STUDY OF EVOLVED STARS AND THEIR CIRCUMSTELLAR ENVIRONMENT IN THE MID-INFRARED

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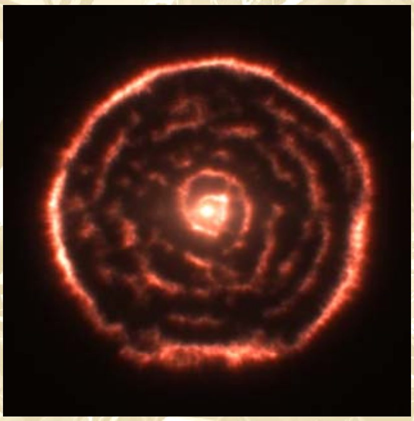
METIS
Mid-infrared E-ELT Imager and Spectrograph

Boundary Conditions

- using the METIS instrument specification (talk by B. Brandl)
- basic properties of objects as presented by M. Groenewegen
- evolved stars not a primary E-ELT science case BUT: "shining examples and common inhabitants "*

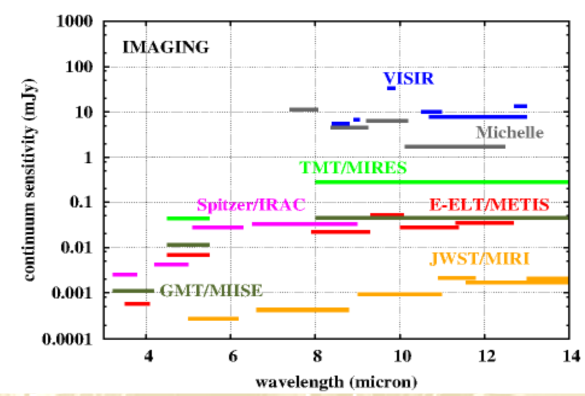


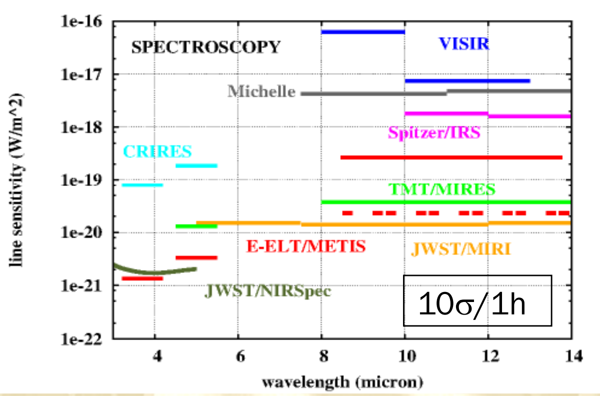
ALMA observations of R Scl (Maercker et al. 2012)

* Why Galaxies Care About AGB Stars II

Assumed Sensitivities

- L,M IFU: R=100000, 1.5“x0.4“ FOV, 18mas slice width
- L, M, N long slit: R= a few 1000, 20-100mas slits (IFU option)
- L,M,N imaging: 18“x 18“ FOV, 9mas & 17mas pixel FOV
- ~5^{mag} gain over existing L,M,N ground-based instruments
- advantage over JWST w.r.t. spectral and angular resolution



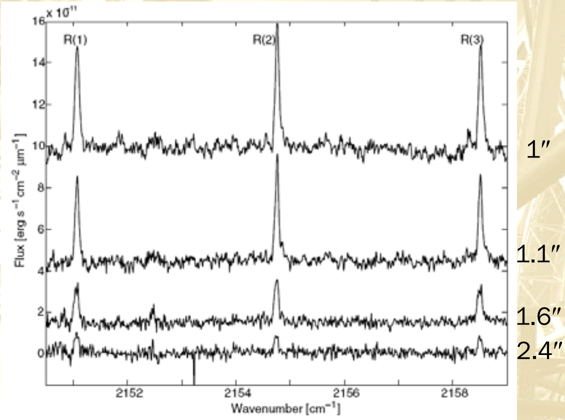


Evolved Stars – FAQ to be Answered

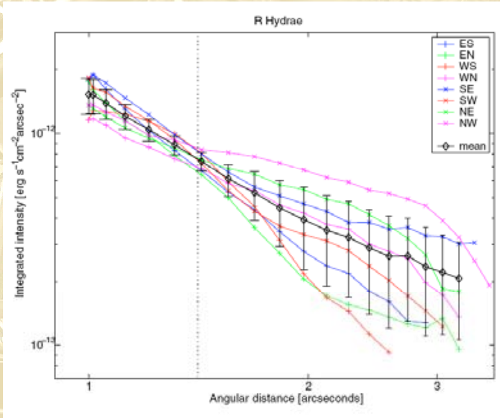
- which physical and chemical processes are relevant for dust formation and mass loss?
- what links the shape and kinematics of the envelopes with the central star at different evolutionary stages?
- how does mass loss depend on metallicity?
- how do the circumstellar disks evolve and what are the similarities to protoplanetary disks?
- what is the evolutionary connection between AGB stars and PNe?
- what is the role of binarity?

Molecular Envelopes in 2(3?)D

- L & M-band: lines from many species important for dust formation and chemistry: CO, H_2O, C_2H_2, SiO,.....
- resolve molecular lines spatially and spectroscopically
  ⇒ spatial and kinematic structure



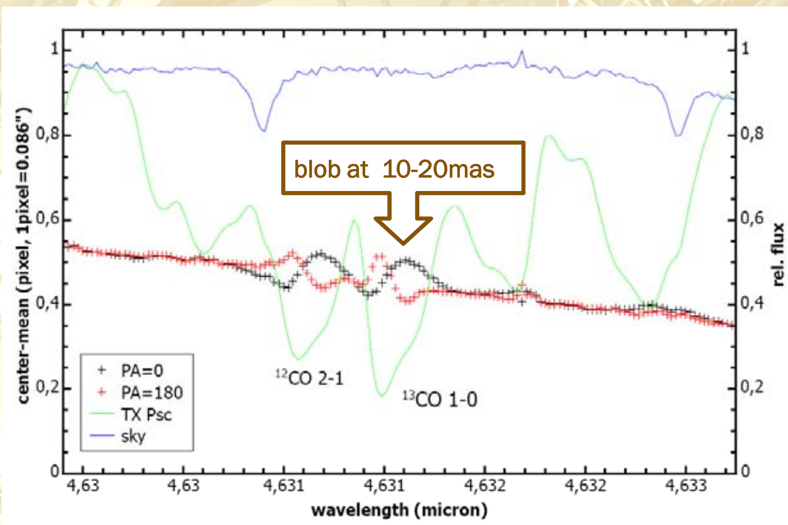
M-band CO-emission spectra to the east of the Mira R Hya (Decin et al. 2008).



M-band CO emission line intensity vs. angular distance from R Hya for eight different directions (Decin et al. 2008).

Molecular Envelopes in 2(3?)D – cont‘d

- linking the envelope to the central star:
  convection, blobs, inner wind structure, companions
- synergies with MATISSE and ALMA

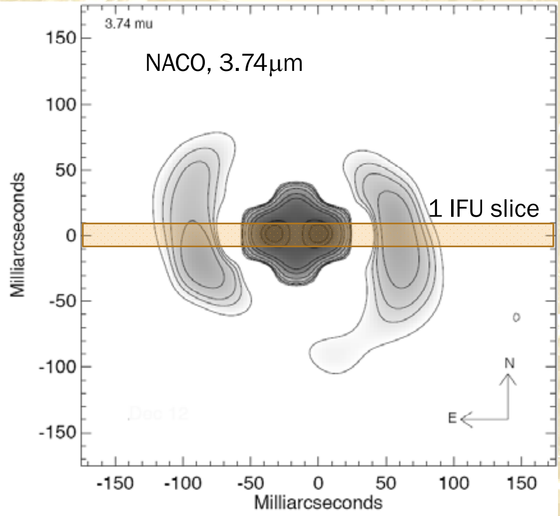


CRIRES spectro-astrometry of the bright Carbon star TX Psc (Hron et al. in prep).

Molecular Envelopes in 2(3?)D – cont'd

Close targets are (too) bright ⇒

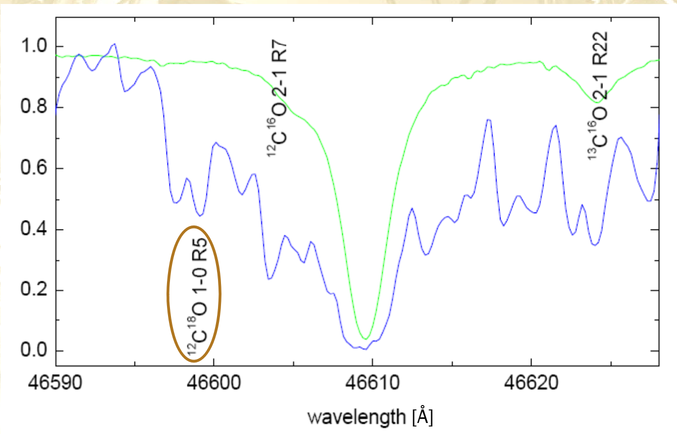
- extend the sampled volume and/or
- avoid/minimize saturation:
  detector, coronagraph, sparse aperture masking?



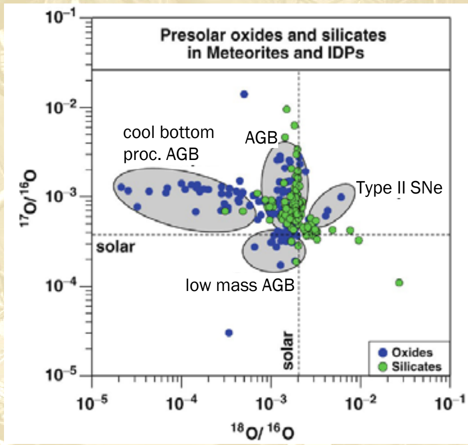
NACO sparse aperture masking image of a bright M-type semiregular variable. Contour levels are 1, 2, 3, 5, 10, 20, 30, 70, 85% of peak (Lykou et al., in prep.).

Molecules and Stellar Evolution

- several isotopic species are accessible to investigate nucleosynthesis and mixing: $^{12}C/^{13}C$, $^{16}O/^{18}O$, $^{24}Mg/^{25}Mg$ ...
- synergy with (NIR)HIRES



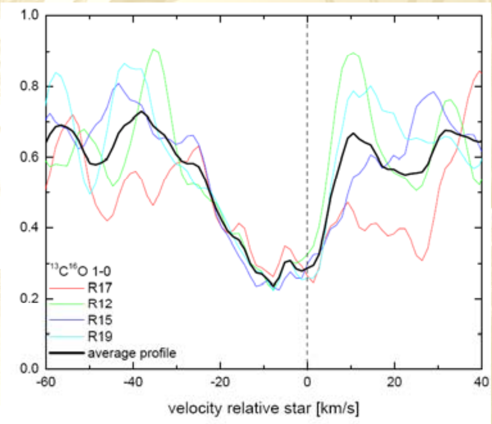
FTS spectrum of o Cet (Lebzelter et al., in prep.).



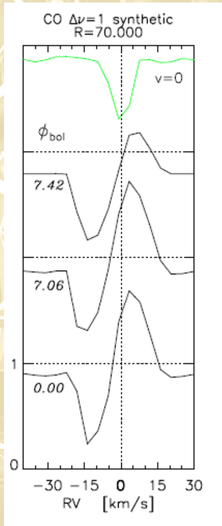
Oxygen isotopic ratios of presolar grains (Ott, 2011, in Henning, „Astromineralogy ")

Gas Enrichment of Galaxies

- use L & M-band molecular lines to estimate gas mass loss rates in local group
- calibrate with L, M & mm-CO data in the Milky Way and dynamic model atmospheres



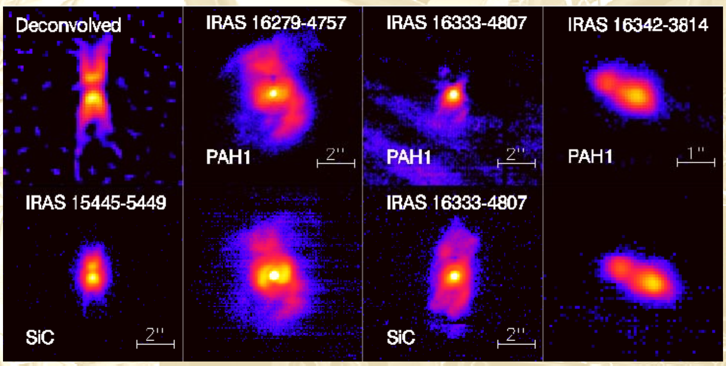
FTS M-band CO line profiles of T Cep, a Mira with a mass loss rate of ~10^{-7} $M_{\odot}$/yr (Lebzelter et al., in prep.).



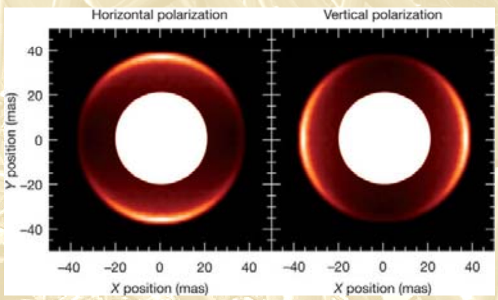
Synthetic CO-profiles from a dynamic model atmosphere with a mass loss rate of 4.10 $^{-6}$ $M_{\odot}$/yr . The uppermost panel shows the profile without taking into account the wind. The lower profiles are for different pulsation phases (Nowotny et al., 2005).

Dusty Envelopes in 2D

- only 25% of current VISIR sample of post-MS objects are resolved
- imaging can extend the sample by almost a factor of 50 ⇒ proper statistics for different object classes
- polarimetric imaging allows to study grain sizes, alignment,...



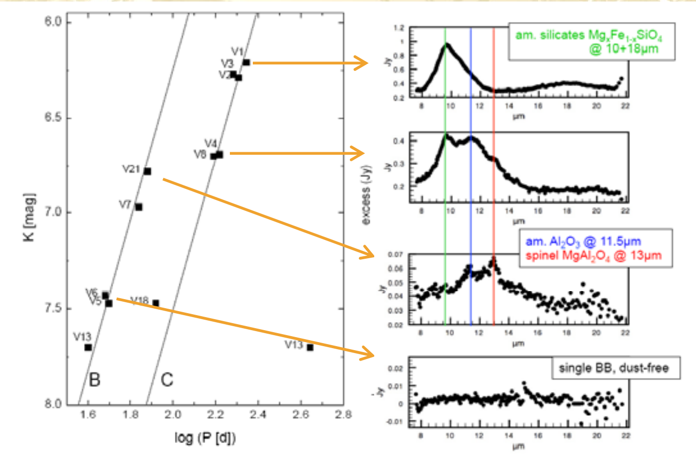
Selection of VISIR images of evolved objects (Lagadec et al. 2011)



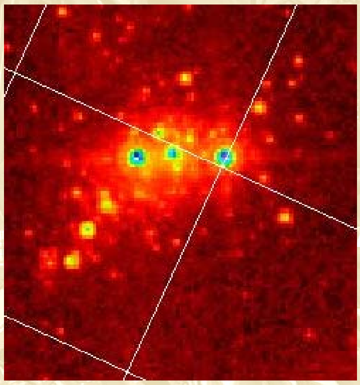
Polarization model predictions for W Hya at 1.2µm (Norris et al. 2012)

Dust Mineralogy

- low-resolution N-band spectra of well resolved sources
  ⇒ mineralogy (composition, crystallinity) vs. location
- low-resolution N-band spectra of individual cluster stars in galaxies ⇒ mineralogy vs. evolutionary stage



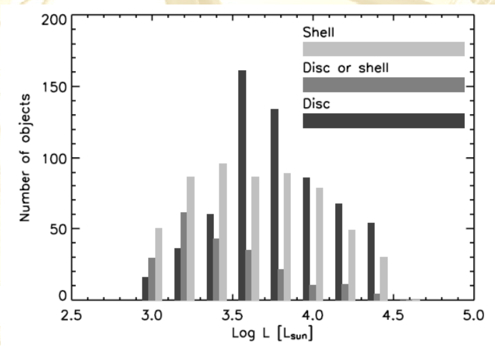
Period luminosity diagram and SPITZER-spectra of evolved variables in 47 Tuc (Lebzelter et al. 2006).



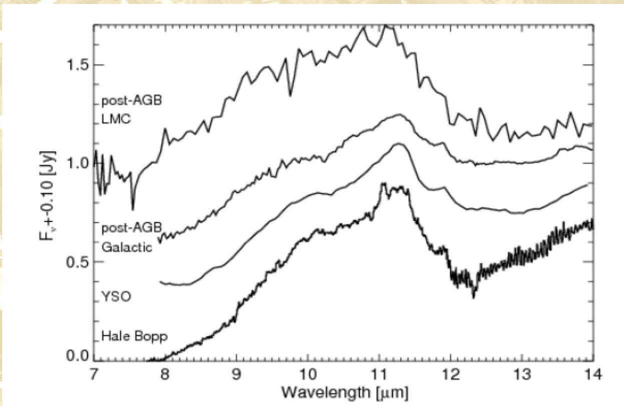
NGC 1978 in LMC at 8µm (SPITZER-SAGE; 2‘ grid).

Disks in the LMC and SMC

- 30% of LMC/SMC post-AGB candidates show disks
  ⇒ importance of disk formation in binary evolution
- N-band spectrosopy: dust mineralogy and correlation between evolution and dust processing
- L- & M-band spectroscopy: abundances and kinematics of hot gas, binary motion



Post-AGB candidates in LMC (van Aarle 2011).

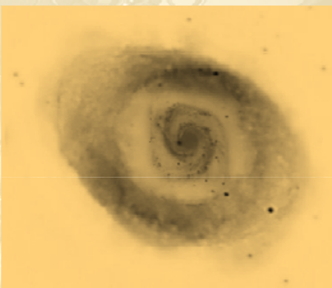


Comparison of silicate emission profiles (van Winckel).

Conclusions

- evolved stars offer broad science cases from stellar evolution to galactic evolution, from nucleosynthesis to dust formation and from the formation of small scale structrures to circumstellar disks
- the mid-IR contains a wide range of diagnostic features for these objects and also poorly explored spectral regions
- high spectral and/or spatial resolution observations in the mid-IR are an excellent complement to JWST, ALMA, VLTI…
- E-ELT opens up MIR studies of individual objects in external galaxies
- evolved stars are generally „easy“ targets to observe and thus good test objects for more challenging observations

Preliminary Announcement



Why Galaxies Care About AGB Stars III

28.7.-1.8.2014 Vienna

www.univie.ac.at/galagb/