Detached shells of dust and gas around carbon AGB stars

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Talk outline

Introduction:

- Detached shells around carbon stars

Observations of scattered stellar light:

- EFOSC2 data: The detached shell around U Ant
- HST data: The detached shells around R Scl and U Cam

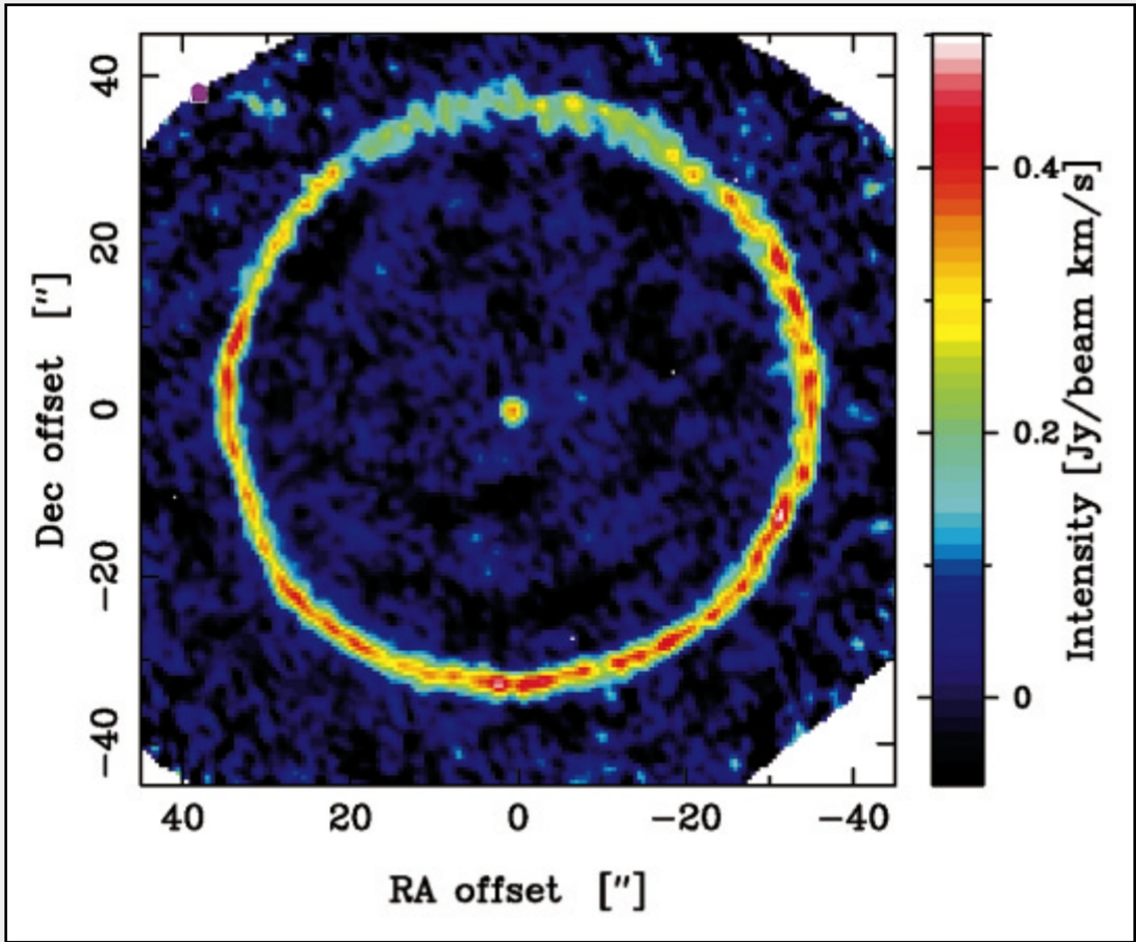
What will ALMA do for us:

- The need for interferometric observations

Conclusions

Detached shells around carbon AGB stars

Background



TT Cyg CO(1-0) (Olofsson et al. 2000)

Detached shells around carbon AGB stars

Background

- currently 7 known sources: S Sct (1988), U Ant (1988), TT Cyg (1990) R Scl (1996), V644 Sco (1996), U Cam (1996), DR Ser (2005)

- only around C-type AGB stars

- large (~10000 AU), geometrically thin $\Delta R/R \approx 0.1$, spherically symmetric
- clumpy density distribution
- possibly connected to change in mass-loss rate during thermal pulses:

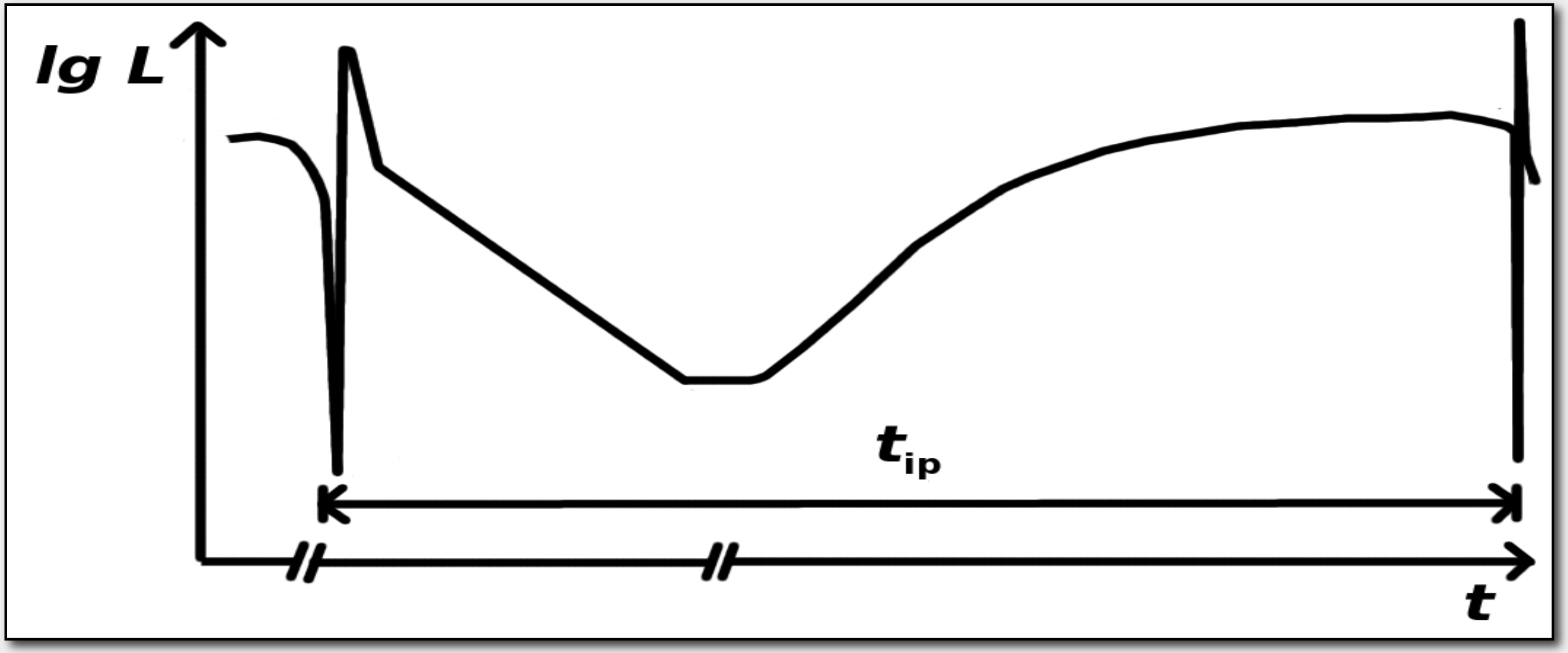
  → two-wind interaction scenario:
  (e.g. Schöier et al 2005, A&A, Mattsson et al. 2007, A&A)

  → increased *dM/dt* and v_{exp} during the pulse

  → the faster wind sweeps up material from pre-pulse mass loss

Detached shells around carbon AGB stars

Background



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Why observe detached shells:

Background

- mass-loss dependence on stellar parameters:
  → Luminosity, radius, effective temperature, etc…
- short term variations in the mass-loss:
  → significant changes in mass-loss rates for a few 100s years
- the behavior of the star during the thermal pulse cycle:
  → nearly impossible to observe a pulse directly
- the structure of the circumstellar medium and formation of PNe
- test of dynamical models

Detached shells around carbon AGB stars
Background

- Problems with previous observations:

  → CO emission depends on excitation and chemistry

  → thin shells, small clumps require high resolution

    → no interferometers in the southern hemisphere (with the right capabilities)

  → not (or only barely) detected in other molecules

  → IR emission from dust often of poor spatial resolution

The detached shells around U Ant, R Scl, and U Cam

Observations of scattered stellar light

- Observations of U Ant:
(Maercker, Olofsson, Eriksson, Gustafsson, & Schöier 2010, A&A)

  - EFOSC2 images in polarisation in Str.y (548.2nm), Na (589.4nm), and Hα (657.7nm) filters
  - EMMI echelle spectra in Na (589.4nm) and K (769.9nm) filters
  - APEX-2a on-the-fly map of CO(3-2) (beam size: 18”)

→ Str. y and Hα: scattering by dust

→ Na: scattering by resonance lines (gas) and dust

→ polarisation shows distribution of the dust

The detached shells around U Ant, R Scl, and U Cam

Observations of scattered stellar light

- Observations of R Scl and U Cam:
(Olofsson, Maercker, Eriksson, Gustafsson, & Schöier. 2010, A&A)

    - Hubble Space Telescope images in f475 (476nm), f606 (590.7nm), and f814 (833.3nm) filters

→ scattering by dust

→ well defined psf, very high spatial resolution (0.026”/pix)

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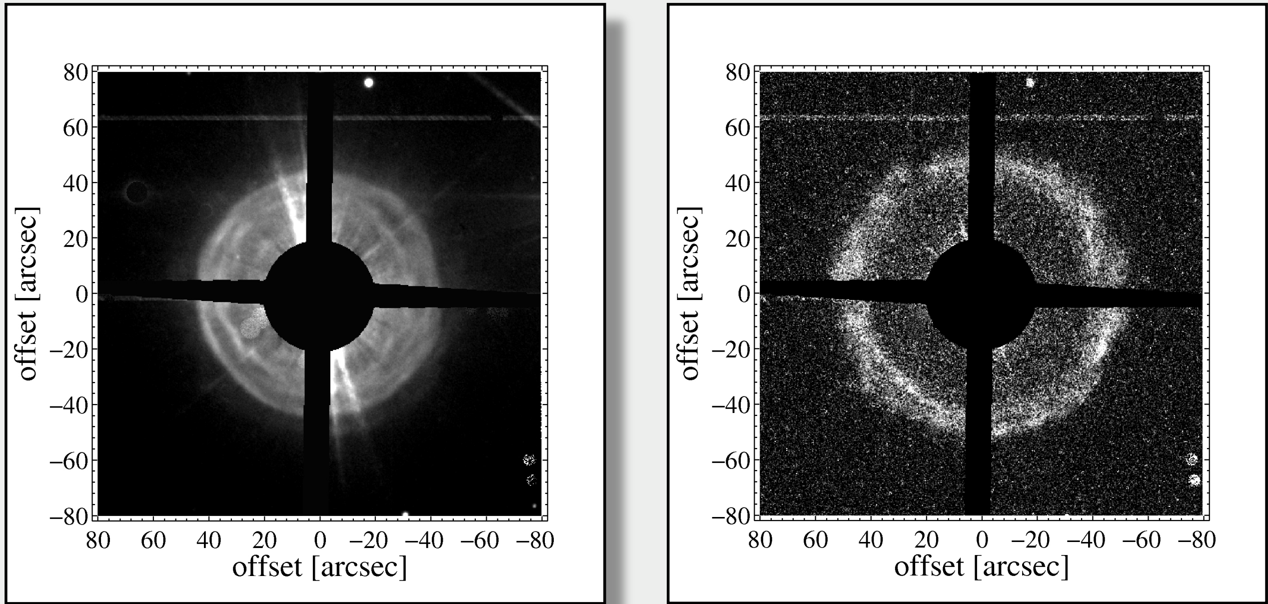
✓ Observations of the detached shells in unprecedented detail

✓ separation of the contributions from the scattering agents (U Ant)

The detached shells around U Ant
EFOSC2 results



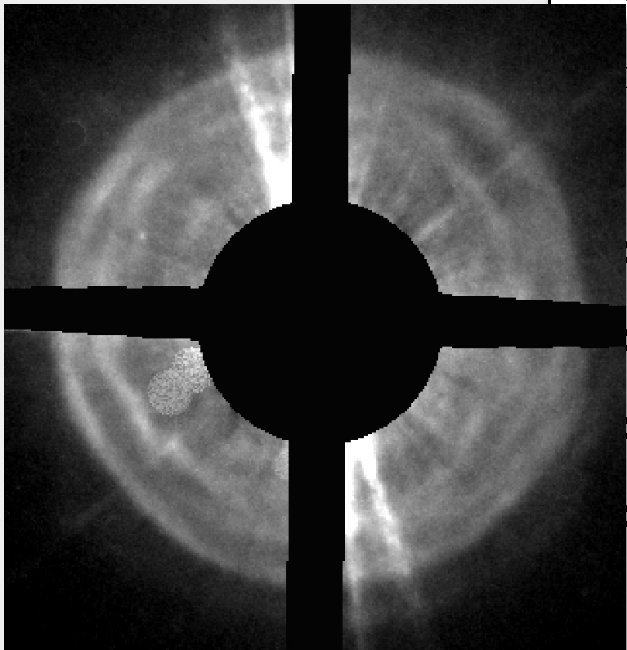
The detached shells around U Ant: total flux (left), polarised flux (right)

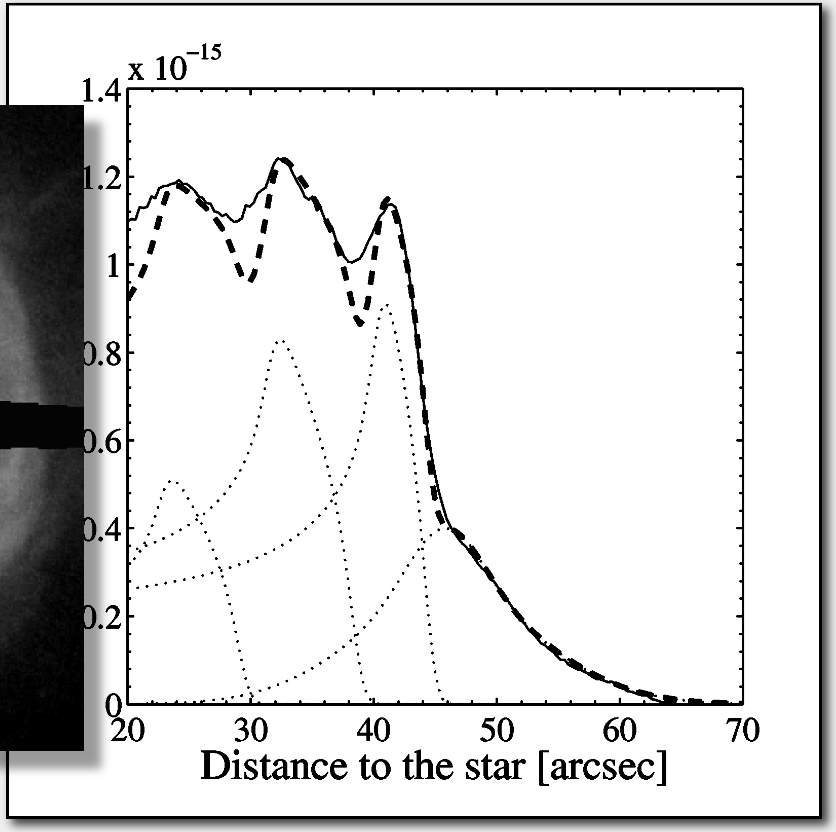
- shell 3 (R=43”) dominated by gas, shell 4 (R=50”) dominated by dust

  → shells 3 and 4 indicate a separation between dust and gas

- age of shell 3 ≈ 2700 years, width corresponds to 150 years
- APEX CO OTF map confirms shell of gas at position of shell 3

The detached shells around U Ant
Multiple shells?

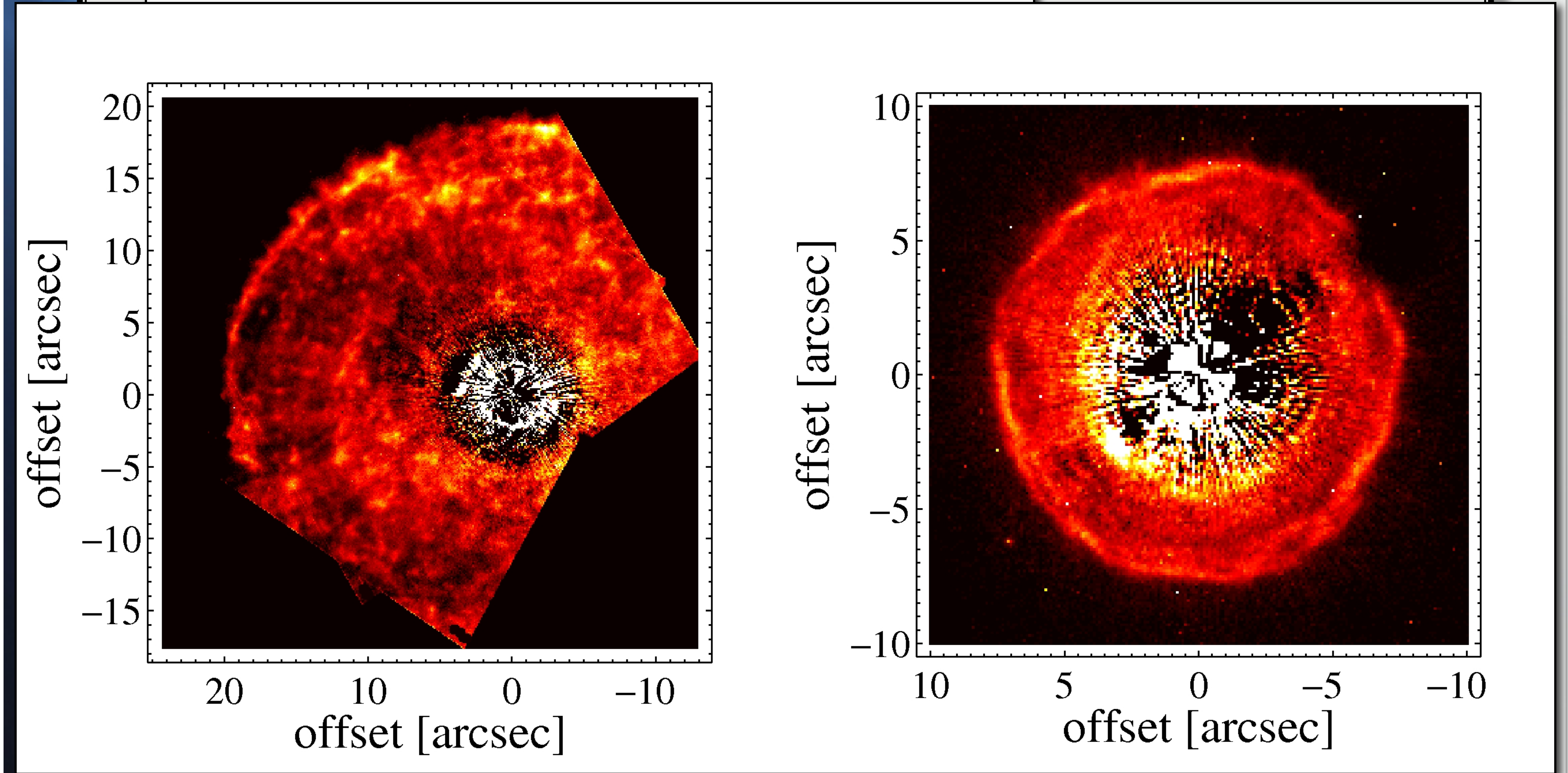




- age difference between shells 2 and 3 ≈600 years
- time scale between thermal pulses 10000 for 4 $M_\odot$
- indication of a more complicated behaviour of L, mass loss, and v_{exp}

The detached shells around R Scl and U Cam

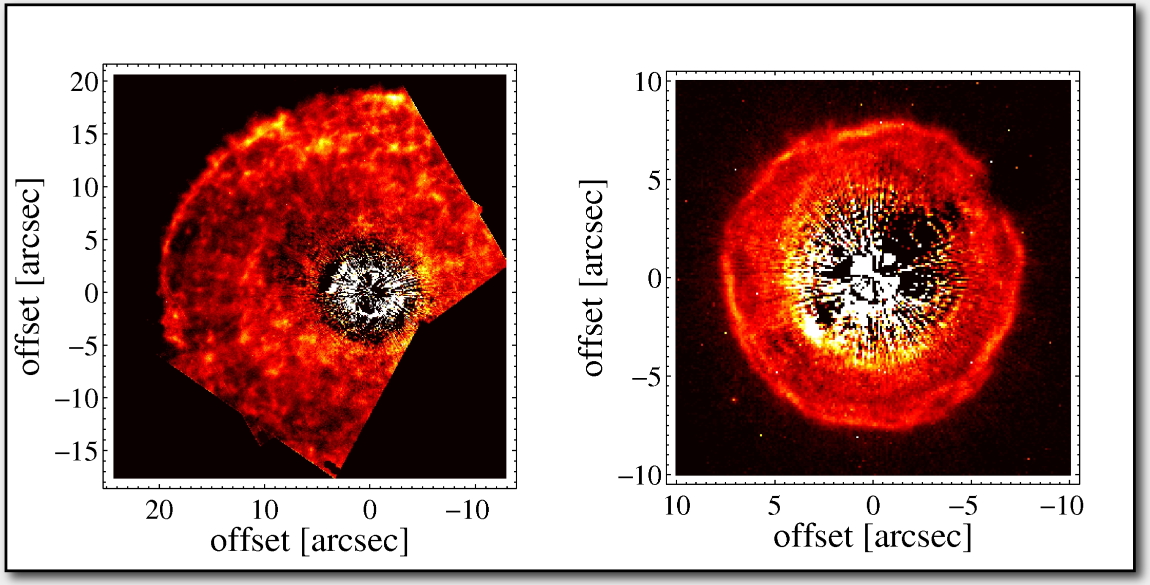
Hubble Space Telescope results



→ most likely due to instabilities in expanding shell

The detached shells around R Scl and U Cam

Hubble Space Telescope results



The detached shells around R Scl (left) and U Cam (right) (Paper IV)

- shells of dust around R Scl (R=19.2”) and U Cam (R=7.7”)
- ages correspond to 1700 yr (R Scl) and 700 yr (U Cam)
- small scale structure (<1”) apparent in R Scl

→ most likely due to instabilities in expanding shell

What ALMA will do for us
The need for interferometry

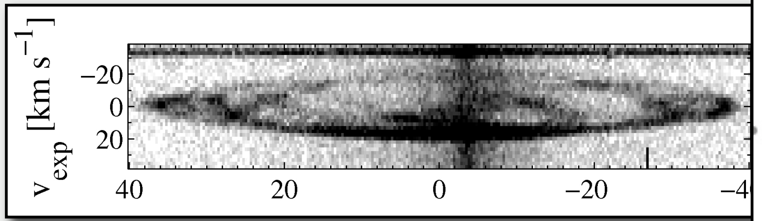
Resolving power:

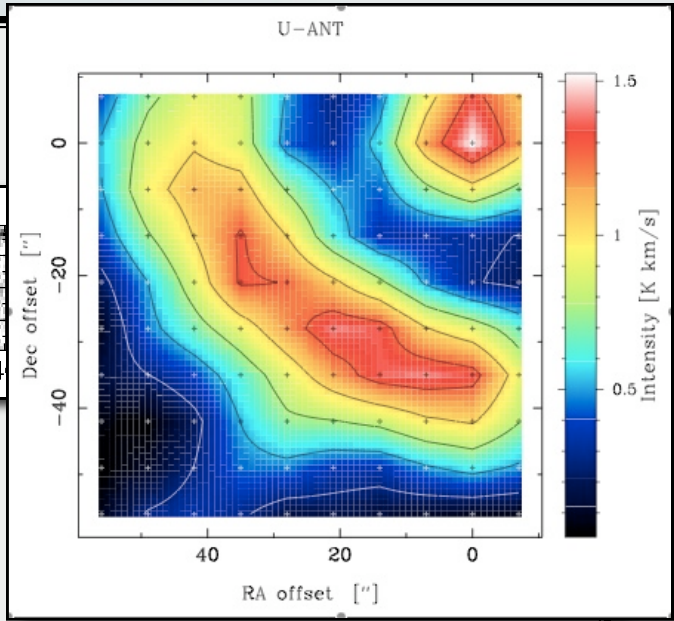
- size and width of the shells around southern objects
- resolved individual clumps, several transitions of CO
  - → sizes, masses, and distribution of clumps
  - → hints on two-wind interaction and mass-loss during the pulse
- multiple shells
  - variation of stellar parameters on short time scales

Sensitivity:

- detection of additional molecules (e.g. HCN in R Scl)

Detached shells around carbon stars
Conclusions





- observed detached shells consistent with models of thermal pulses and interacting winds
- EFOSC2 observations indicate a separation of the gas and dust (U Ant)
- multiple shells indicate a more complicated thermal pulse behaviour (U Ant)
- small scale structure may indicate two-wind interaction (R Scl)
- unique way to study the thermal pulse phenomenon
- ALMA will be important for progress in investigating detached shells

Thank you!