SAGE: Surveying the Agents of Galaxy Evolution
SAGE-Spectroscopy: The Life Cycle of Dust and Gas in the Magellanic Clouds

Evolved carbon stars in the Magellanic Clouds: photometric versus spectroscopic IR identification

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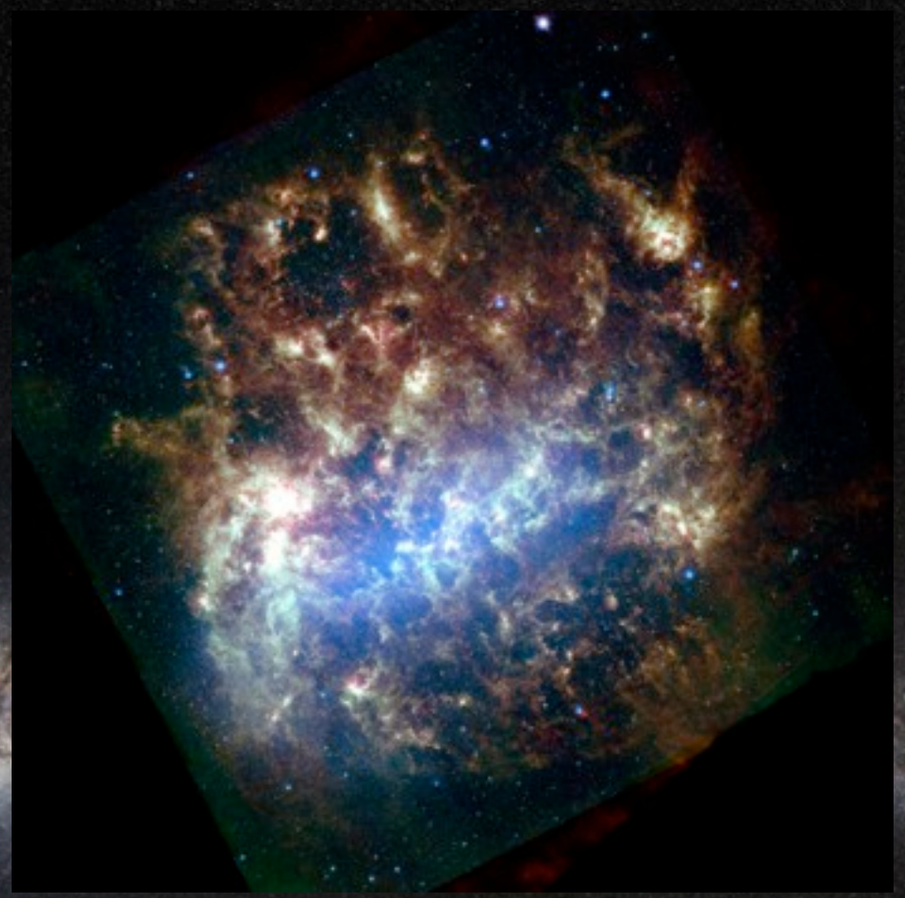
The Magellanic Clouds

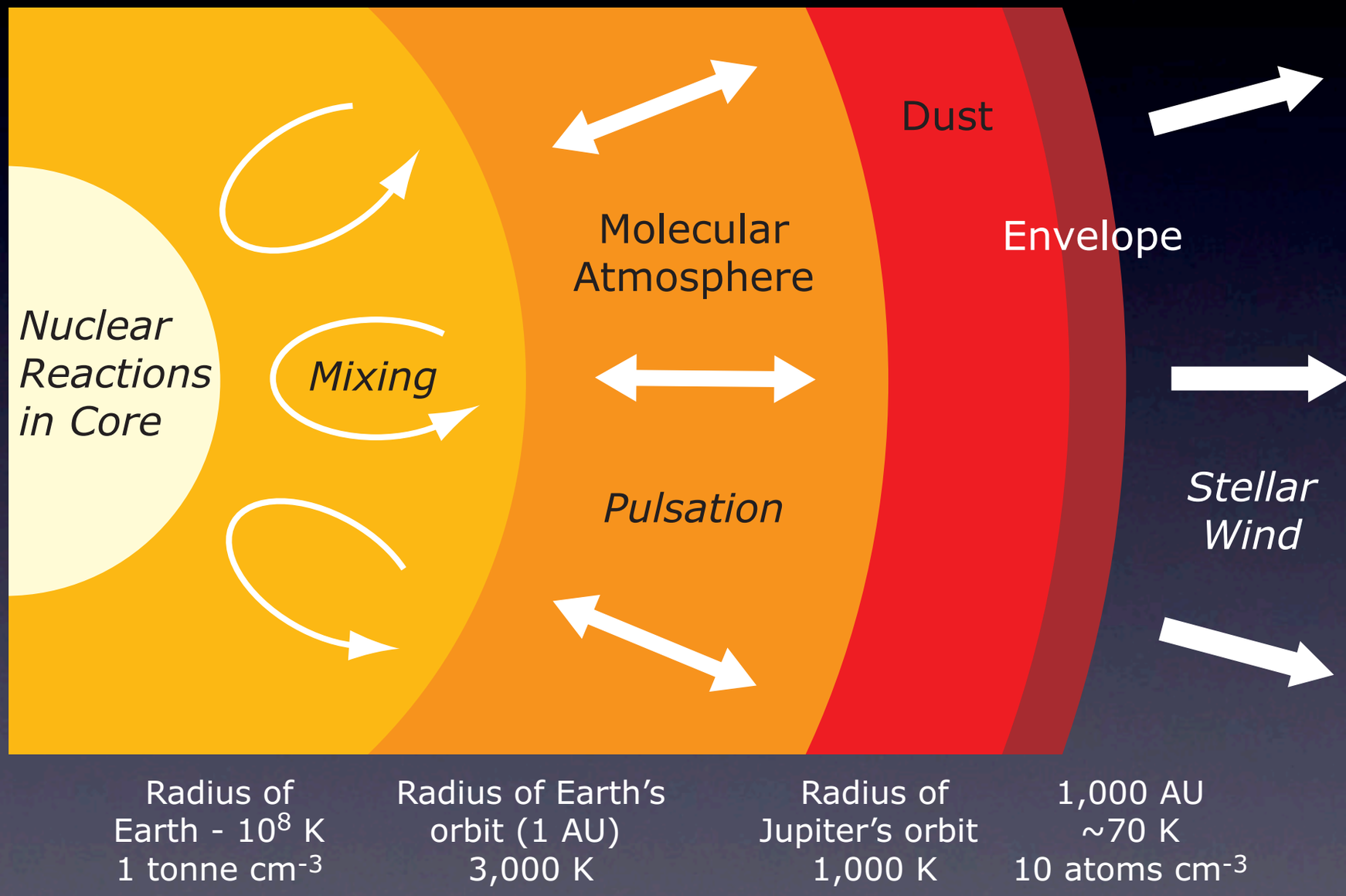


SMC: Karl Gordon (STScI) and the SAGE-SMC team. LMC: M. Meixner, K. D. Gordon (STScI) and the SAGE team. MW: ESO/Serge Brunier.

SAGE: Surveying the Agents of Galaxy Evolution

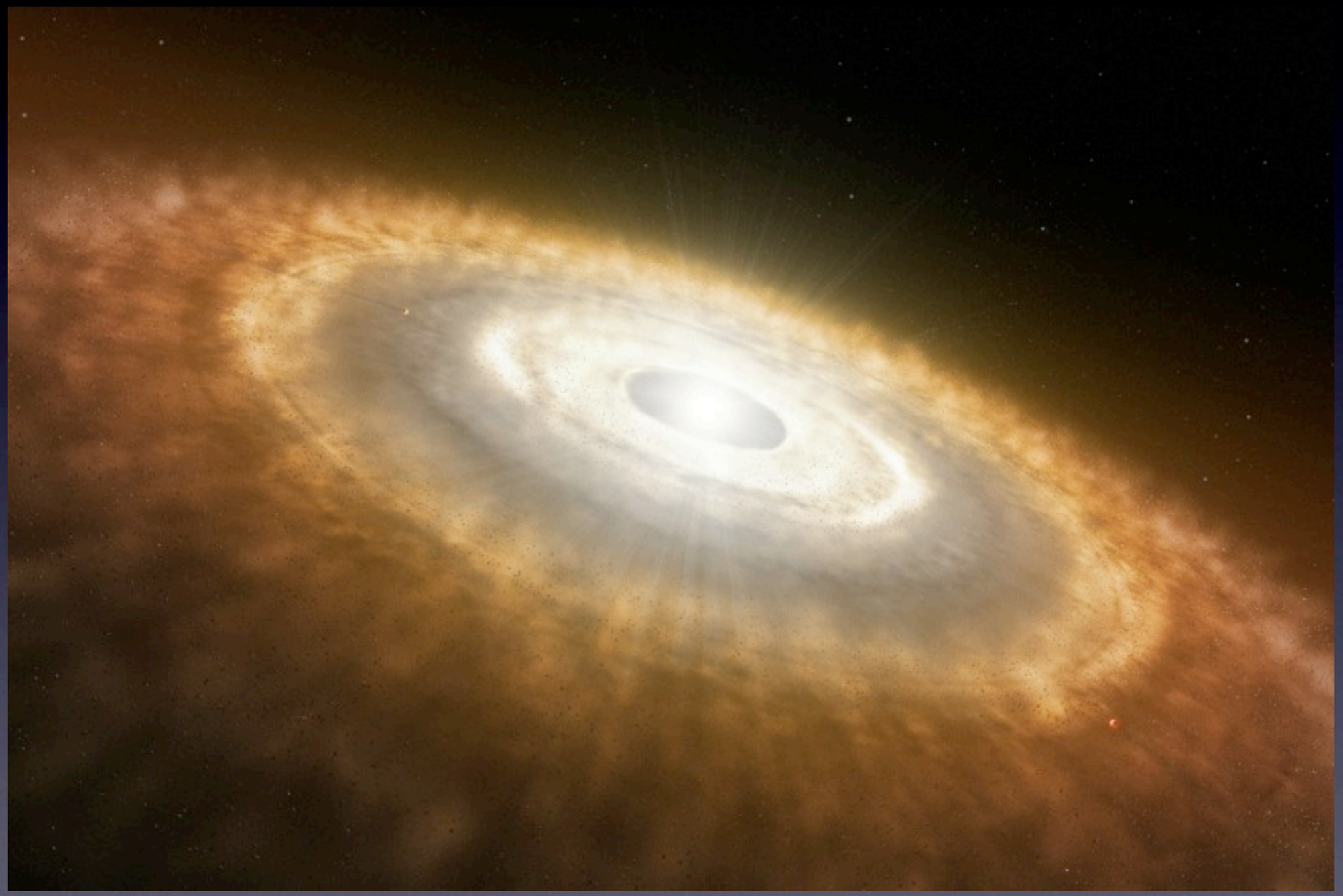
- Tracing the life cycle of observable matter that drives the evolution of a galaxy's appearance
- Key phases traced via dust emission in the ISM
- Newly forming stars and evolved dying stars
- Spitzer IR images of the LMC and SMC
- Spitzer spectroscopy of dust in LMC and SMC
- Herschel to trace coldest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

Dust production in AGB stars



Schematic View of an Asymptotic Giant Branch (AGB) Star

Dusty disc around evolved YSO

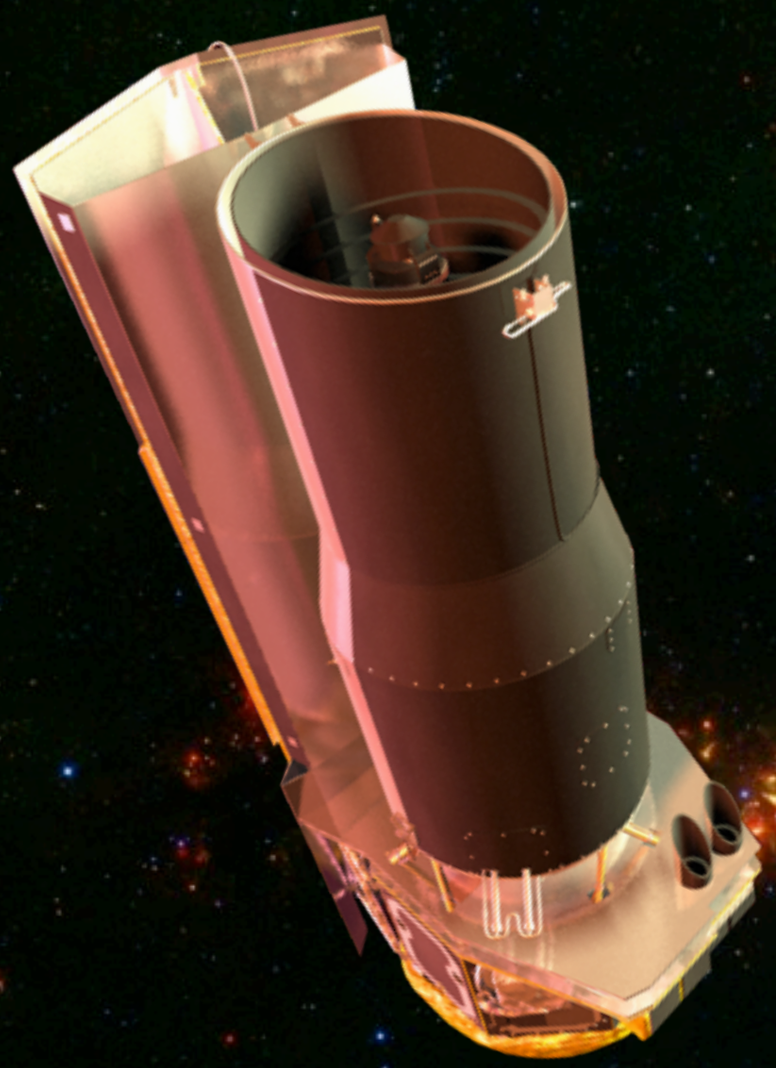


Artist's impression of a young star surrounded by a protoplanetary disc in which planets are forming (ESO/L. Calçada)

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 μm:
Low-resolution, short-wavelength 5.3–14 μm
Low-resolution, long-wavelength 14–40 μm
High-resolution, short-wavelength 10–19.5 μm
High-resolution, long-wavelength 19–37 μm

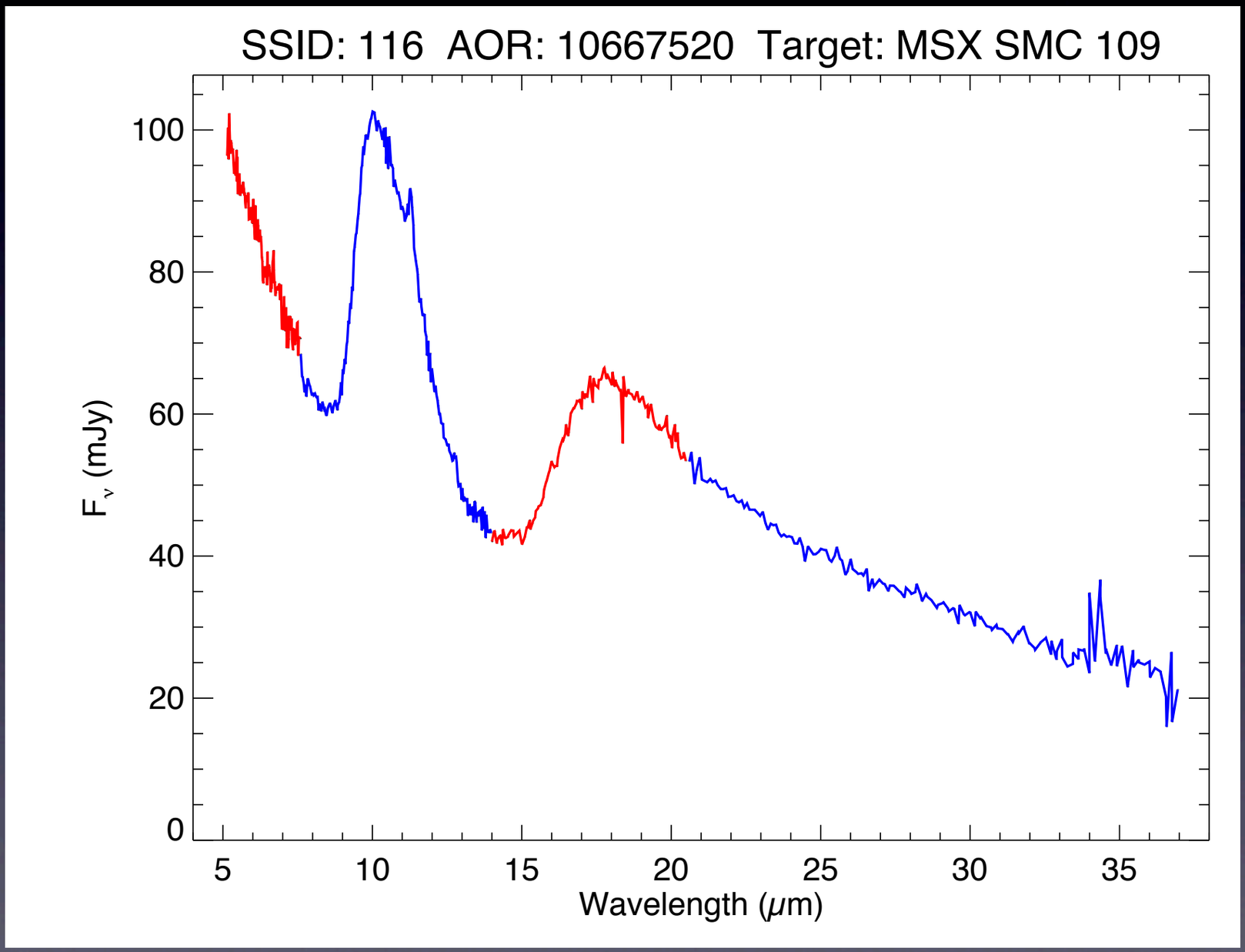
InfraRed Array Camera (IRAC)

Images at 3.6, 4.5, 5.8 and 8.0 μm

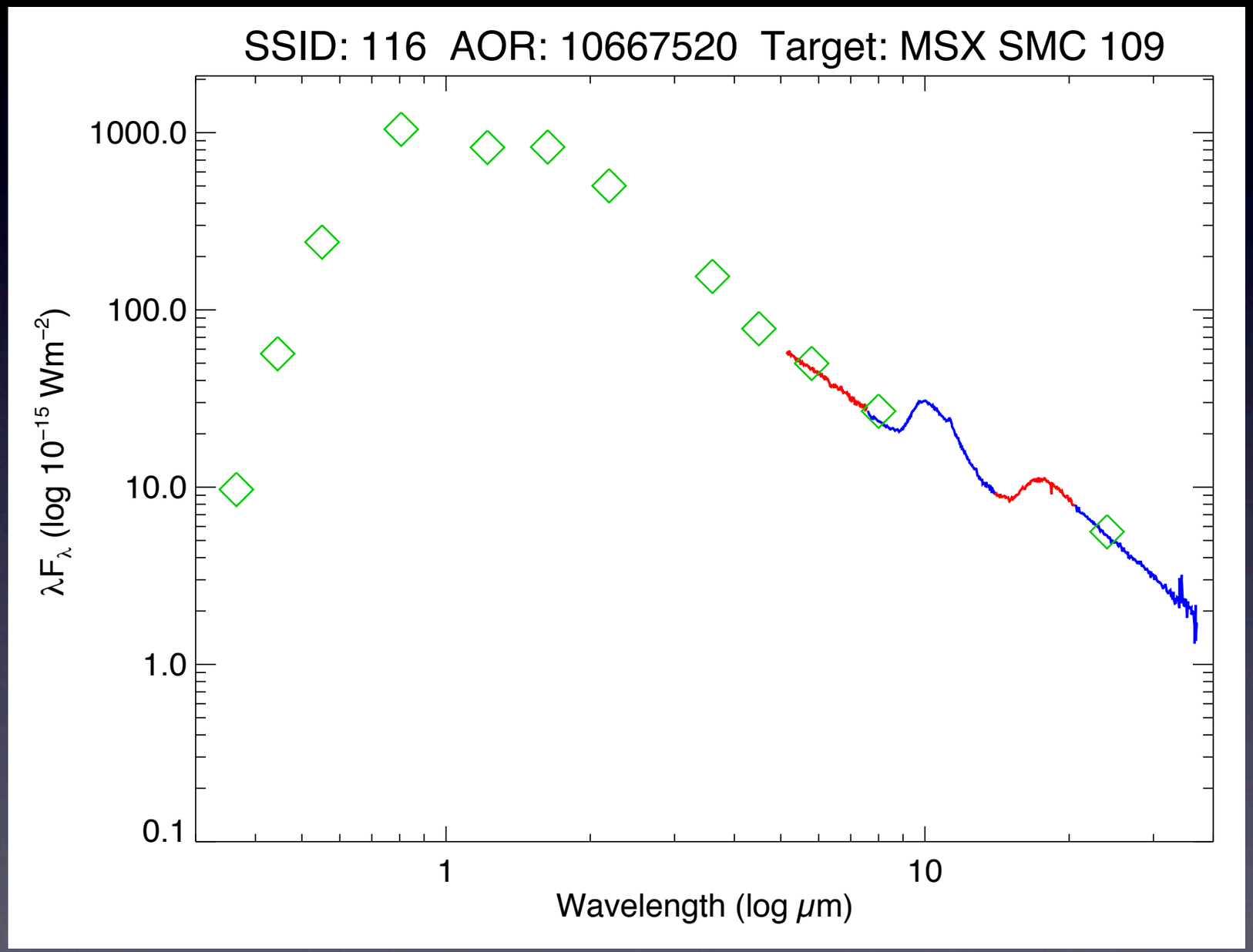
Multiband Imaging Photometer (MIPS)

Images at 24, 70 and 160 μm
Spectra from 50–100 μm

Example IRS spectra



SED: photometry plus spectra



Calculate bolometric luminosity L_{bol}

Point source classification

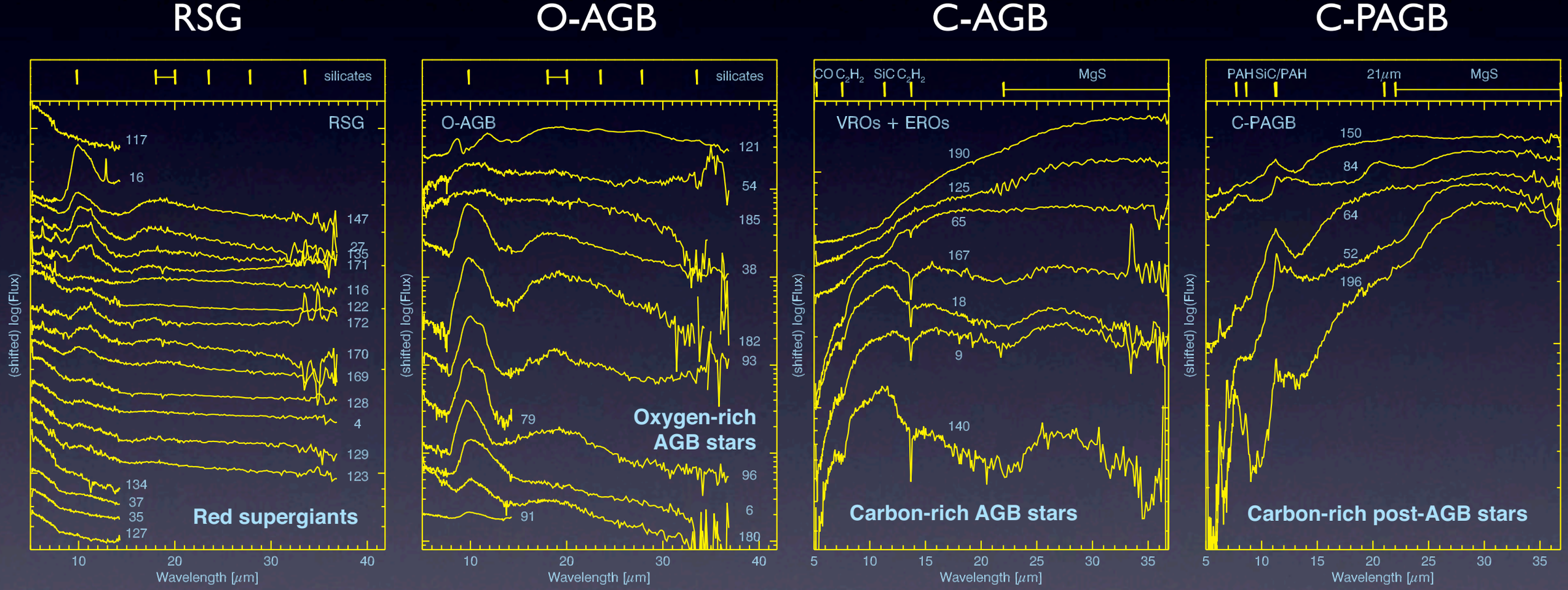
1,000 IRS staring mode observations in LMC (including 197 from SAGE-Spec legacy program)*

~250 IRS staring mode observations in SMC

- Spitzer IRS spectra (λ = 5.2–38 μm),
- Associated UBVIJHK, IRAC and MIPS photometry
- Luminosity, variability and age
- Other information
- Navigate decision tree
- For SMC now a web based process

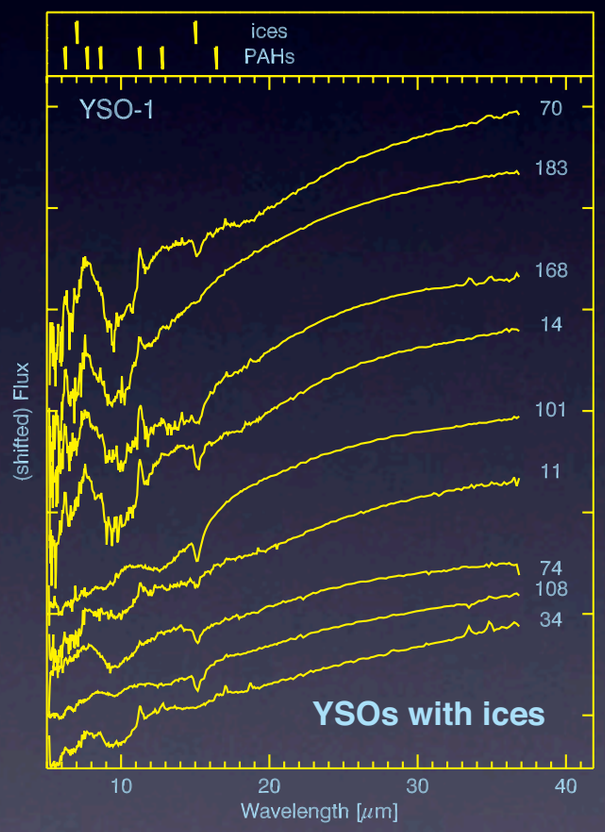
**Woods et al. 2011*

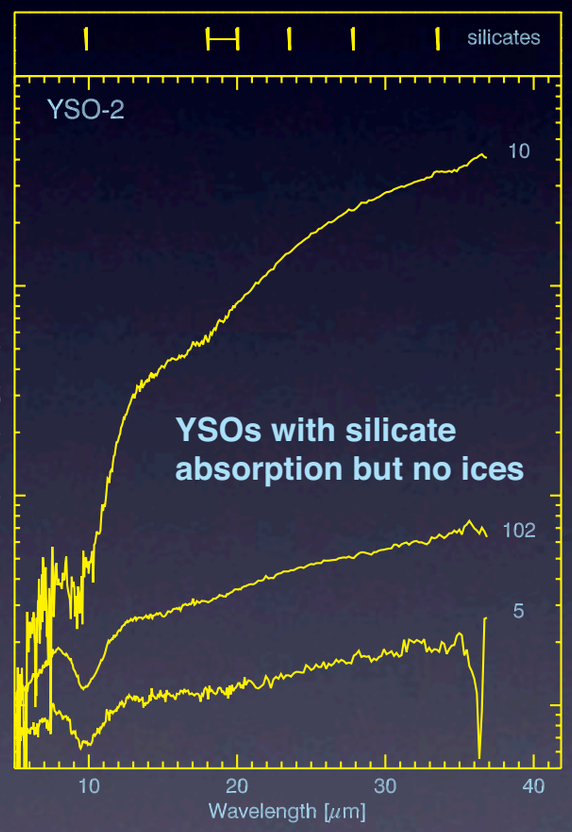
Evolved stars

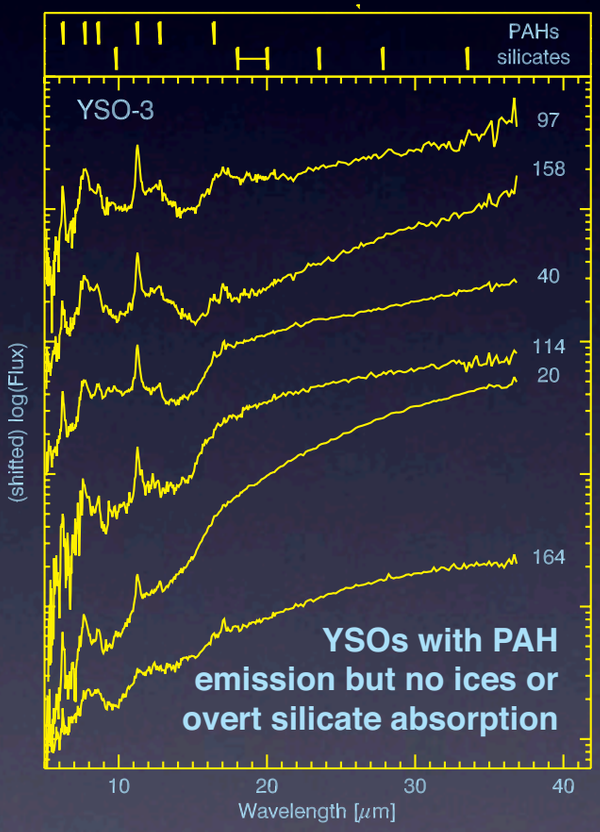


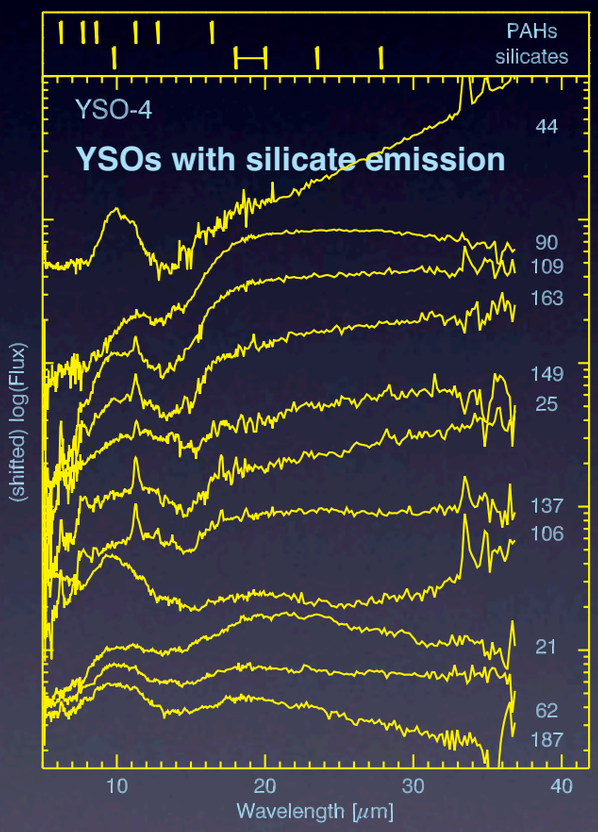
Woods et al. 2011

Young Stellar Objects



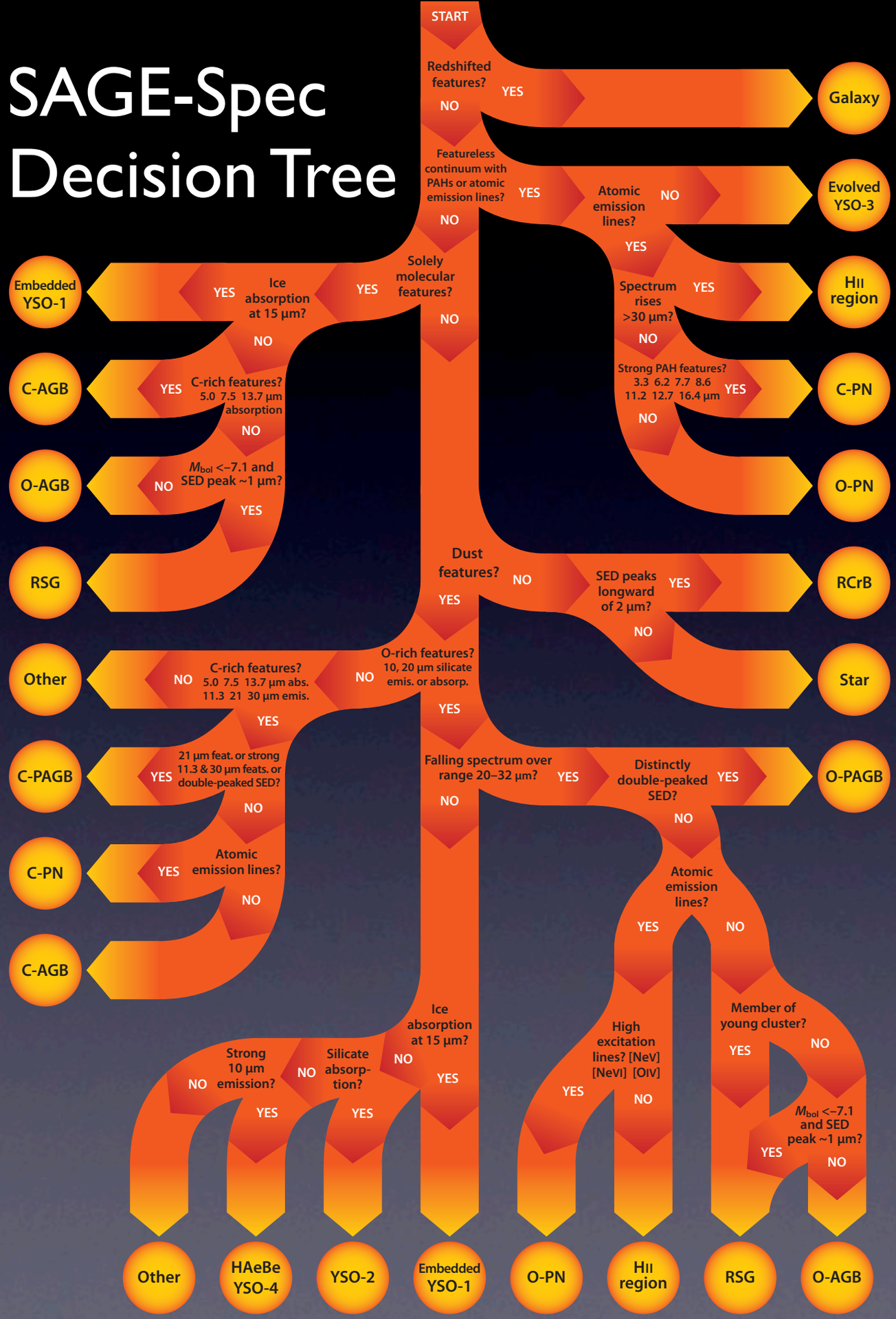






Woods et al. 2011

SAGE-Spec Decision Tree



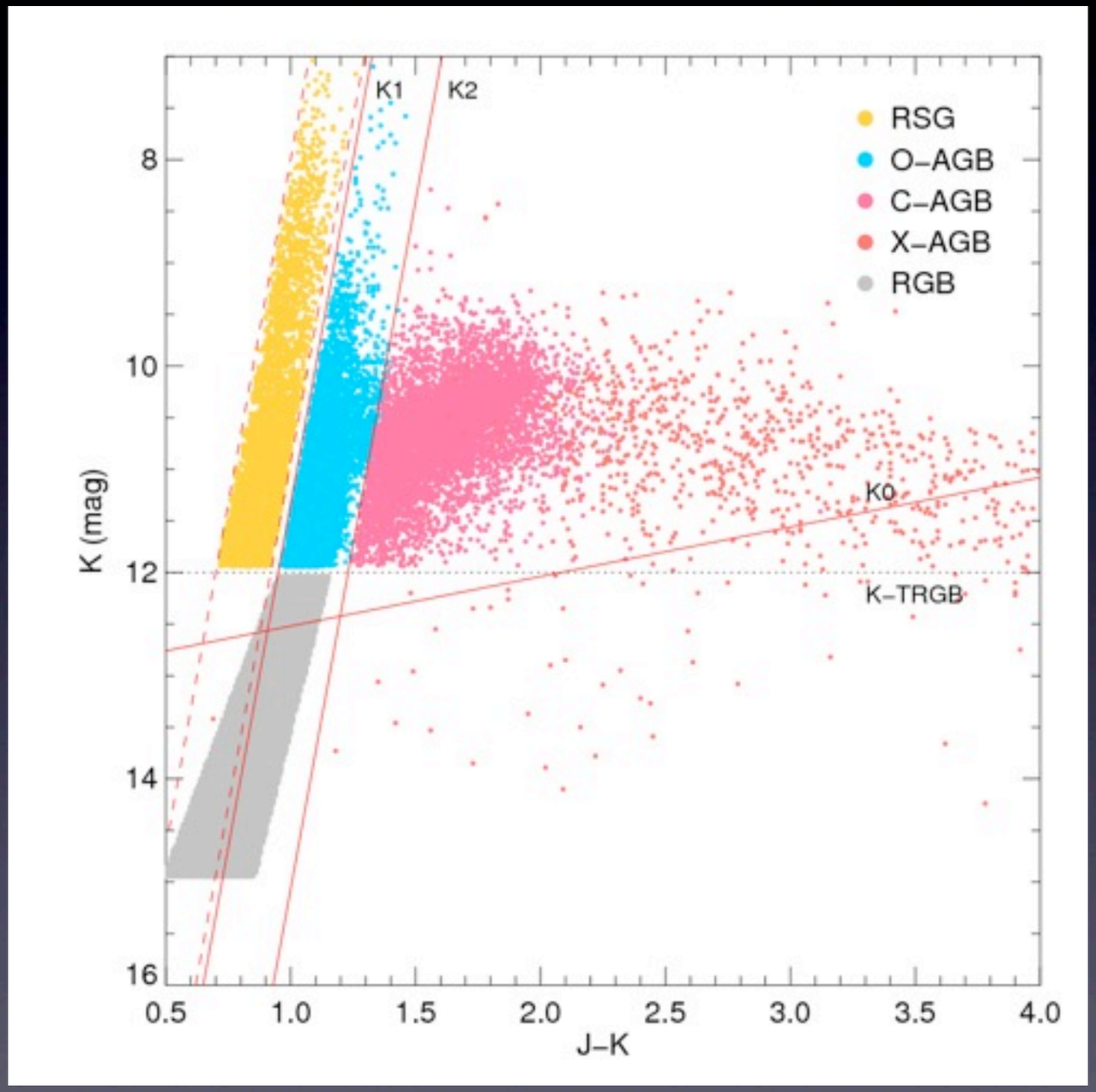
Ruffle et al. 2012

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*	42
	(*inc. RVTau	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

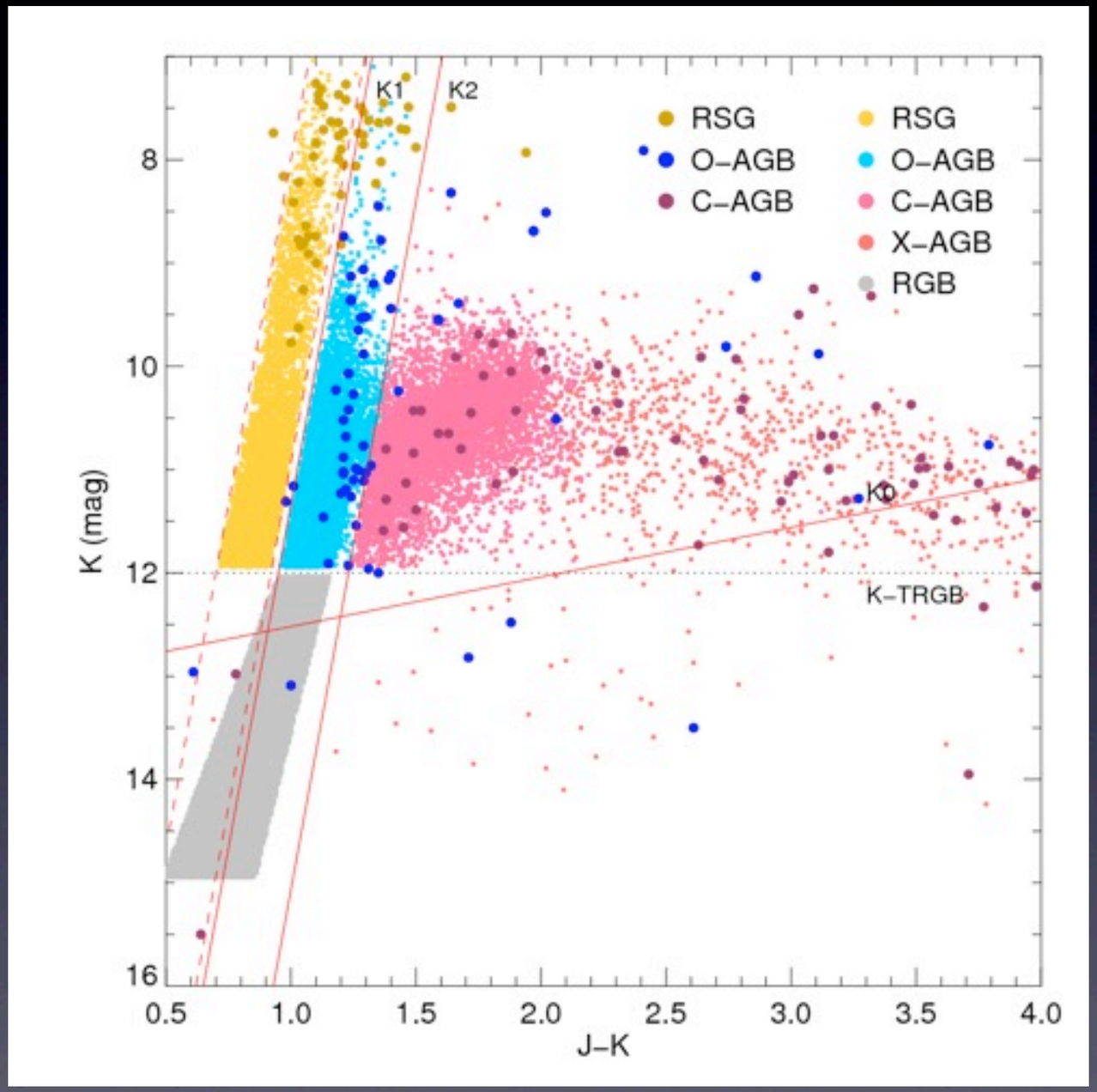
Ruffle et al. 2012

LMC photometry: RSG and AGB



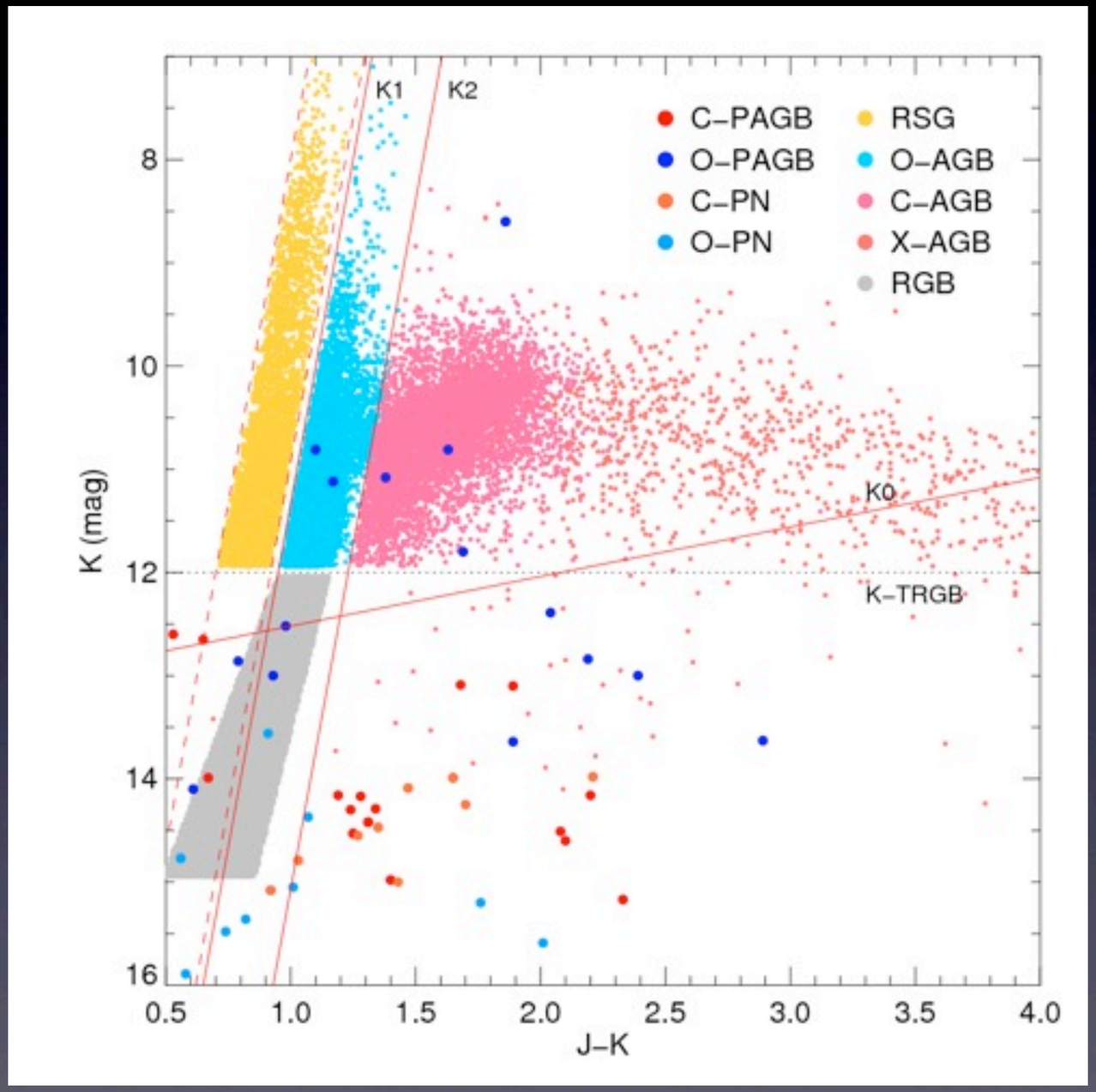
AGB cuts after Cioni et al. 2006, RSG cuts after Boyer et al. 2011.

LMC photo vs spec: RSG and AGB



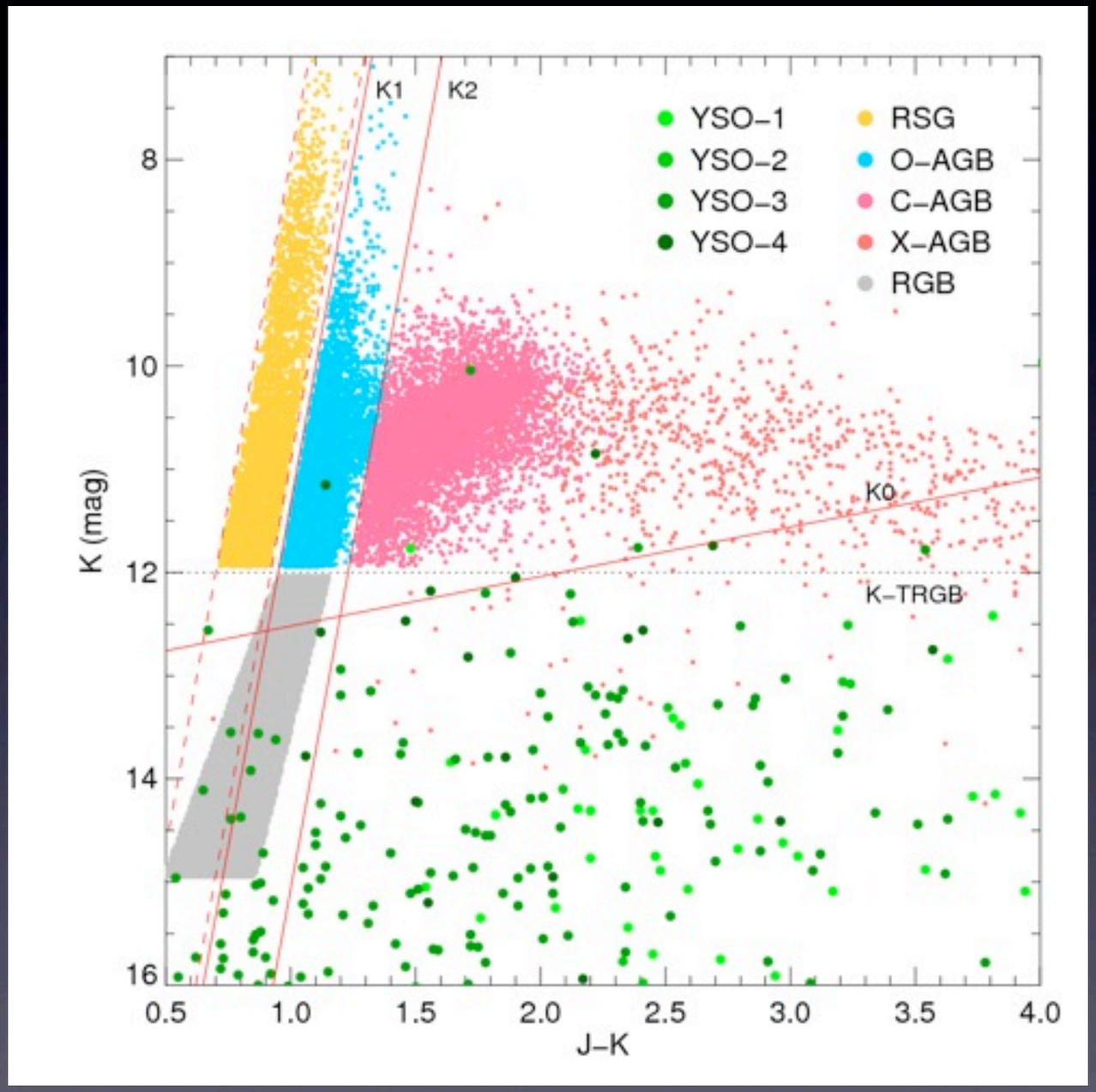
AGB cuts after Cioni et al. 2006, RSG cuts after Boyer et al. 2011.

LMC photo vs spec: PAGB and PN



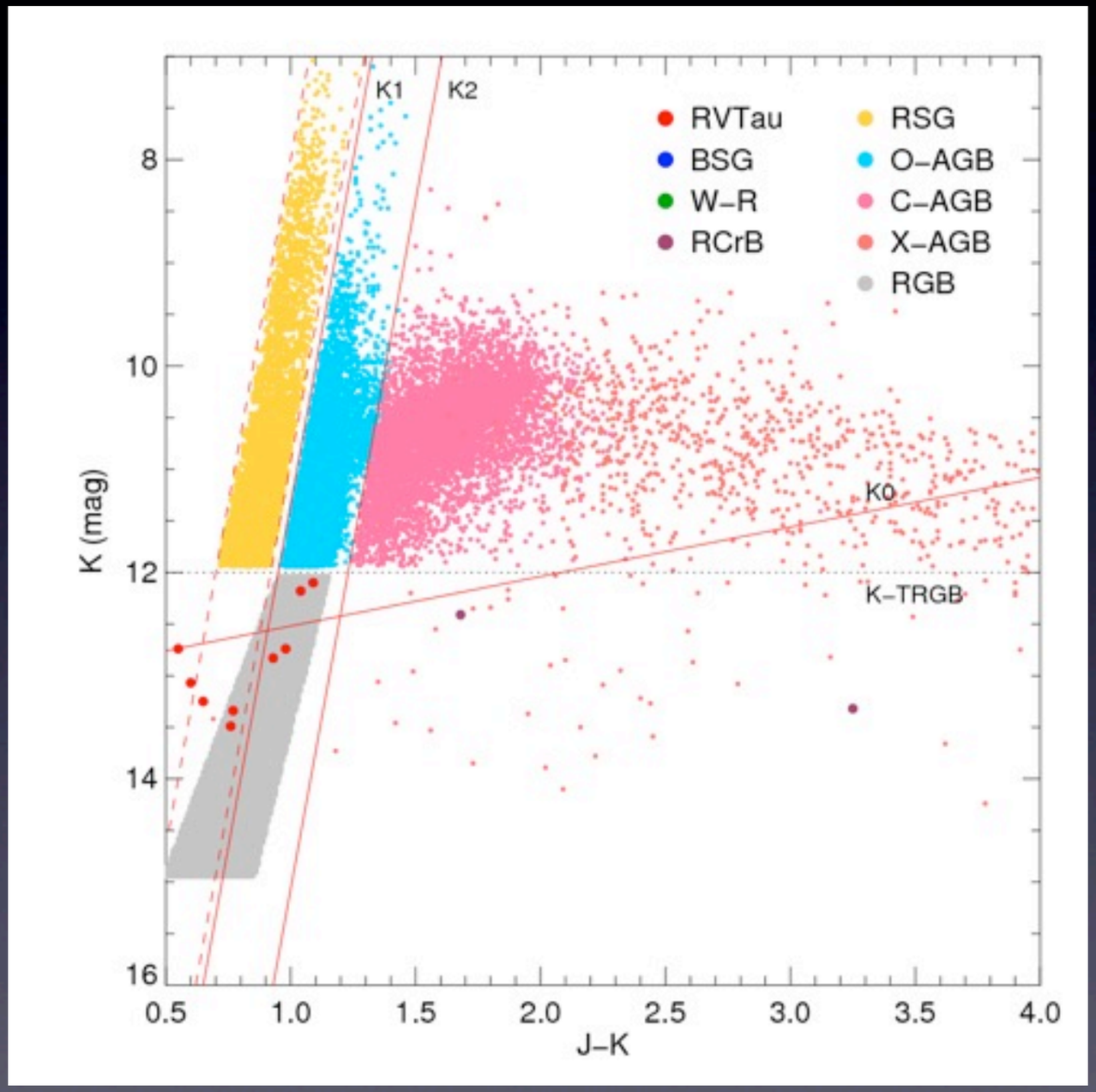
AGB cuts after Cioni et al. 2006, RSG cuts after Boyer et al. 2011.

LMC photo vs spec: YSOs



AGB cuts after Cioni et al. 2006, RSG cuts after Boyer et al. 2011.

LMC photo vs spec: Others



AGB cuts after Cioni et al. 2006, RSG cuts after Boyer et al. 2011.

Conclusion

- Spectral classifications act as check on colour classification schemes
- SEDs should allow calculation of dust budget
- Robustness of relying on photometric colours when identifying evolved carbon stars?
- Implications of misidentification when calculating dust inputs to the ISM
- Oxygen rich anomaly?

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