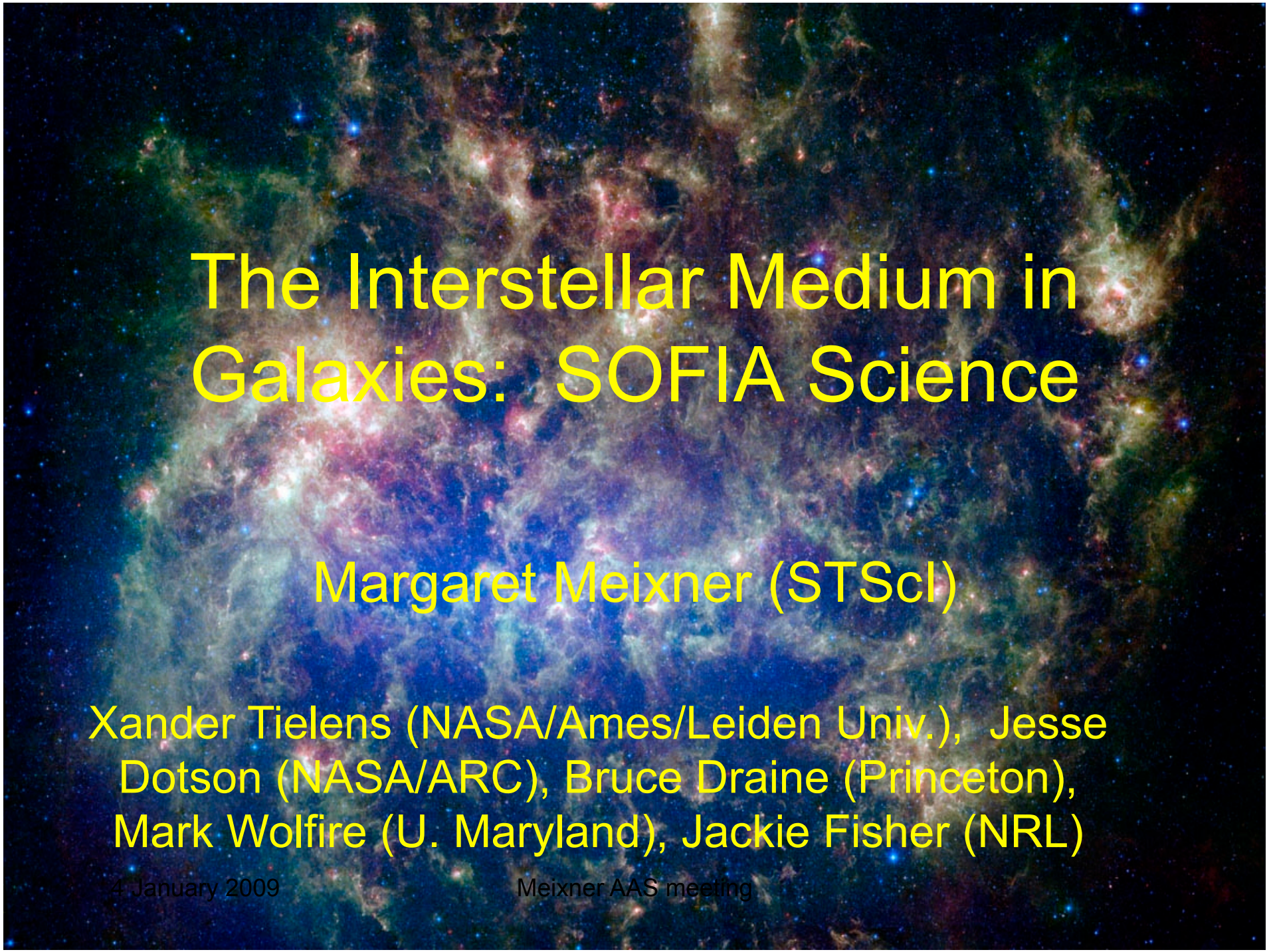


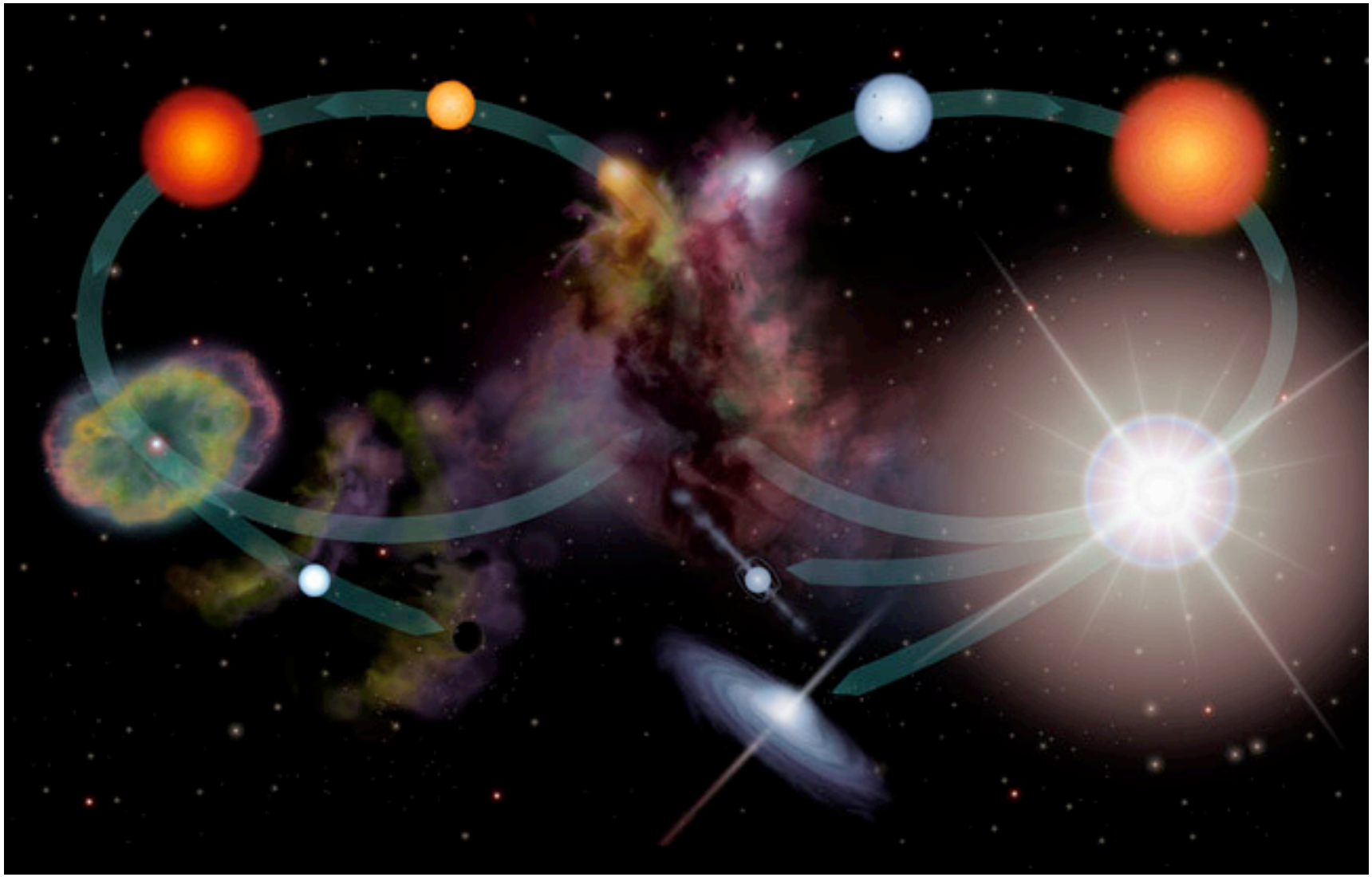
The Interstellar Medium in Galaxies: SOFIA Science

Margaret Meixner (STScI)

Xander Tielens (NASA/Ames/Leiden Univ.), Jesse Dotson (NASA/ARC), Bruce Draine (Princeton), Mark Wolfire (U. Maryland), Jackie Fisher (NRL)

The Life Cycle of the Interstellar Medium (ISM):

Intermediate mass stars High mass stars

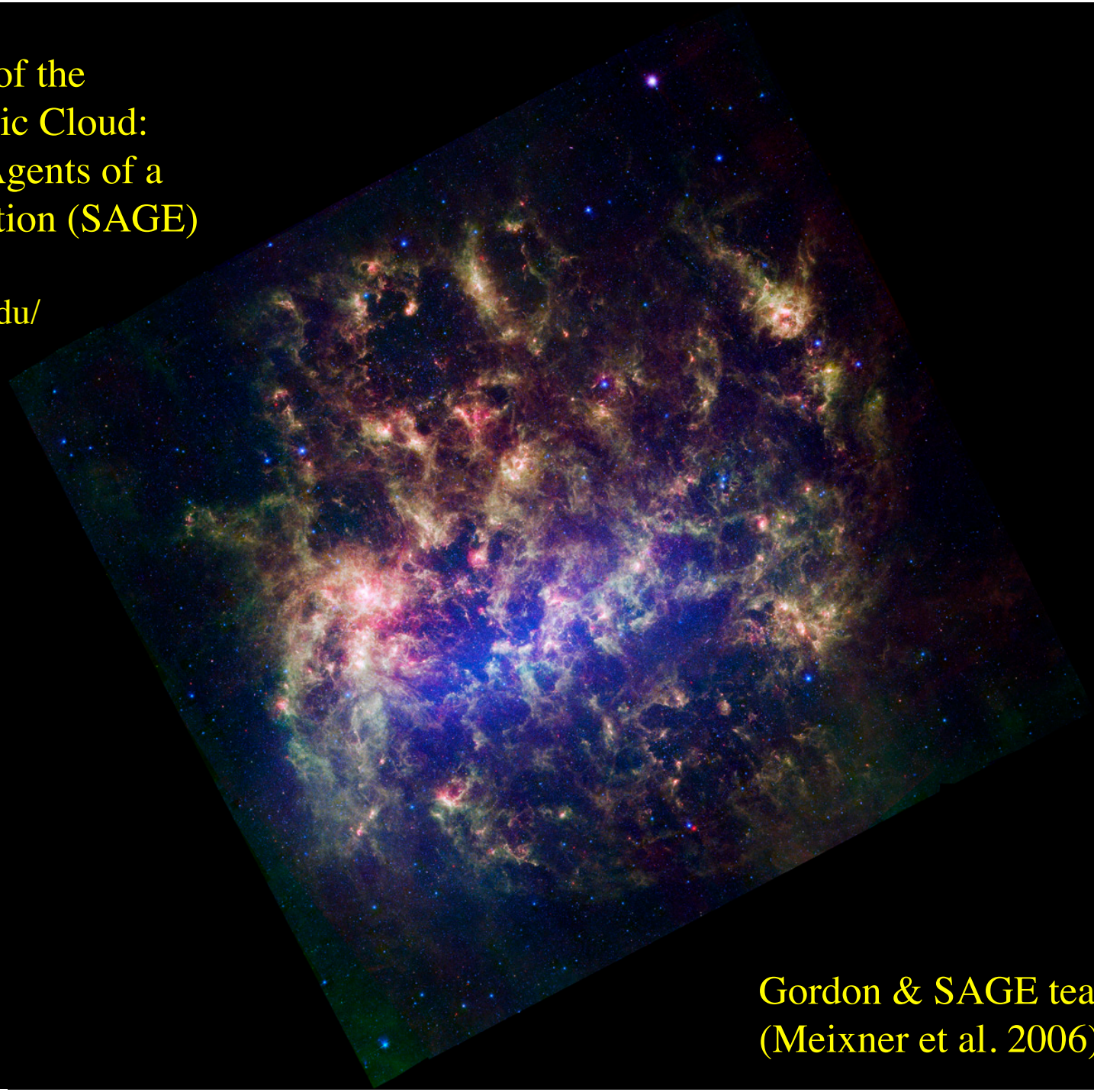


credit: http://hea-www.cfa.harvard.edu/CHAMP/EDUCATION/PUBLIC/ICONS/

SOFIA Investigations are key to understanding ISM and Stellar Feedback:

- SOFIA is great for spectral imaging of bright sources and extended regions, and can address many questions of physics and chemistry of the ISM.
- What are the physical processes that regulate the interaction of massive stars and their environment?
  - Stellar Radiative Impact: HII and Photodissociation Regions (PDRs)
  - Stellar Shock impacts: Supernovae and YSO stellar bipolar outflows
- What is the origin of dust in the Milky Way & other galaxies ?
  - Contributions by Evolved Star Circumstellar shells
  - Processing and growth of dust in ISM
- What is the role of large and complex molecules, such as Polycyclic Aromatic Hydrocarbons(PAHs) in the ISM?
  - Unique spectroscopic identification requires large infrared wavelength coverage

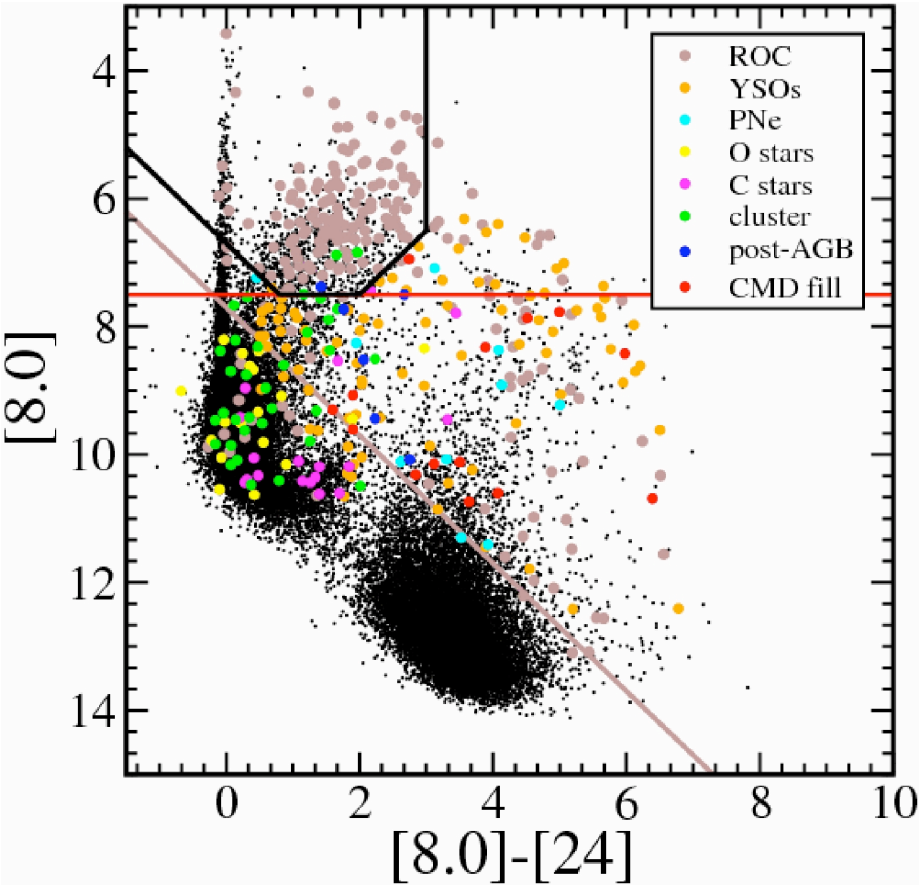
Spitzer Survey of the
Large Magellanic Cloud:
Surveying the Agents of a
Galaxy's Evolution (SAGE)
PI: Meixner
http://sage.stsci.edu/

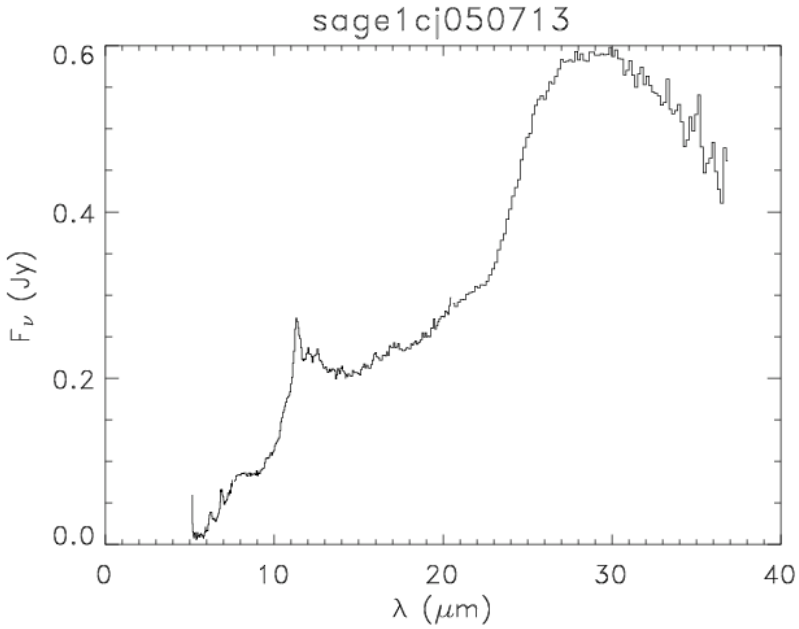


IRAC 3.6 μm
IRAC 8.0 μm
MIPS 24 μm

Gordon & SAGE team
(Meixner et al. 2006)

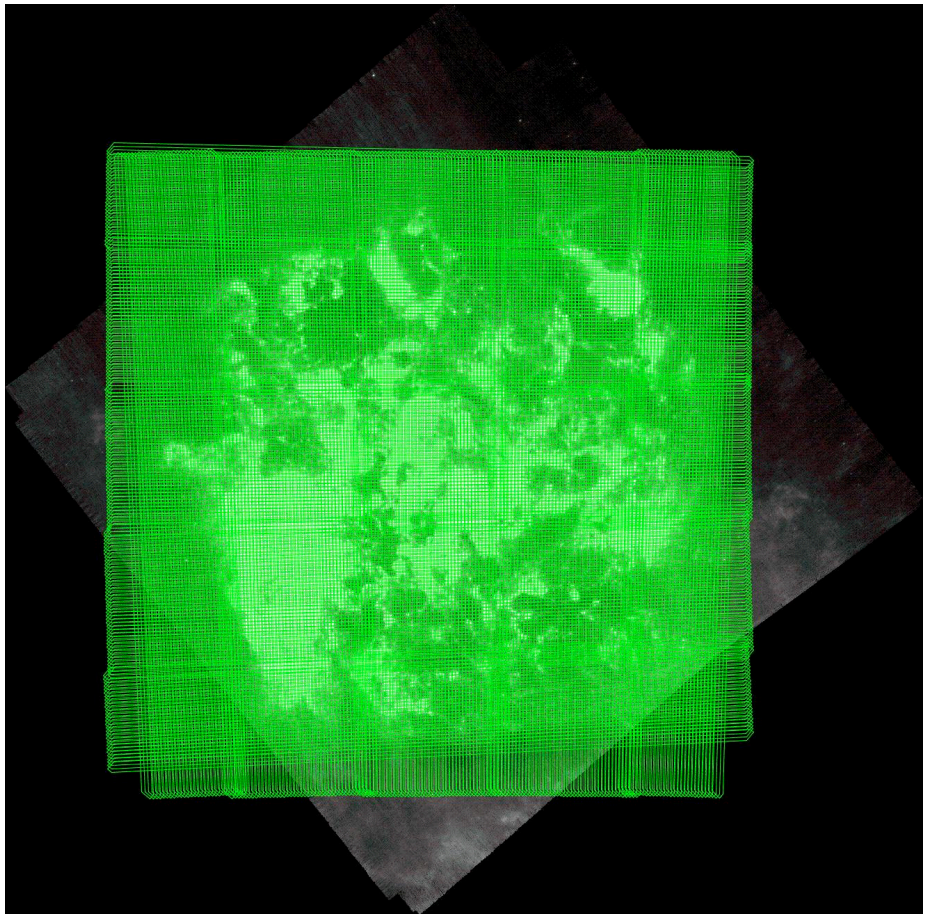
SAGE Spectroscopy: Spitzer IRS & MIPS SED of SAGE-LMC



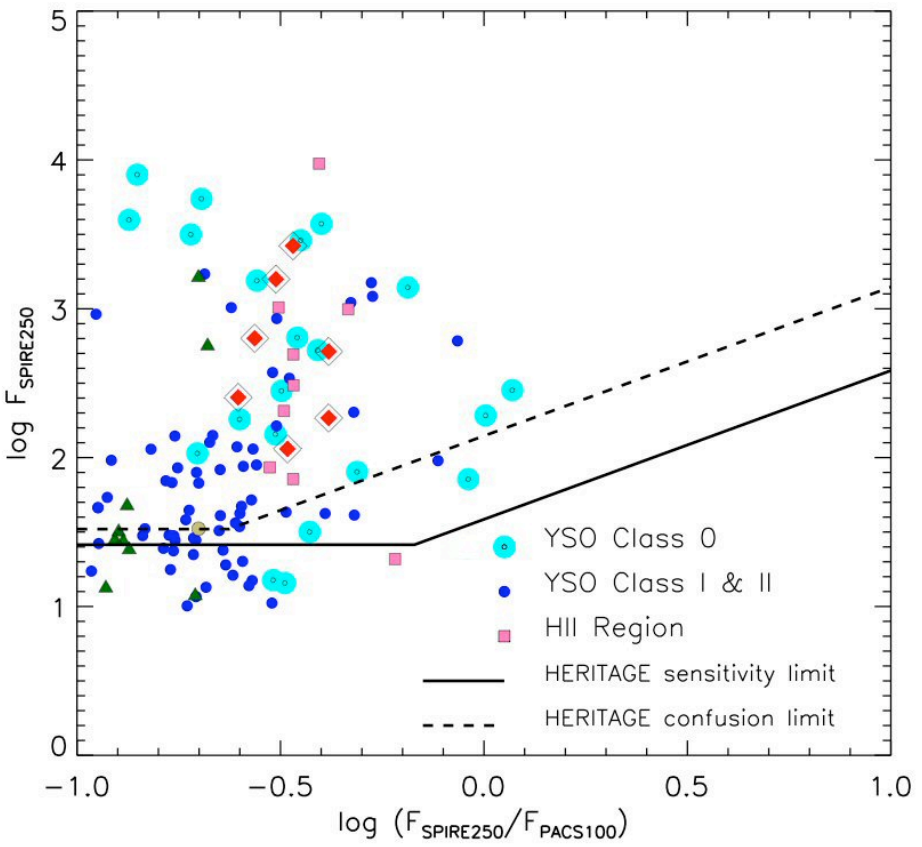


PIs:Kemper & Tielens
SAGE-Spec Team

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



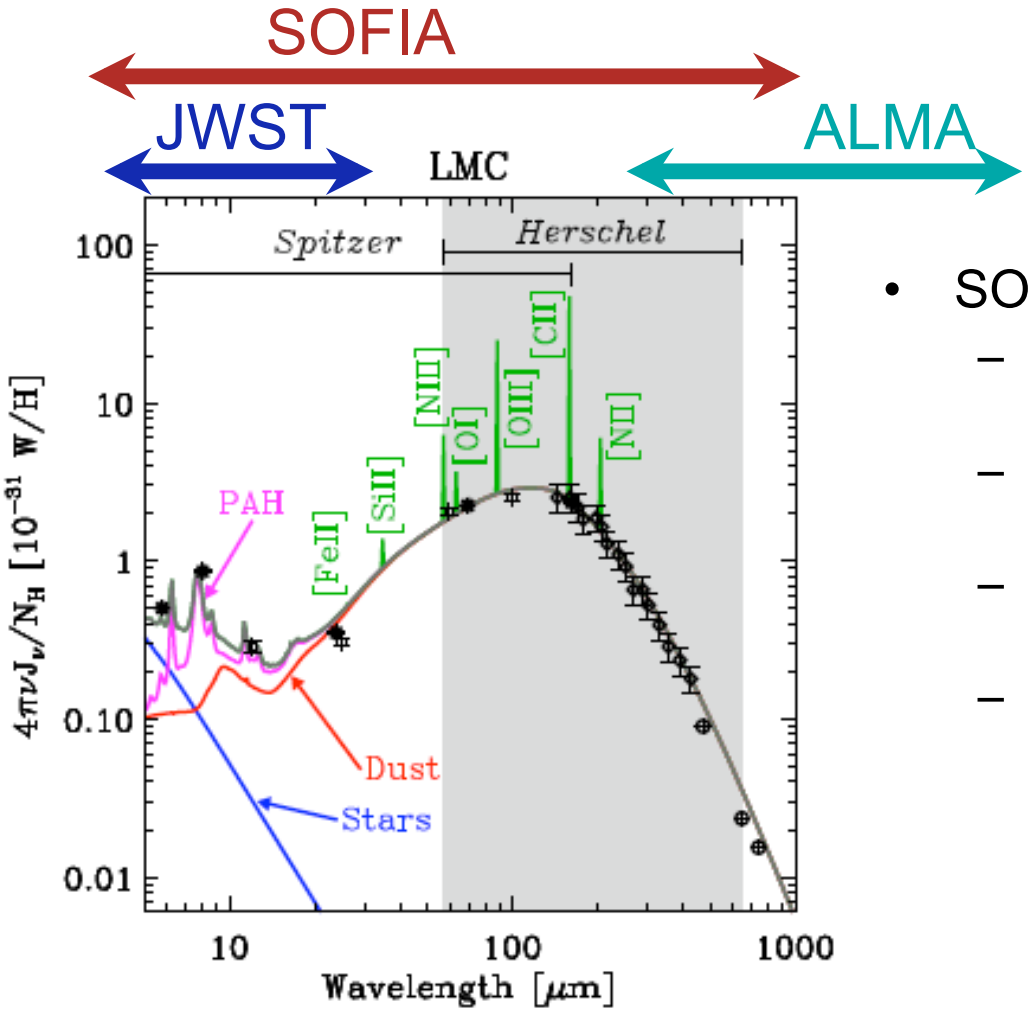
SPIRE coverage on SAGE-LMC image



HERITAGE will detect circumstellar dust from massive stars.

PI: Meixner, HERITAGE team

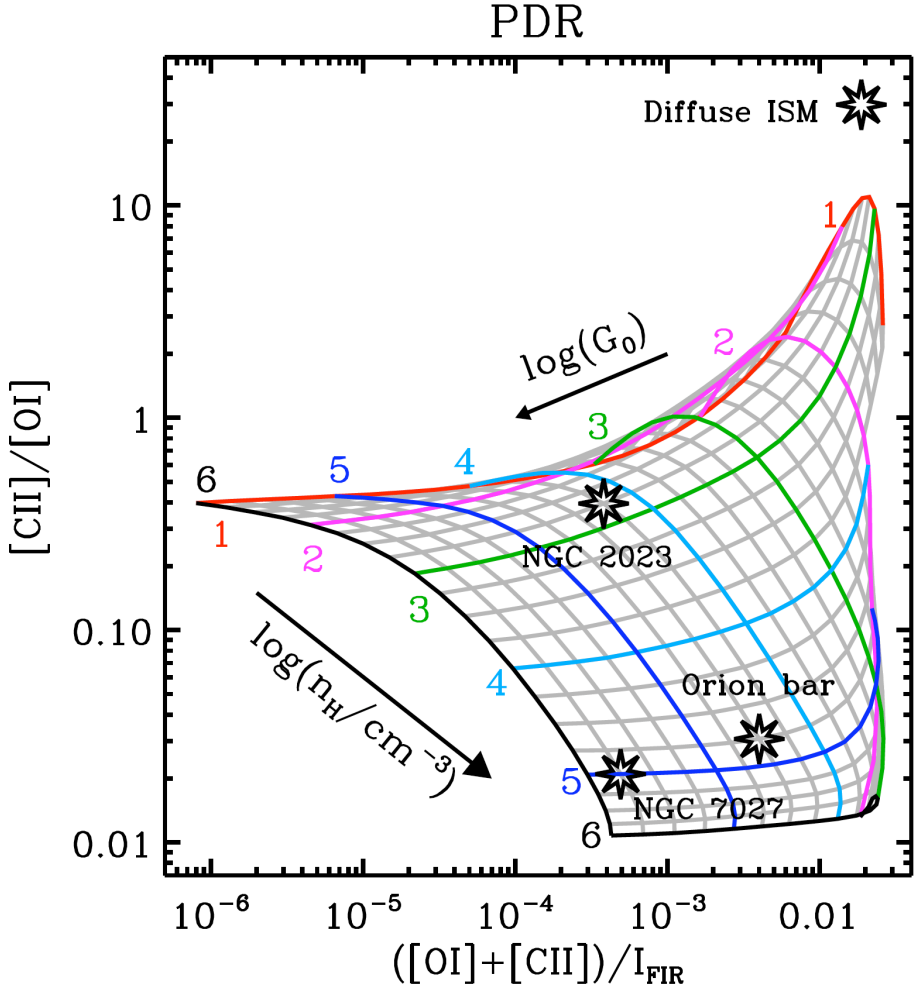
SOFIA is the critical Spectroscopic Machine to complement Spitzer and Herschel



- SOFIA Instrument capabilities:
  - Spectroscopy over a wide wavelength range
  - Spectroscopy at a wide range of spectral resolutions
  - Spectral-imaging over a large region
  - Technology development & new instrumentation

Massive Stars and the ISM: Photodissociation Regions (PDRs)

- What is the interrelationship of massive stars, HII regions, and their associated PDRs ?
- What are the infrared spectroscopic signatures of regions of massive star formation ?
- How do these signatures depend on the physical conditions, including density, stellar radiation field, and metallicity ?

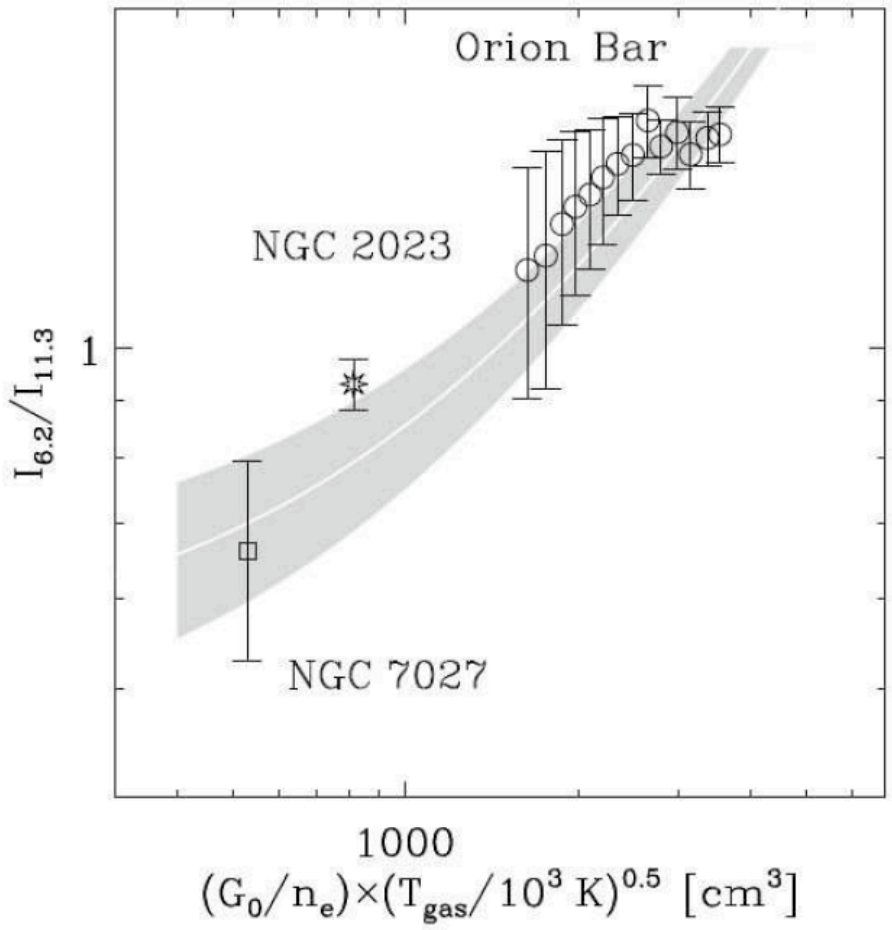


Kauffman et al. 1999

Massive Stars and the ISM: Photodissociation Regions (PDRs)

SOFIA Programs: SOFIA is ultimately suited to studying the theoretical relations of PDRs:

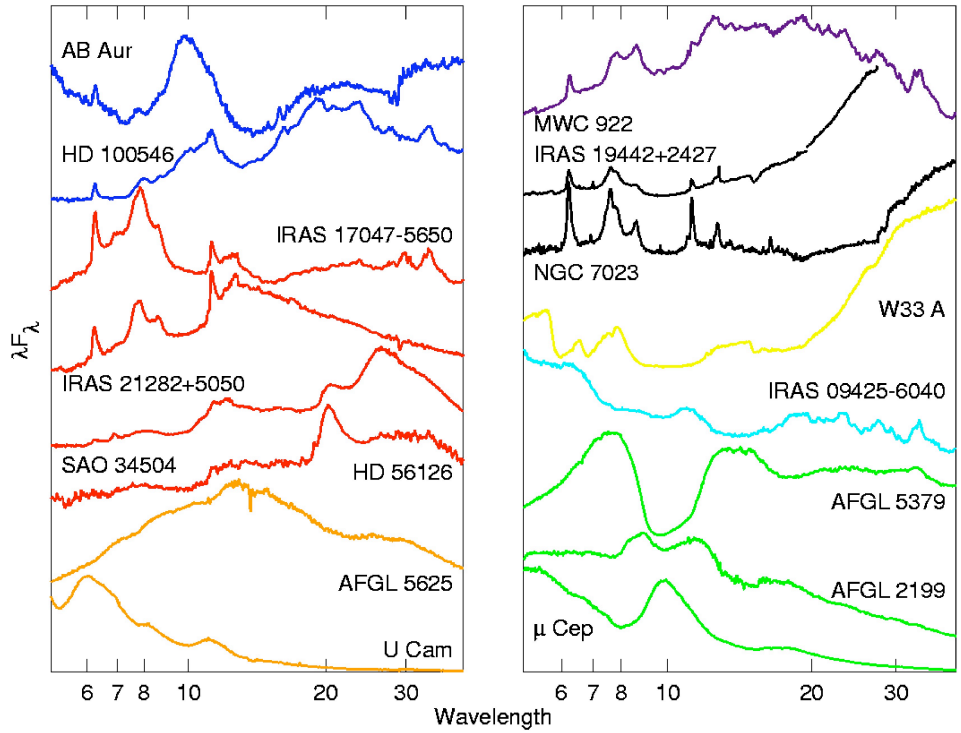
- [CII] 158 micron, [OI] 63 and 146 micron are main cooling lines
  - spectrally map these cooling lines with FIFI-LS,
  - GREAT high-res spectroscopy for kinematics of PDR gas
- H2 lines provide gas temperature: FORCast spectral line mapping
- Far infrared (FIR) intensity: HAWC in continuum
- Polycyclic Aromatic Hydrocarbons (PAHs) are main sources of photo-electric heating: FORCAST mapping
- Relate all of these aspects for carefully selected regions that probe the range of density, temperature, metallicity and UV fields



Galliano et al. 2008

The Diversity and Origins of Dust in the ISM: Evolved Star Contributions

- What are the characteristics of dust injected by different stellar sources ?
- What is the contribution of low mass versus massive stars to the ISM budget ?
- What does this imply for the lifecycle of dust and gas in galaxies ?

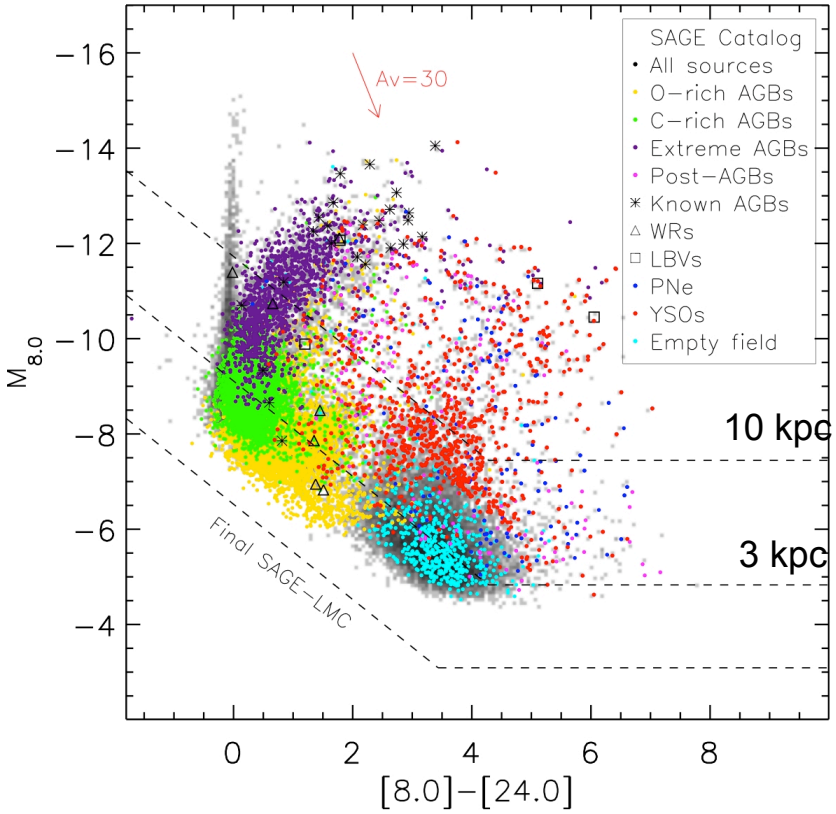


The rich and spectrally diverse stardust revealed by ISO & Spitzer requires systematic study.

The Diversity and Origins of Dust in the ISM: Evolved Star Contributions

SOFIA Program

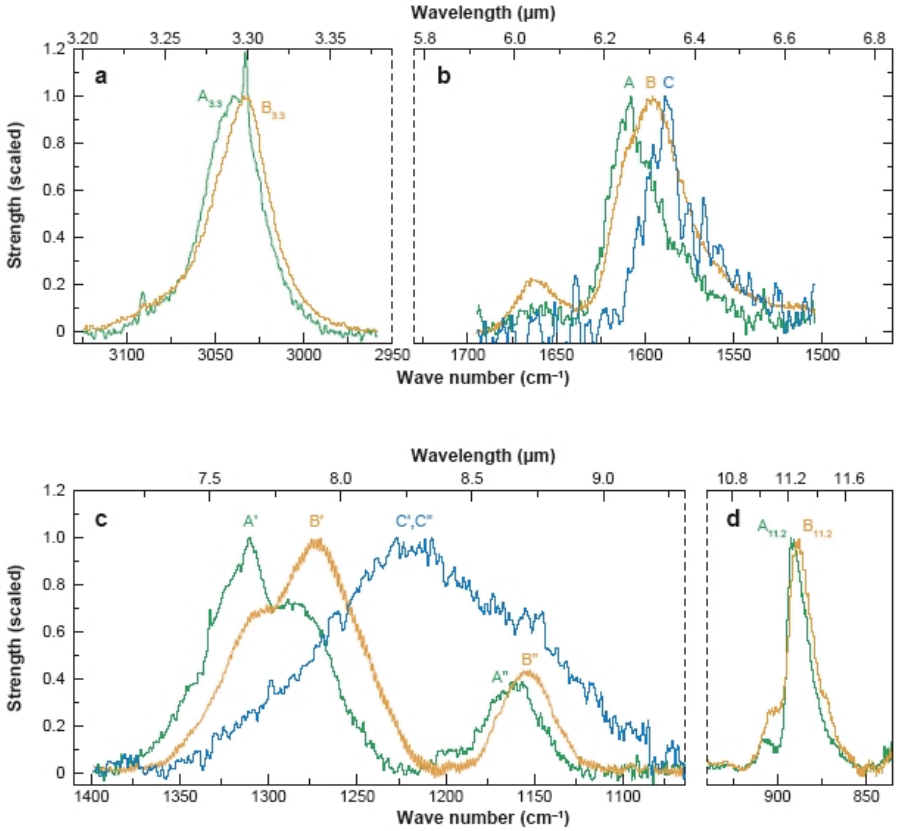
- SOFIA can provide a full census of stardust injected into the Milky Way and compare it to local interstellar dust characteristics
- 5-40 μm spectroscopy (R=200-1000) using FORCAST in grism mode, 10 sigma limits in Fig.
- Sample of local stardust sources in the Milky Way
- Complements programs of:
  - LMC/SMC: Spitzer/IRS
  - Local group galaxies: JWST/MIRI



Milky Way Evolved Star Sample as based on SAGE-LMC population studies and FORCAST sensitivity limits

The Role of Large, Complex Molecules in the ISM: Unique Identification of PAHs

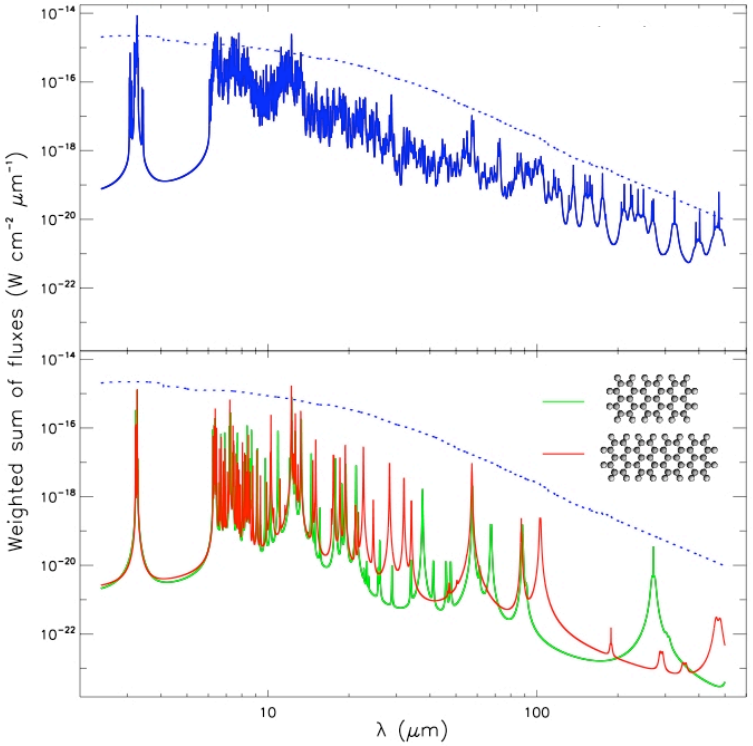
- What is the census of complex molecules from evolved stars to the ISM?
- What processes affect the PAH population in the ISM?
- What is the complex molecular inventory in regions of star formation particularly in the terrestrial habital zone ?



Families of PAHs identified by Peeters et al. in mid-IR.

The Role of Large, Complex Molecules in the ISM: Unique Identification of PAHs

- The far-IR 'drum head' modes are highly molecule specific
- SOFIA can measure all vibrational modes of interstellar PAHs
- Moderate resolution (R=200-1000) spectroscopy from 5-200 μm
- High resolution follow up using GREAT & CASIMIR can resolve P-Q-R branch structure of lowest vibrational transitions
- Sample of objects with different conditions and different PAH family to probe chemical evolution and key processes



Top: Predictions of IR spectra for 20 PAHs in Red Rectangle
Bottom: Two Spectra of Individual PAHS
Mulas et al. 2006

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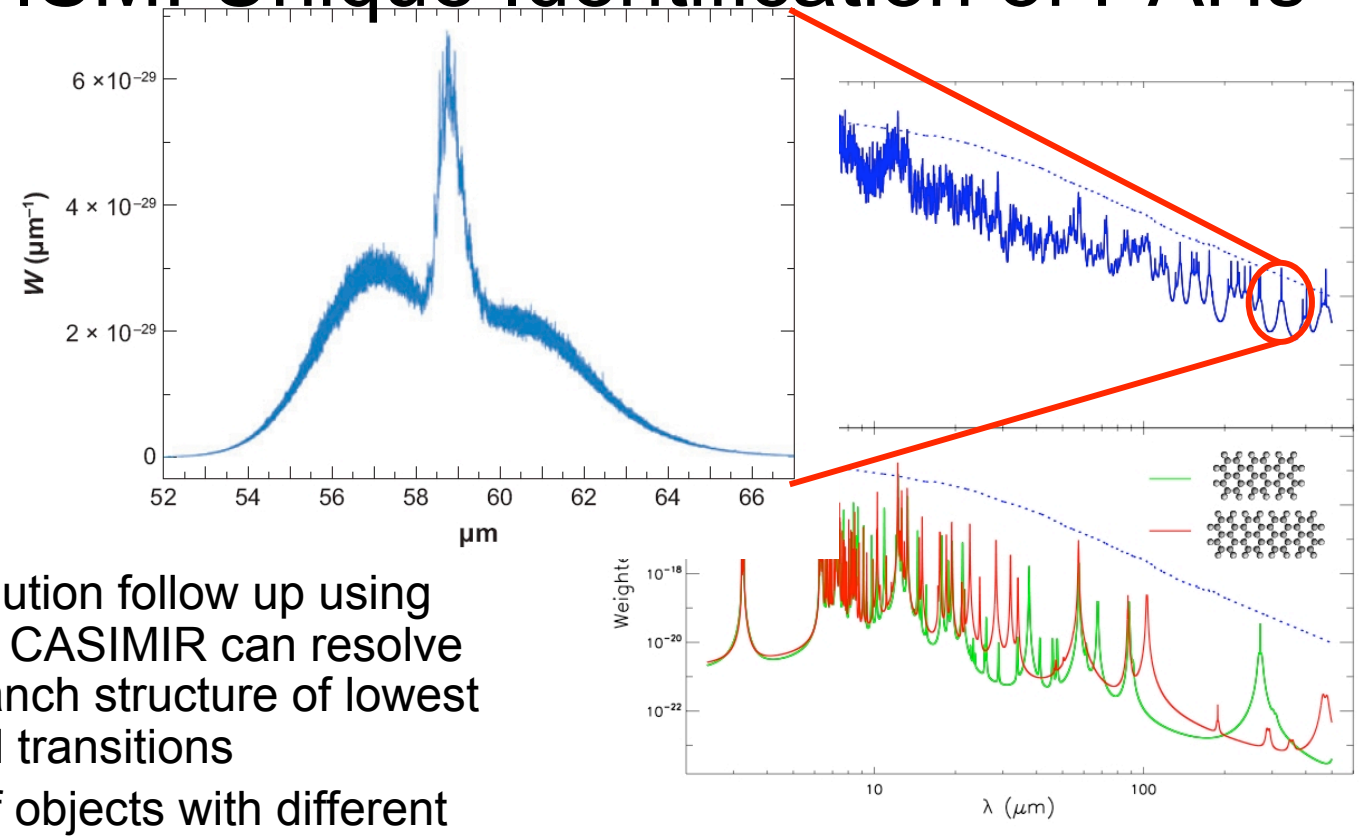

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