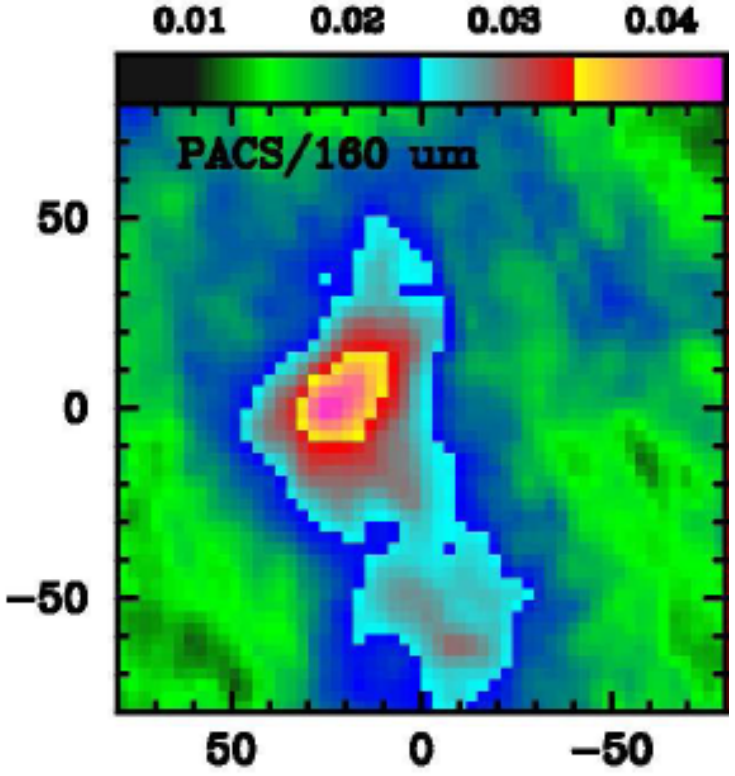


Boyer et al. 2010

HERITAGE will detect the circumstellar dust from the most massive stars at all stages of their evolution.



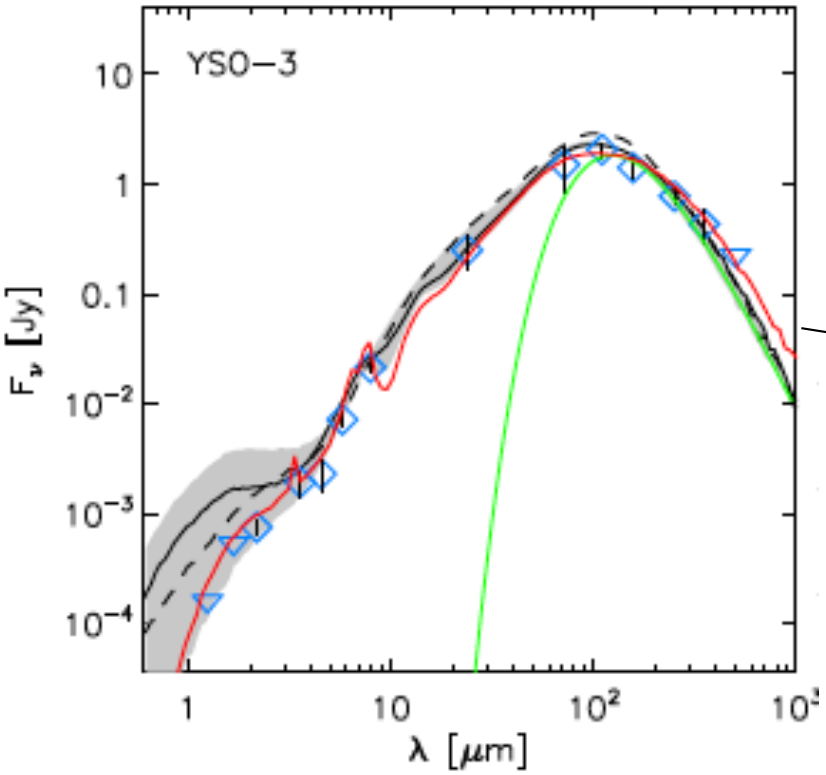
See poster by van Loon, Otsuka et al. on SNR N49 poster session 2

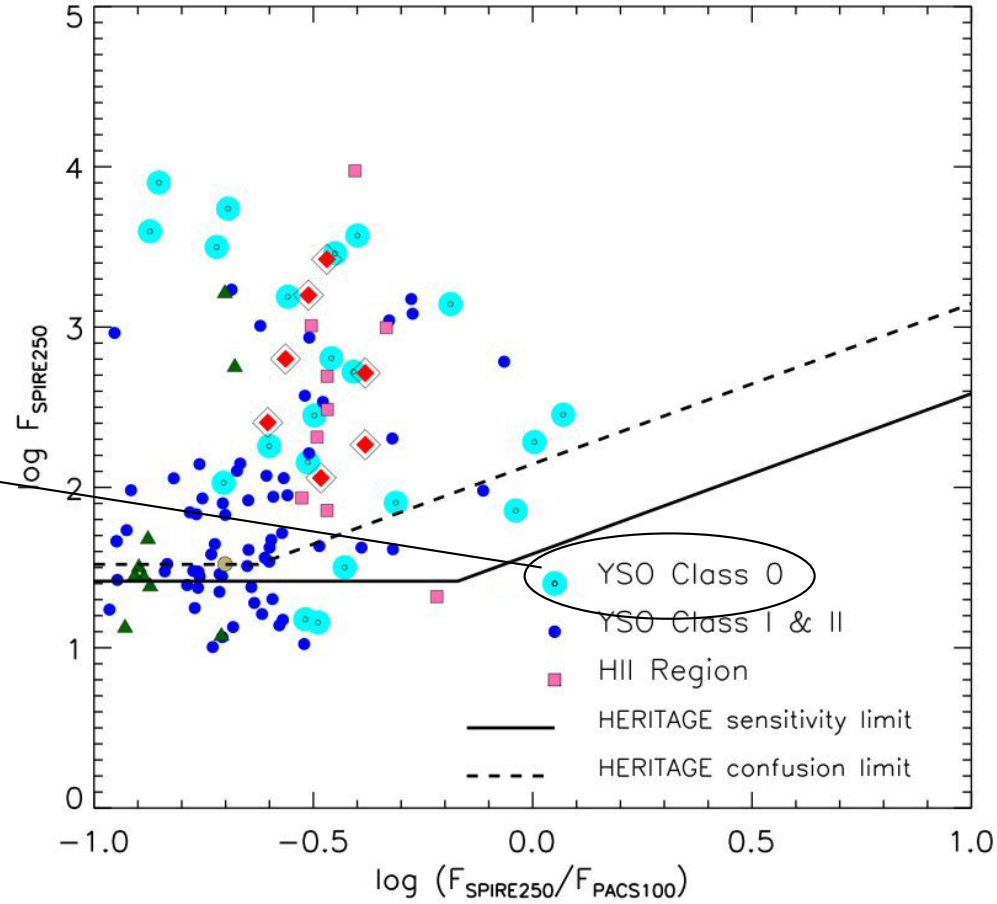


Otsuka et al. 2010

HERITAGE will detect the circumstellar dust from the most massive stars at all stages of their evolution.

See talk by Israel/ Sewilo in session A8

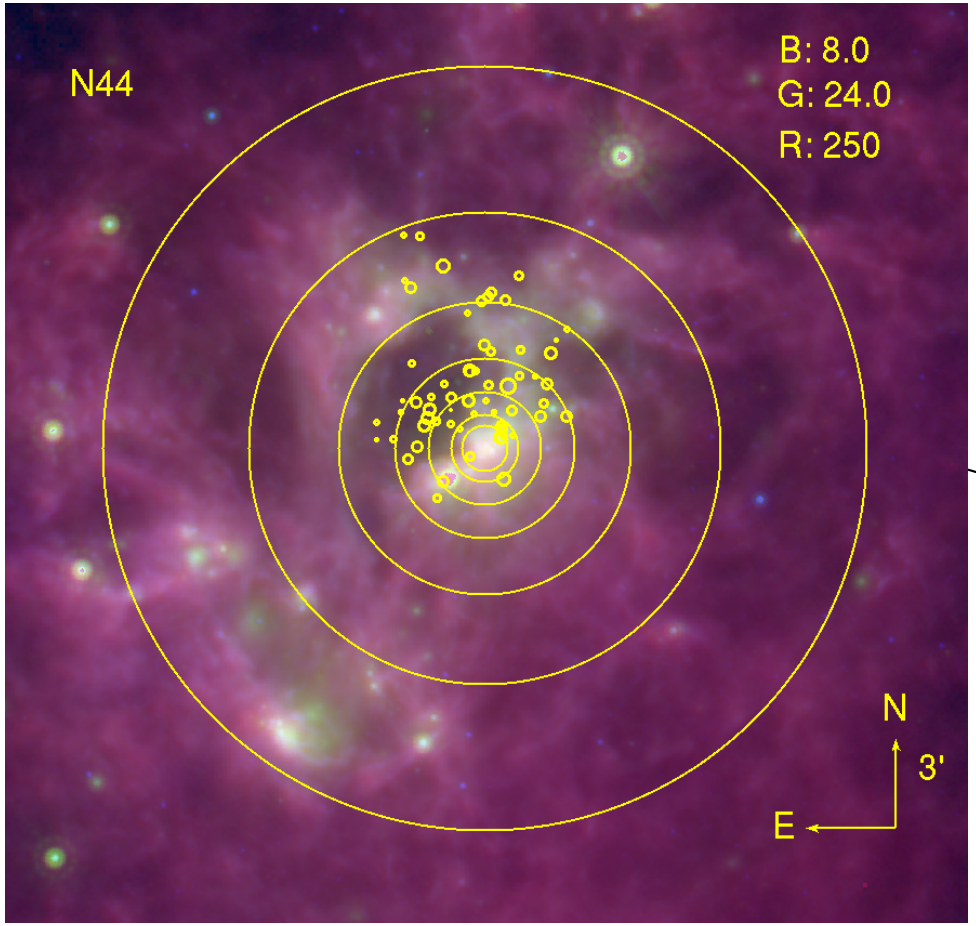


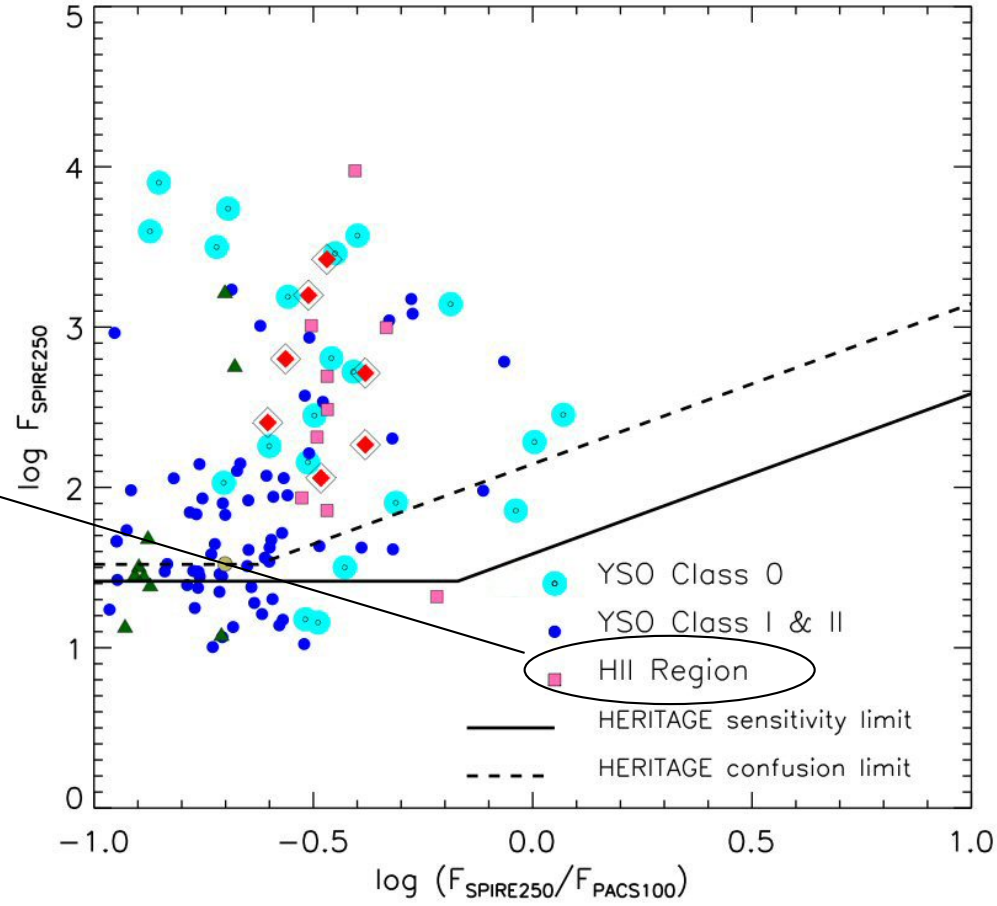


Sewilo et al. 2010

HERITAGE will detect the circumstellar dust from the most massive stars at all stages of their evolution.

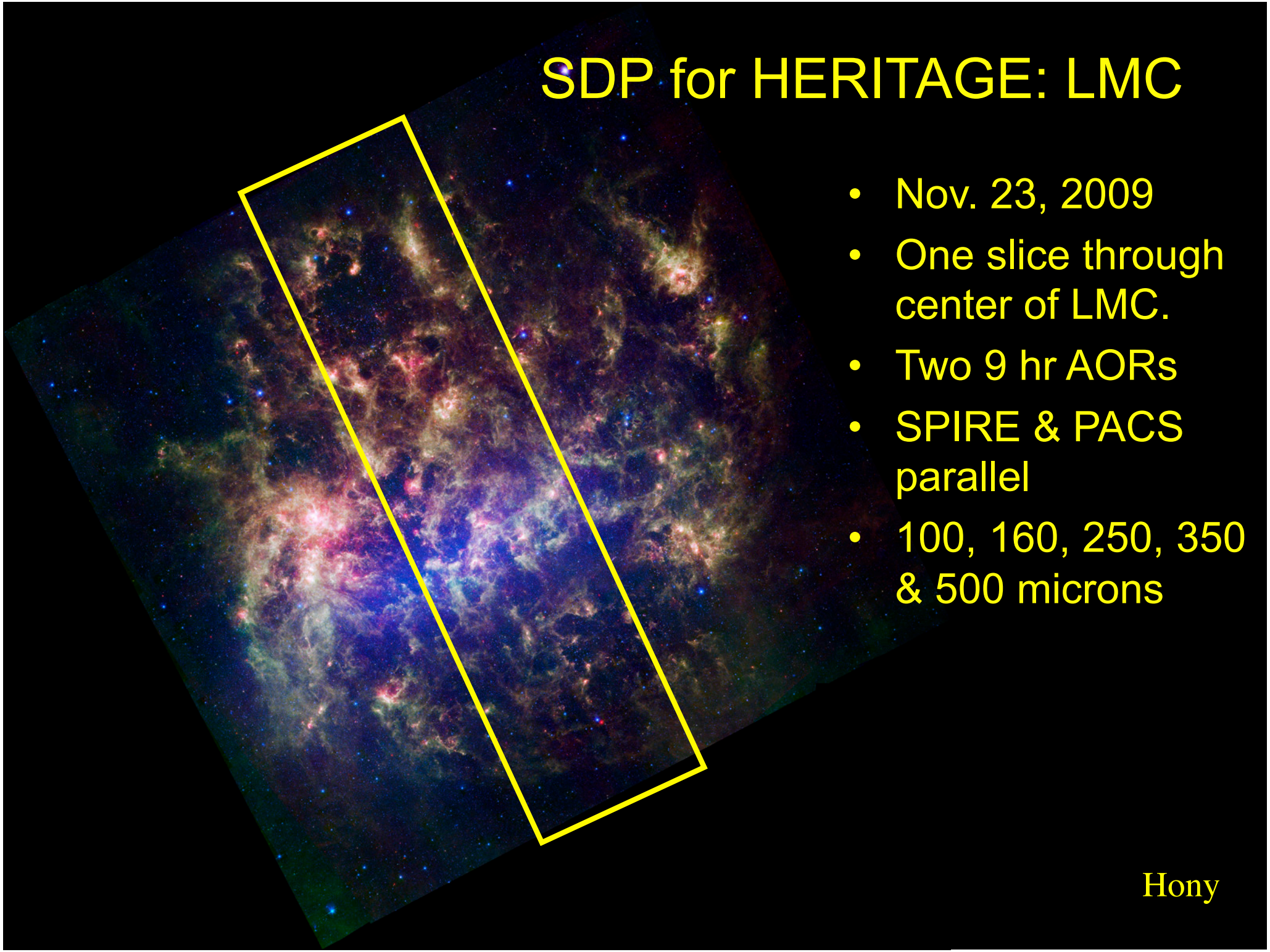
See poster by Hony et al.





Hony et al. 2010

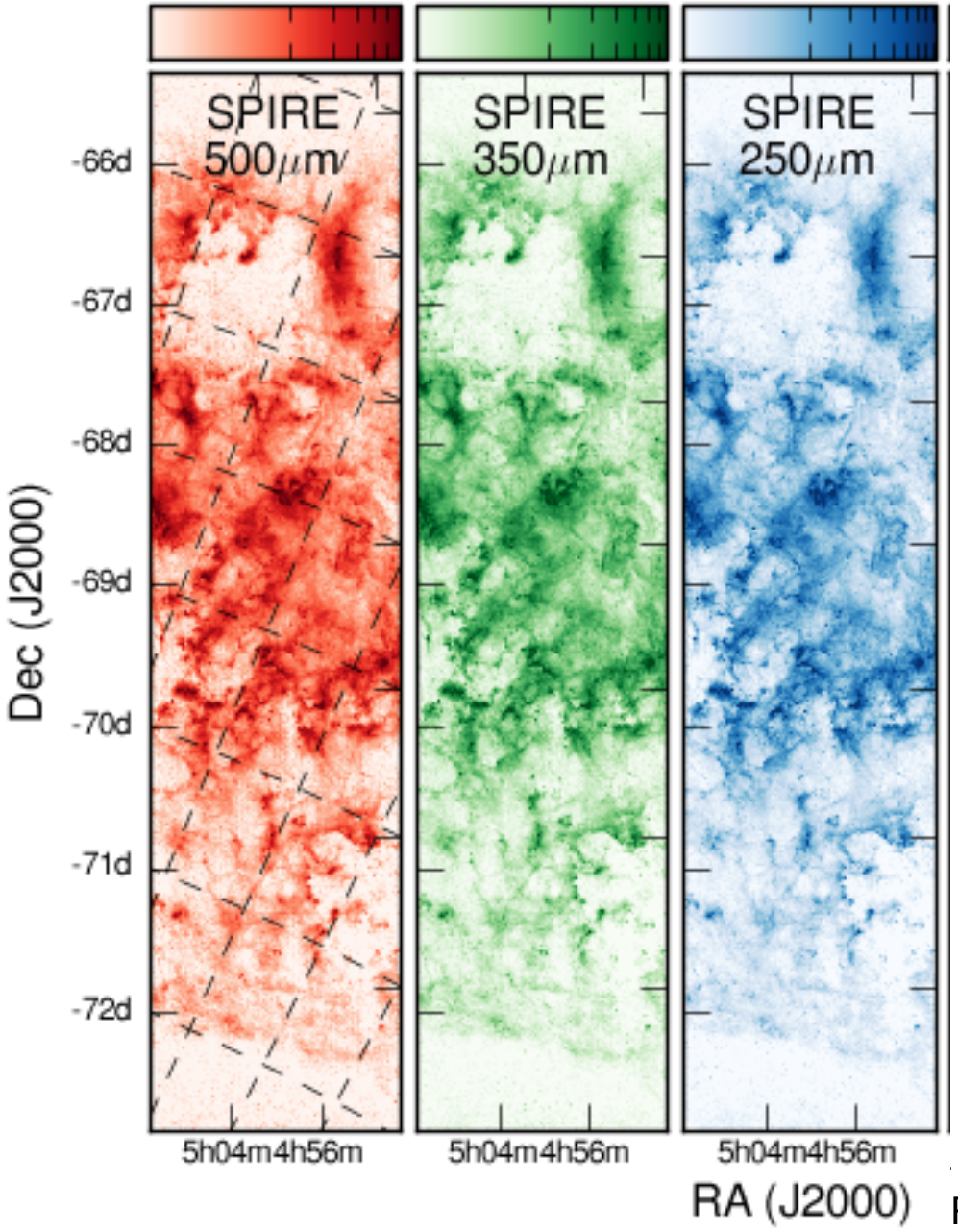
SDP for HERITAGE: LMC



- Nov. 23, 2009
- One slice through center of LMC.
- Two 9 hr AORs
- SPIRE & PACS parallel
- 100, 160, 250, 350 & 500 microns

Hony

HERITAGE SDP strip



SPIRE Data processing:

-HIPE 2.0 +
-background subtraction from off LMC end points
-15% calibration error
-comparison with SAGE-MIPS 24 μm to improve astrometry
-very low level striping is expected to improve with cross scans in final HERITAGE data

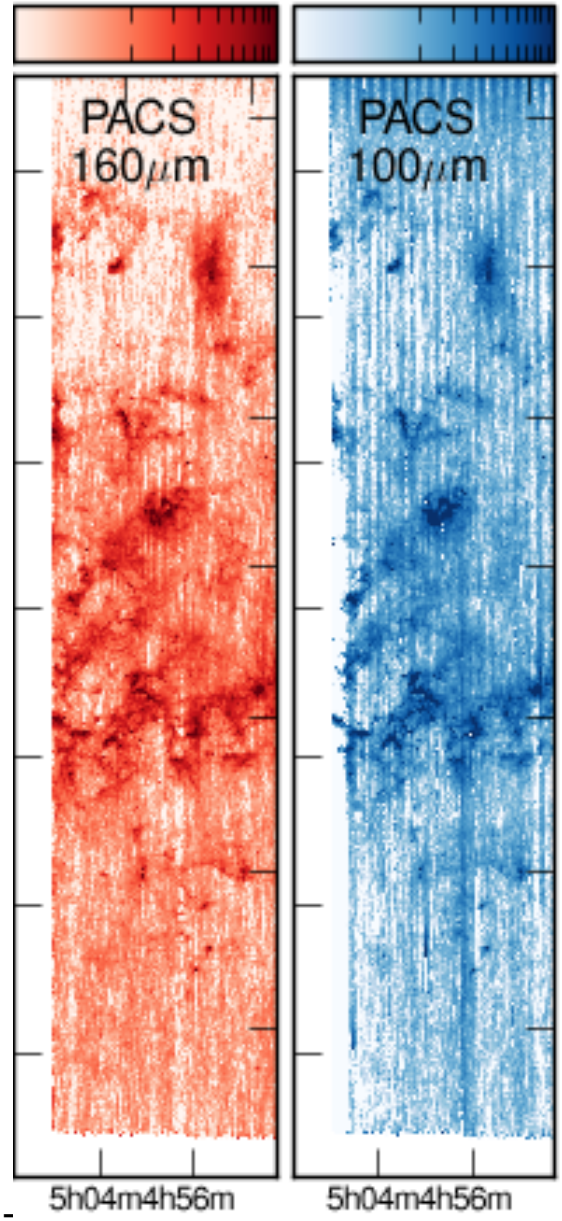
First Results
RITAGE team

Meixner et al. 2010

HERITAGE SDP strip

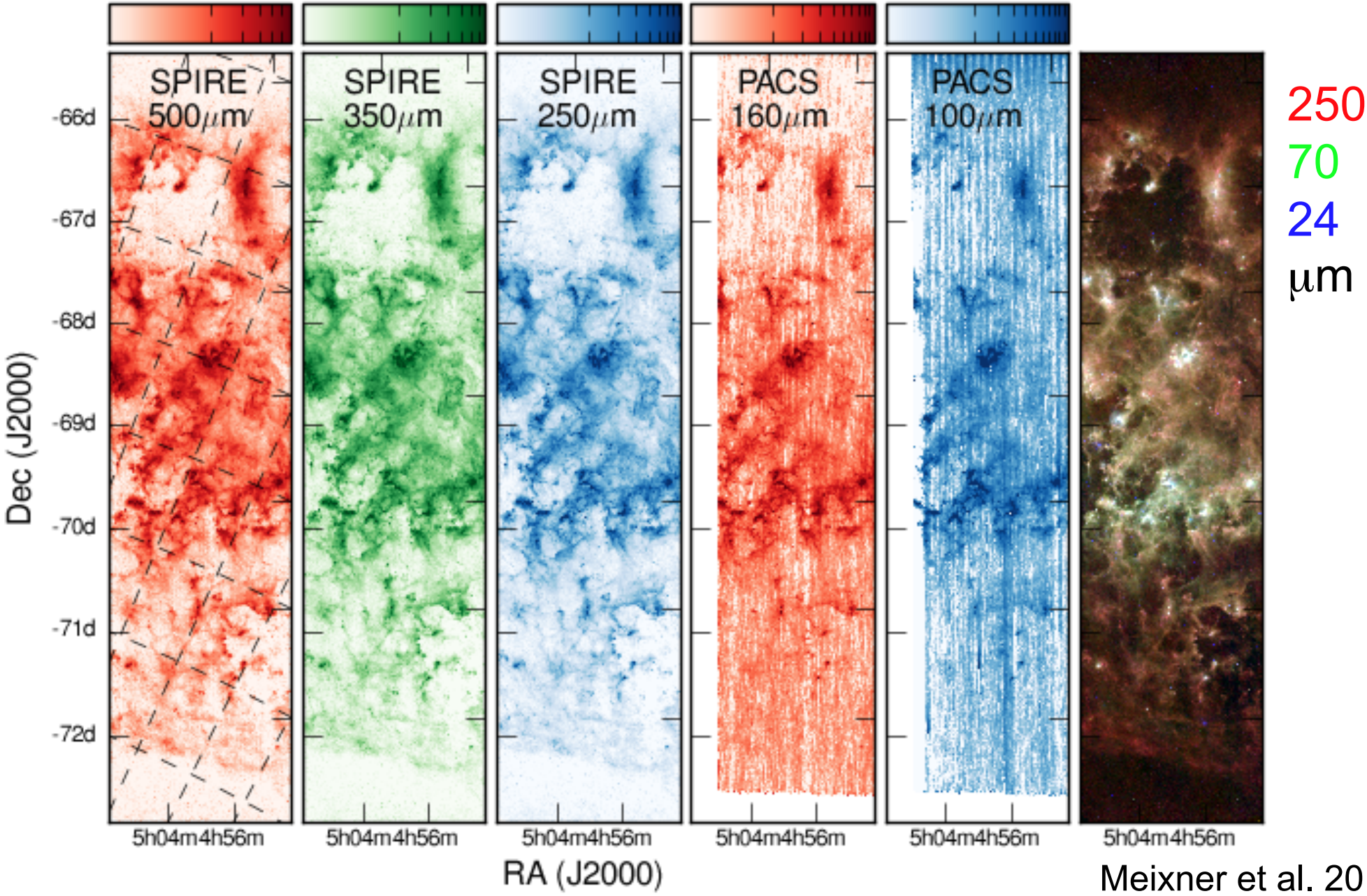
PACS Data processing:

-HIPE 2.0 + deglitch
-background subtraction from off LMC end points
-flux calib HIPE 1.2
-20% calibration error,
compared MIPS 160 & PACS 160 => 15 % agreement
-comparison with SAGE=> some 6" random pointing offsets
-striping expected to improve with cross scans in final HERITAGE Data => used only for point & compact sources, not diffuse ISM



Meixner et al. 2010

HERITAGE SDP strip



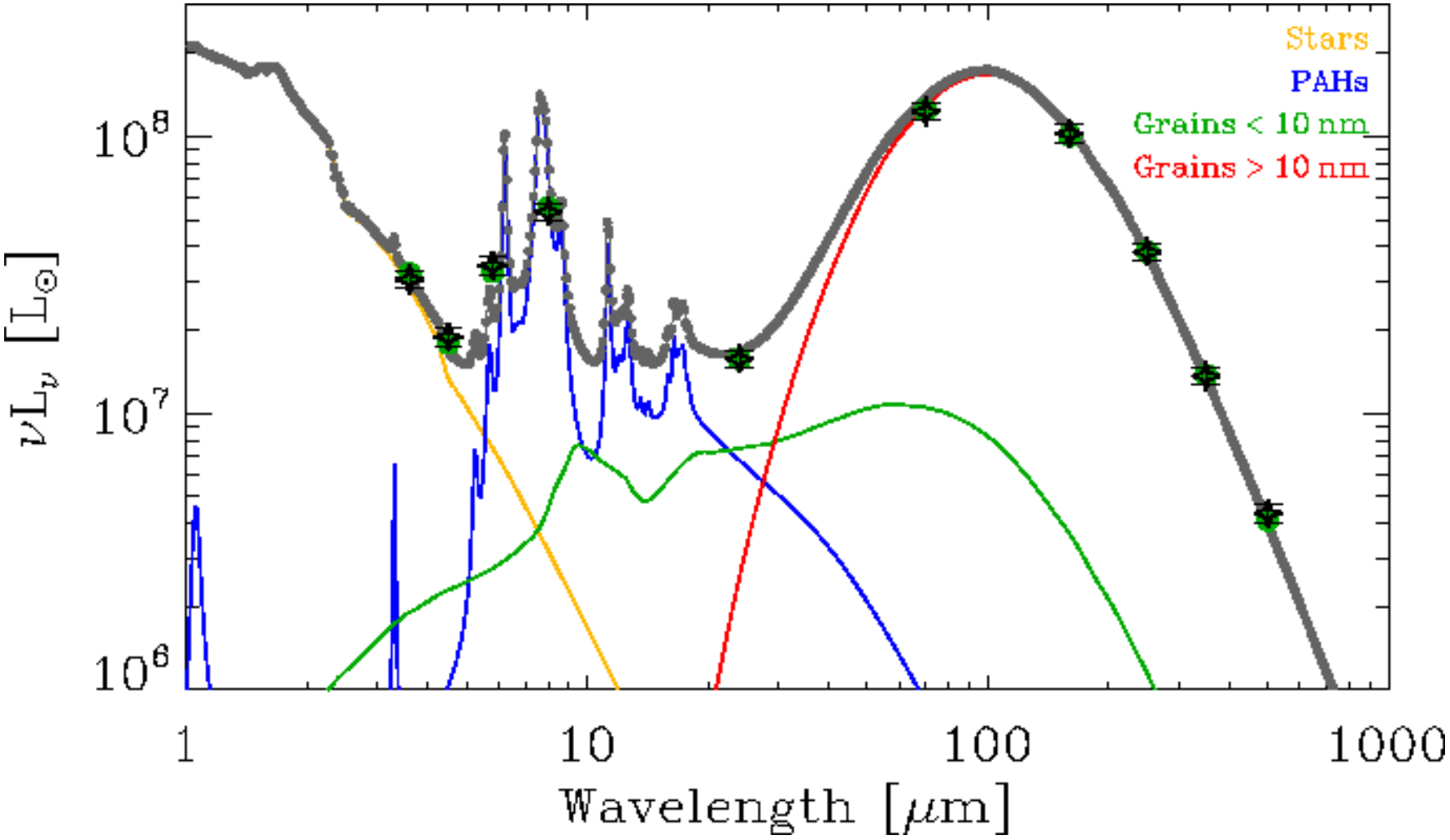
Meixner et al. 2010

LMC SDP Dust Models

Parameter	Model 1	Model 2
Dust name	Galactic, Zubko et al (2004)	LMC, Galliano et al. in prep.
Composition	Silicate, graphite, rel. solar abundance (Draine & Li 2007)	Silicate, amporphous carbon (Rouleau & Martin 1991)
Submm emissivity, β	2	<2
U_{avg} (solar neigh.)	2 (+0.4, -0.5)	9 (+1.0, -1.3)
f_{PAH} (solar neigh.)	0.85	0.64

Meixner et al. 2010
Galliano et al. in prep.

SED fit to the whole strip



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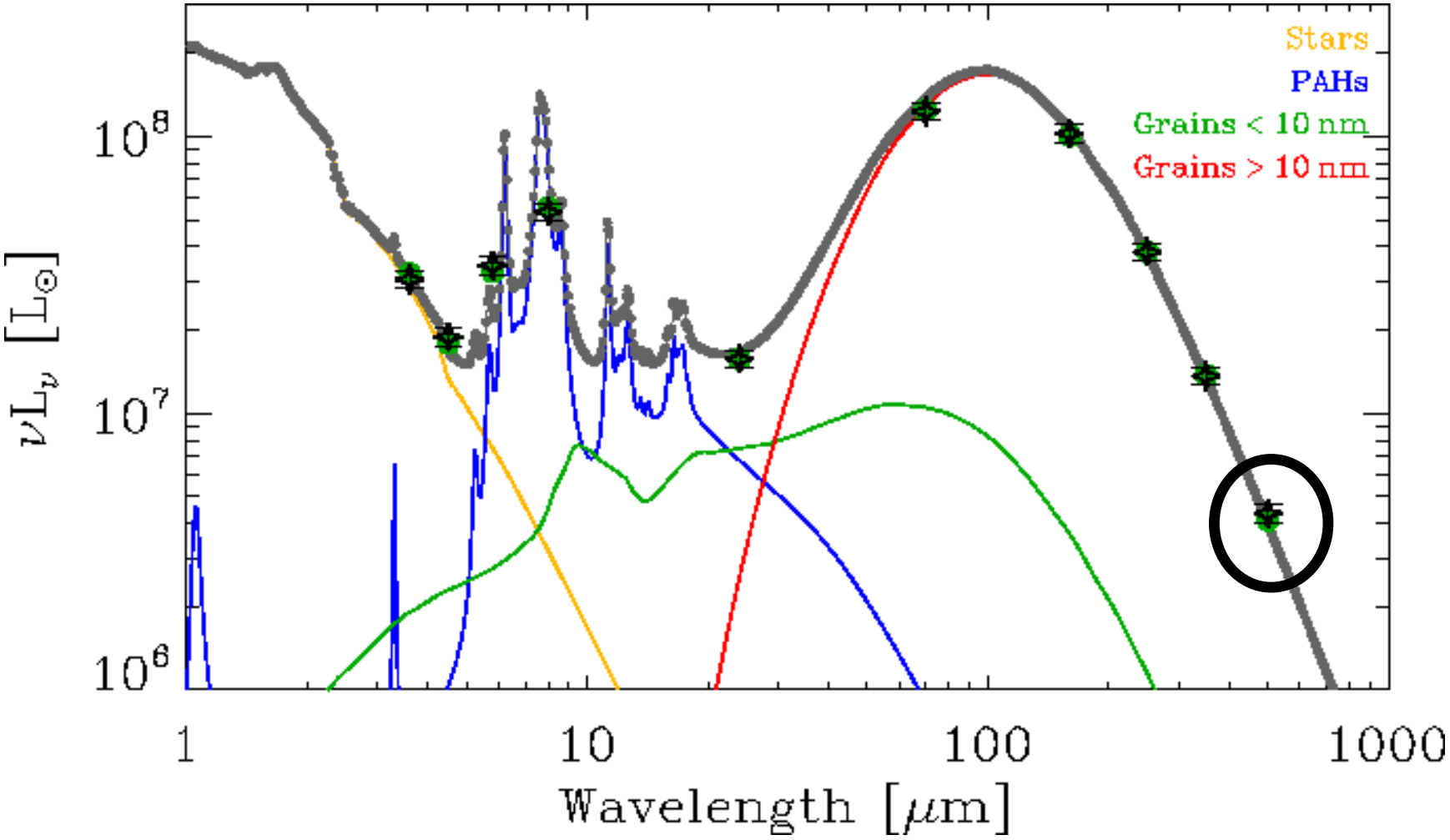

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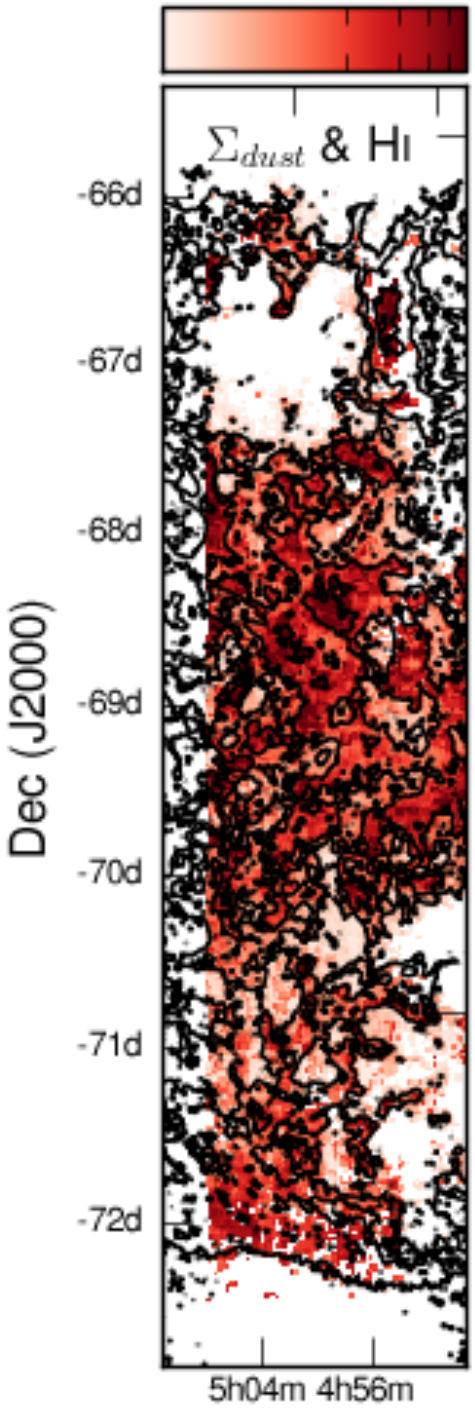
U_{avg} (solar neigh.)	2 (+0.4, -0.5)	9 (+1.0, -1.3)
f_{PAH} (solar neigh.)	0.85	0.64
500 μm excess	17%	6%

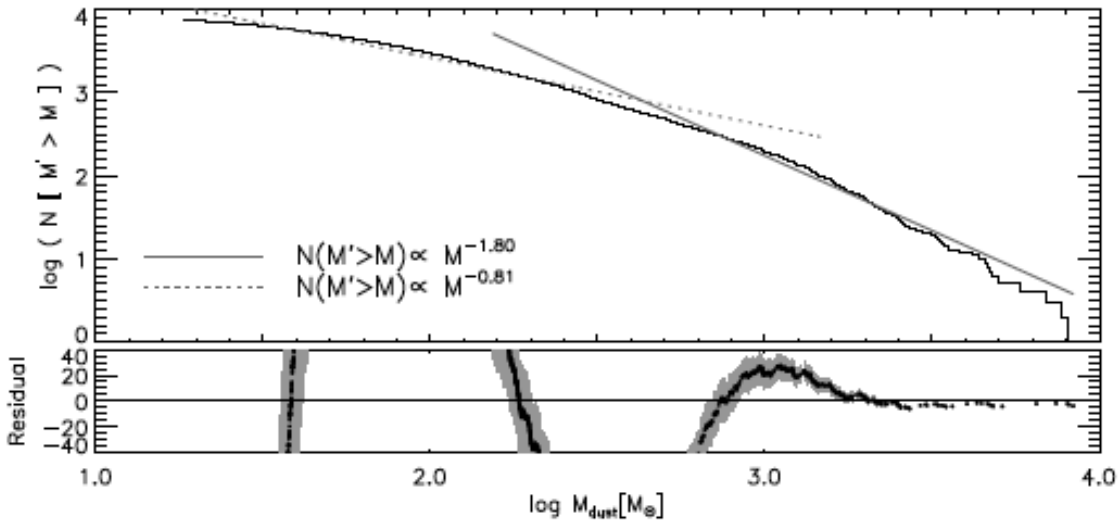
Meixner et al. 2010
Galliano et al. in prep.



Models and Analysis of SDP strip by pixel

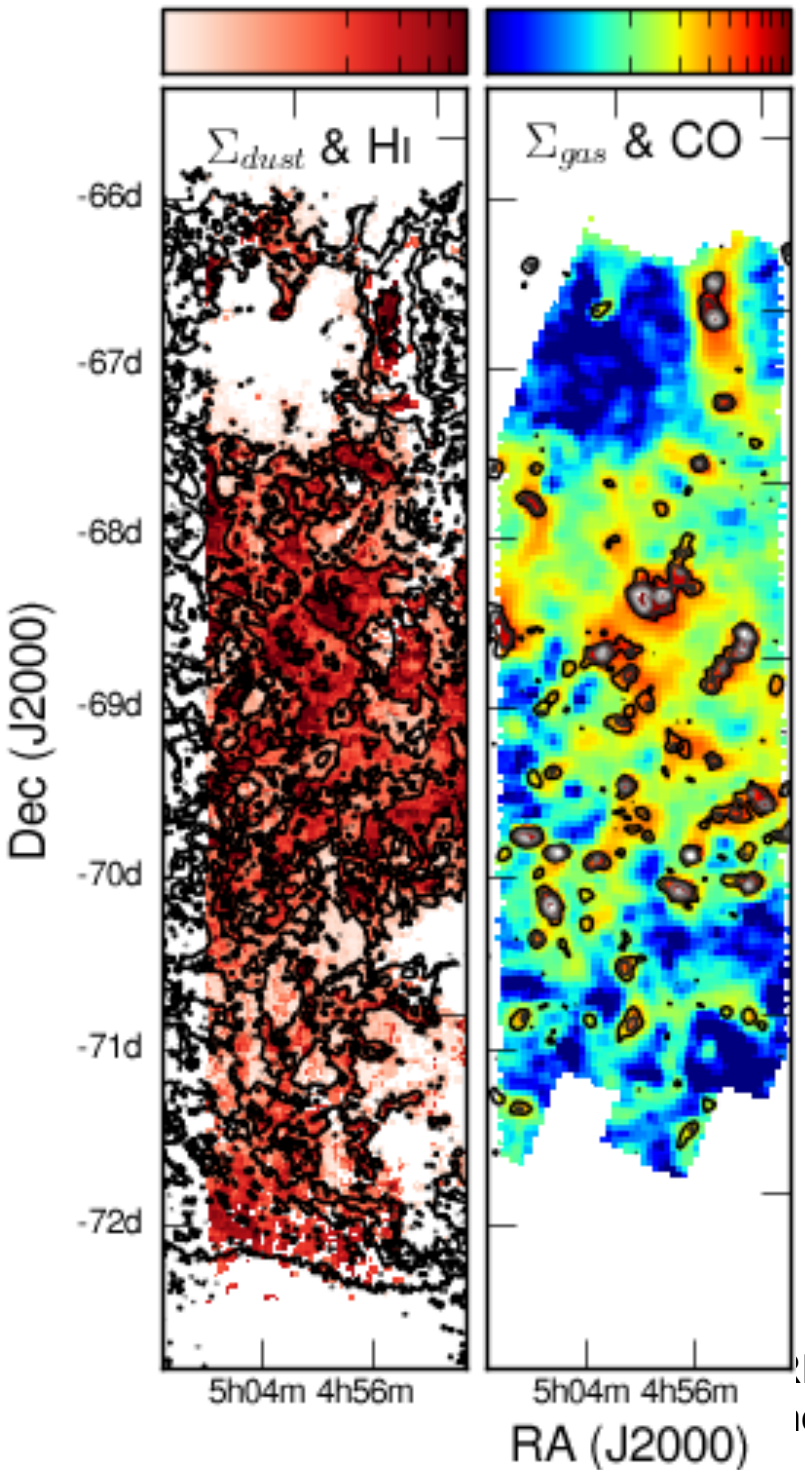
-Dust Mass Distribution,
Model 2 (LMC): Σ_{dust}=0-0.255 $M_{\odot}pc^{-2}$
red scale, (see also Bernard et al. talk)

-HI gas contours, similar to dust,
see talk by Kim et al. Session A3:



HERITAGE - First Results
Meixner & HERITAGE team

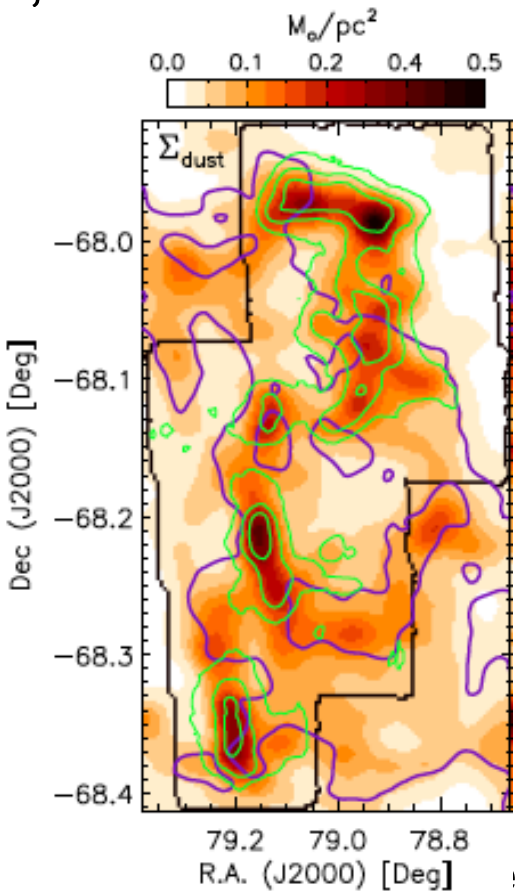
Meixner et al. 2010
Galliano et al. in prep.



Models and Analysis of SDP strip by pixel

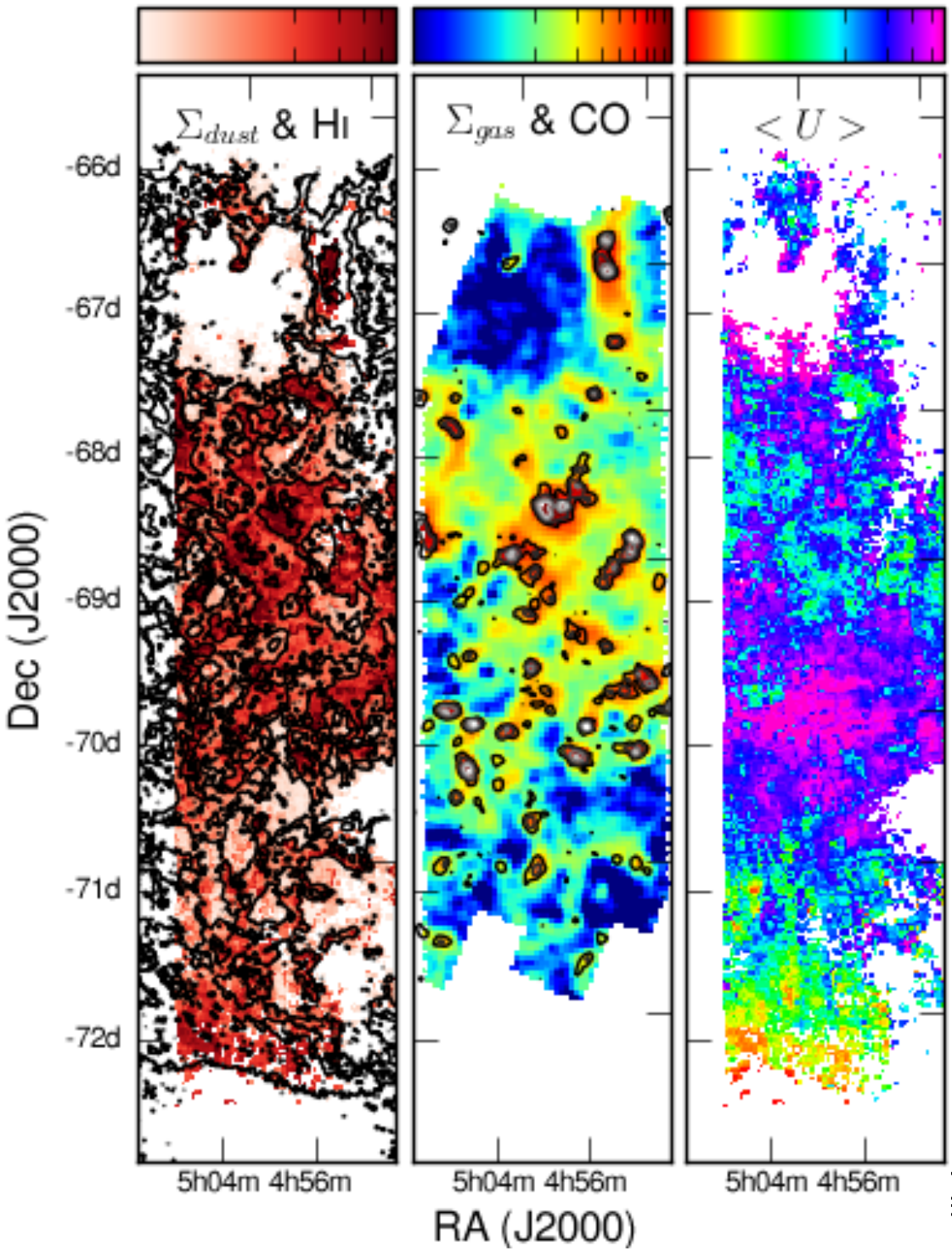
-Gas Mass Distribution,
Σ_{dust}=0-90 $M_{\odot}pc^{-2}$
color scale

-CO gas contours,
see poster by Roman-Duval et al., Poster Session 2



ITAGE - First Results
er & HERITAGE team

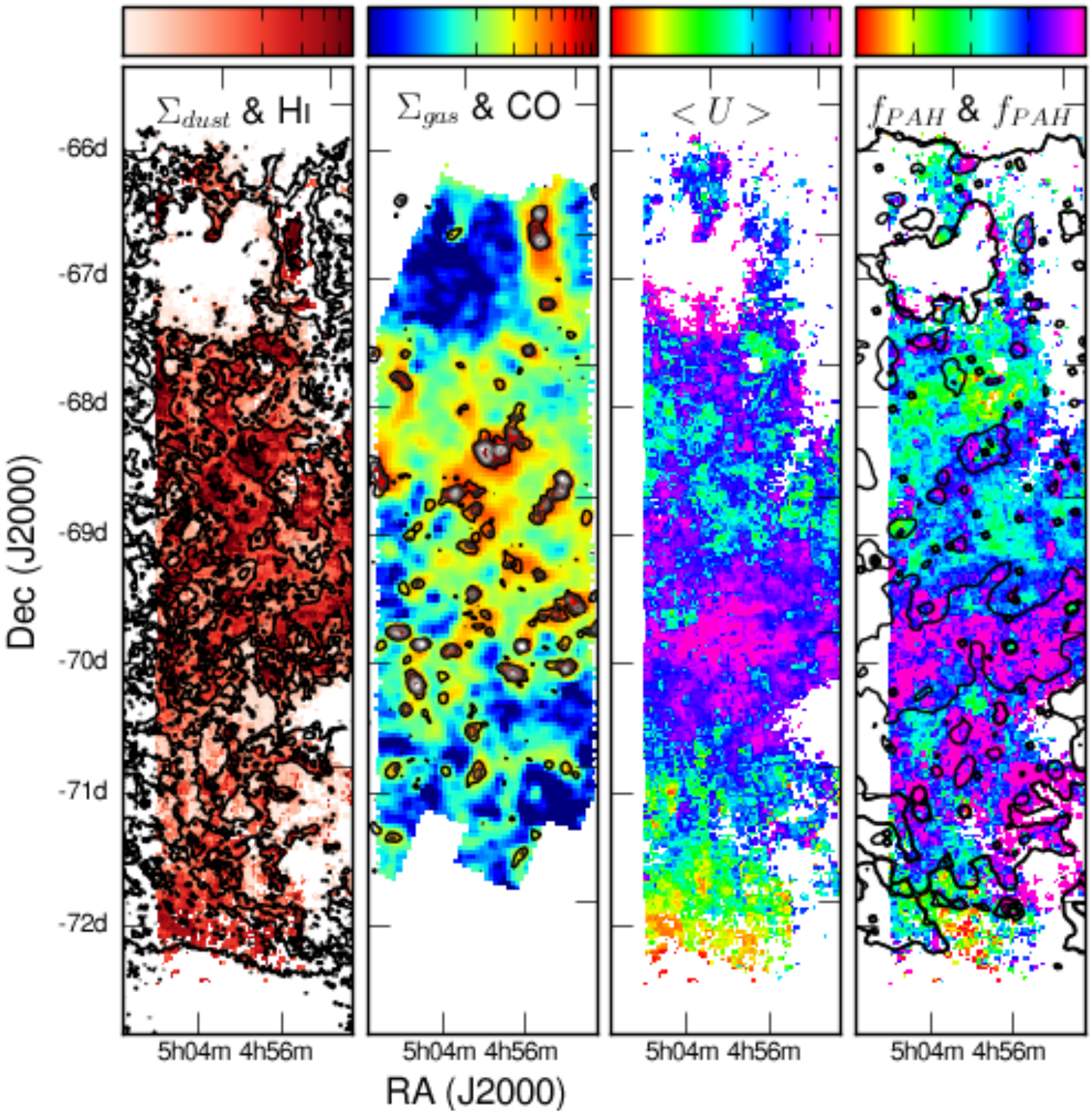
p.



Models and Analysis of SDP strip by pixel

-average starlight Intensity,
<U> or U_{avg}
Model 2: 0 - 20

Meixner et al. 2010
Galliano et al. in prep.

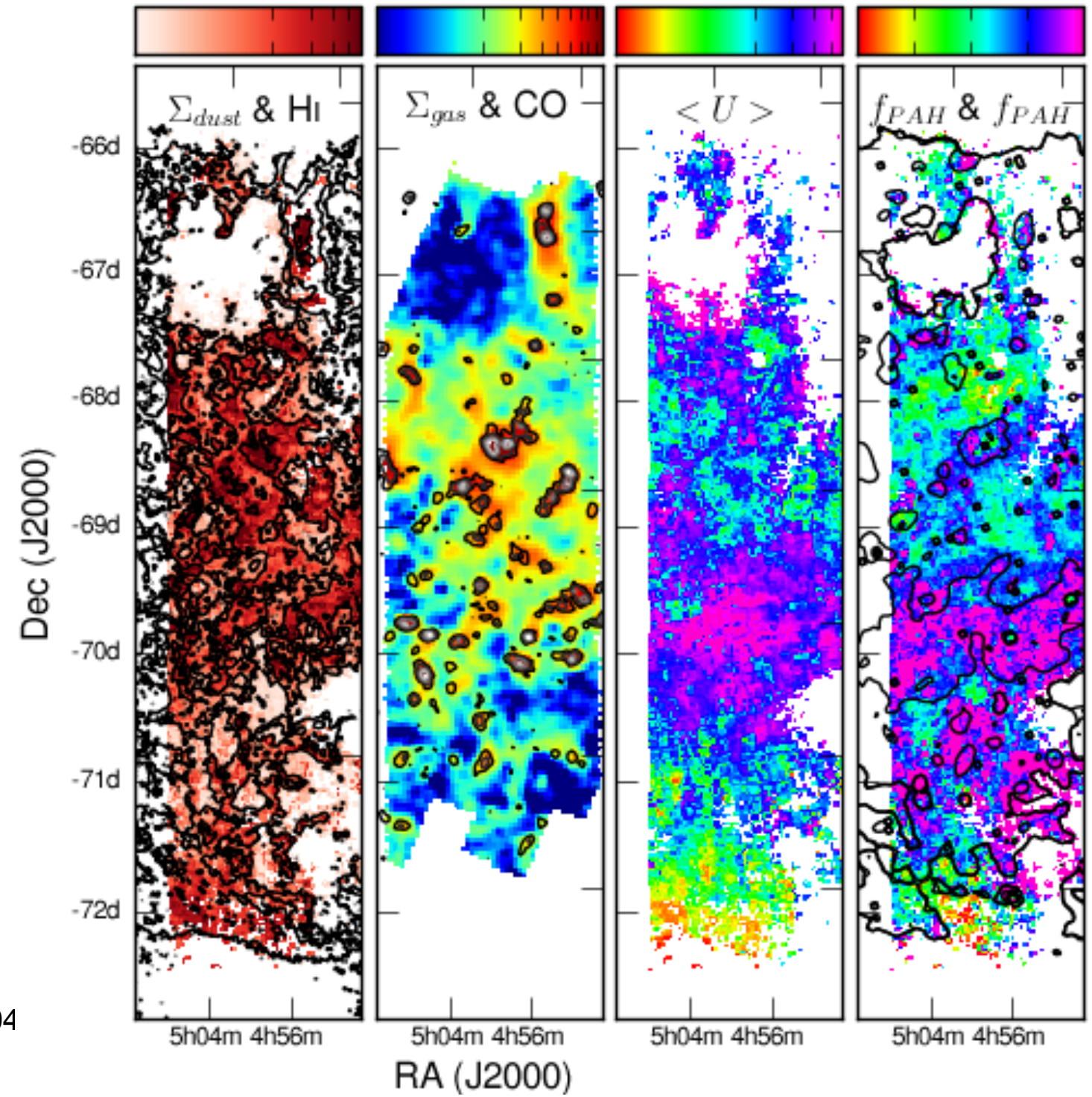


Models and Analysis of SDP strip by pixel

f_{PAH}:
Model 2: 0-0.8
Solar units
of 0.046

Contours:
Paradis et al. (2009)

Meixner et al. 2010
Galliano et al. in prep.


Σ_{dust} & HI
Σ_{gas} & CO
$< U >$
f_{PAH} & f_{PAH}
-66d
-67d
-68d
-69d
-70d
-71d
-72d
Dec (J2000)
5h04m 4h56m
5h04m 4h56m
5h04m 4h56m
5h04m 4h56m
RA (J2000)

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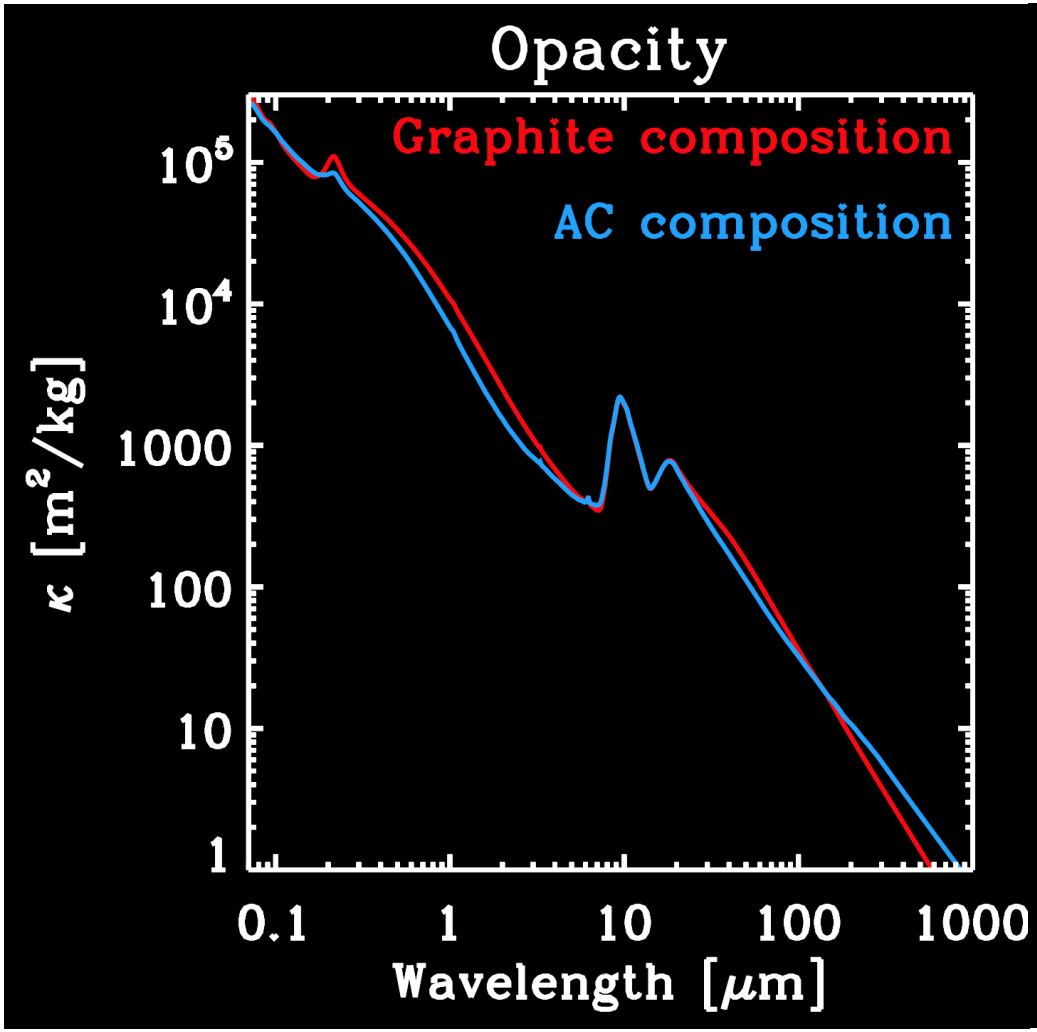
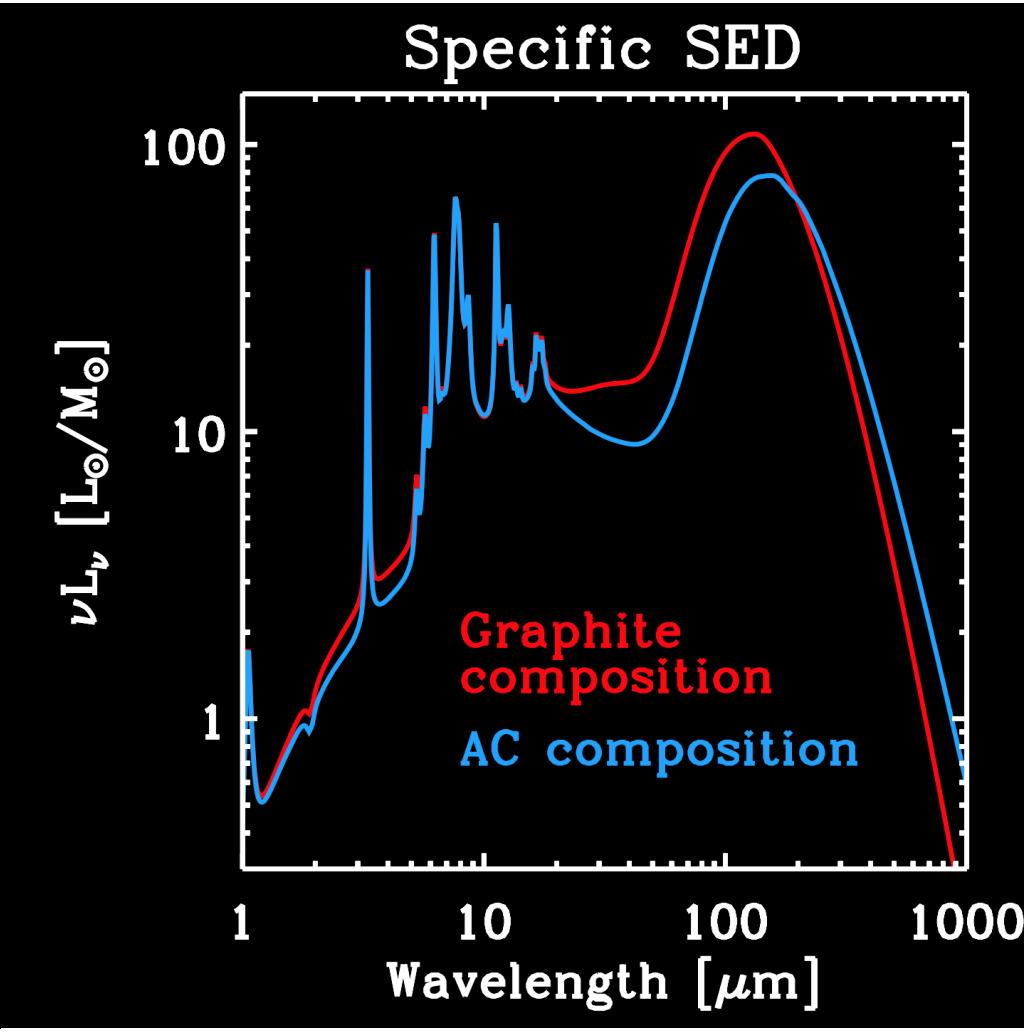
Submm emissivity, β	2	<2
U_{avg} (solar neigh.)	2 (+0.4, -0.5)	9 (+1.0, -1.3)
f_{PAH} (solar neigh.)	0.85	0.64
500 μm excess	17%	6%
M_{gas}/M_{dust} in strip	65 (+15, -18)	287 (+25, -42)

Compare: Galactic M_{gas}/M_{dust} is ~150, and LMC has less metals.

Meixner et al. 2010
Galliano et al. in prep.

=> There is too much dust mass: the new SPIRE observations allow us to show that the LMC is dominated by grains with non standard submm emissivity (ß<2).





In general, amorphous carbons (AC):

✓ are more transparent => need higher U to reach a given T;

✓ have a flatter submm slope (ß≈1) => account for submm emission with less mass.

HERITAGE SDP Results Summary

- Data produces results in all three areas of science goals: ISM, evolved stars and YSOs
- Gas-to-dust mass ratios indicate that dust in the LMC is different than Galaxy: lower emissivity ($\beta<2$) in submm is required
- Result agrees with Bernard/Gordon et al 2010; and Aguirre et al. (2003)
- Confirm excess of PAH dust in LMC bar

Thank You to the Herschel Mission Observatory Staff & Instrument teams

- Merci
- Gracias
- Grazie
- Dank u
- Vielen Dank

- For all their hard work to provide us with the opportunity for the longest wavelengths