# Low Metallicity Dwarf Galaxies: Bridging the Gap Between the Local Universe and Primordial Galaxies

★ First Results from Herschel ★

*The SPIRE Local Galaxies Working Group (SAG 2)*

*Presented by Suzanne Madden, CEA Saclay, France*

# Outline

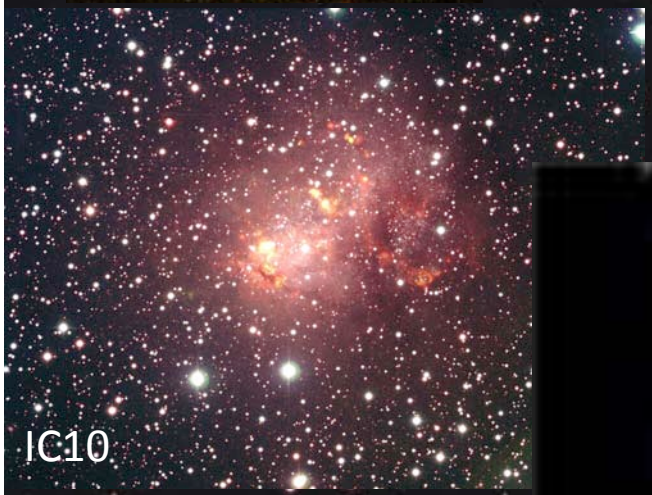
- Goals of the dwarf galaxy survey
- First Results:  PACS & SPIRE Maps & preliminary SEDs
  - NGC 1705
  - NGC 6822
  - IIZw 40
- First results from PACS spectroscopy in dwarfs
  - He 2-10 (from SHINING – PACS GT)

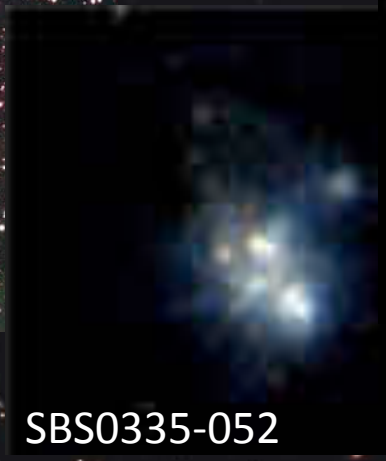
# Zoo of dwarf galaxies in the local universe


NGC 1705


NGC 6822


IZw18


IC10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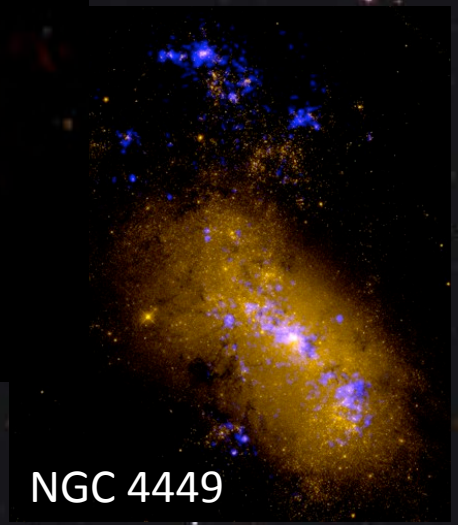
NGC 5253


NGC 4449

# The Dwarf Galaxy Survey - Science

1. Nearby dust-poor laboratories - Low metallicity. Conditions similar to early universe galaxies

2. Dwarf galaxies (as low as 1/50 Zsolar), as labs to study of the evolution of the dust and gas properties

3. Effects of less metals on star formation process.
   Dust enrichment in primeval environments <----> essential for enhancement of SF activity

4. How much star formation activity is actually hidden even in dust-poor environments?

5. What galactic properties and processes control the dust and gas evolution? How are ISM structure, star formation activity and metallicity related ?

*Requires a cohesive program of SPIRE & PACS FIR/submm photometry and spectroscopy; other complementary data*

# The Dwarf Galaxy Survey – Strategy

Well sampled Spectral Energy Distributions (SEDs) =>

- *Mapping of all PACS & SPIRE bands + Spitzer MIPS + IRAC*

Diagnostic tracers of HII regions, PDRs, Diffuse Ionised Medium =>

- *PACS spectroscopy + Spitzer IRS*

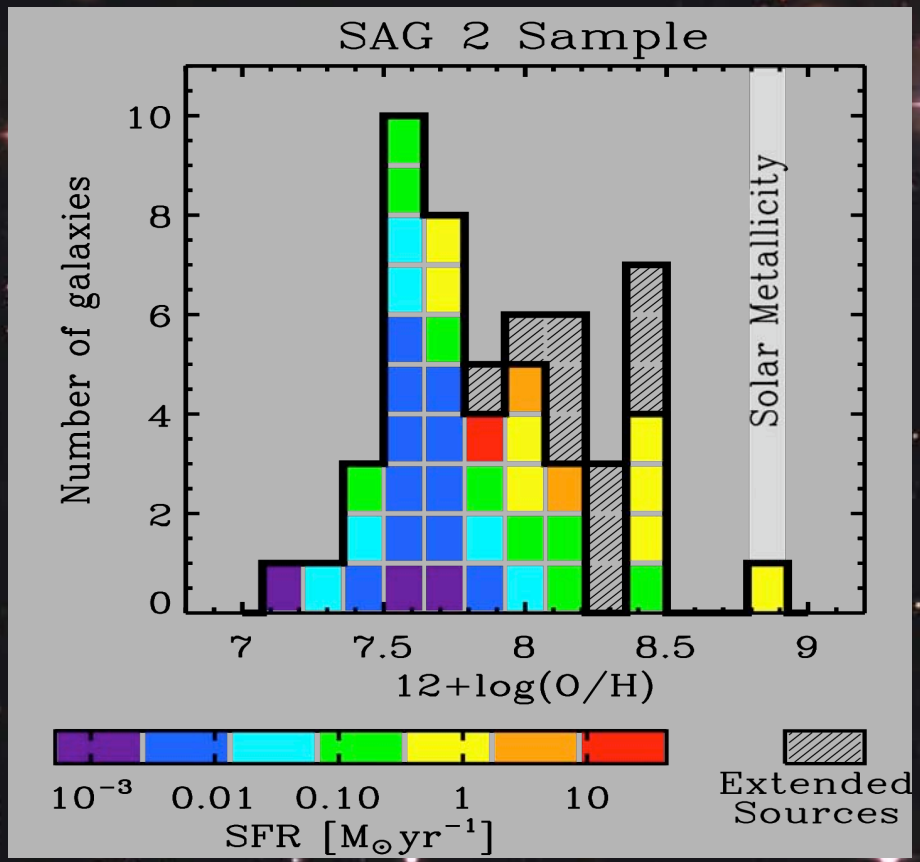
[CII] 158 μm Most important cooling lines of the atomic gas.
[OI] 63 μm Probes the conditions in PDRs - the largest fraction
[OI] 145 μm of the neutral medium in a galaxy.

[NII] 122 μm
[NII] 205 μm
[NIII] 57 μm
[OIII] 88 μm

Conditions in the ionized medium. Diagnostics of absolute level and excitation of star forming ) activity and of $n_e$ @ low density (< $10^3$ $cm^{-3}$) DIM

***Abundances*** ***i.e. [NIII]/[OIII]***
***Densities*** ***i.e. [NII], [OIII], [SIII] line pairs***
***Gas pressure*** ***i.e. [OI] pairs***
***UV hardness & intensity*** ***[NII]/[NIII]. [SIII]/[OIII] pairs***
***ISM filling factor***

# The Dwarf Galaxy Survey - Targets




55 galaxies: statistical information in most metallicity bins

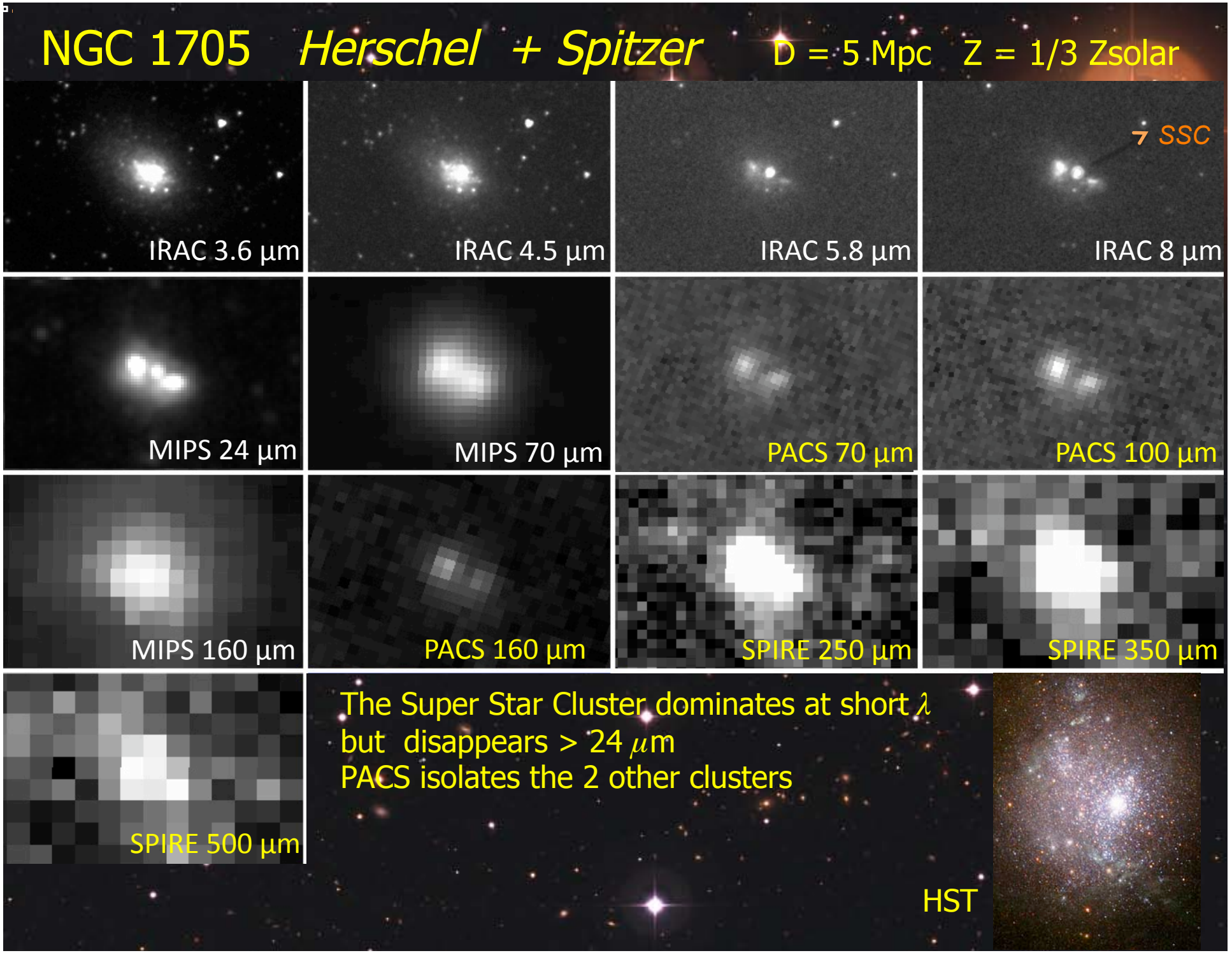
All sources observed with all 3 Spitzer instruments

*Source Selection*

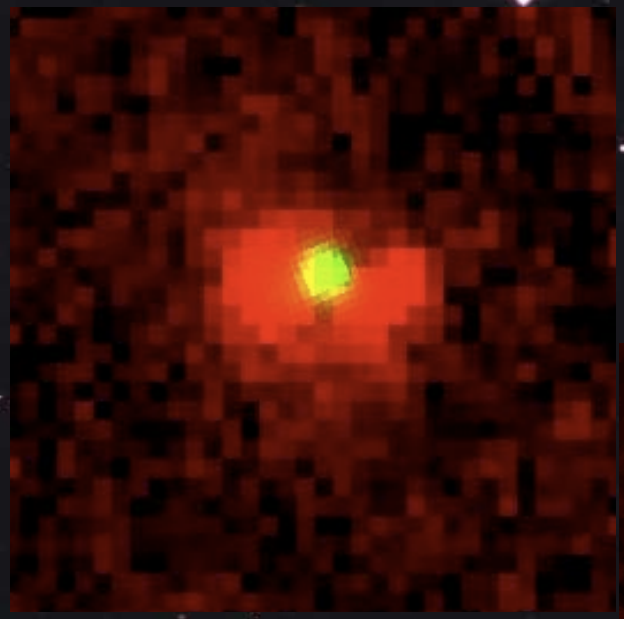
Fill metallicity bins:
~ 5 to 9 galaxies in
7 bins where possible

Extremely low metallicity galaxies: 1/50 to 1/20

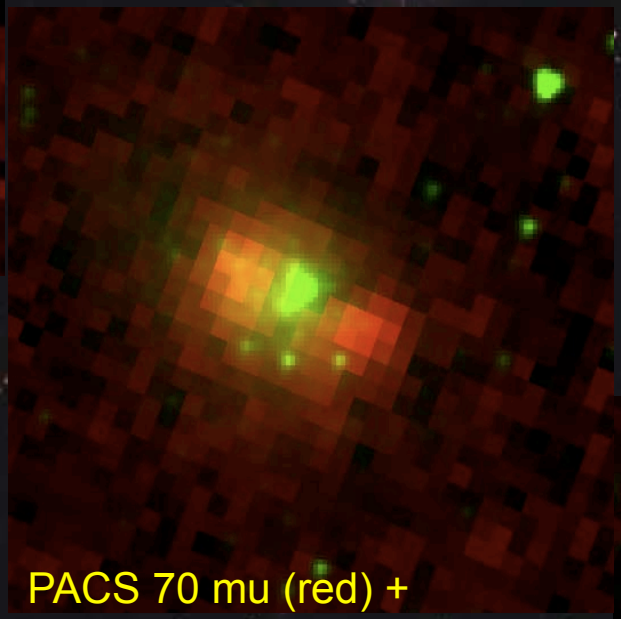
The well-known extended galaxies of the local group


NGC 1705 Herschel + Spitzer
D = 5 Mpc Z = 1/3 Zsolar
SSC
IRAC 3.6 µm
IRAC 4.5 µm
IRAC 5.8 µm
IRAC 8 µm
MIPS 24 µm
MIPS 70 µm
PACS 70 µm
PACS 100 µm
MIPS 160 µm
PACS 160 µm
SPIRE 250 µm
SPIRE 350 µm
SPIRE 500 µm
The Super Star Cluster dominates at short λ
but disappears > 24 µm
PACS isolates the 2 other clusters
HST

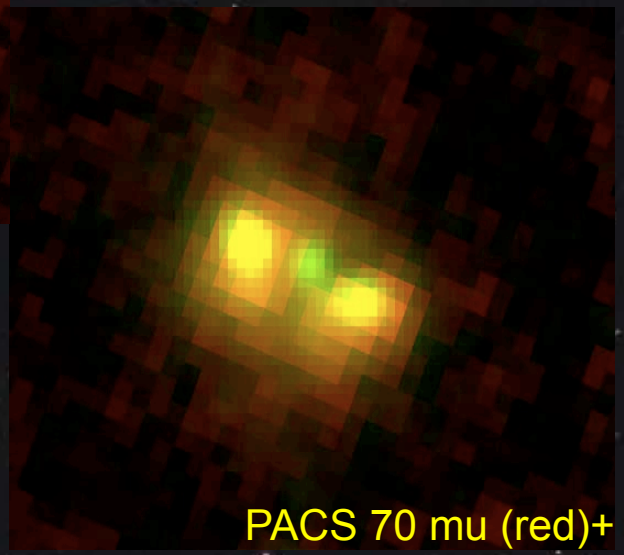
# NGC 1705



PACS 70mu (red)+
GALEX FUV (green)



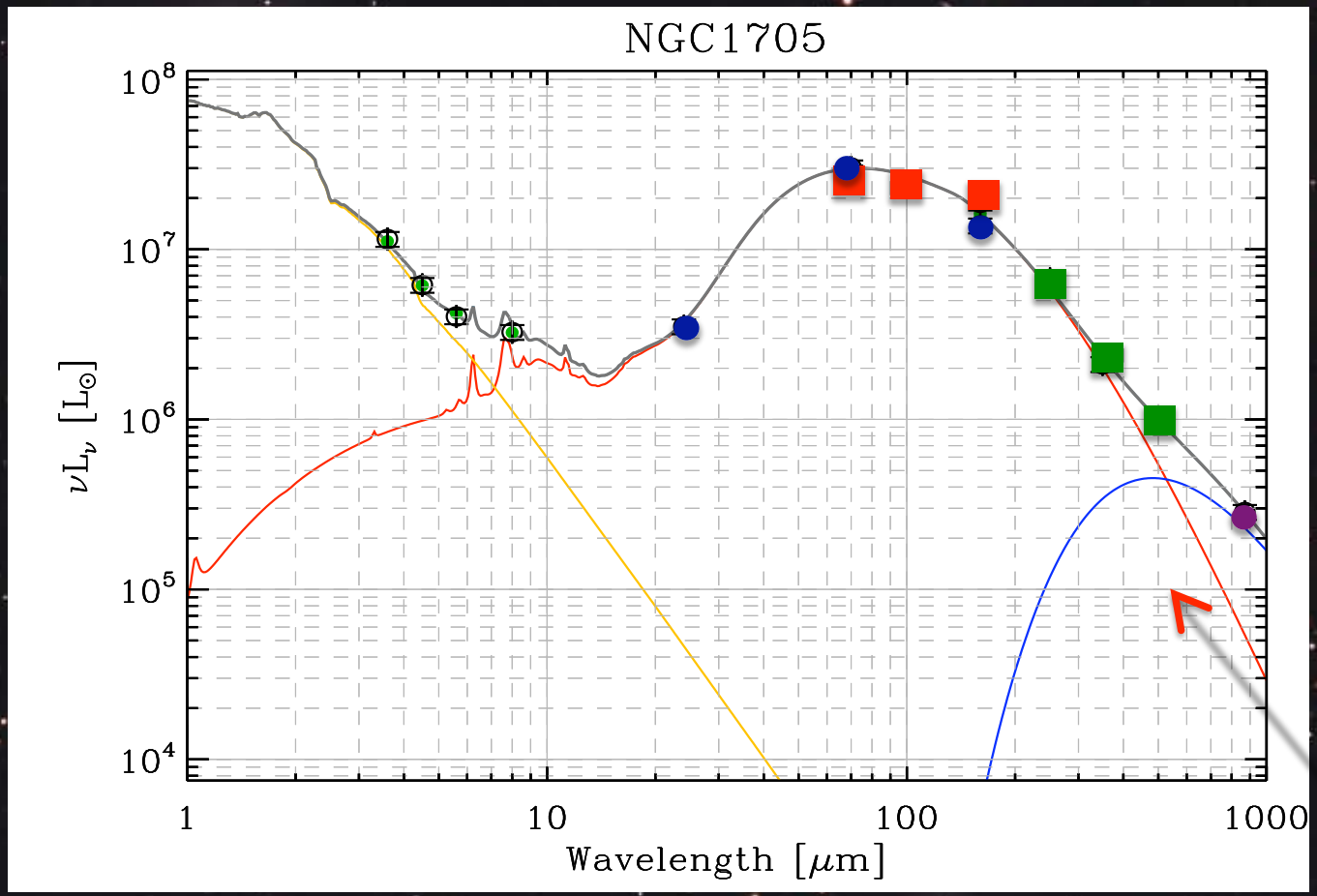
PACS 70 mu (red) +
IRAC 3 mu (green)



PACS 70 mu (red)+
MIPS 24 mu (green)

# NGC 1705 – *preliminary* global SED

*IRAC + MIPS + PACS + SPIRE + Laboca 870 mu*




MIPS

PACS

SPIRE

LABOCA

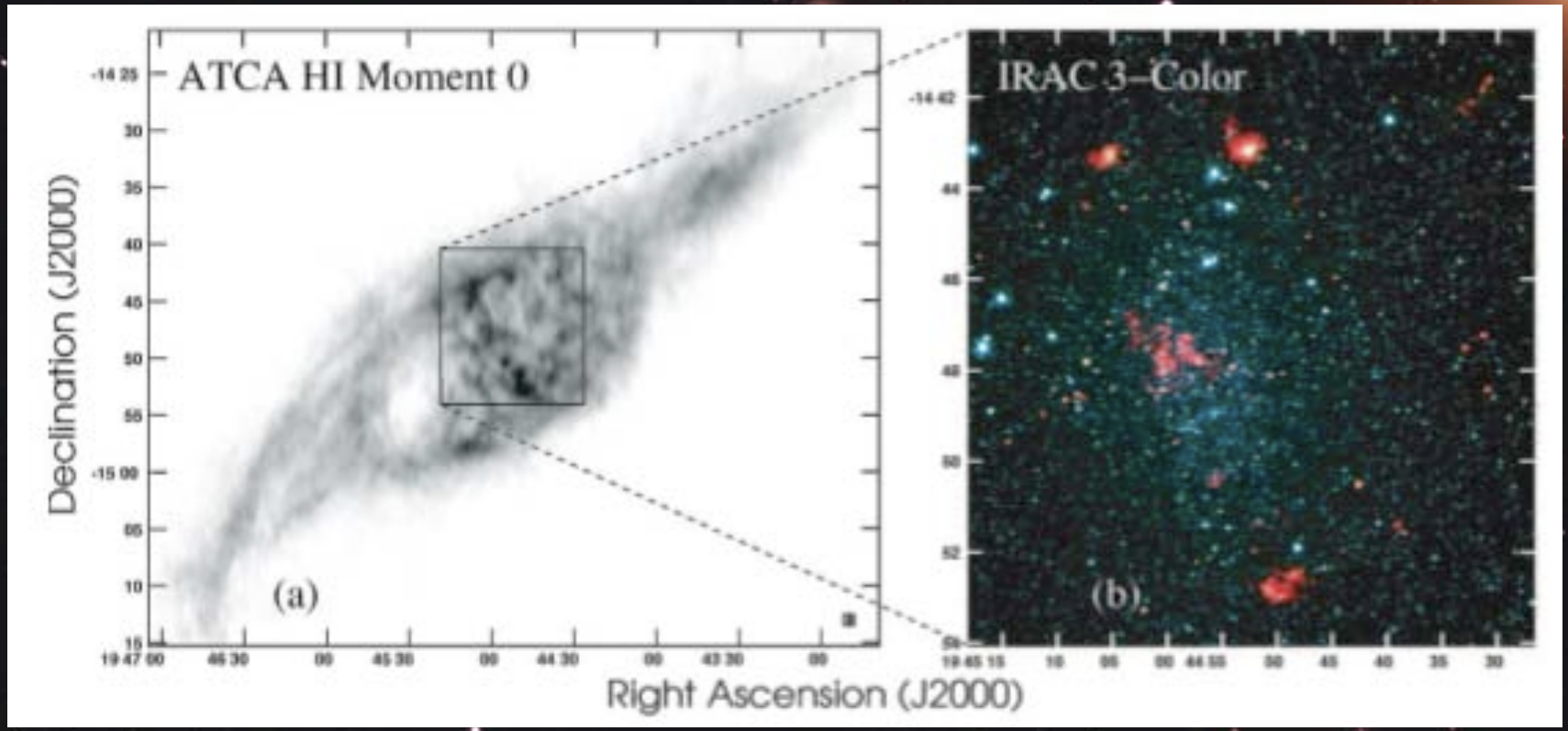
Very cold dust component:

T dust ~ 6 K

$\beta$ = 1.0

SED model based on Galliano et al 2008 & Galametz et al 2009

# NGC 6822




*Cannon et al 2006*

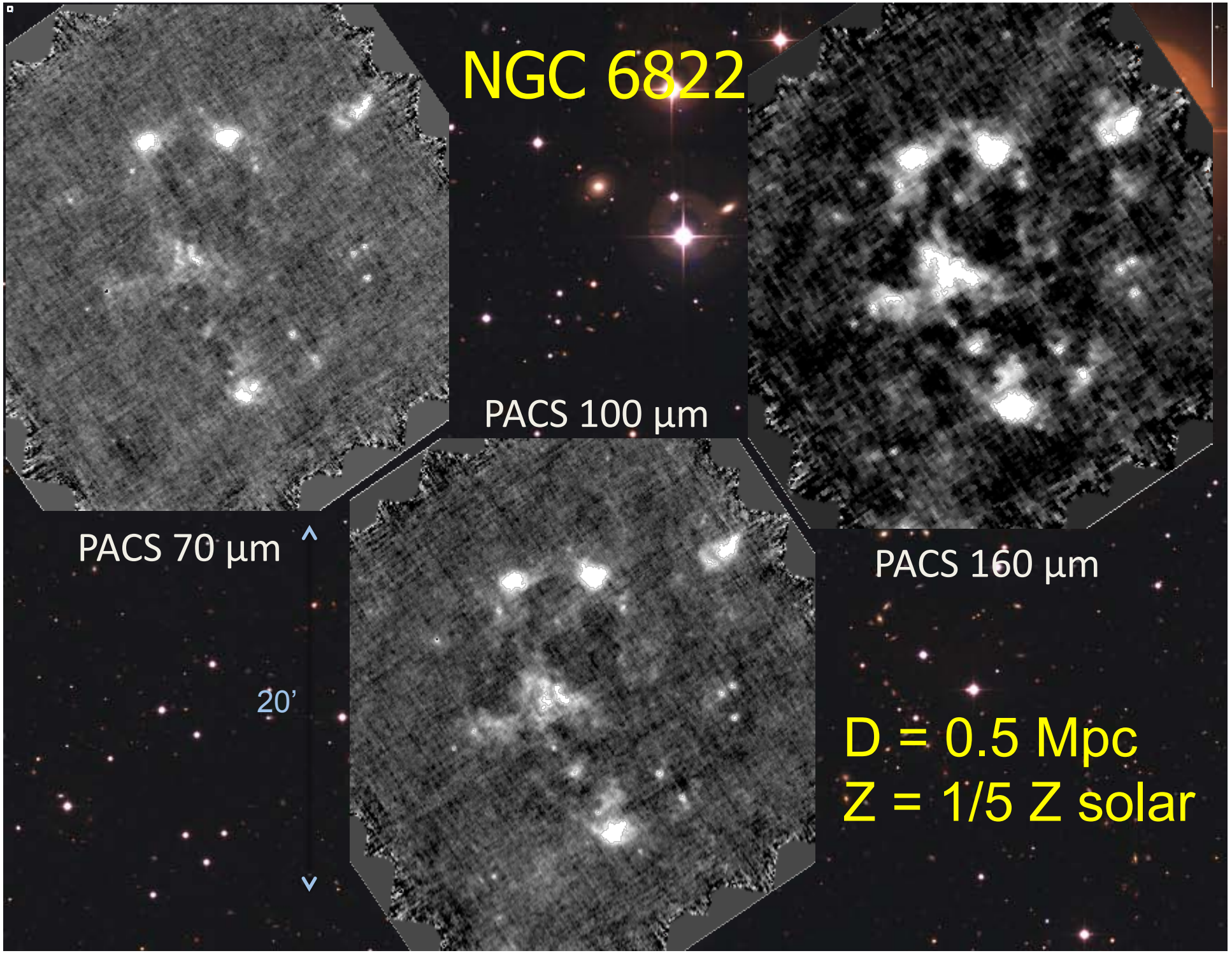
## Atomic gas: 1.3 degrees

All the star formation activity

Confined to 20’ region

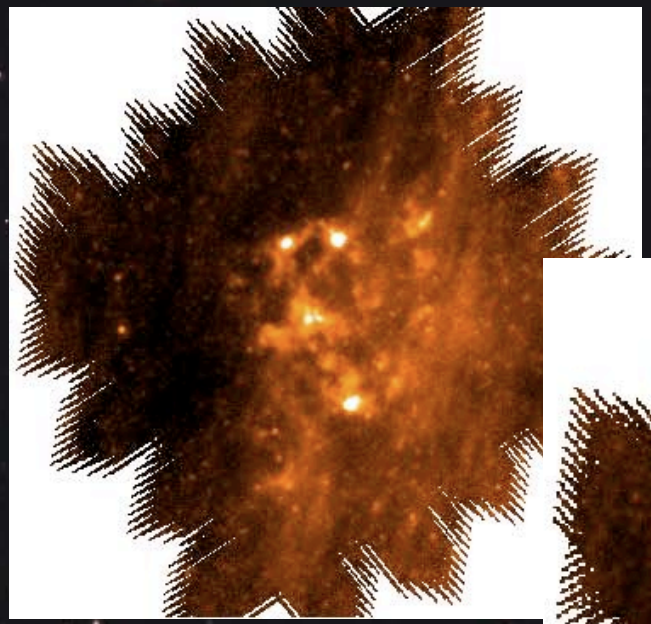
D = 0.5 Mpc

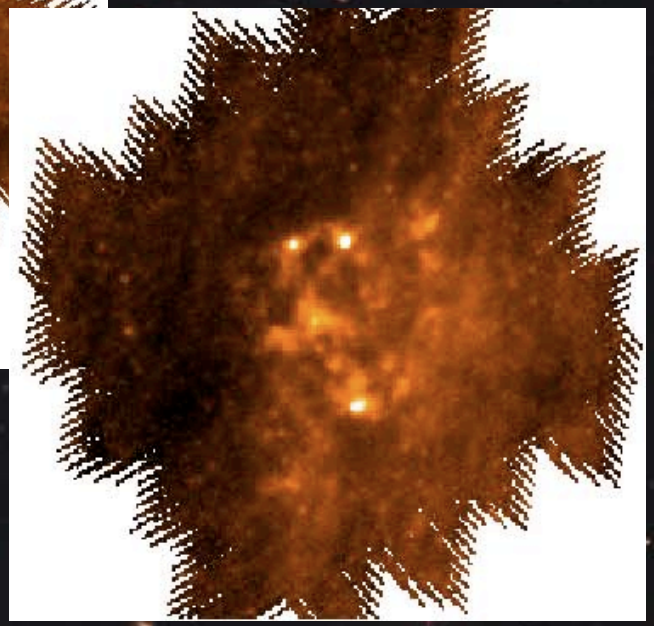
Z = 1/5 Z solar


NGC 6822
PACS 100 µm
PACS 70 µm
PACS 160 µm
20’
D = 0.5 Mpc
Z = 1/5 Z solar

# NGC 6822

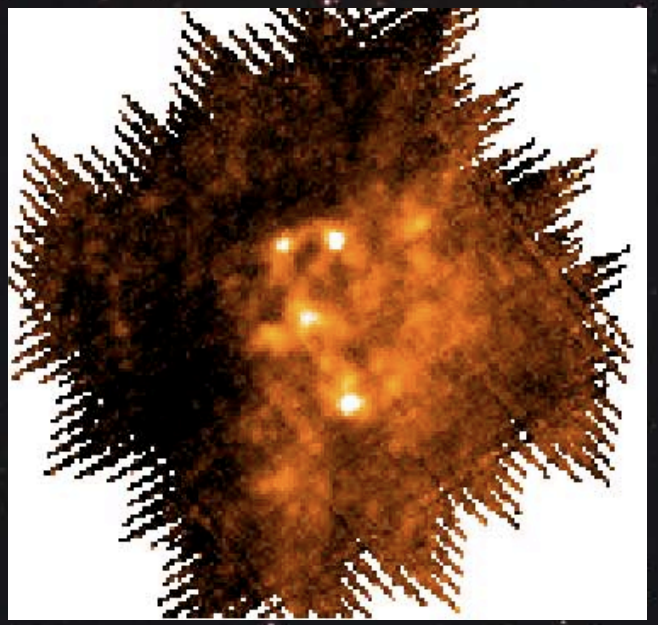
SPIRE 250 μm





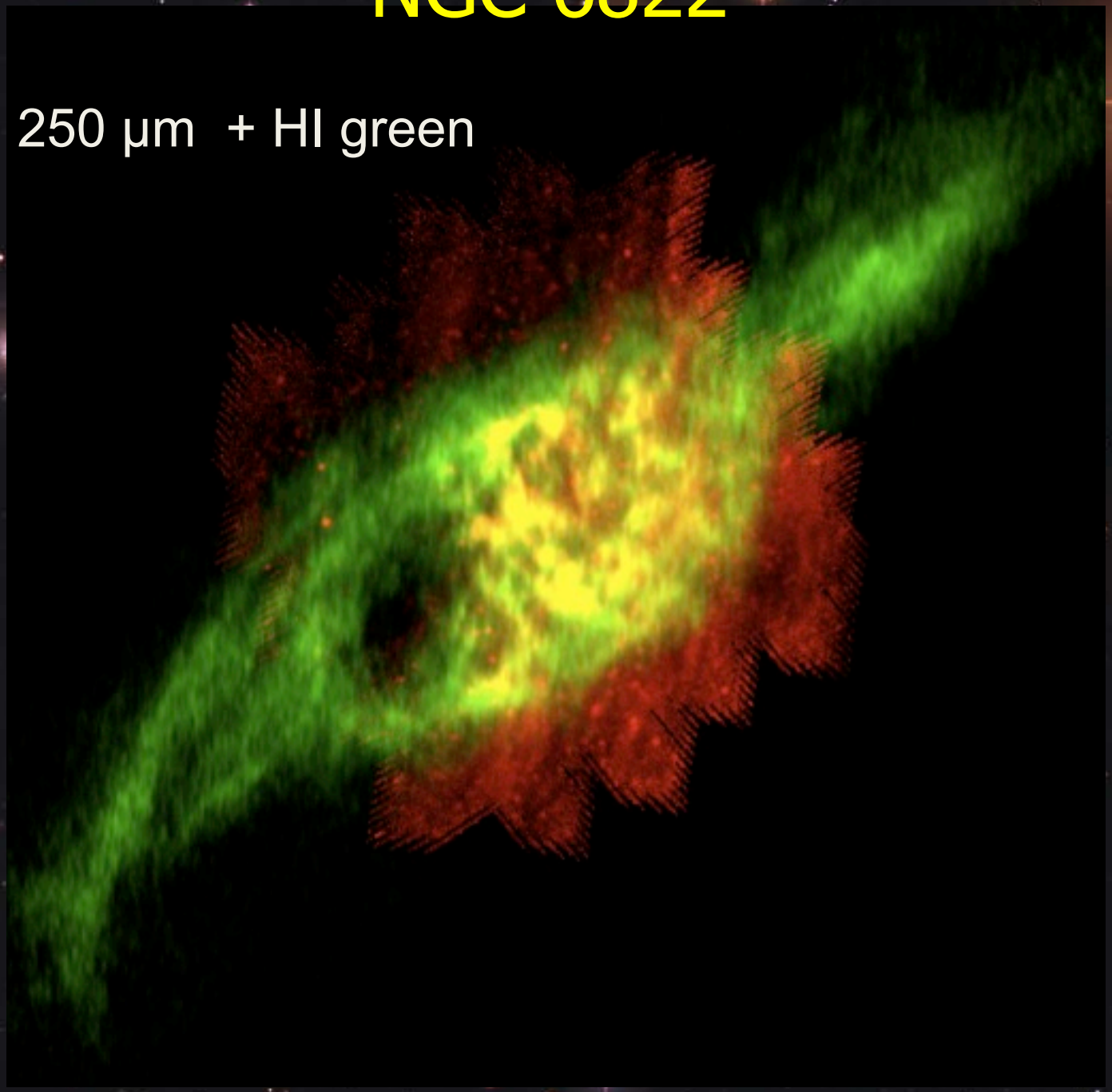
SPIRE 350 μm

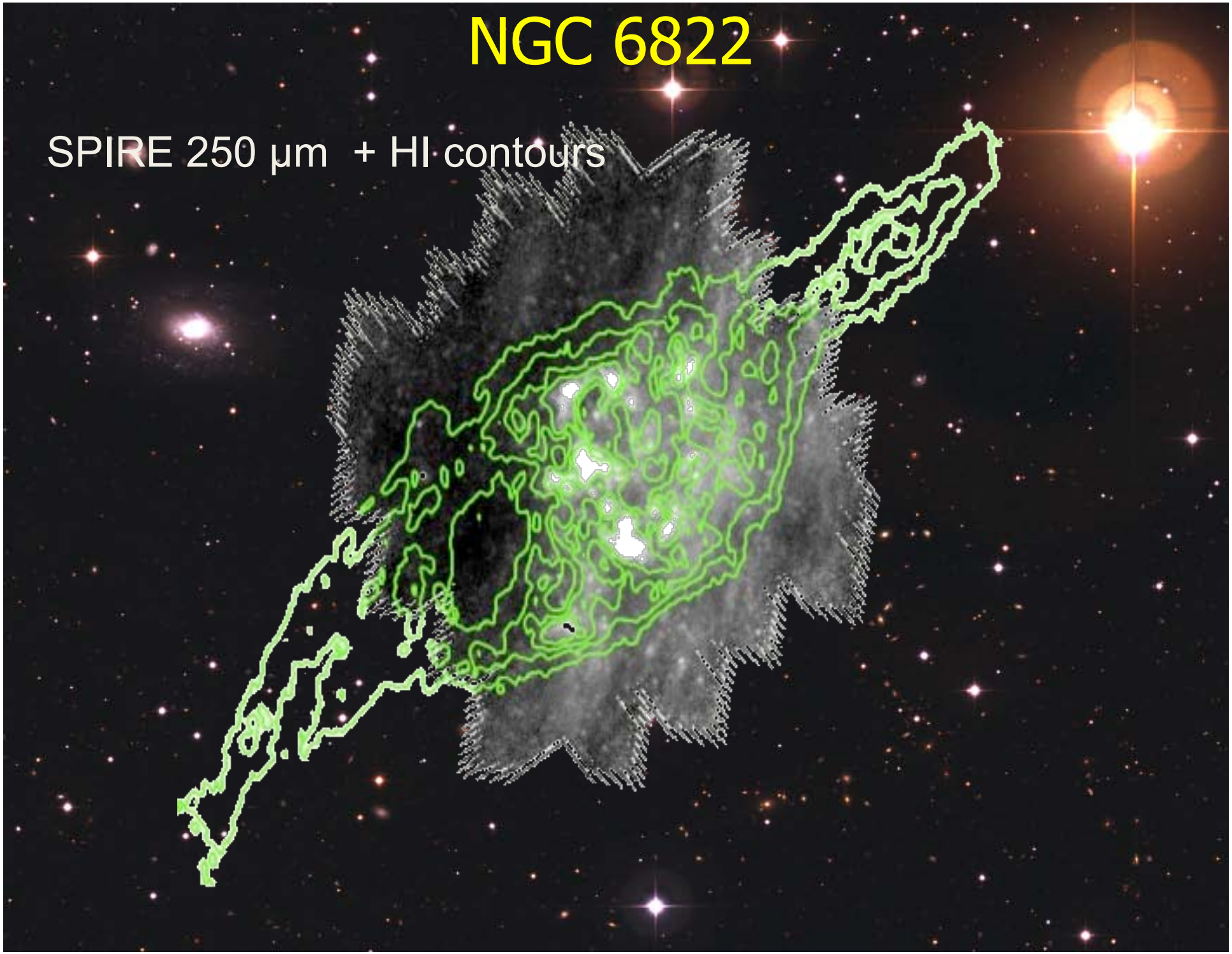
SPIRE 500 μm



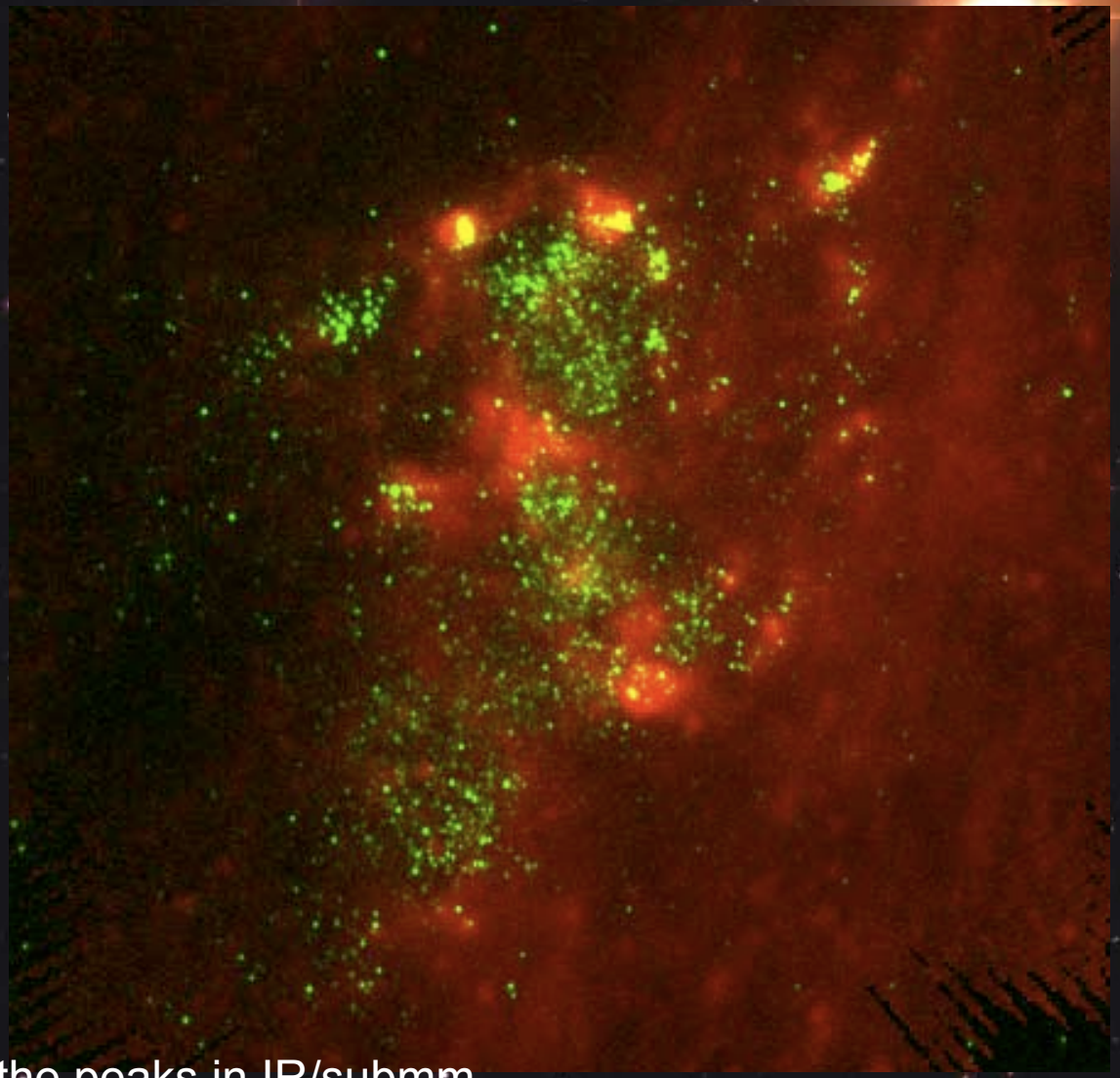
# NGC 6822

SPIRE 250 μm + HI green




NGC 6822
SPIRE 250 μm + HI contours

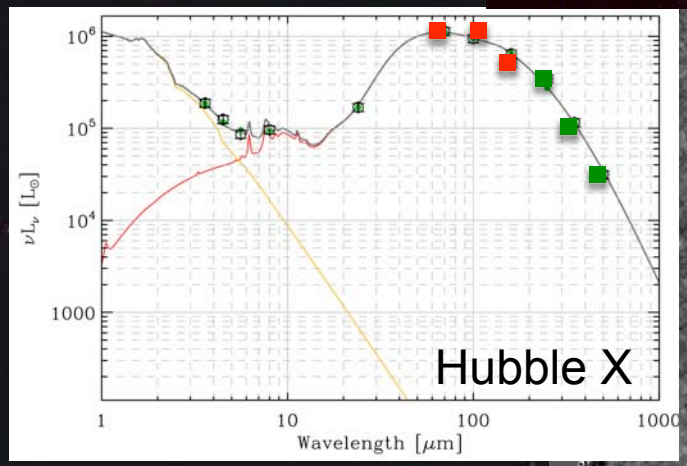
# NGC 6822

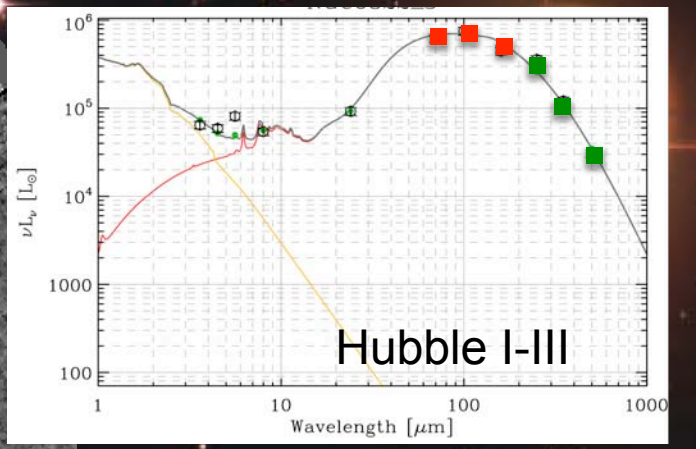


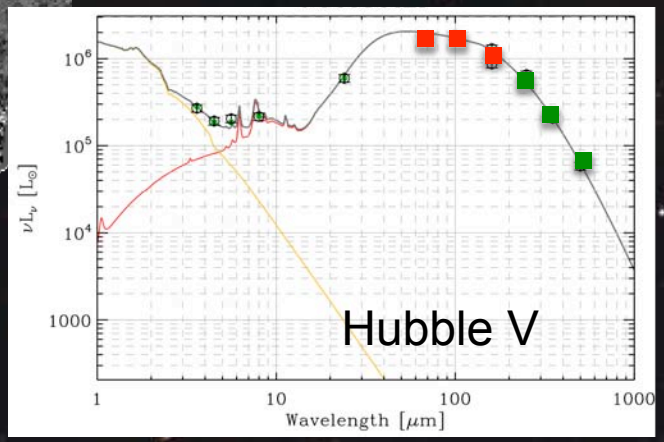
SPIRE 250 µm (red)
GALEX FUV (green)

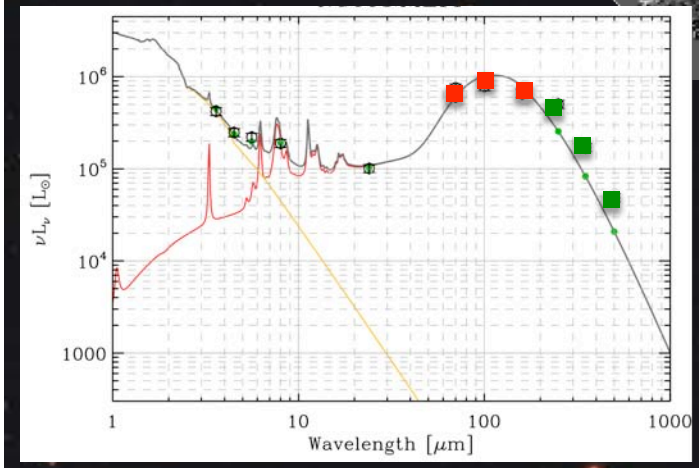
FUV corresponds to the peaks in IR/submm
FUV fills in submm holes Age effect?

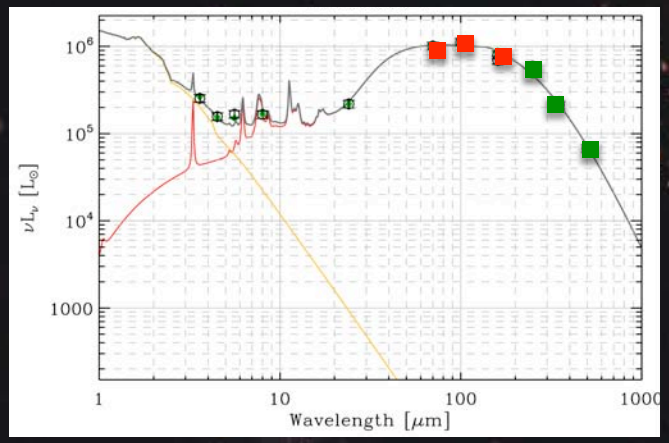
# NGC 6822; Preliminary SEDs of star clusters



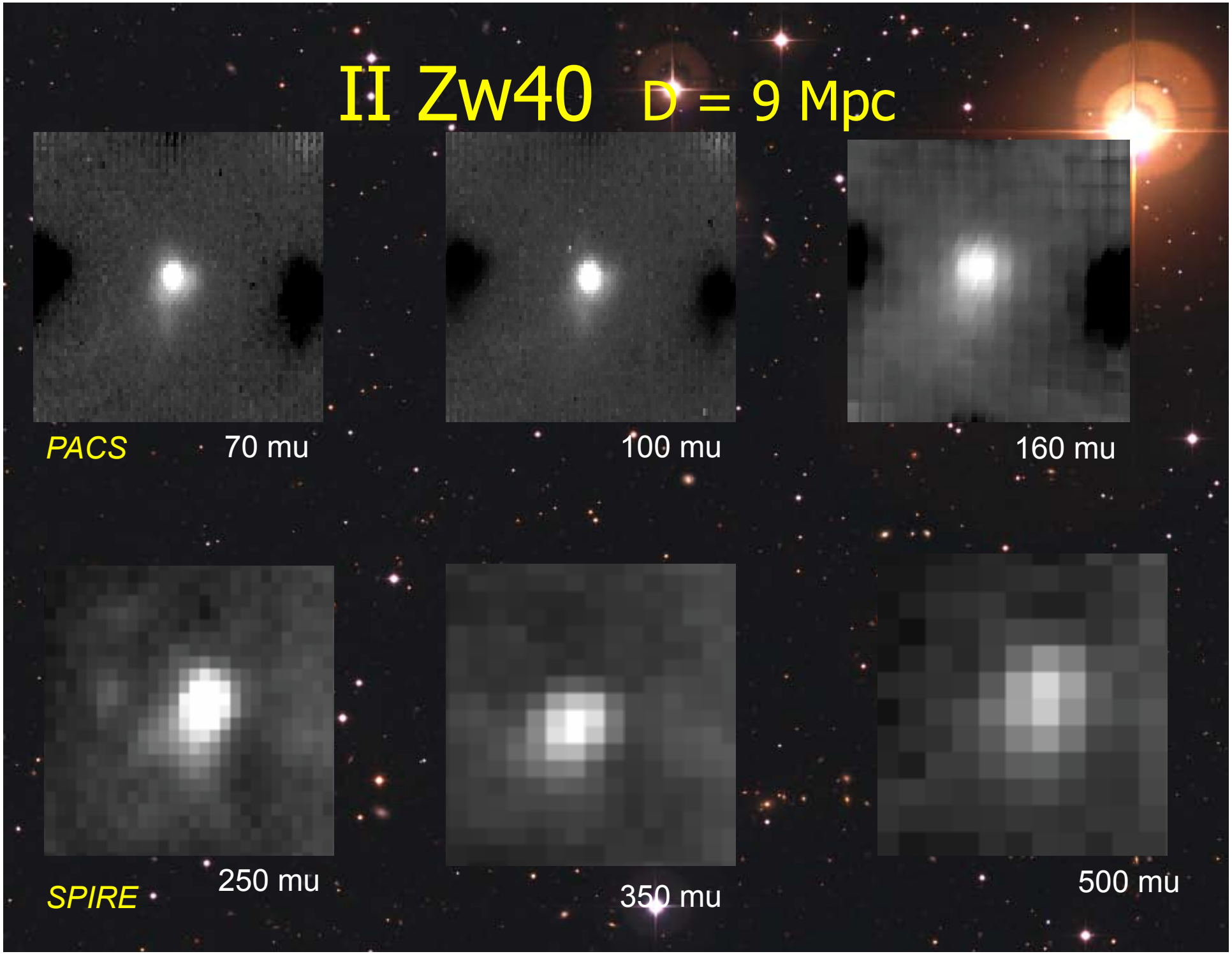



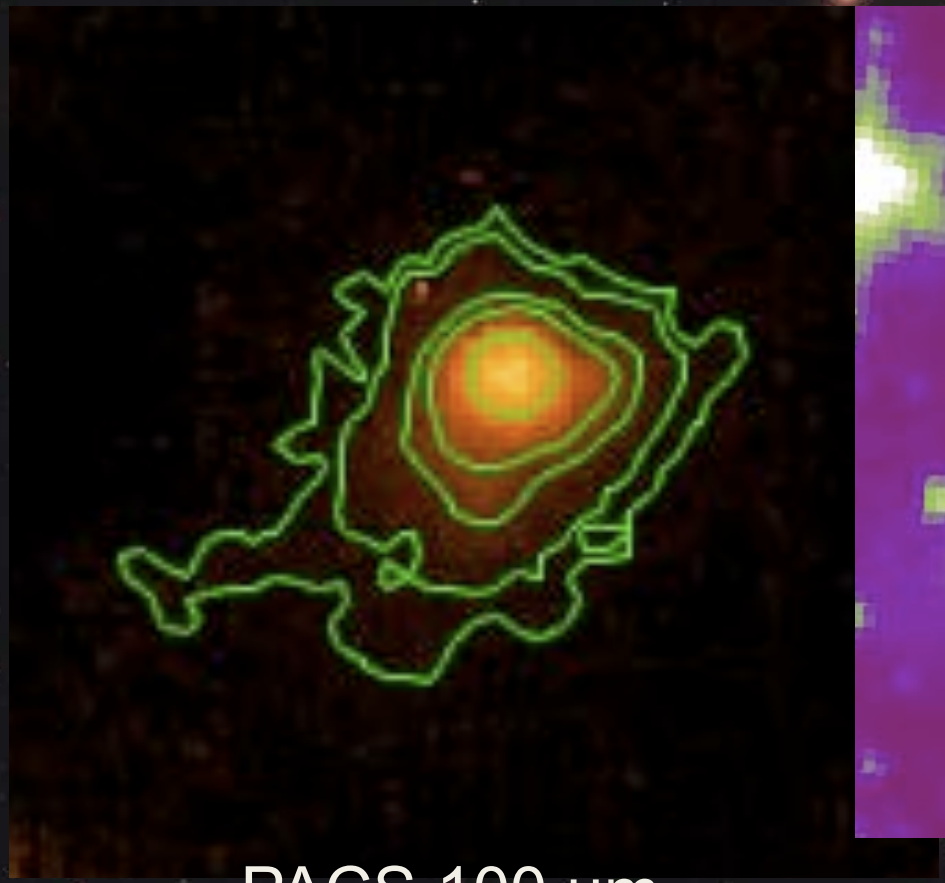




PACS

SPIRE


II Zw40 D = 9 Mpc
PACS
70 mu
100 mu
160 mu
SPIRE
250 mu
350 mu
500 mu

# II Zw40



PACS 100 μm
(image & contours)

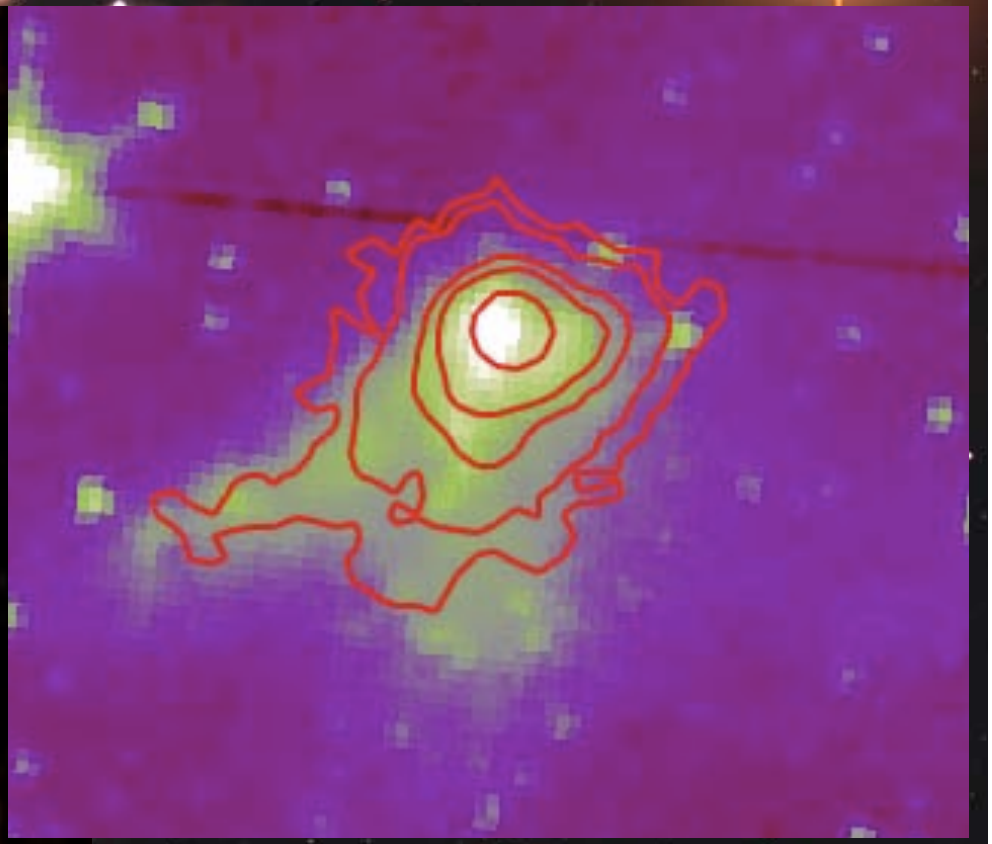
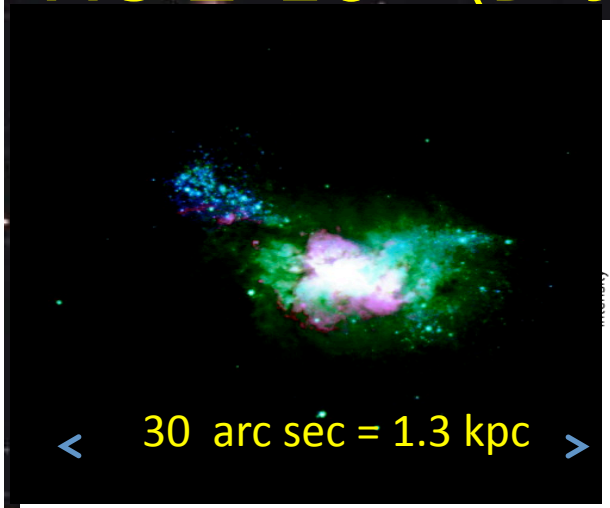
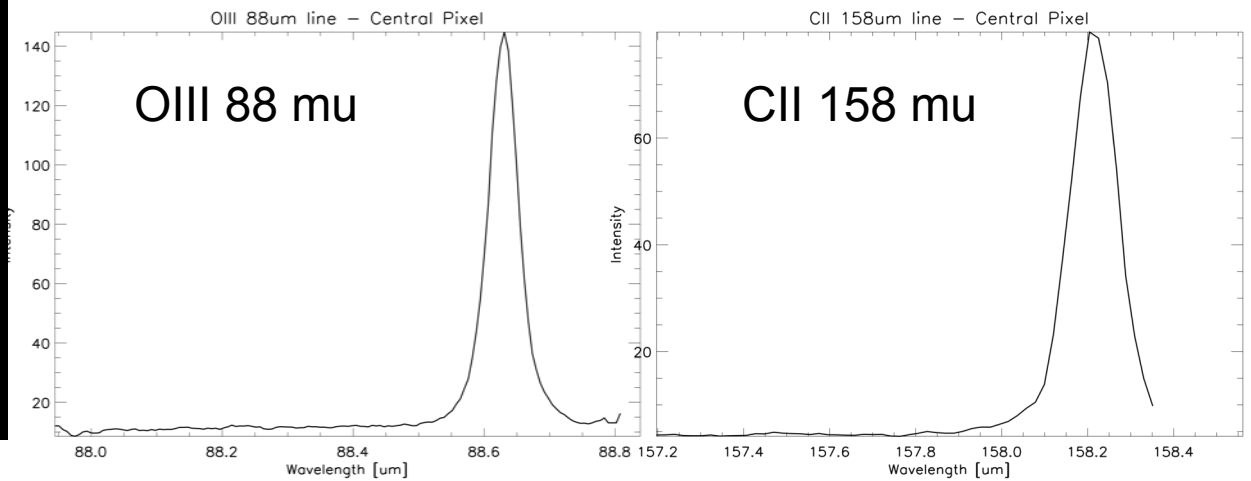


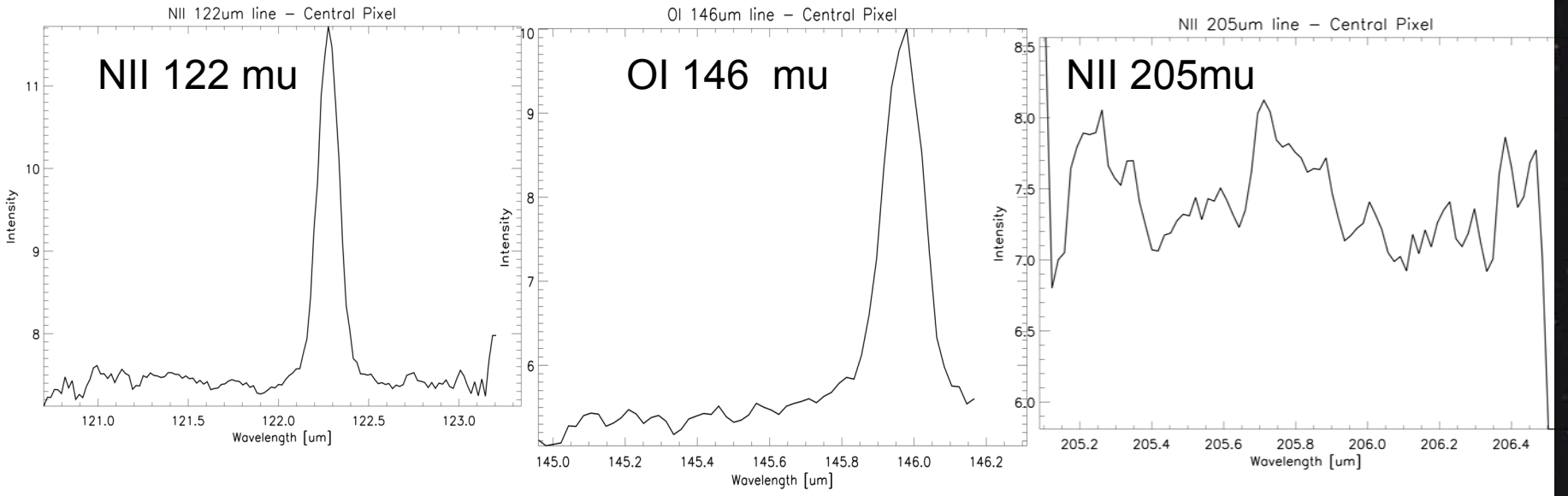
Image: IRAC 3.6 μm
Contours: PACS 100 μm

D = 10 Mpc  Z = ¼ Zsolar

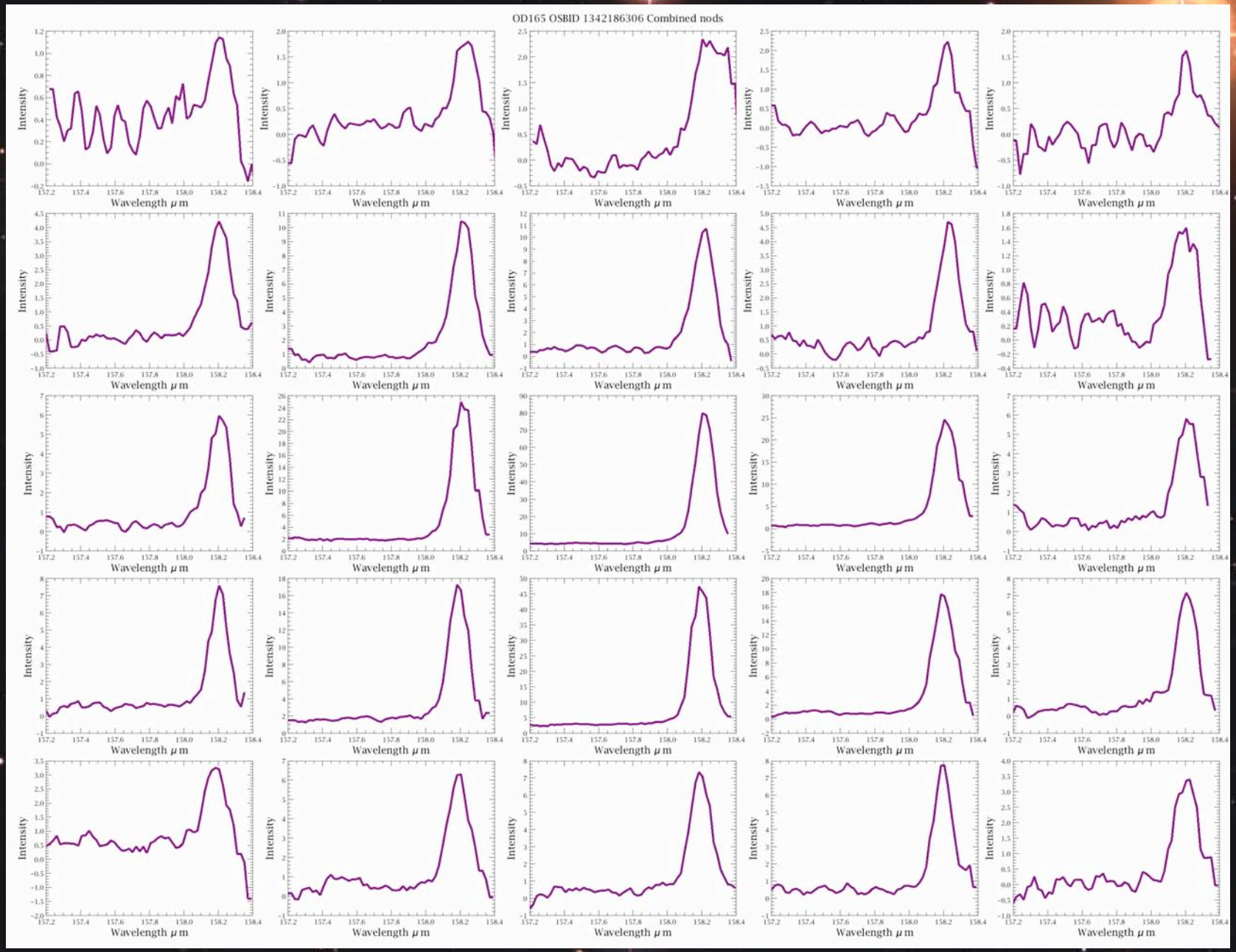
# Spectroscopy Dwarf Galaxies (SHINING)
# He 2-10 (D=9 Mpc)_



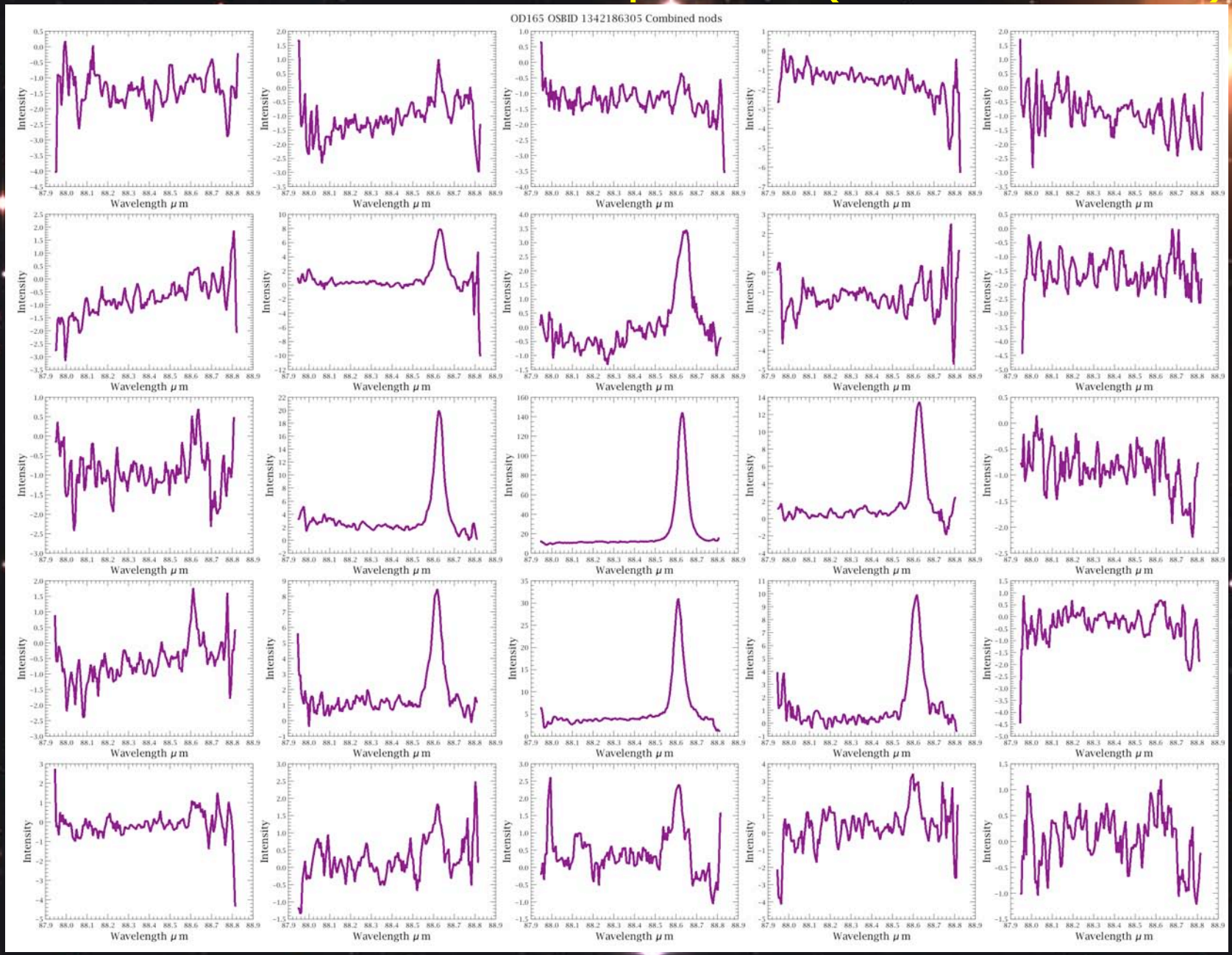



# He 2-10 CII 158 mu chop-nod (SHINING GTKP)



# He 2-10 OIII 88mu chop-nod (SHINING GTKP)



# Conclusion (or rather, the beginning)

- The spatial resolution of Herschel photometry:
  - new opportunity for detailed analyses of *individual* SF regions in low metallicity galaxies.
- The sensitivity & mapping capability of PACS spectroscopy:
  - 7 strong FIR fine structure lines – will be powerful diagnostics.
  - CII line widely distributed throughout low metallicity galaxies; OIII surprisingly luminous throughout galaxies.
  - OIII/CII > 2 on galactic scale. *OIII may be a workhorse diagnostic for dwarf galaxies*
- Herschel is bringing *new promises for understanding the nature of the starforming regions within dwarf galaxies.*

# SPIRE Nearby Galaxies Science Working Group (SAG 2) members

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Institutes: UCL, Imperial College, Caltech, Marseille, IAC, Univ Cardiff, NASA Goddard, CEA, Univ Colorado, Univ Sussex, MSSL, IPAC, Padova, IAP, IFSI, Univ. Hertsfordshire, McMaster Univ. Observatory Strasbourg, Univ. Ghent, Univ Vienna

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