

*SAGE: Surveying the Agents of Galaxy Evolution*

*SAGE-Spectroscopy: The Life Cycle of Dust and Gas in the Magellanic Clouds*

# *Identification of Spitzer-IRS staring mode targets in the Magellanic Clouds*

Paul Ruffle

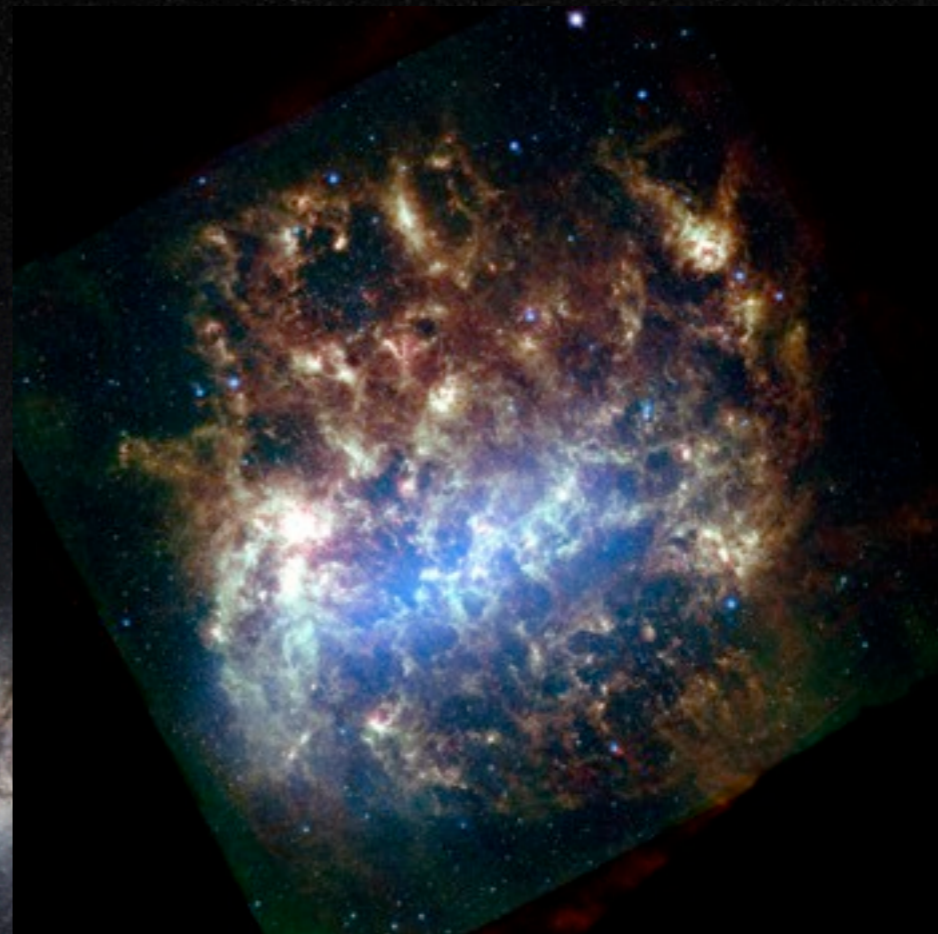
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Martha Boyer (STScI) · Kathleen Kraemer (Boston College)

Greg Sloan (Cornell University) · Massimo Marengo (Iowa State University)

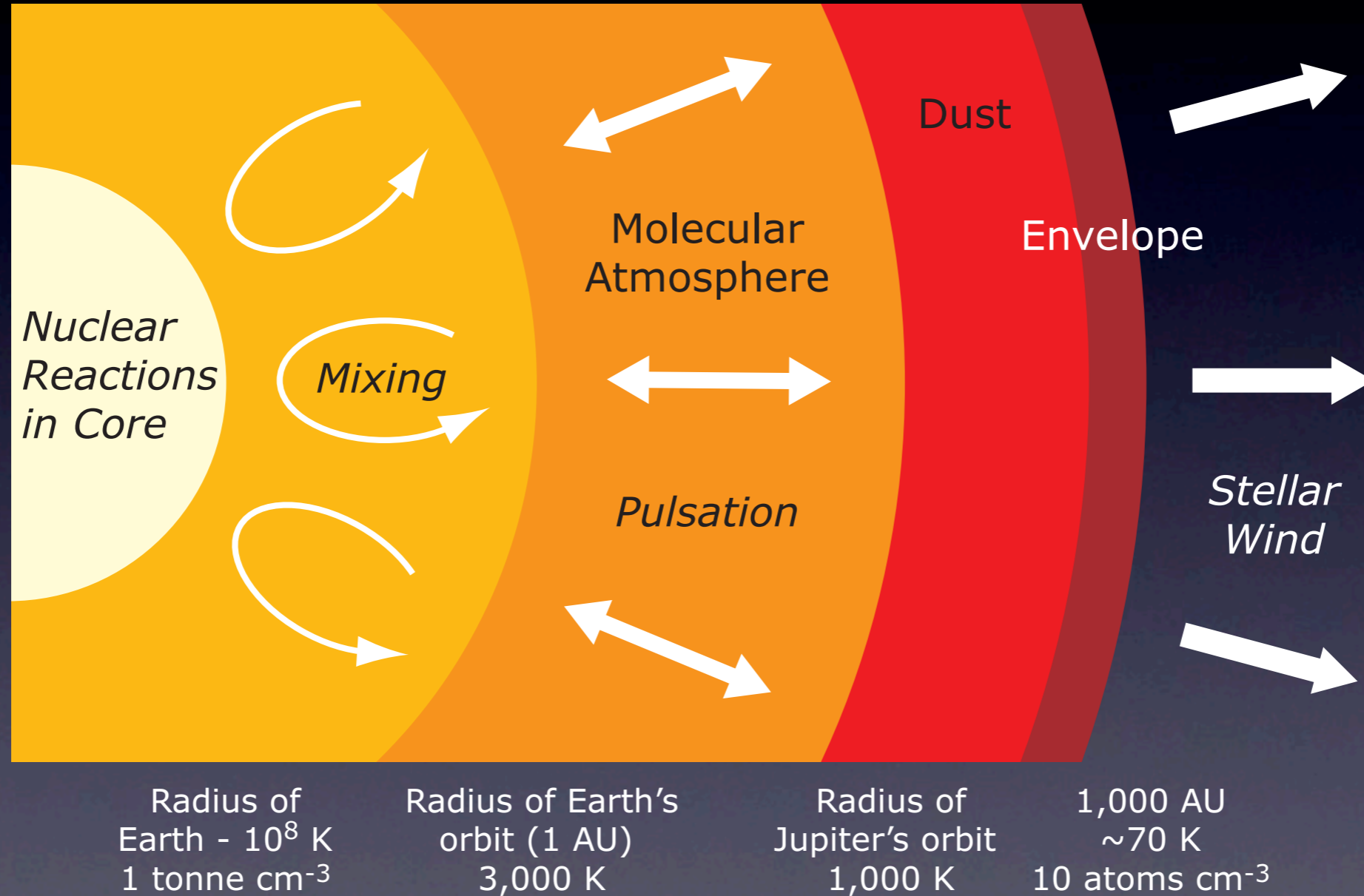
# The Magellanic Clouds



# SAGE: Surveying the Agents of Galaxy Evolution

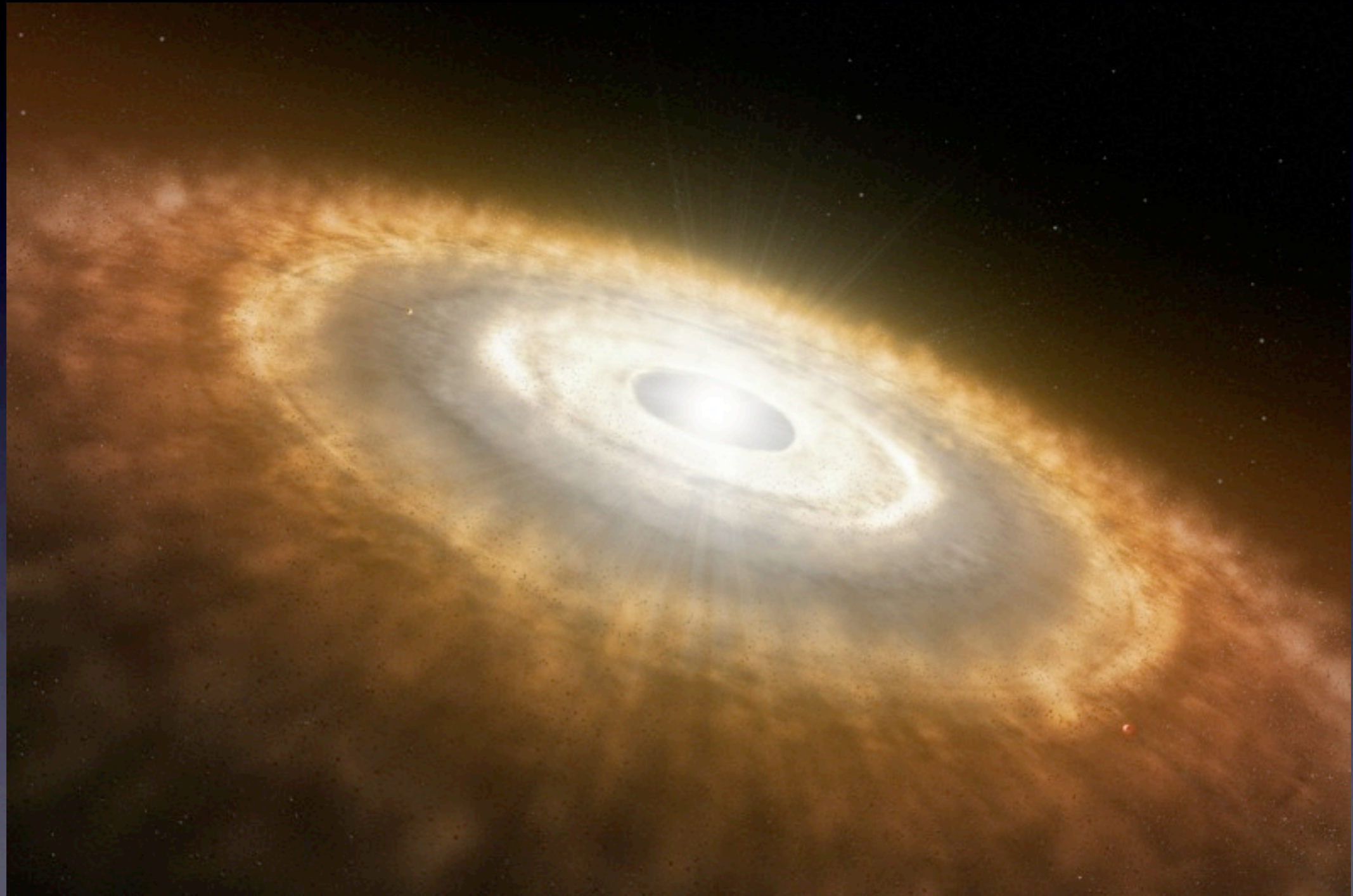
- Tracing the life cycle of observable matter that drives the evolution of a galaxy's appearance
- Key phases traced via dust emission in the ISM
- Newly forming stars and evolved dying stars
- Spitzer IR images of the LMC and SMC
- Spitzer spectroscopy of dust in LMC and SMC
- Herschel to trace coldest dust in LMC and SMC

# Dust production in AGB stars



Schematic View of an Asymptotic Giant Branch (AGB) Star

# Dusty disc around evolved YSO

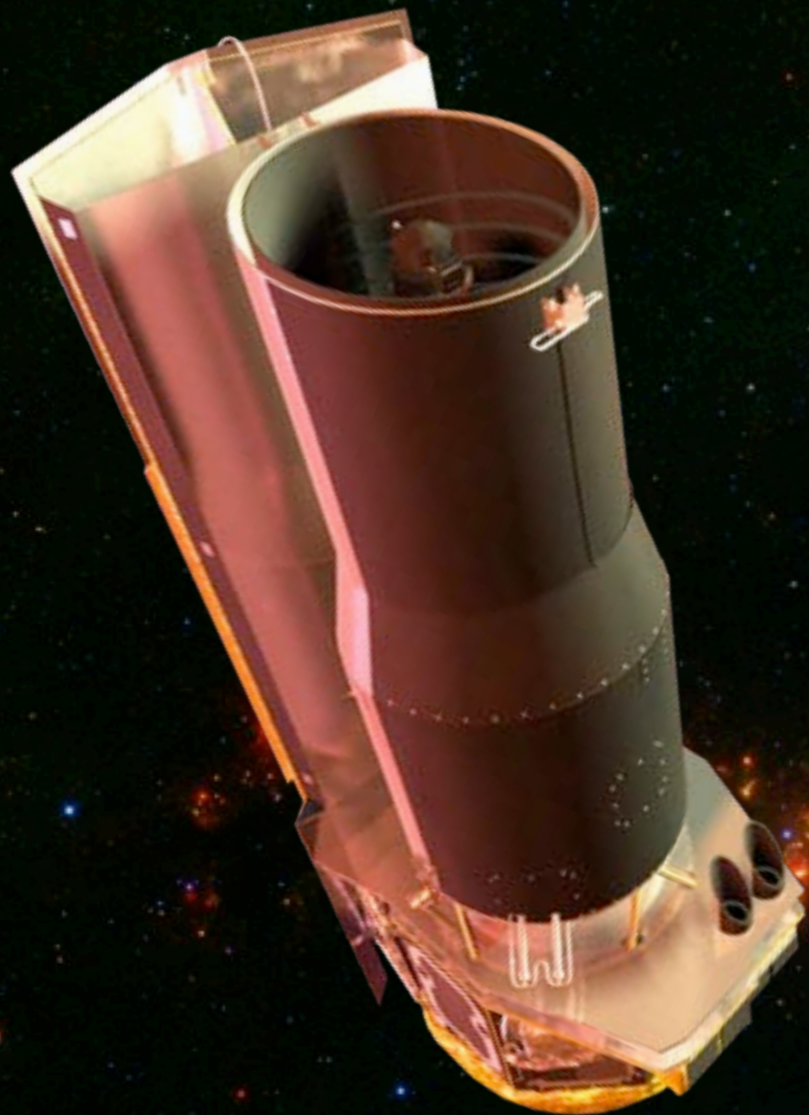


Artist's impression of a young star surrounded by a protoplanetary disc in which planets are forming (ESO/L. Calçada)

# SAGE-Spec: The life cycle of dust and gas in the Magellanic Clouds

- SED spectroscopy program using Spitzer's  
*InfraRed Spectrograph (IRS)*  
*InfraRed Array Camera (IRAC)*  
*Multiband Imaging Photometer for Spitzer (MIPS)*
- Composition, origin and evolution of dust
- Analysis of spectra will help identify  
*Young Stellar Objects, Red SuperGiants, HII regions,*  
*AGB stars, post-AGB stars, Planetary Nebulae*
- Link observed IRAC and MIPS colours of objects to their IRS spectral type

# Spitzer Space Telescope



## InfraRed Spectrograph (IRS)

*Four modules covering from 5–40  $\mu\text{m}$ :*

*Low-resolution, short-wavelength 5.3–14  $\mu\text{m}$*

*Low-resolution, long-wavelength 14–40  $\mu\text{m}$*

*High-resolution, short-wavelength 10–19.5  $\mu\text{m}$*

*High-resolution, long-wavelength 19–37  $\mu\text{m}$*

## InfraRed Array Camera (IRAC)

*Images at 3.6, 4.5, 5.8 and 8.0  $\mu\text{m}$*

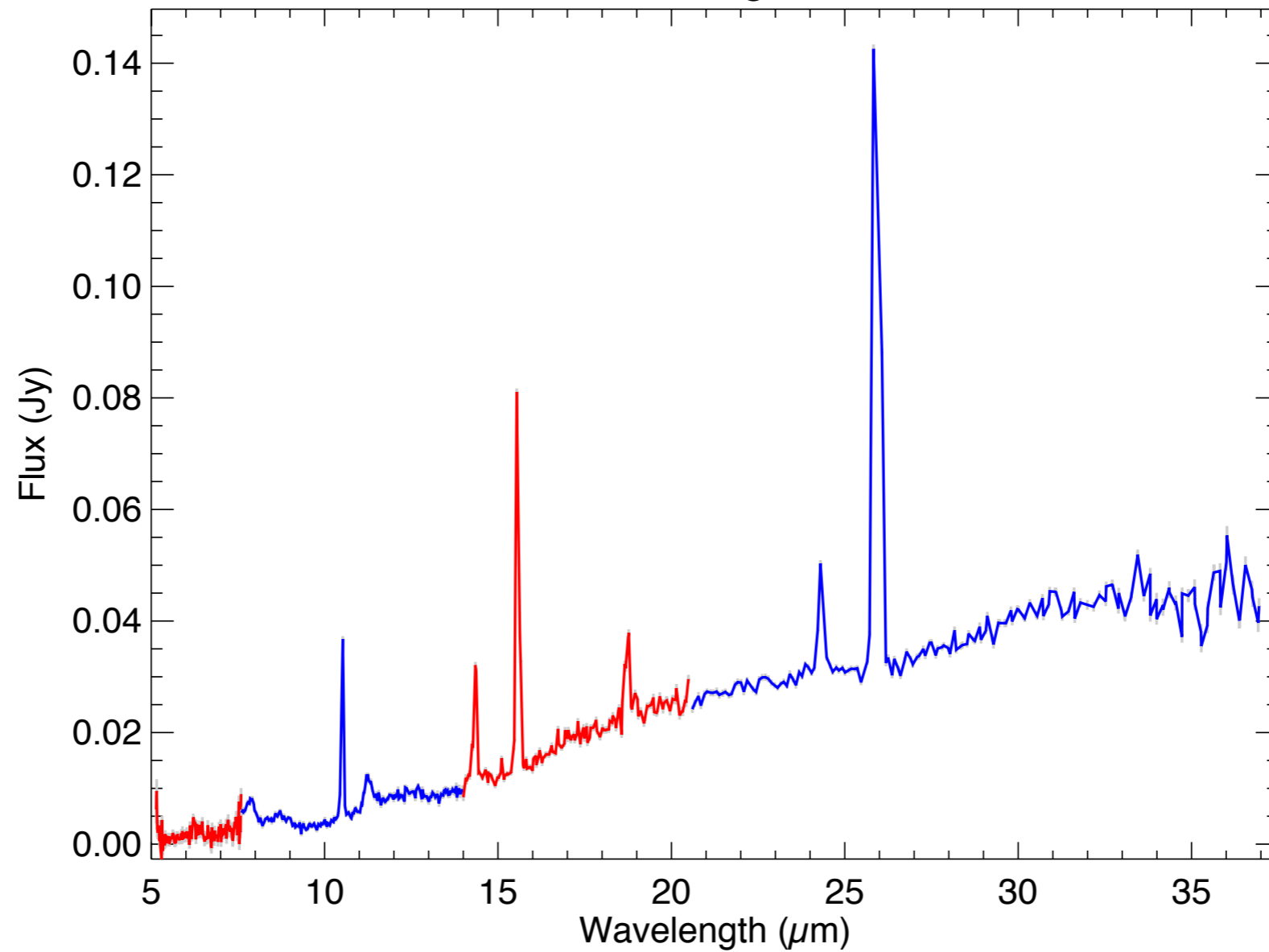
## Multiband Imaging Photometer (MIPS)

*Images at 24, 70 and 160  $\mu\text{m}$*

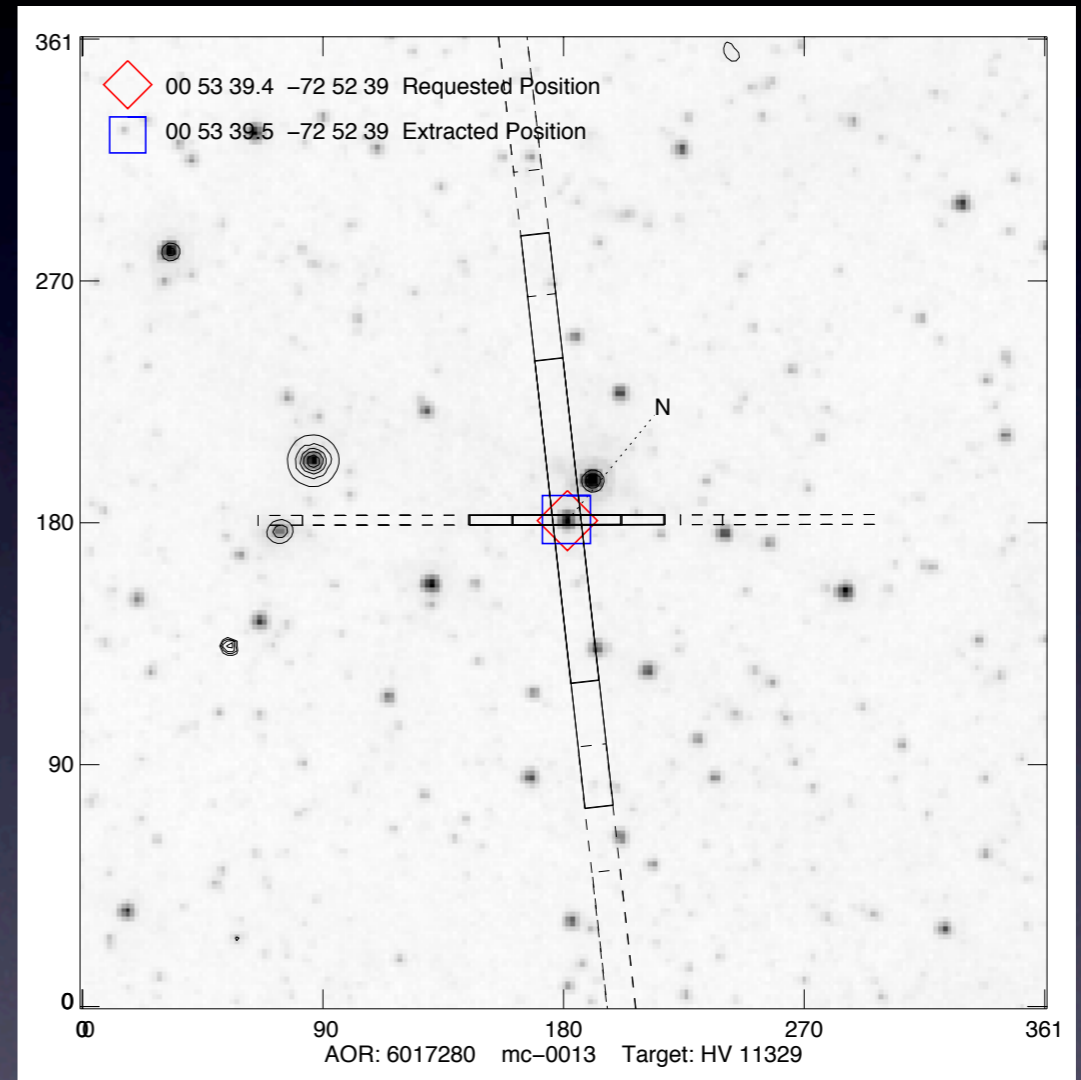
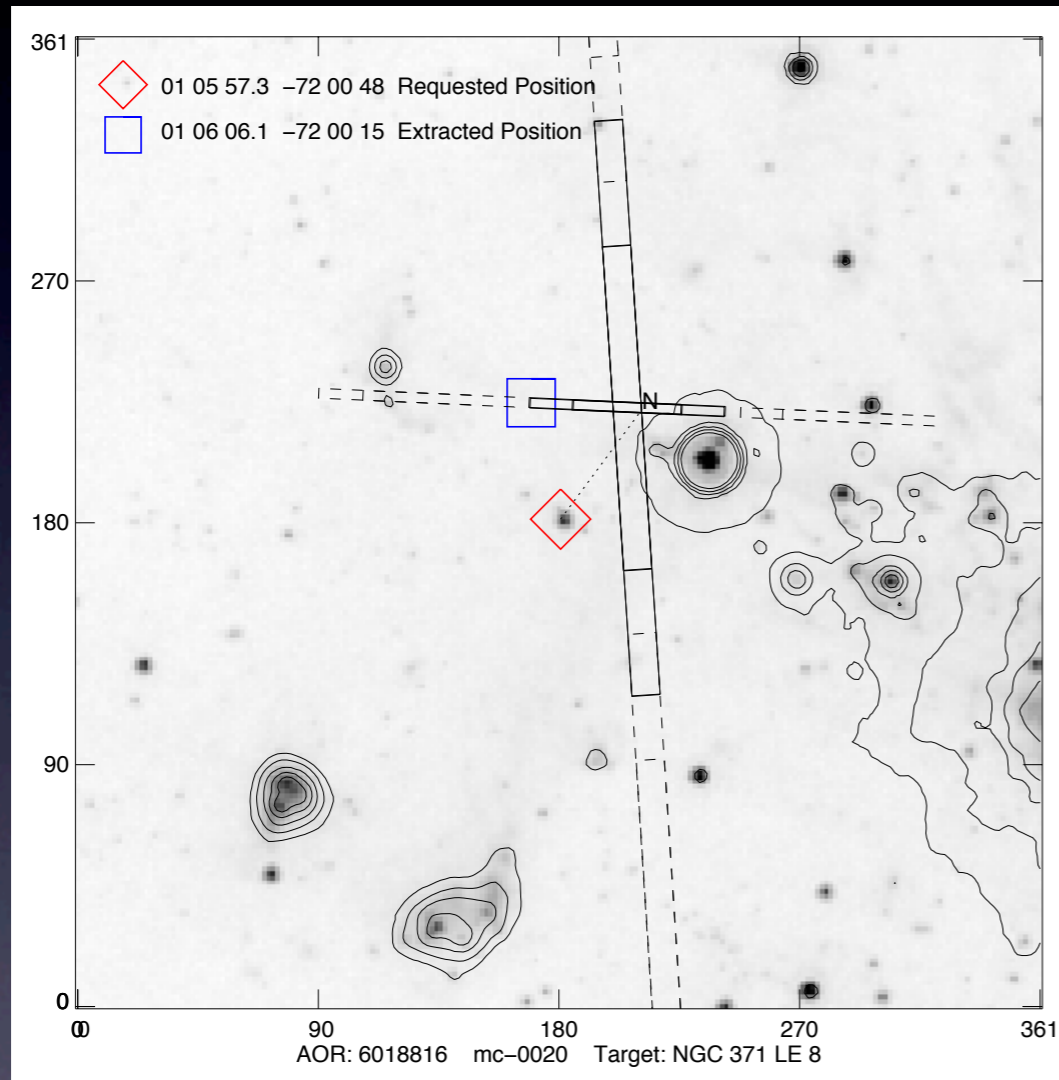
*Spectra from 50–100  $\mu\text{m}$*

# Example IRS spectra

AOR: 14709248 Target: SMP\_SMC\_2



# Photometry position pitfalls



# Point source classification

*1,000 IRS staring mode observations in LMC  
(including 197 from SAGE-Spec legacy program\*)*

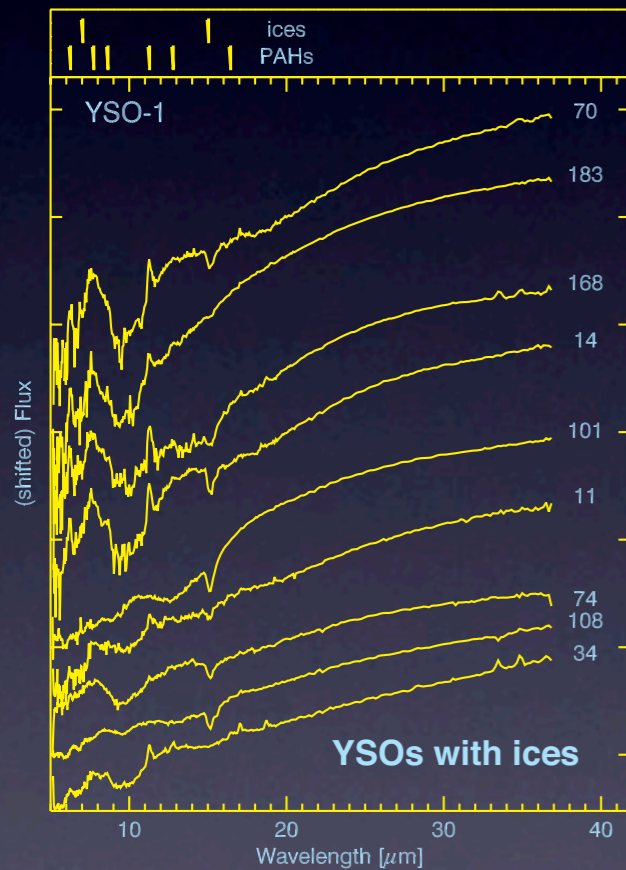
*~250 IRS staring mode observations in SMC*

- Spitzer IRS spectra ( $\lambda = 5.2\text{--}38 \mu\text{m}$ ),
- Associated UBV<sub>I</sub>JHK, IRAC and MIPS photometry
- Luminosity, variability and age
- Other information
- Navigate decision tree
- For SMC now a web based process

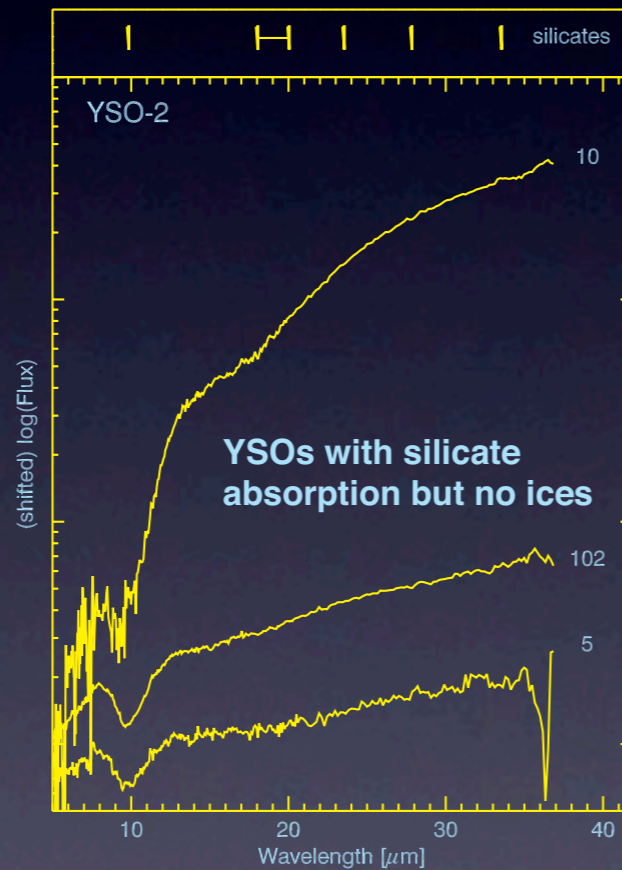
*\*Woods et al. 2011*

# Young Stellar Objects

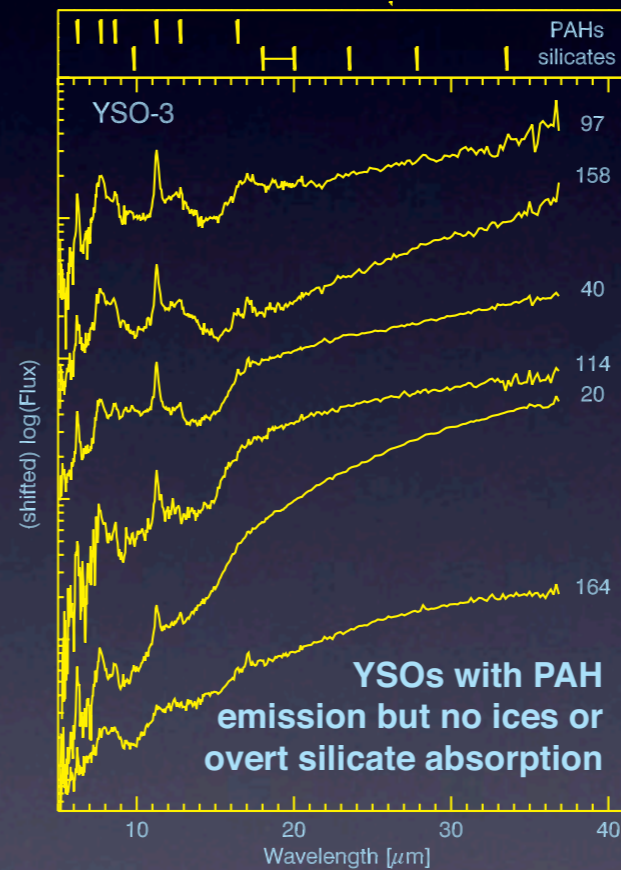
YSO-1 Embedded



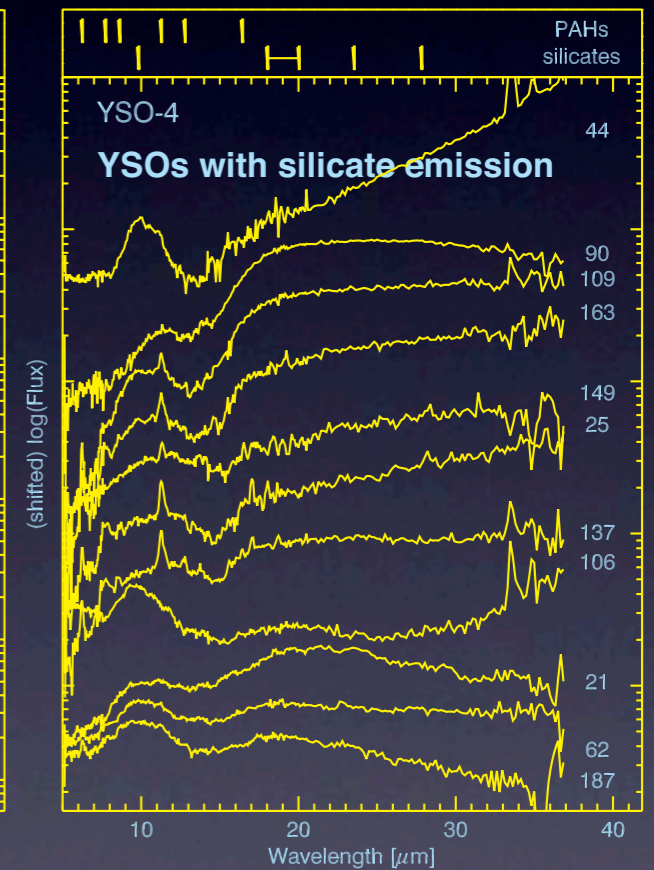
YSO-2



YSO-3 Evolved

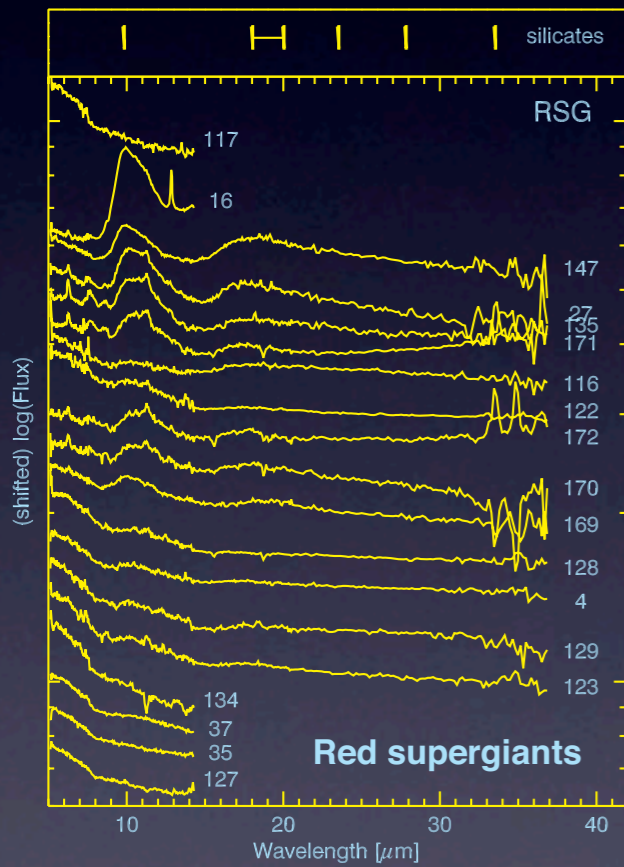


YSO-4 HAeBe

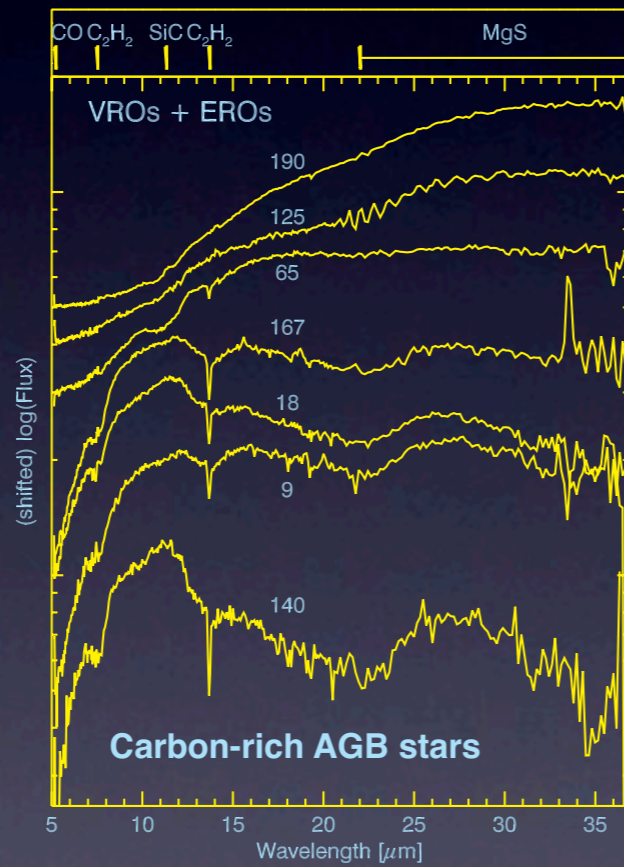


# Evolved stars

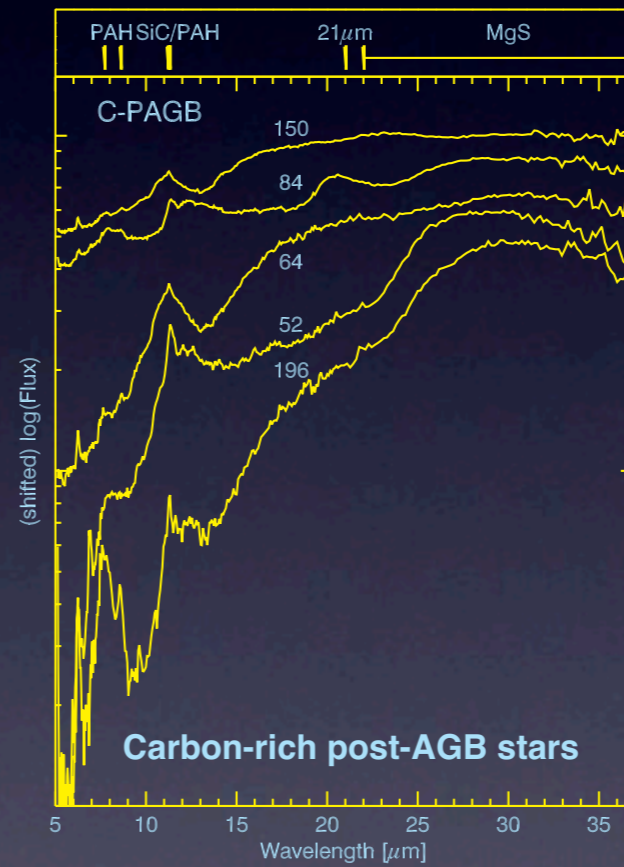
## RSG



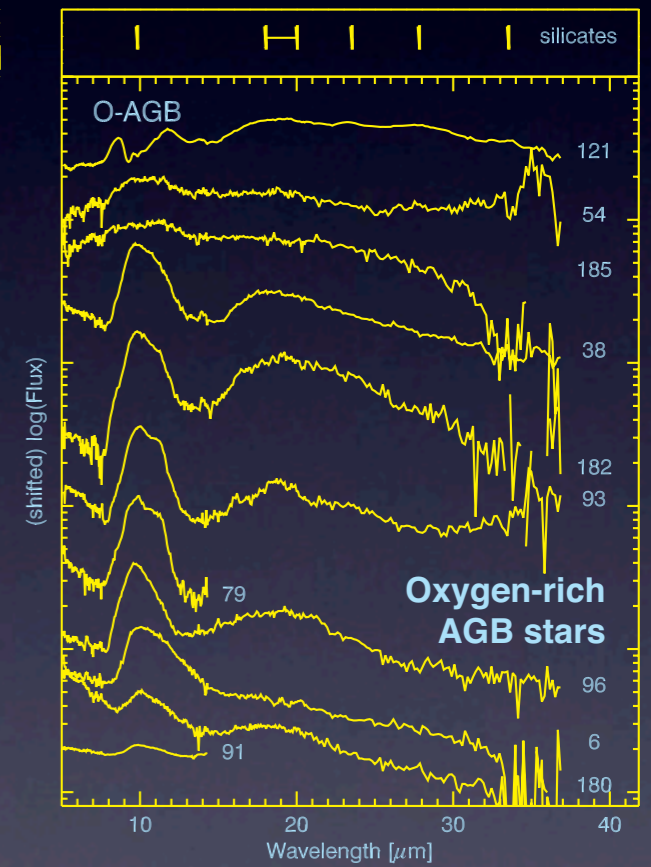
## C-AGB



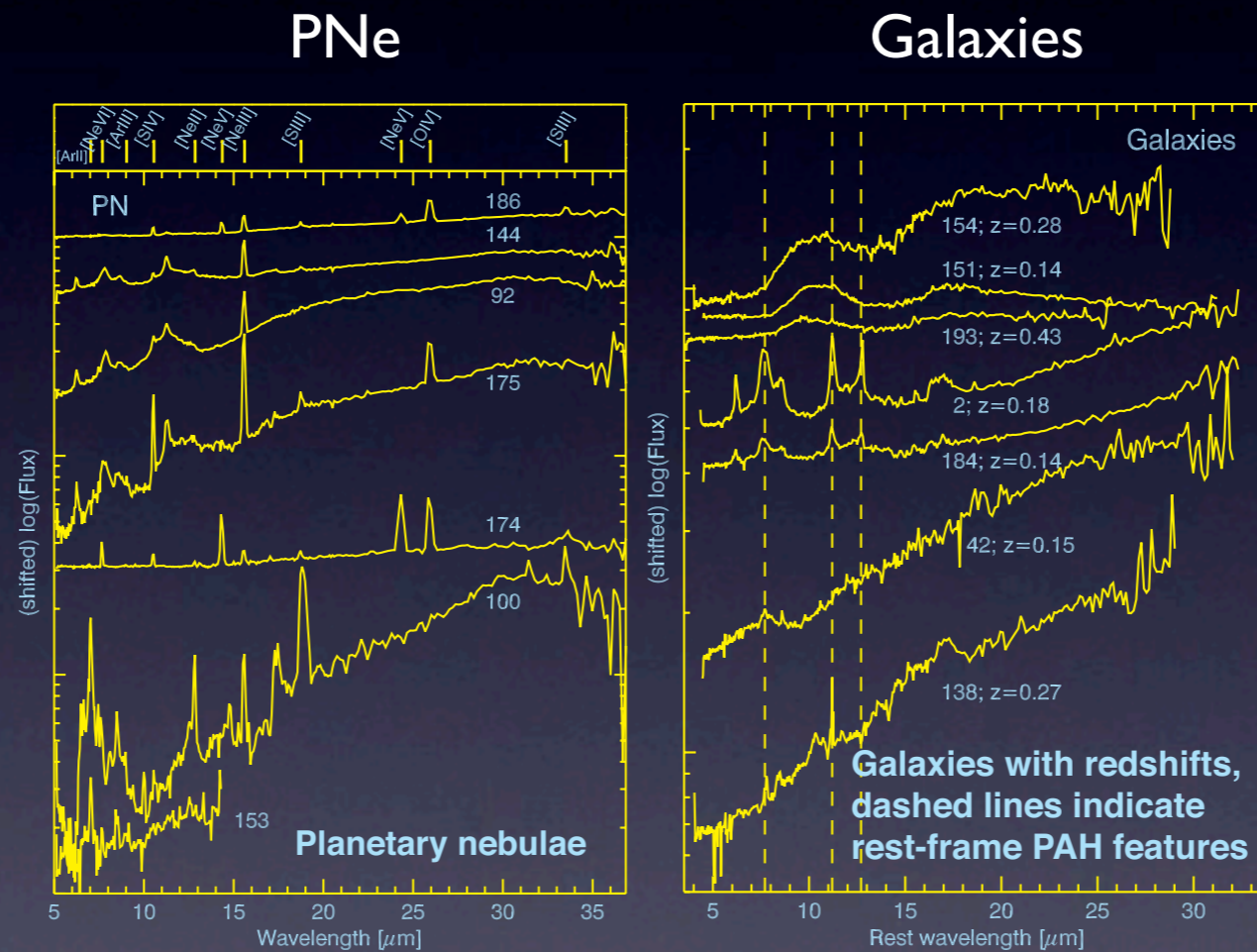
## C-PAGB



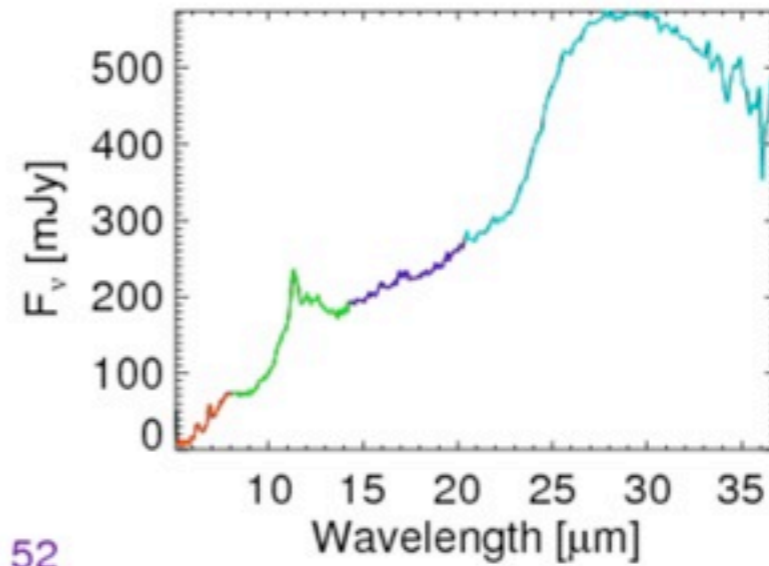
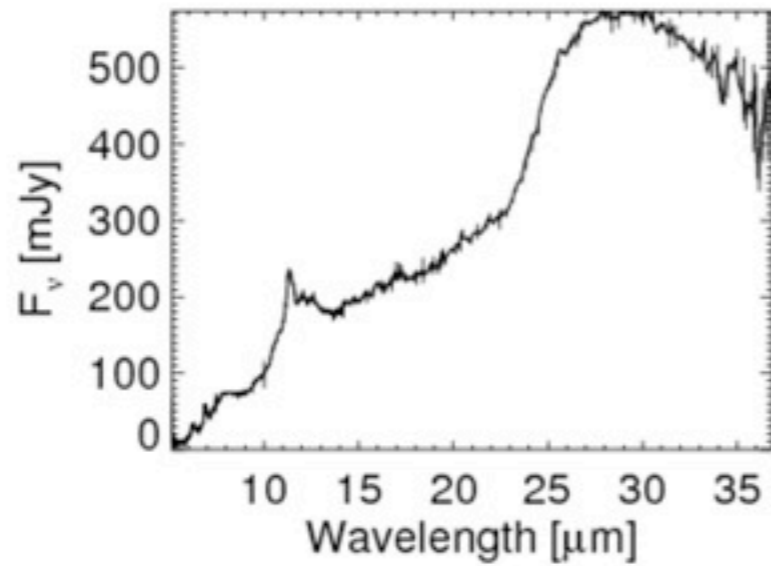
## O-PAGB



# Planetary nebulae and galaxies

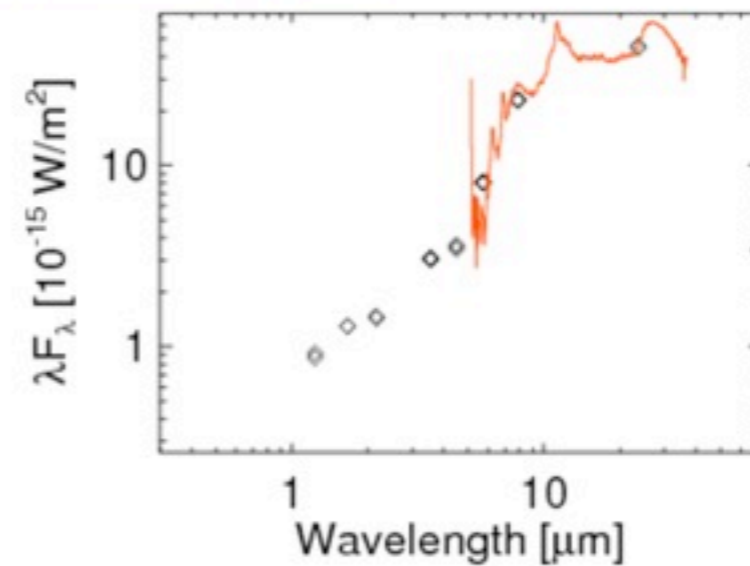
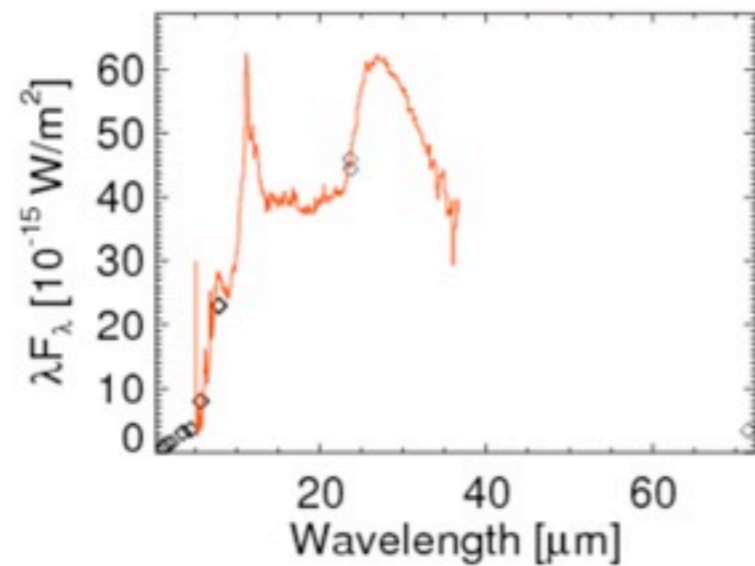


# Photometry with Spectra



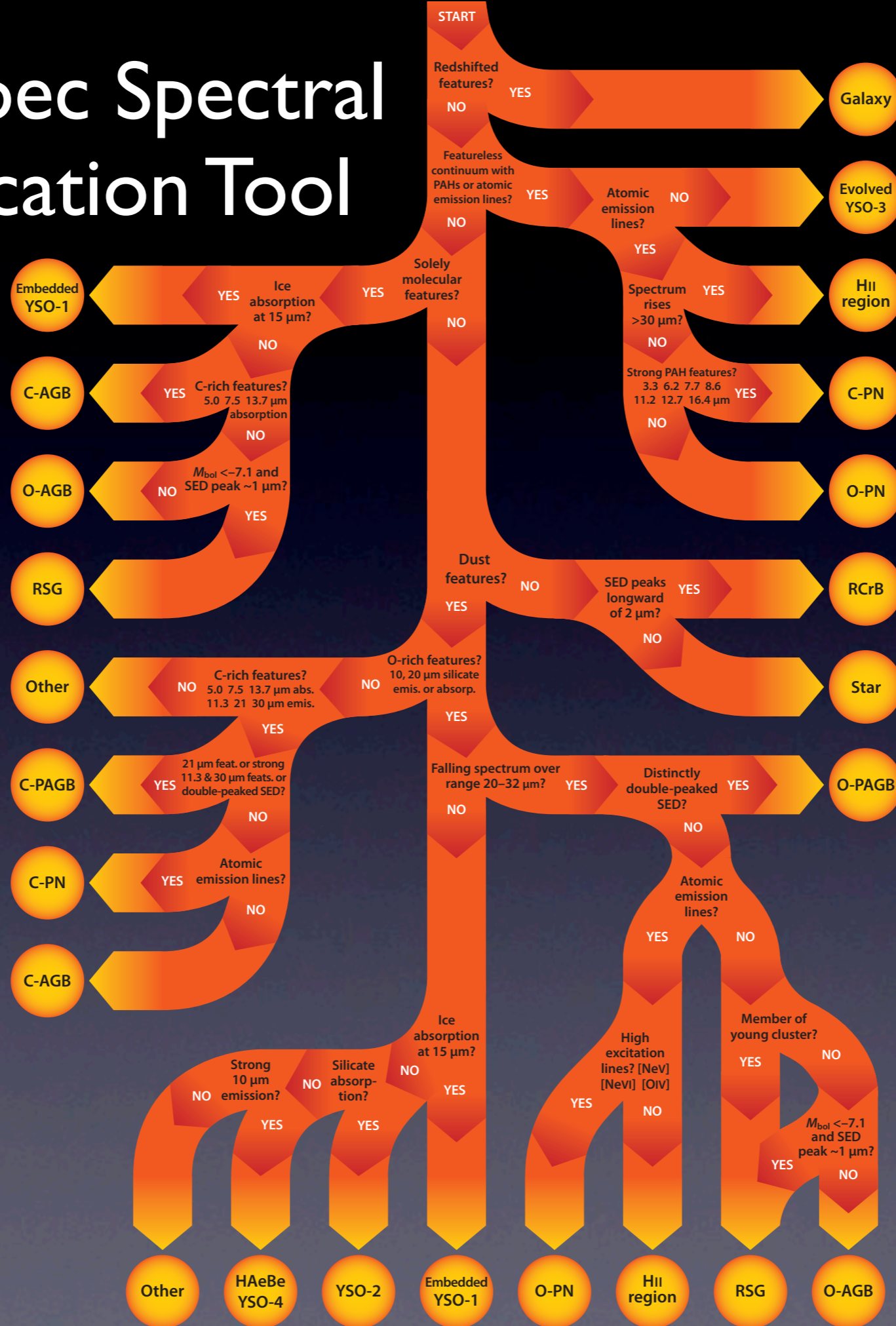
52

SSTISAGE1C\_J050713.91-674846.6

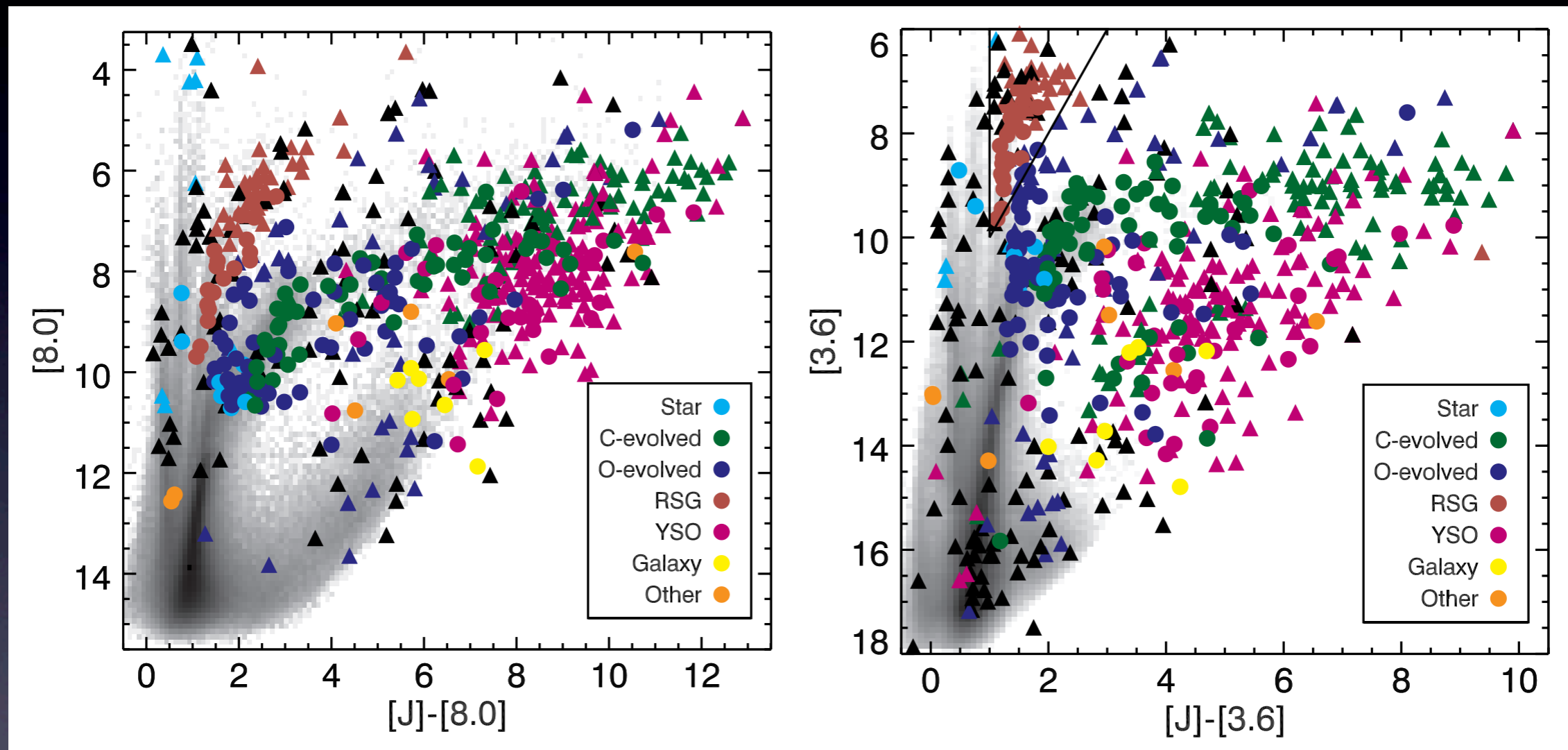


Classified as a carbon-rich post-AGB star (C-PAGB)

# SAGE-Spec Spectral Classification Tool



# Interim LMC results



Example CMD distributions for 1,000 LMC point sources.

O-AGB, O-PAGB, O-PN and C-AGB, C-PAGB, C-PN classifications are merged into two broad groups.

The cut for RSGs on the right can be clearly distinguished from other oxygen-rich evolved stars.

The greyscale backgrounds show a Hess diagram of the entire SAGE-LMC sample.

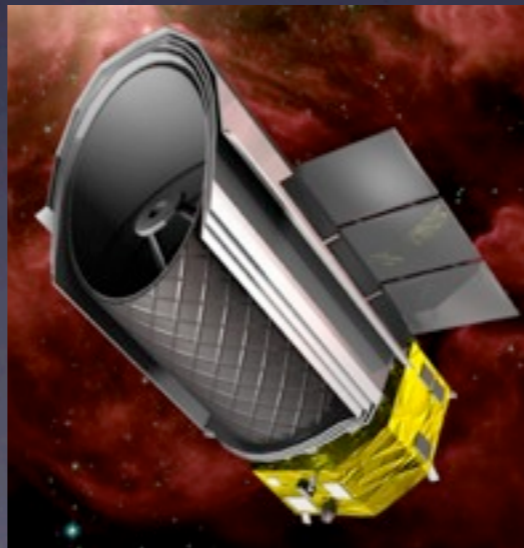
Black points are sources that still need to be classified.

# Interim LMC results

Code	Object Type	Count
YSO	Young Stellar Objects	321
STAR	Stellar photospheres	35
C-AGB	Carbon-rich AGB stars	152
O-AGB	Oxygen-rich AGB stars	98
RSG	Red SuperGiants	67
C-PAGB	Carbon-rich post-AGB stars	26
O-PAGB	Oxygen-rich post-AGB stars* (*inc. RVTau	42 9)
C-PN	Carbon-rich planetary nebulae	29
O-PN	Oxygen-rich planetary nebulae	32
HII	HII regions	105
GAL	Galaxies	7
UNK	Unknown	8
UNC	Unclassified	78

# Implications and questions

- Spectra act as check on colour classifications
- SEDs should allow calculation of dust budget
- Can we stack spectra for each object type?
- Can we predict bulk photometry from spectra?
- Predict high- $z$  low metallicity galaxy colours?
- Future missions:  
M31 with *SPICA*  
at 5–210  $\mu\text{m}$



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