E-ELT METIS* AND MATISSE: PROSPECTS FOR AGB-STARS

J. Hron¹, J. Blommaert², L. Decin², T. Lebzelter¹, C. Paladini³,¹, H. Van Winckel² and the METIS and MATISSE teams

(1) Universitätssternwarte Wien, Austria
(2) Instituut voor Sterrenkunde, K.U.Leuven, Belgium
(3) Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Belgium

*Alias E-ELT-MIR
GENERAL ASPECTS

• AGB-stars offer lots of astrophysics:
  ➢ nucleosynthesis and strong mixing
  ➢ cool, inhomogeneous photospheres with variety of dust and molecular species
  ➢ pronounced variability (pulsation+...)
  ➢ extended circumstellar envelopes with significant mass loss
  ➢ presence of disks and asymmetries
  ➢ role in galactic evolution

• AGB-stars not a primary (METIS/MATISSE) science case BUT: "shining examples and common inhabitants"*

* Why Galaxies Care About AGB Stars II
AGB-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 to 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?
AGB-Stars and the thermal IR
MATISSE

- 2nd generation VLTI-instrument: L,M,N band, 4 telescope combiner ("imaging"!), spectral resolution 30-5000, L/N-sensitivities 0.15/1 Jy (UTs, without fringe tracker)
- Consortium: Nice (PI), Leiden, Heidelberg, Bonn, Kiel, Wien
- Start of operations 2017/2018
• One of three defined E-ELT instruments (PI Leiden)
• 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: 20“x 20“ FOV, 9mas & 17mas pixel FOV
• \( \sim 5^{\text{mag}} \) gain over existing L,M,N ground-based instruments
• advantage over JWST w.r.t. spectral and angular resolution

![Graph showing line sensitivity vs. wavelength for various instruments, with METIS highlighted.](image)
Molecular Envelopes in 2(3?)D

- 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

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

L-band Visibilities predicted from dynamical model atmospheres.
Molecular Envelopes in 2(3?)D – cont’d

close targets are (too) bright for METIS ⇒

• extend the sampled volume and/or avoid saturation: detector, coronagraph, sparse aperture masking
• imaging with MATISSE

Simulated L-Band images of a Betelgeuze-like star.
(MATISSE Science case).

NACO sparse aperture masking image of a bright M-type semiregular variable. Contour levels are 2, 5, 10, 20, 50, 80% of peak (Lykou et al., subm.).
Molecules and Stellar Evolution

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

![FTS spectrum of o Cet (Lebzelter et al., in prep.).](image1)

![Oxygen isotopic ratios of presolar grains (Ott, 2011, in Henning, „Astromineralogy“)](image2)
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 \( \sim 10^{-7}\) \(\text{M}_\odot/\text{yr}\) (Lebzelter et al., in prep.).

Synthetic CO-profiles from a dynamic model atmosphere with a mass loss rate of \(4 \times 10^{-6}\) \(\text{M}_\odot/\text{yr}\). 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

- direct METIS imaging can increase sample of resolved post-MS objects by almost factor of 50 ⇒ proper statistics for different object classes
- interferometric N-band imaging to link dust structures to molecules

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

Reconstructed image of a C-rich star (PIONIER, H-band; Paladini et al., talk)
Dust Mineralogy

- spatially resolved N-band spectra / spectro-interferometry ⇒ 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).

Change of Silicate-signature in MIDI- visibilities with baseline length (Klotz et al., in prep.).
Disks

- 30% of LMC/SMC post-AGB candidates show disks
  - N-band spectroscopy: dust mineralogy and correlation between evolution and dust processing
  - L- & M-band spectroscopy: abundances and kinematics of hot gas, binary motion
- MATISSE: detailed structure of galactic objects

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Post-AGB candidates in LMC (van Aarle 2011).  
Comparison of silicate emission profiles (van Winckel).
Conclusions

- (post-) AGB stars offer broad science cases
- the thermal 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 thermal IR are an excellent complement to JWST & ALMA
- E-ELT opens up MIR studies of individual objects in galaxies
- AGB-stars are generally „easy“ targets to observe and thus good test objects for more challenging observations.
- SO: start thinking about the science you want to do!