Steps towards disentangling asymmetric AGB winds using MATISSE: the case of X TrA

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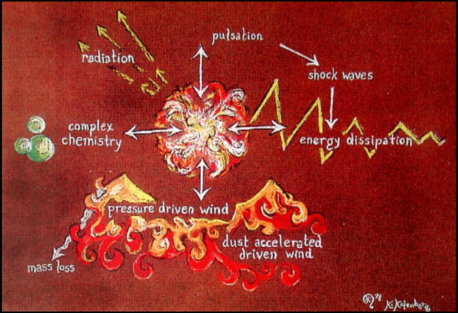
AGB stars and mass-loss



Origins of mass-loss. Painting by Kathrien Kohlenberg

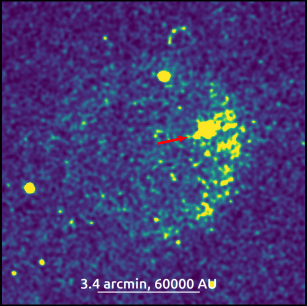
- Asymptotic giant branch stars:
  - significant mass-loss
  - complex wind formation mechanism
    - pulsation enhanced dust-driven outflow
- Many open questions – e.g. geometry of outflows

- AGB atmospheres & CSEs – many mechanisms at play
  - pulsations, convection, companions, ISM
  - deviations from spherically symmetric, continuous outflows
- AGB to PN transition – major difference in observed structures
- Need to look at all scales to understand what's going on

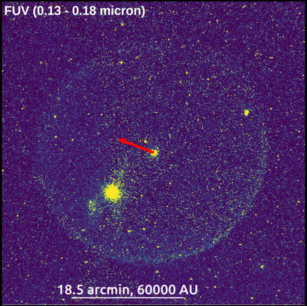
AGB & PN discrepancy

- How do we get from (mostly) symmetric wind structures seen around AGB stars to (mostly) asymmetric PNe?
- major morphology changes – seemingly fast transition

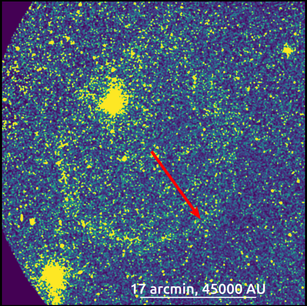
Răstău+2023



U Ant – irregular, C-type



β Gru – semi-regular, M-type



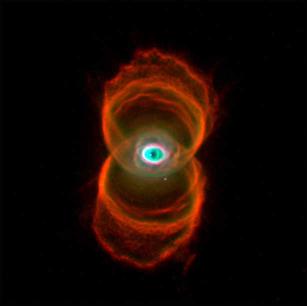
R Dor – semi-regular, M-type

AGB & PN discrepancy

- How do we get from (mostly) symmetric wind structures seen around AGB stars to (mostly) asymmetric PNe?
- major morphology changes – seemingly fast transition

Southern Ring Nebula, JWST

NGC 2392, HST



Hourglass Nebula, HST

- need to better understand the formation and evolution of AGB winds

MATISSE BIN-AGB Large program

- Origin of deviations
  - intrinsic, extrinsic
- Many asymmetric structures/outflows – few known companions, especially within 10 R_*
- Different methods of finding companions:
  - radial velocity measurements
  - astrometry
  - interferometry (infrared, sub-mm, radio)
- need high spatial resolution observations

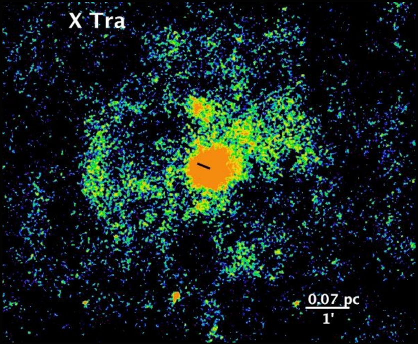
- VLTI/MATISSE
  - LM band – 3-5 μm, 3 mas spatial resolution
  - N band – 8-13 μm, 10 mas spatial resolution
    - can probe the dust-forming regions – up to 10 R_*
    - can probe dust and gas at the same time

MATISSE BIN-AGB Large program (2)

- BIN-AGB Large program – PI Claudia Paladini
  - 180 hours of observing time
  - sample of 10 AGB stars with asymmetric environments
    - M, S and C-type
    - single, suspected and known binaries
  - large team handling data reduction, image reconstruction & modelling
- Analysis of sample:
  - inner-wind properties
  - dust chemical properties
  - causes for asymmetry in the outflows
- One paper already out – V Hya, Planquart+2024

My role: analyse X TrA data

- C-type, irregular variable (Lb)
- no indications of binarity so far
- SiC dust spectral features at $\approx 4\,\mathrm{R}_*$ (MIDI, Paladini+2017)
  - MIDI spectra $\rightarrow$ diameter $\approx$ 22-39 mas
- $\dot{\mathrm{M}} \approx 1.8 \cdot 10^{-7}\,\mathrm{M}_{\odot}/\mathrm{yr}$
- infrared ring morphology

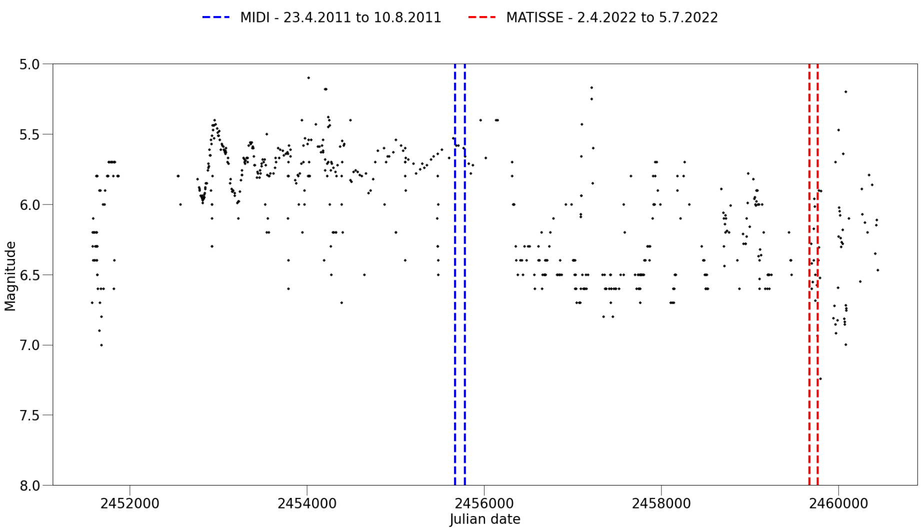


Herschel/PACS image of X TrA ($70\,\mu$m), Cox+2012

- MATISSE observations cover $2 - 10\,\mathrm{R}_*$

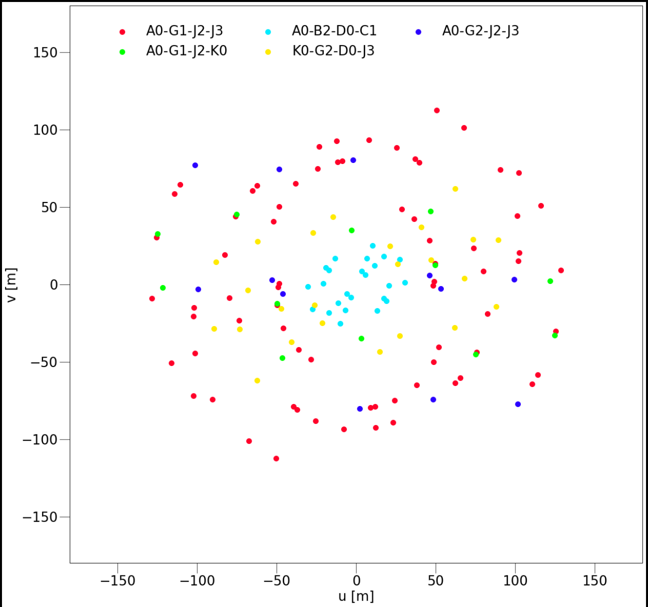
My role: analyse X TrA data (2)

Light curve of X TrA – 1.1.2000 to 1.6.2024 (AAVSO – V)



My role: analyse X TrA data (2)

uv-coverage L-band data (3.1 – 3.8 μm)



Method

- reduce the data – Matisse Python tools (MATISSE Consortium)
- Quality check (QC):
  - QC $\rightarrow$ calibration $\rightarrow$ QC
  - QC via Python codes developed by J. Drevon
- select wavelength ranges used – probe specific features
  - L-band – 3.12 to 3.20 μm (C_2H_2 & HCN absorption band)
  - L-band – 3.60 to 3.65 μm (pseudo-continuum)
- geometric modelling of data $\rightarrow$ size estimates
- Image reconstruction – multiple algorithms
  - MiRA, Thiébaut 2008
  - SQUEEZE, Baron+2010
  - IRBis, Hoffman+2014
    - helps confirm results & weed out skepticism

What next?

- X TrA
  - N-band data
  - more in-depth analysis coming – paper in the works
    - → second C-type star from the sample to be analysed
    - → first with no confirmed companion
- High angular resolution imaging – essential for understanding the origins of AGB mass-loss
- Future steps:
  - close-up → extended environment
  - hydrodynamical modelling work

Stay tuned!

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