The Nearby Evolved Stars Survey

The gas and dust return to the Galactic ISM

Peter Scicluna

Ishigaki

EAYAM, 15th November 2017

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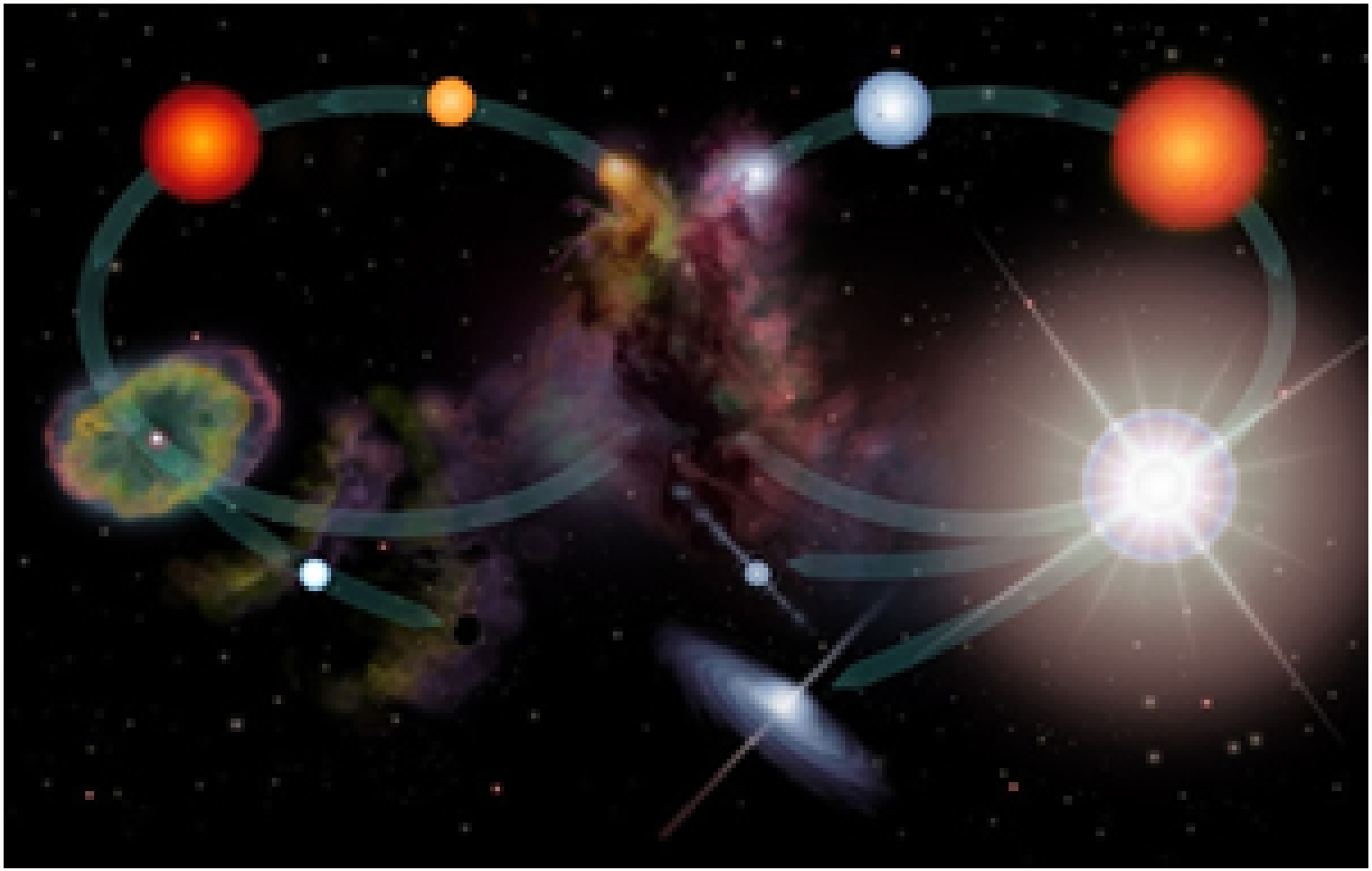
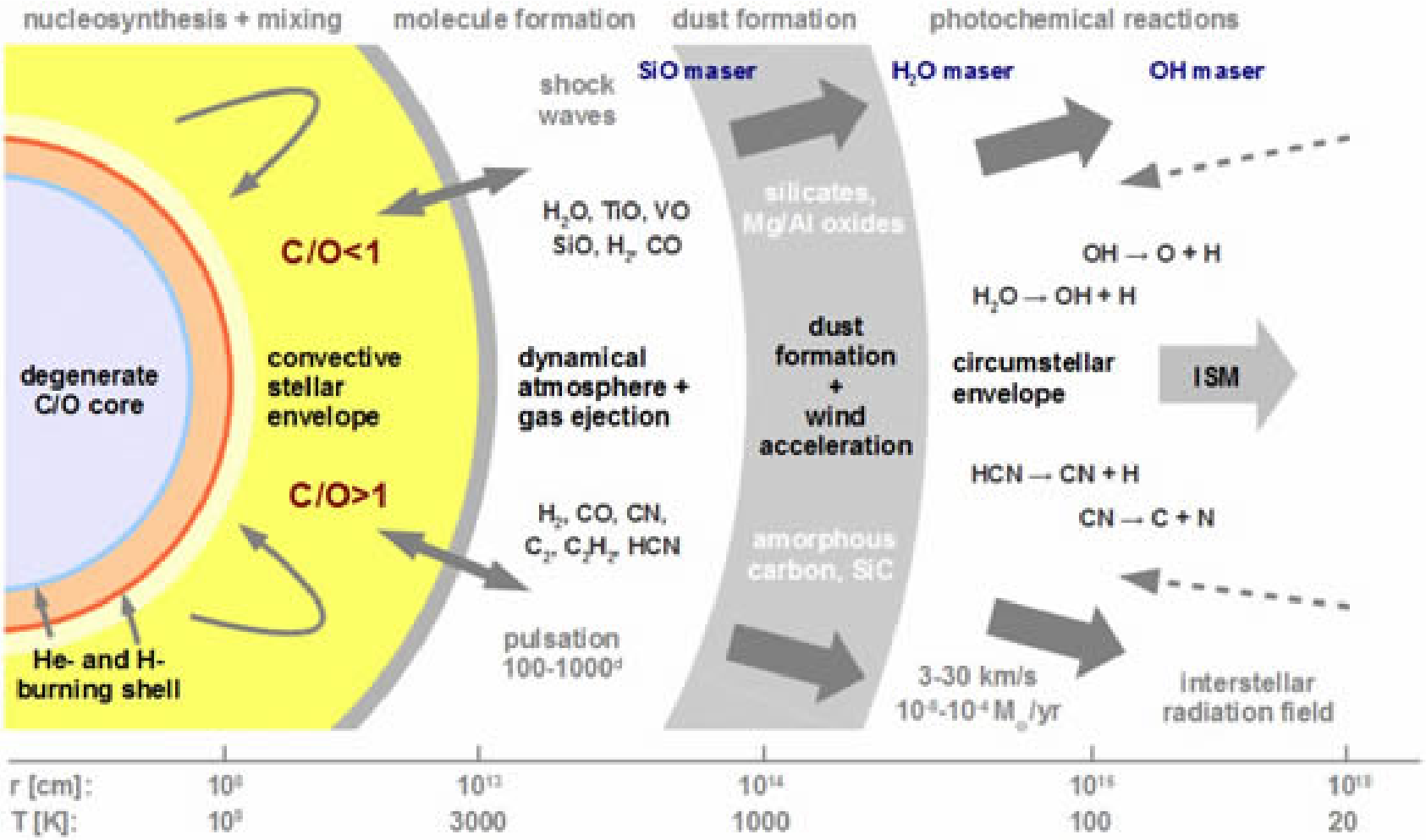
J. Wouterloot (EAO); J. He (YNAO & CASSACA, China); J. Cami (UWO, Canada);
H. Shinnaga (Kagoshima, Japan); Se-Hyung Cho (KASI, Korea) and the NESS team

Evolved stars, mass loss and the lifecycle of matter



AGB stars


nucleosynthesis + mixing
molecule formation
dust formation
photochemical reactions
degenerate C/O core
convective stellar envelope
C/O<1
C/O>1
He- and H-burning shell
shock waves
H2O, TiO, VO SiO, H2, CO
dynamical atmosphere + gas ejection
H2, CO, CN, C2, C2H2, HCN
pulsation 100-1000d
SiO maser
silicates, Mg/Al oxides
dust formation + wind acceleration
amorphous carbon, SiC
3-30 km/s
10-6-10-4 M⊙/yr
H2O maser
OH → O + H
H2O → OH + H
circumstellar envelope
HCN → CN + H
CN → C + N
OH maser
ISM
interstellar radiation field
r [cm]:
T [K]:
10^8
10^3
10^13
3000
10^14
1000
10^15
100
10^18
20

The Nearby Evolved Stars Survey

The dust and gas return to the Galactic interstellar medium

Led by ASIAA, including > 70 members from all EAO regions, CfA, and Europe

39 nearest dusty AGB stars + wedding-cake survey within 2 kpc (300 stars)

$\Rightarrow 1^{st}$ volume–limited survey of Galactic AGB stars

Multiple telescopes, multiple transitions

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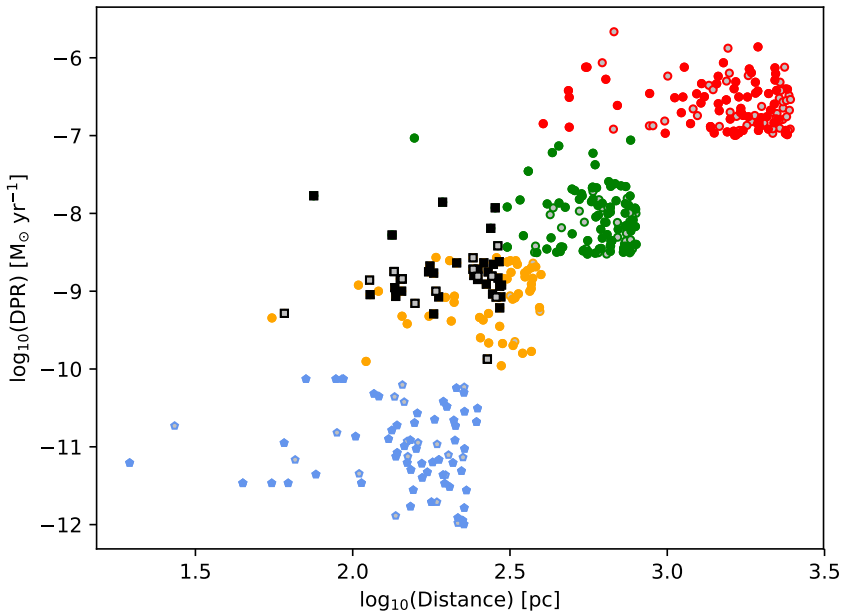
- 50 hrs JCMT S17A (complete, PI: P. Scicluna)
- 515 hour JCMT Large program (2017-2020, PI: P. Scicluna)
- 21 hrs ASTE (approved, PI: S. Wallstrom)



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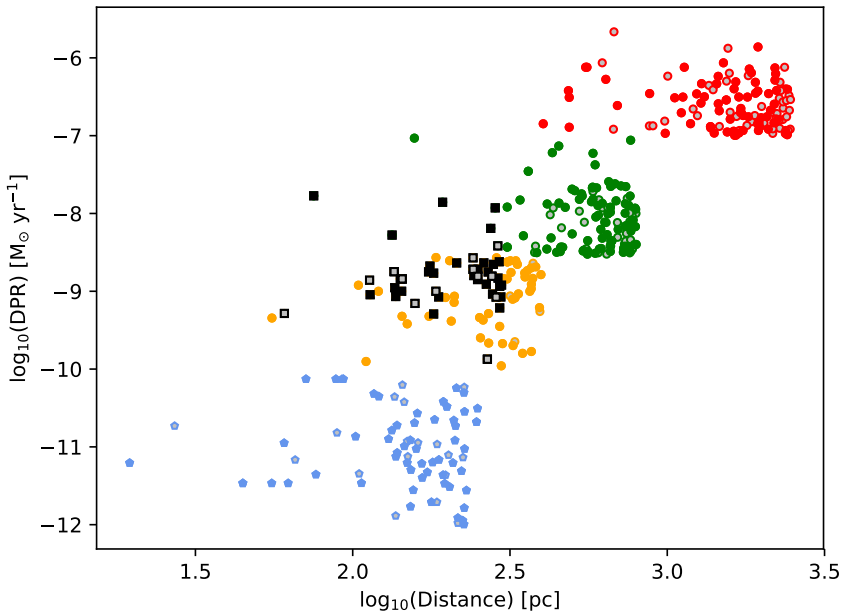
Proposed/planning:

- ALMA (PI: S. Srinivasan)
- APEX (PI: S. Wallstrom)
- SMA



JCMT Large programs

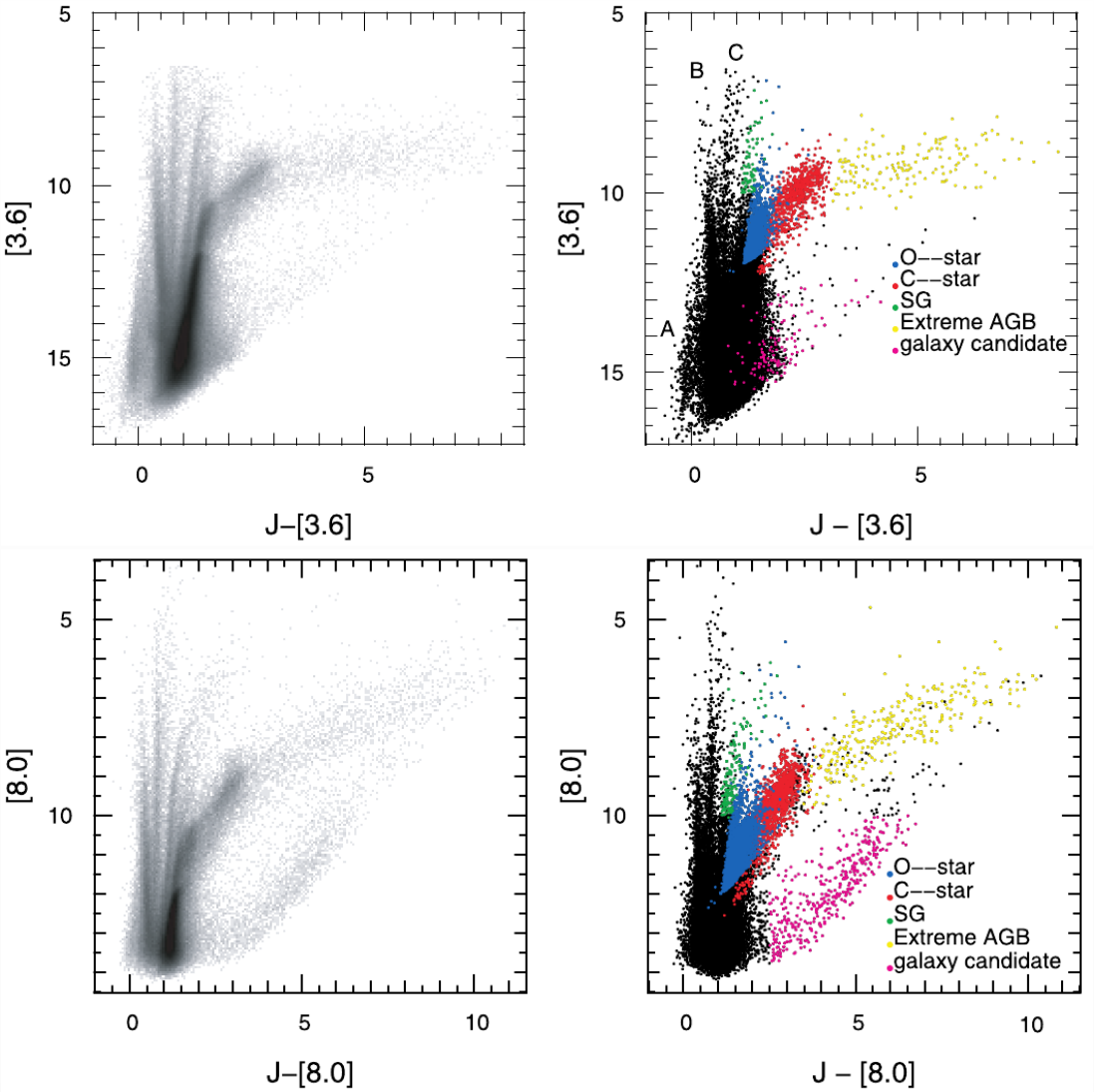
- EAO: new organisation, new community
- JCMT: Still very powerful (largest sub-mm telescope, fast mapping)
  - Build large ($\gtrsim 50$ people) collaborations
  - Large projects (> 200 hours)
  - Must include members from all EAO/JCMT regions
- Two rounds so far (every $\sim$ 1.5 years)
- Most recent round approved 2017 (including NESS)
- Run until 2020
- Open to anyone in JCMT regions (get in touch if you want to join us!)

NESS: Objectives

- Total gas and dust return to local ISM
- Gas-to-dust ratios
- Physics of mass loss
- Sub-mm dust properties
- Mass-loss history
- ^{13}CO / ^{12}CO
- Galactic AGB population

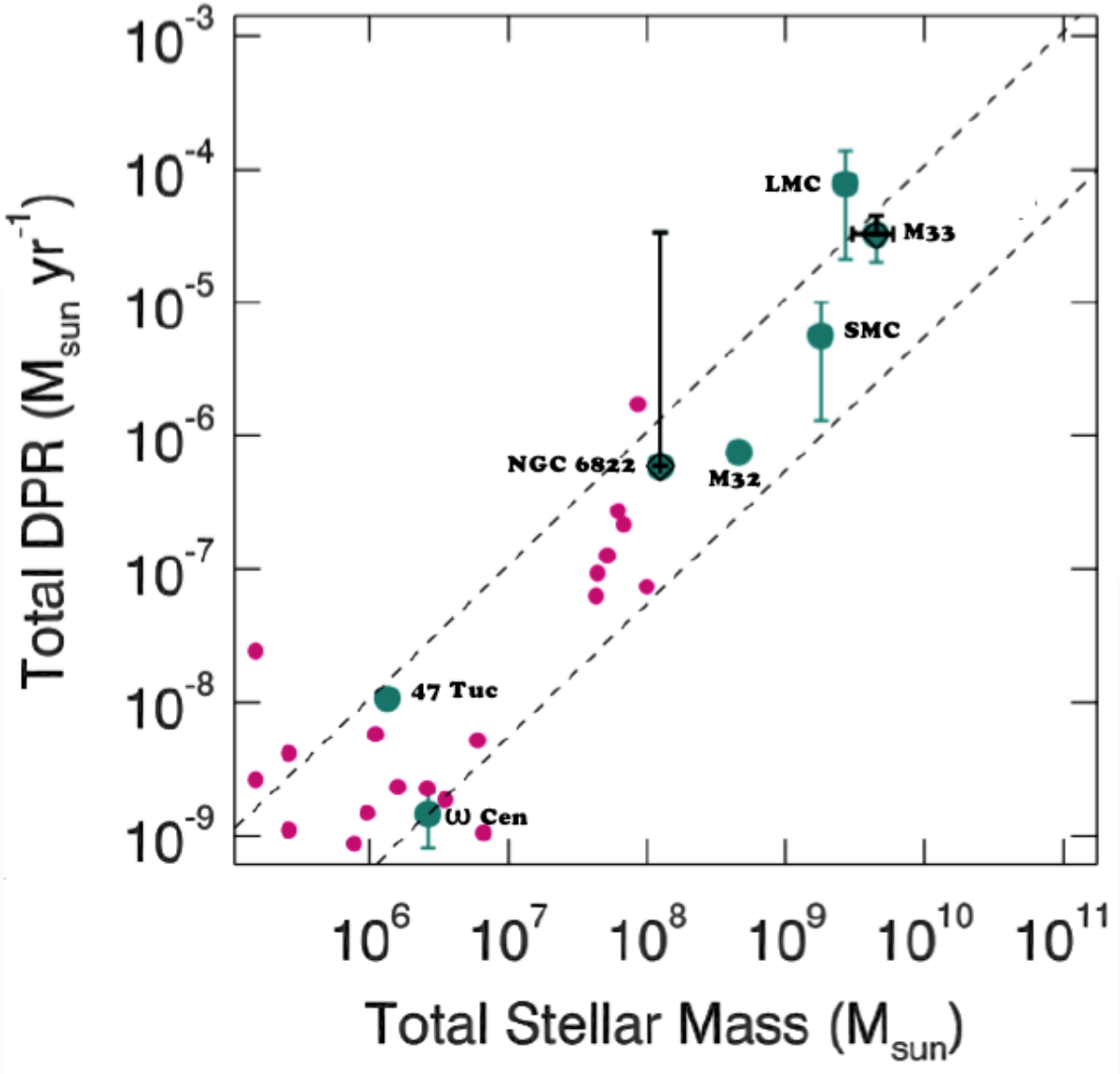
Total gas and dust return to local ISM

Measuring (dust) mass return



- E.g. SAGE
- Find dusty (MIR-bright) sources
- Classify - YSOs/AGB/RSG etc. & chemisty
- Compute DPR
  - Empirical relations
  - radiative transfer
- Add up all contributors
- Dominated by extreme AGBs

Blum et al. 2006



S. Srinivasan

- Milky Way?
- Last attempt: Gehrz 1989
- SCUBA-2: total dust mass
  - Cold dust
  - Present-day mass-loss from mid-IR

CO Lines as a mass-loss tracer

e.g. Knapp & Morris 1985

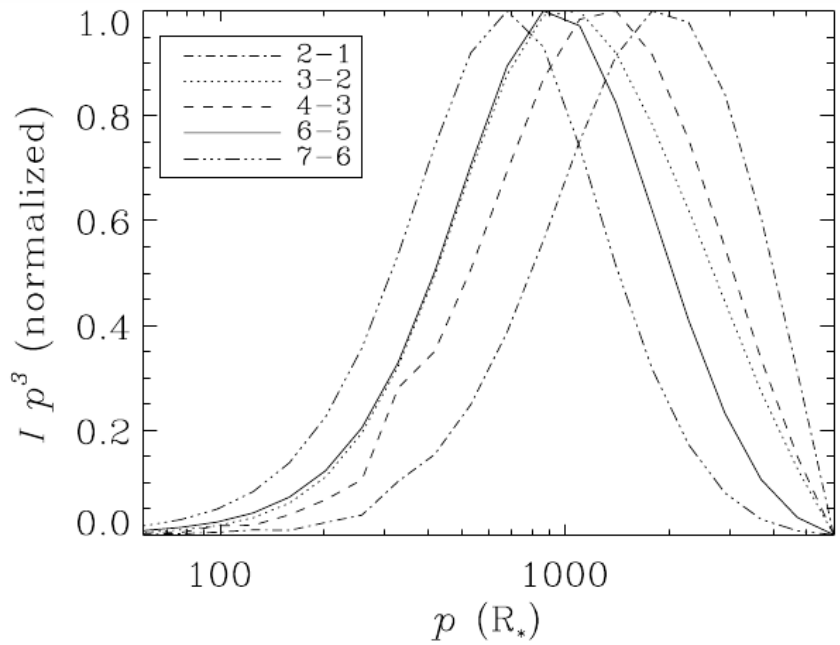
- Multiple CO line profiles
- Radiative transfer (comoving frame)
- fit $T(R)$, v & $\dot{M}$
- Still need assumptions, e.g. $\frac{CO}{H_2}$
- HARP & RxA: gas mass loss
  - ^{12} & ^{13}CO lines
  - Low-J lines → compare with cold dust
- Only really possible for Galactic sources

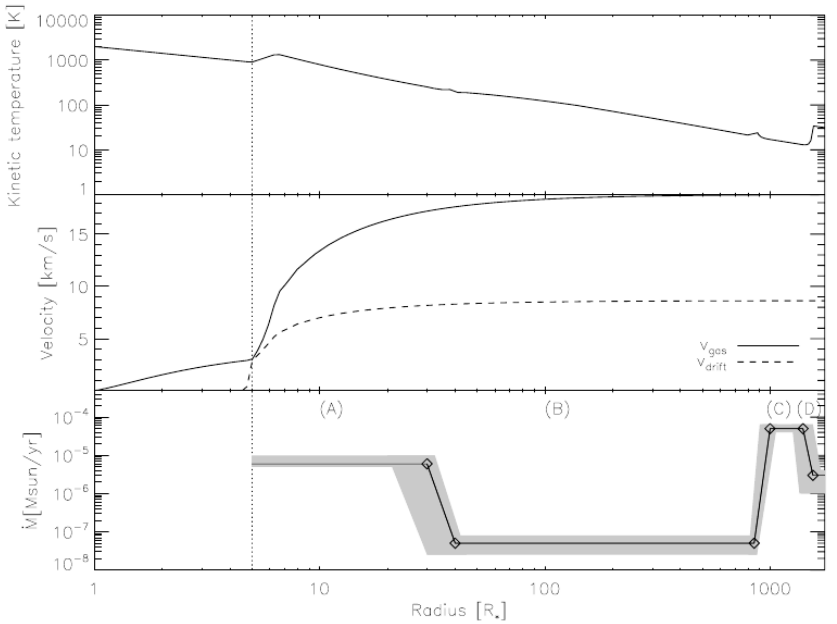
NESS ⇒ Dust and Gas return for volume-limited sample! – Improve on Knapp 1985 measure of dust-to-gas ratio too.

Physics of mass loss

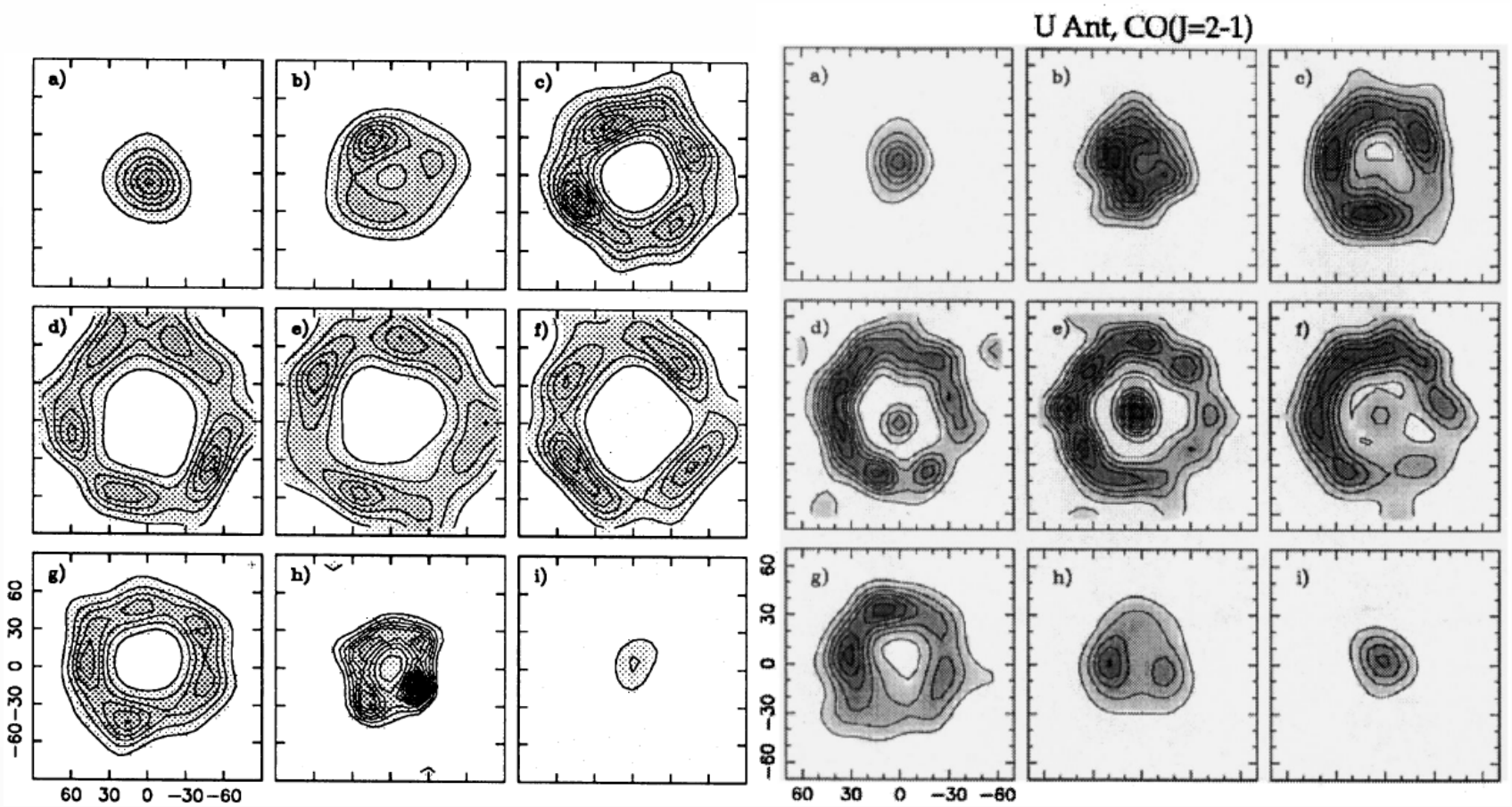
- Wind driving
  - outflow velocity
  - → pulsation/dust
  - momentum-transfer efficiency
- Onset of dust driving?
- Connection with other properties e.g.
  - dust composition
  - stellar properties
  - ...

Mass-loss history

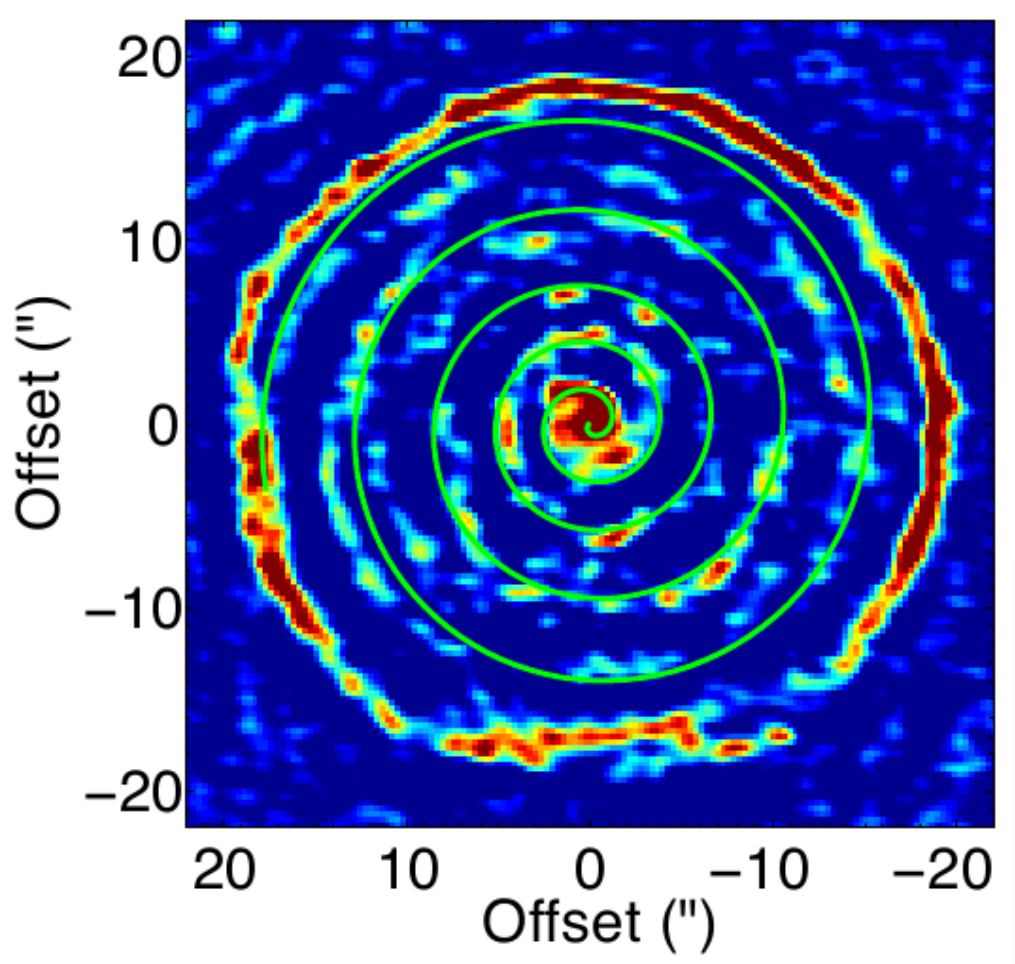




Kemper et al., 2003; Decin et al., 2007



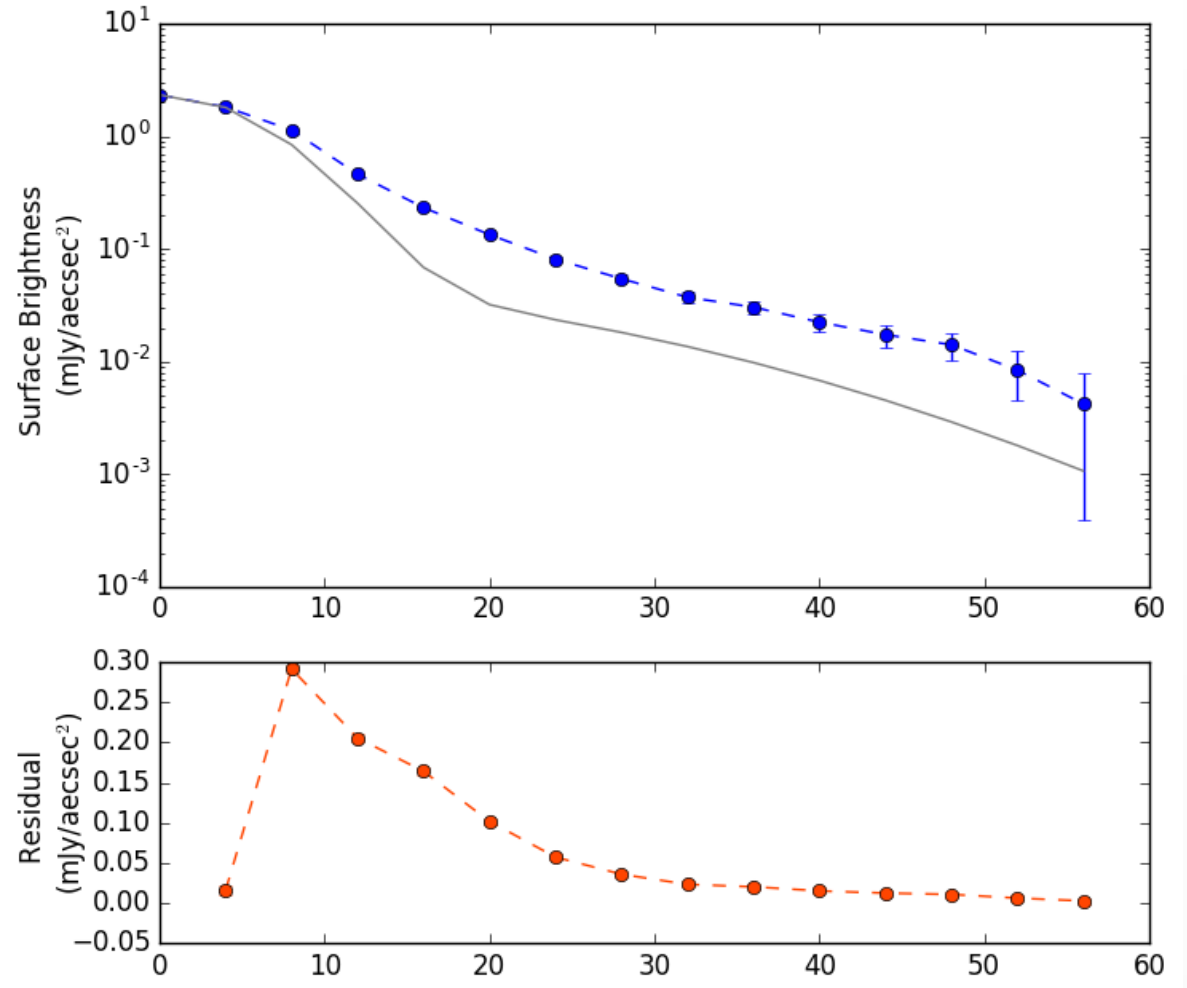
Left: S Sct - Olofsson et al. 1992 *Right*: U Ant - Olofsson et al. 1996



Maercker et al 2012

Extended emission with the JCMT

Dharmawardena et al., in prep - CIT 6, SCUBA2 850



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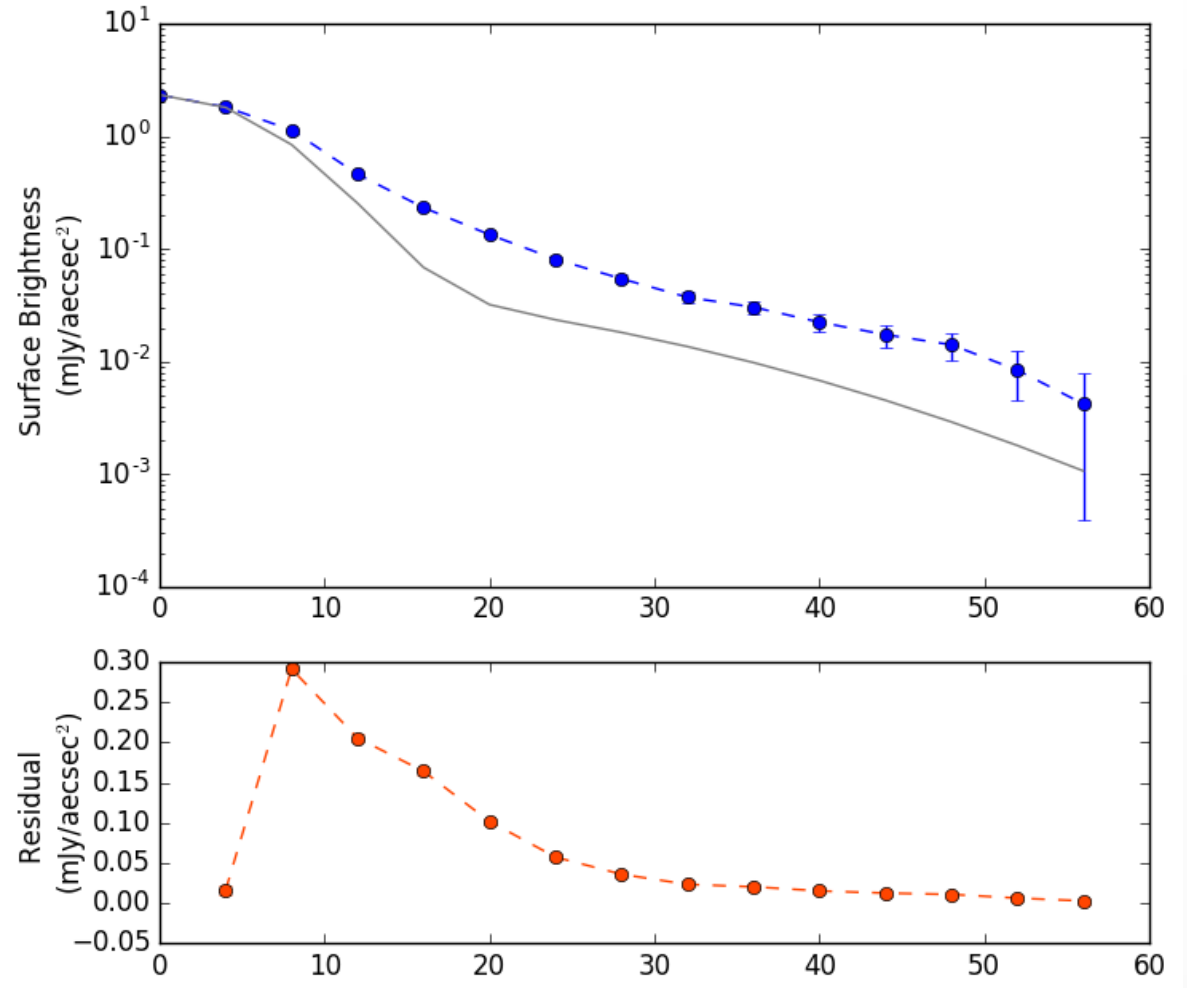
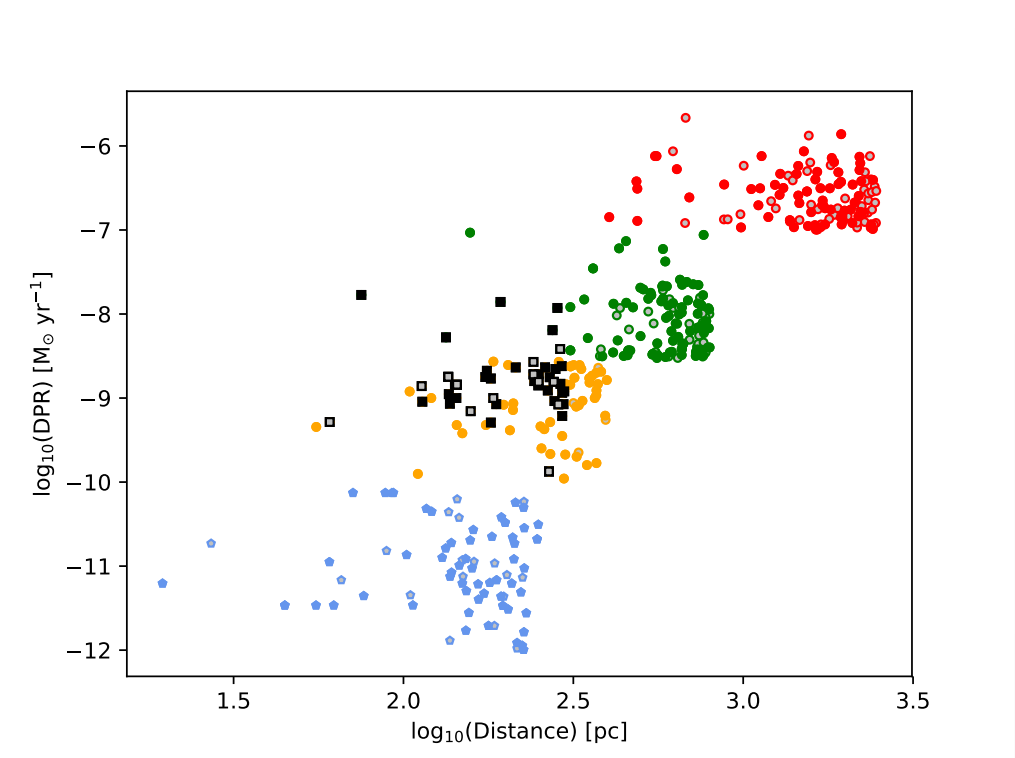


NESS will map 39 sources in detail:

- Line and continuum mapping
- $\dot{M}$ variations
- resolved gas-to-dust ratios
- CO dissociation
- deviations from symmetry?

Galactic AGB population

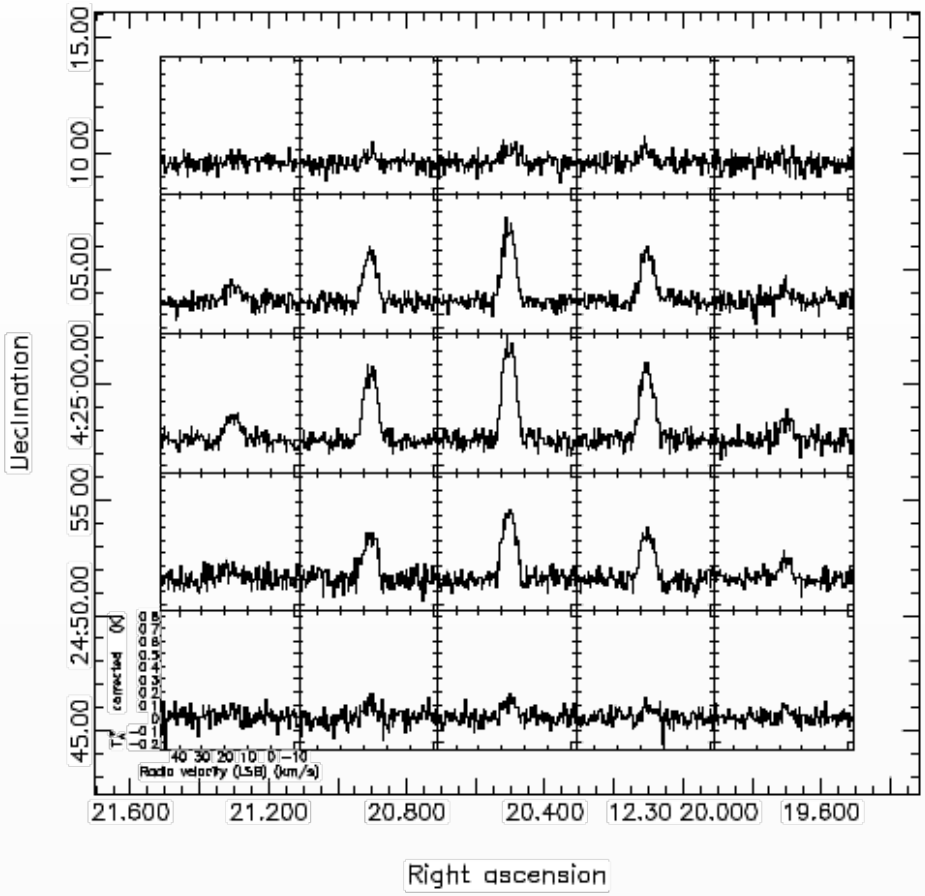


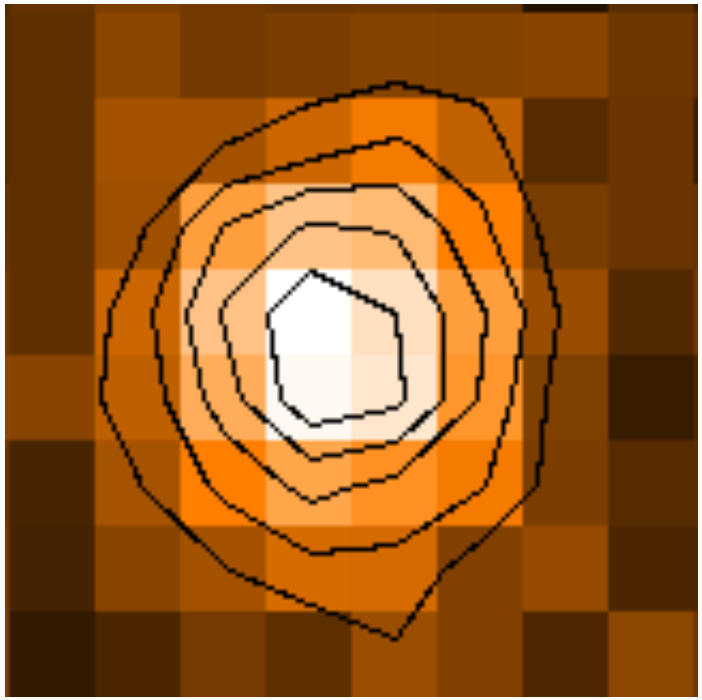
- Dependence of outflow properties on stellar properties
- Dust condensation
  - Efficiency: $\dot{M}_D$ vs. $\dot{M}$
  - Sequence: MIR features vs. $\dot{M}$
  - $\dot{M}$ vs. v - change in radiation pressure with condensation sequence?
- $^{13}C/^{12}C$
- Constraints for evolution and population models

First data

Large program now ~ 30% complete

CO(3-2) vs 850 μm continuum: BK Vir





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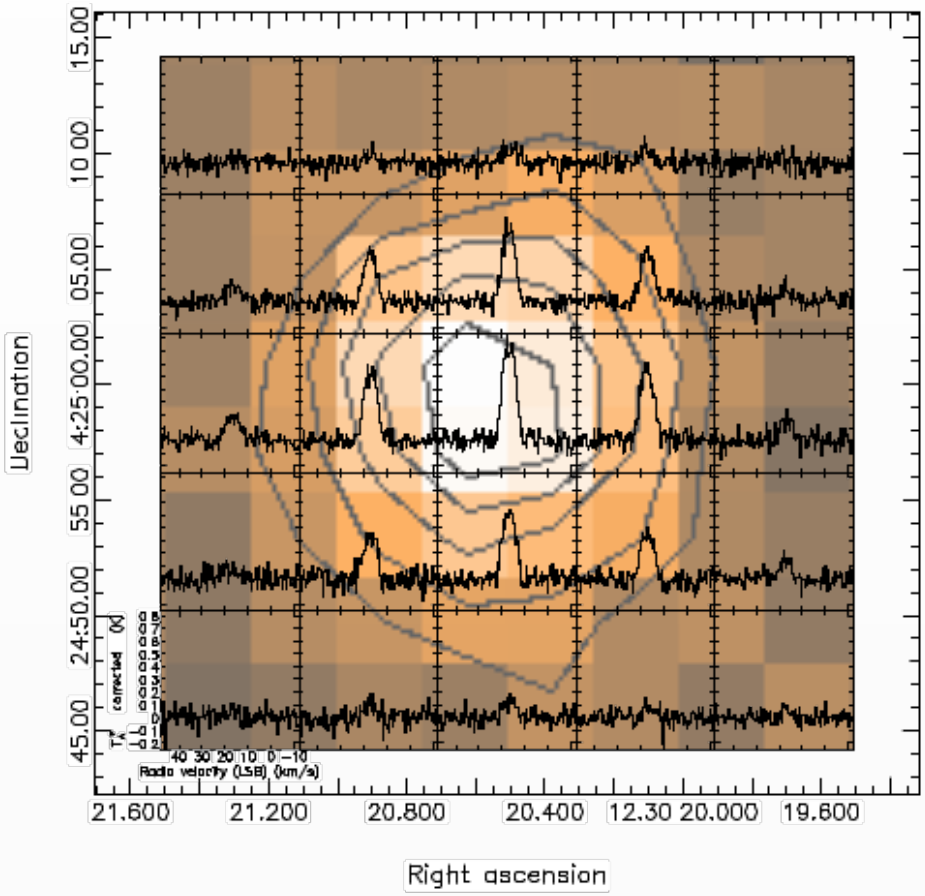

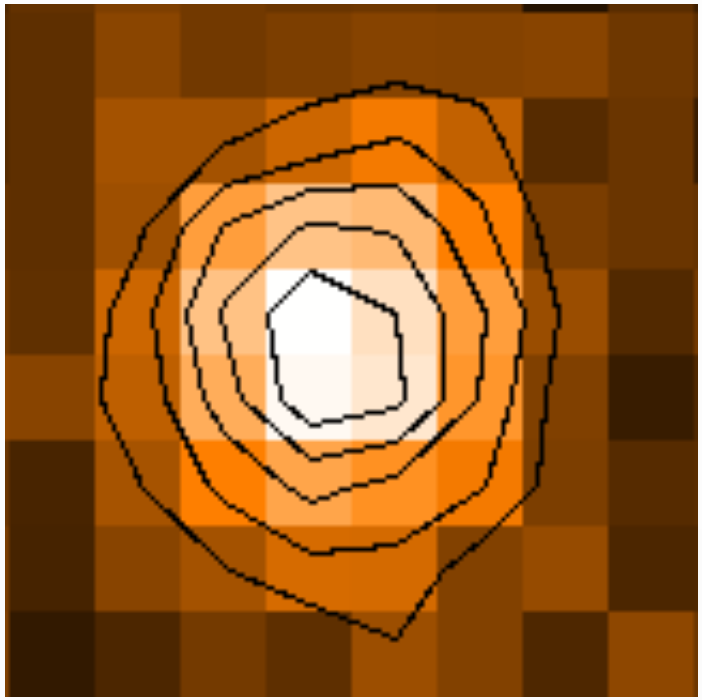

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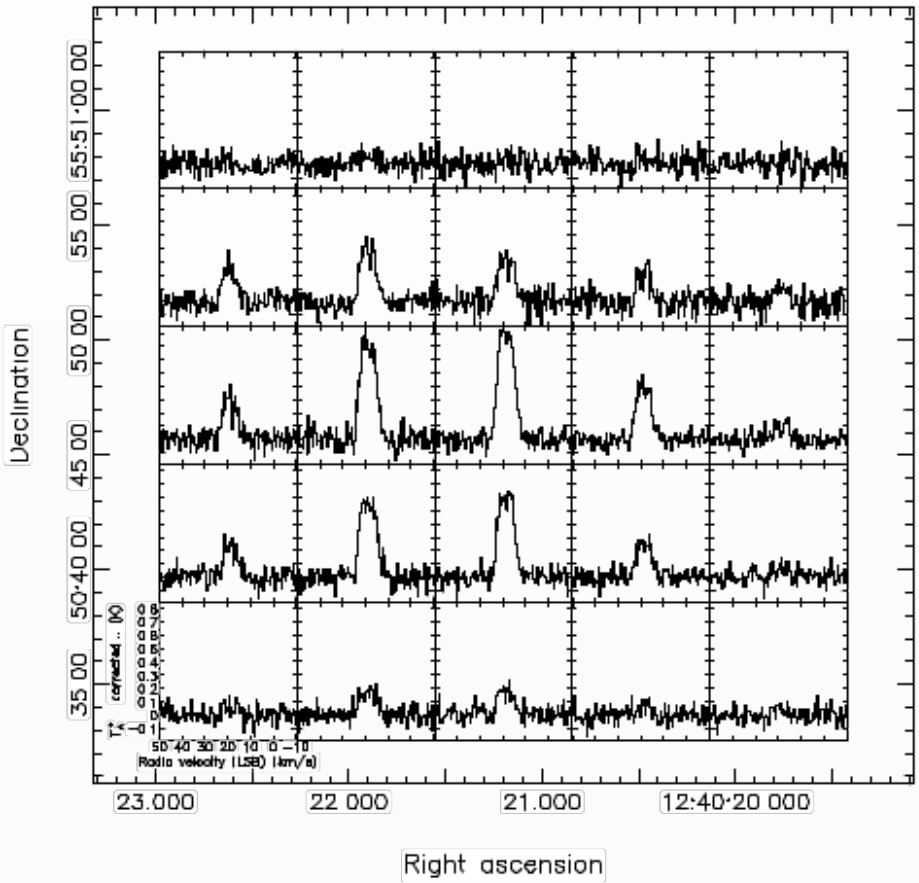
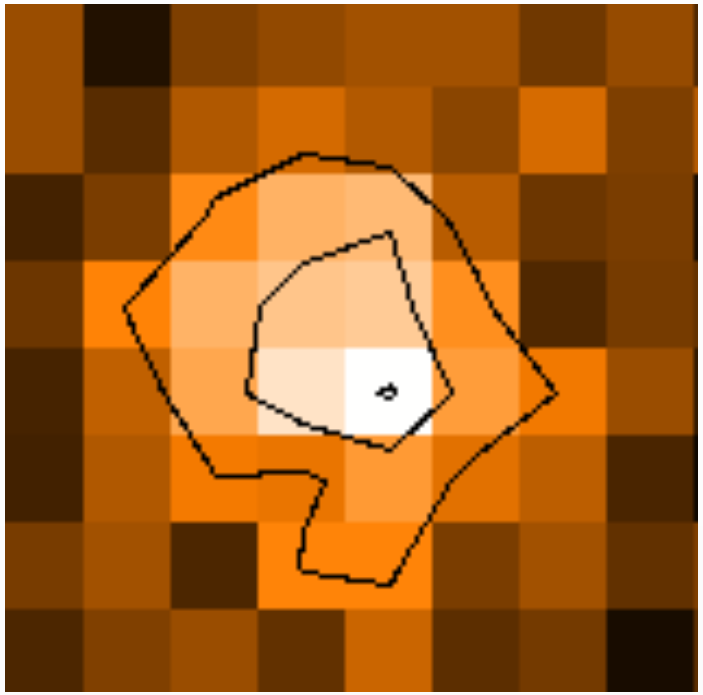
CO(3-2) vs 850 μm continuum: Y UMa





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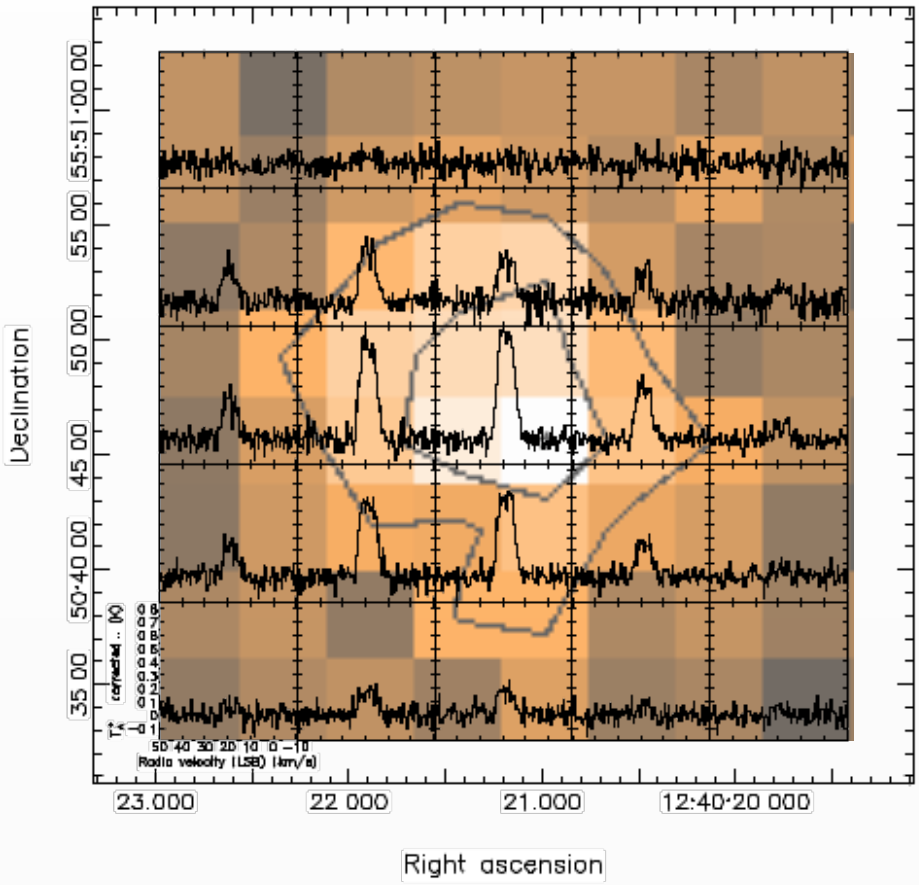

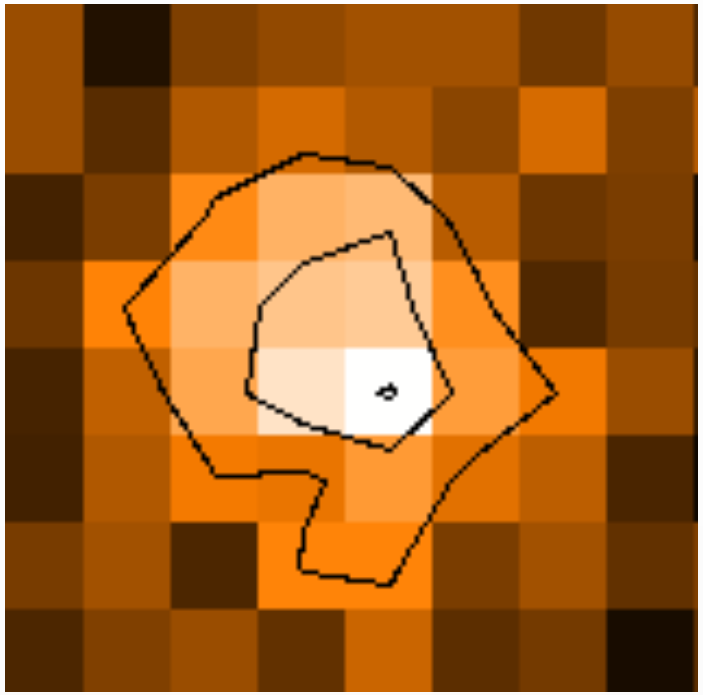

Summary

- (Dust-)Mass return in nearby galaxies well studied
- Gas only possible locally
  - both required to understand mass loss
- Variability important
  - most of mass-loss occurs in short bursts
- NESS: submm survey of all dust-producing local AGB stars
  - first volume-limited survey
  - robust constraints on local mass return
  - gas-to-dust ratios
  - statistics of AGB stars
  - solve everything!
- Now is a good time to get involved!

Contact me (if you're from outside the EAO regions) or your regional coordinator (EAO regions – Taiwan: Me; China: Jinhua He; Korea: Se-Hyung Cho; Japan: Hiroko Shinnaga; UK: Iain McDonald; Canada: Jan Cami)