

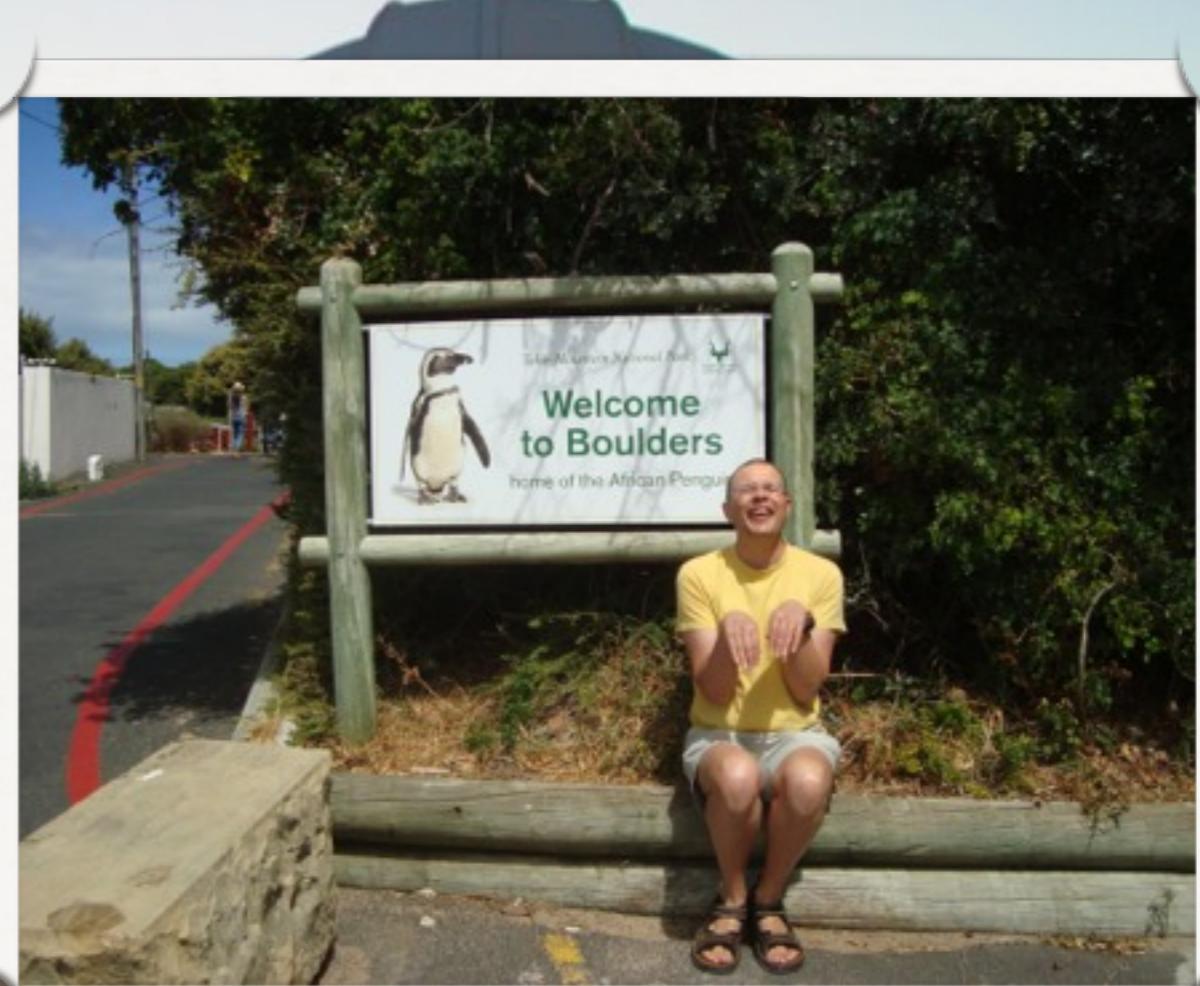
# 3D Models of Symbiotic Binaries



Shazrene Mohamed (SAAO)

Ph. Podsiadlowski (Oxford), R. Booth (Oxford), S. Ramstedt (Uppsala),  
M. Maercker (AlfA). W. Vlemmings (Chalmers)

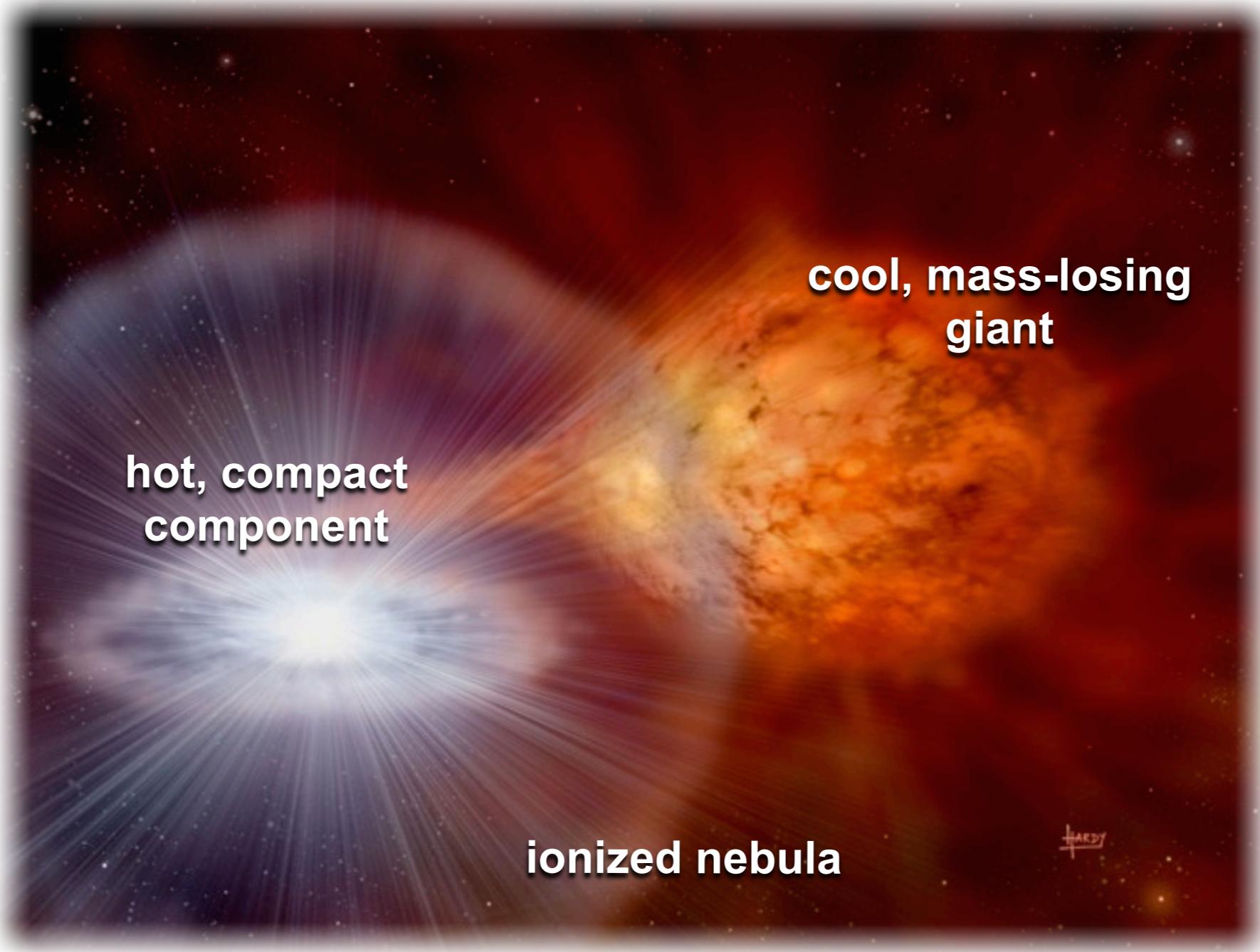
# 3D Models of Symbiotic Binaries



Shazrene Mohamed (SAAO)

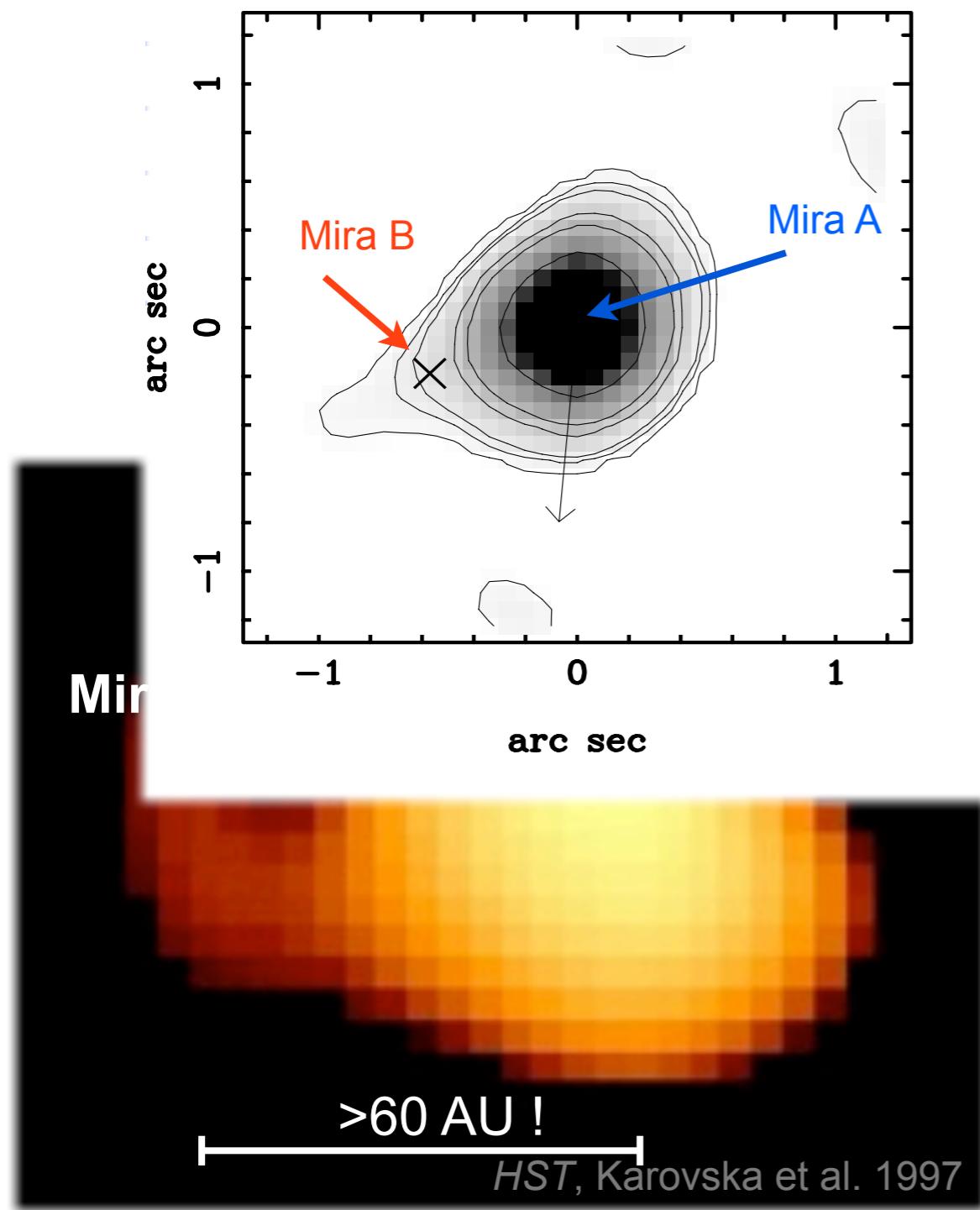
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# Symbiotic Binaries

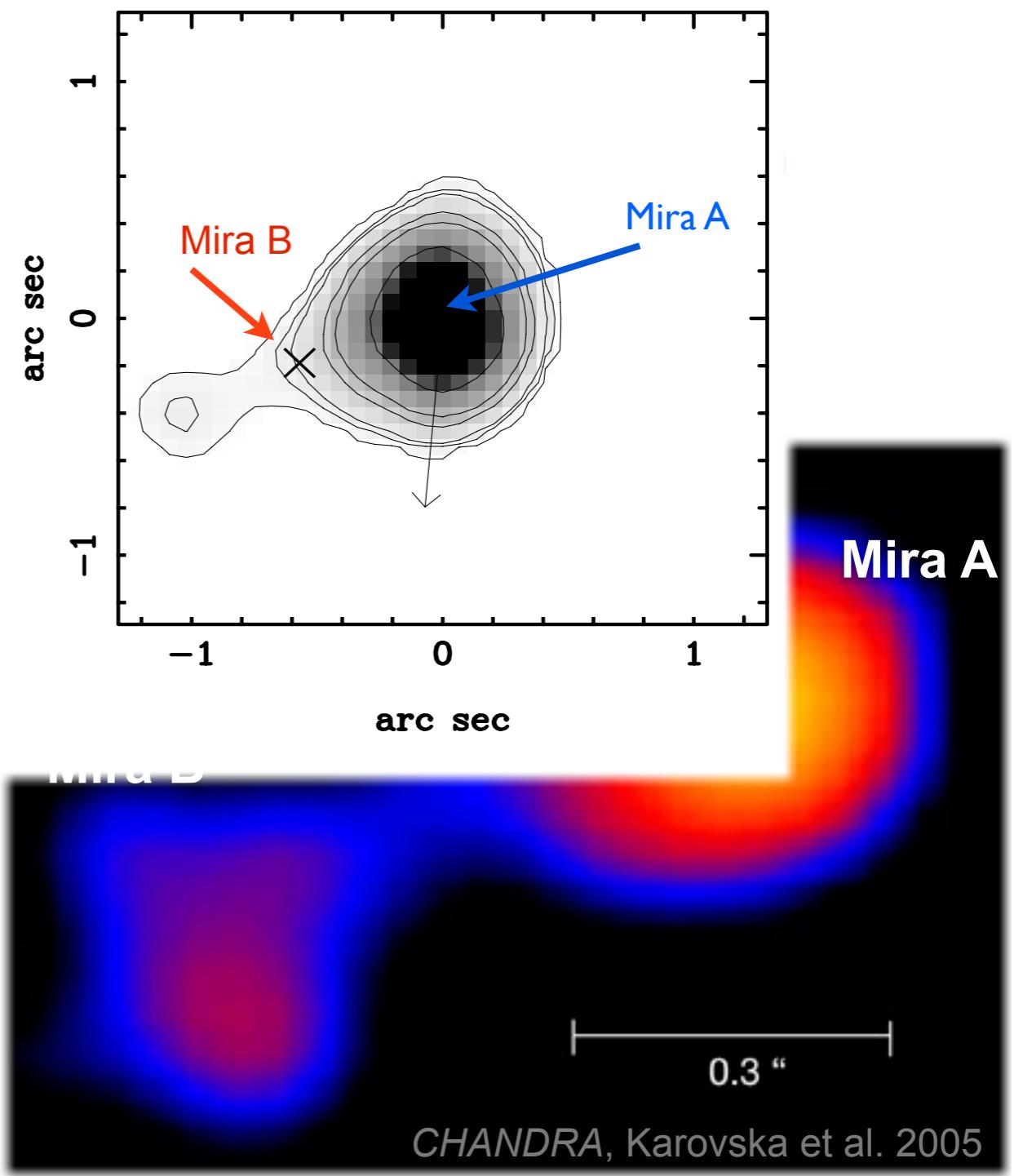


# Mira “The Wonderful”

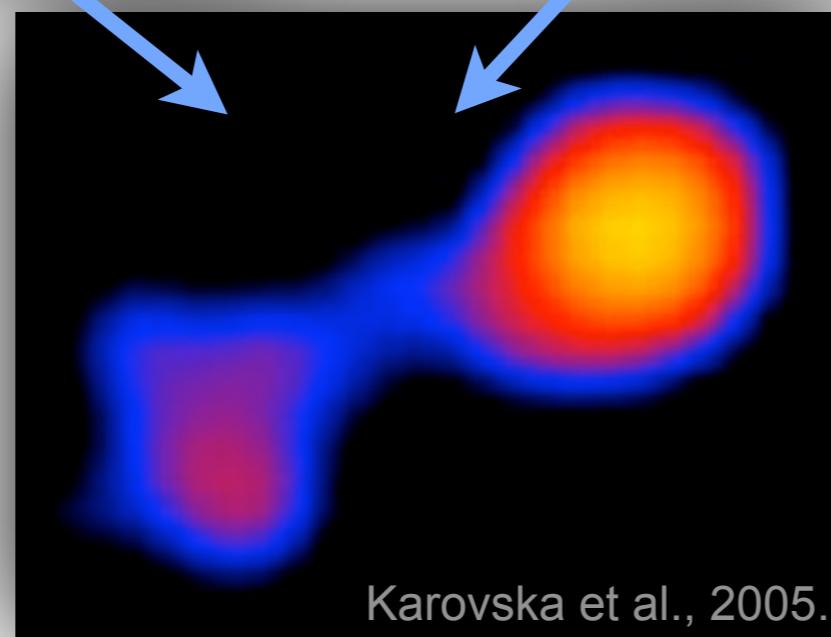
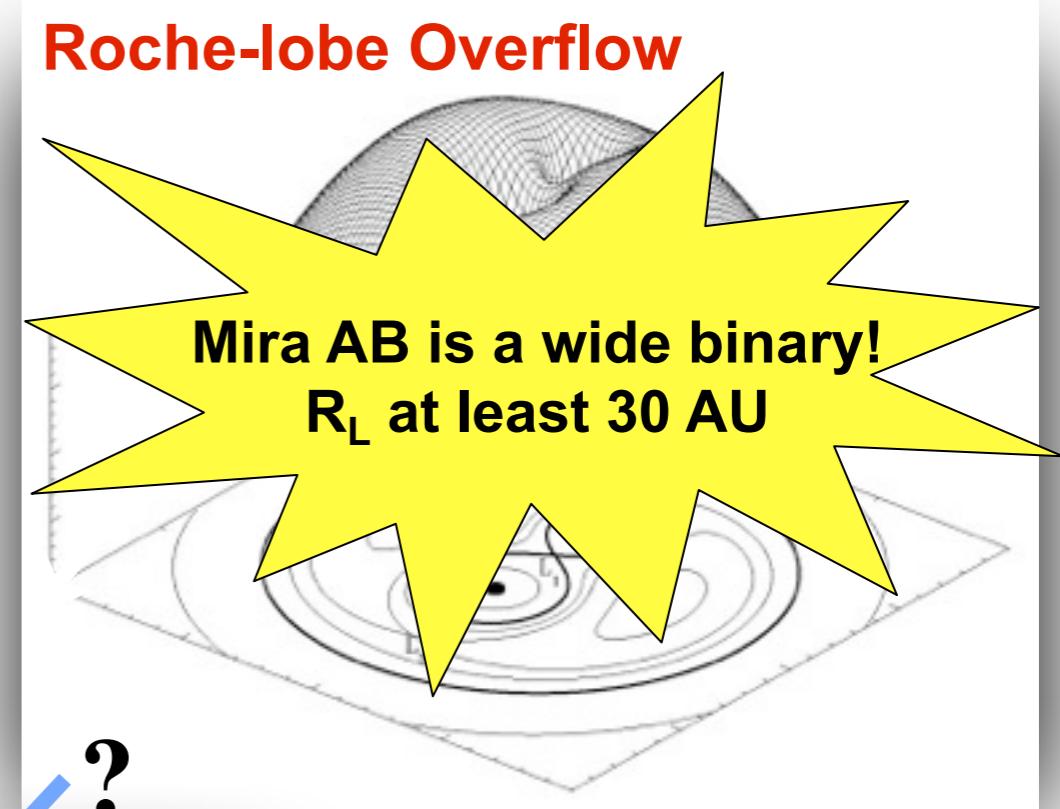
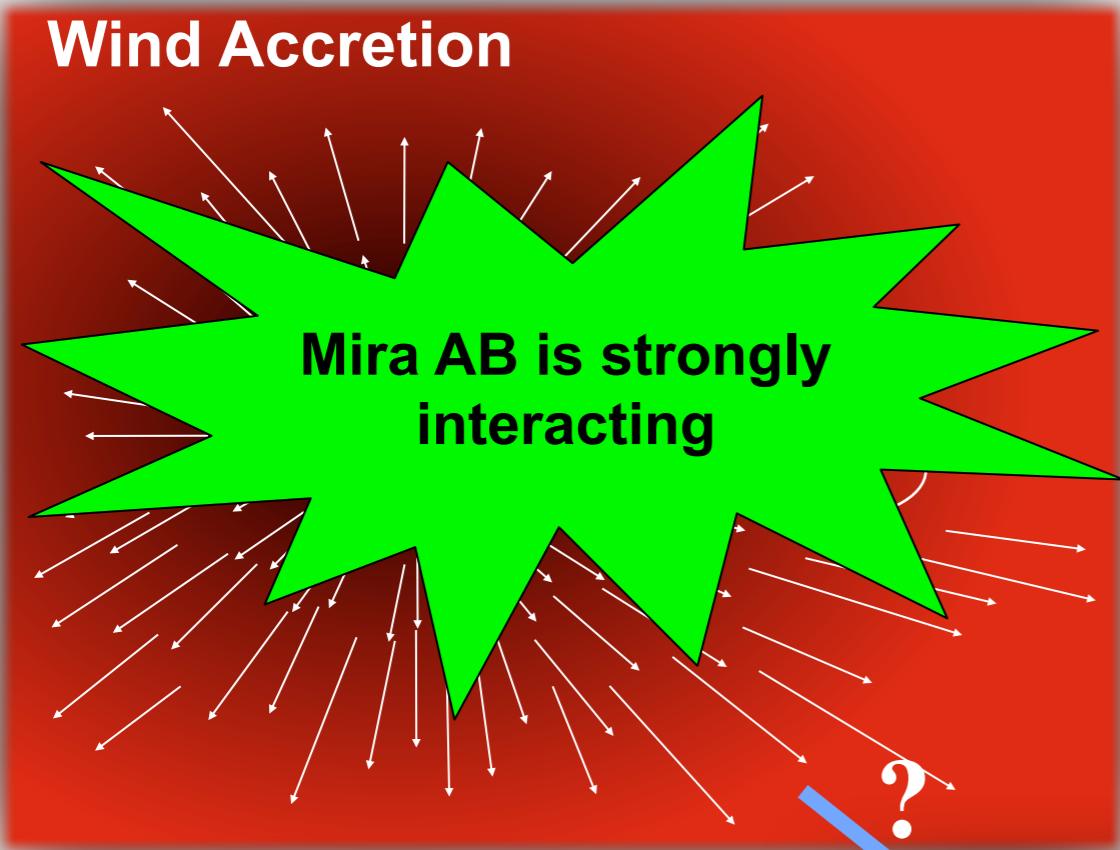
Marengo et al. 2001  $9.8 \mu\text{m}$



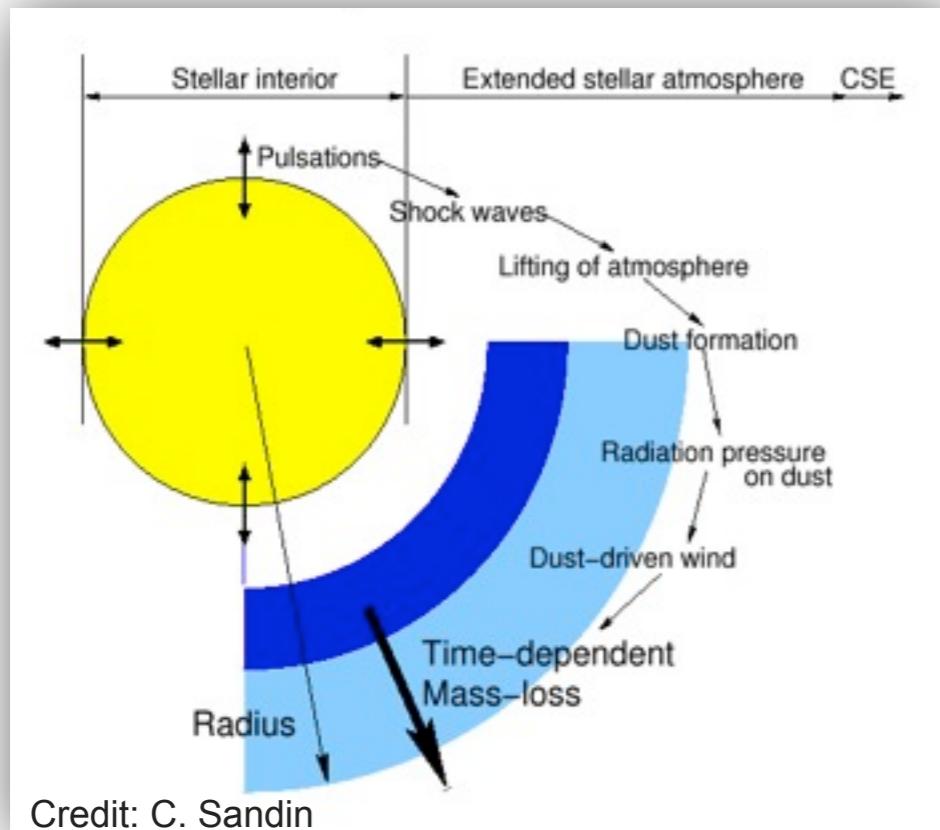
$11.7 \mu\text{m}$



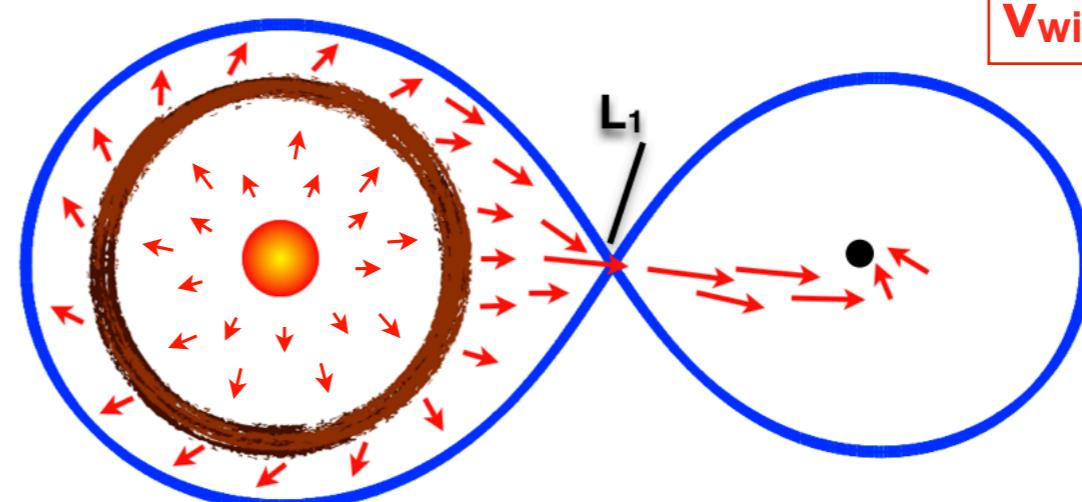
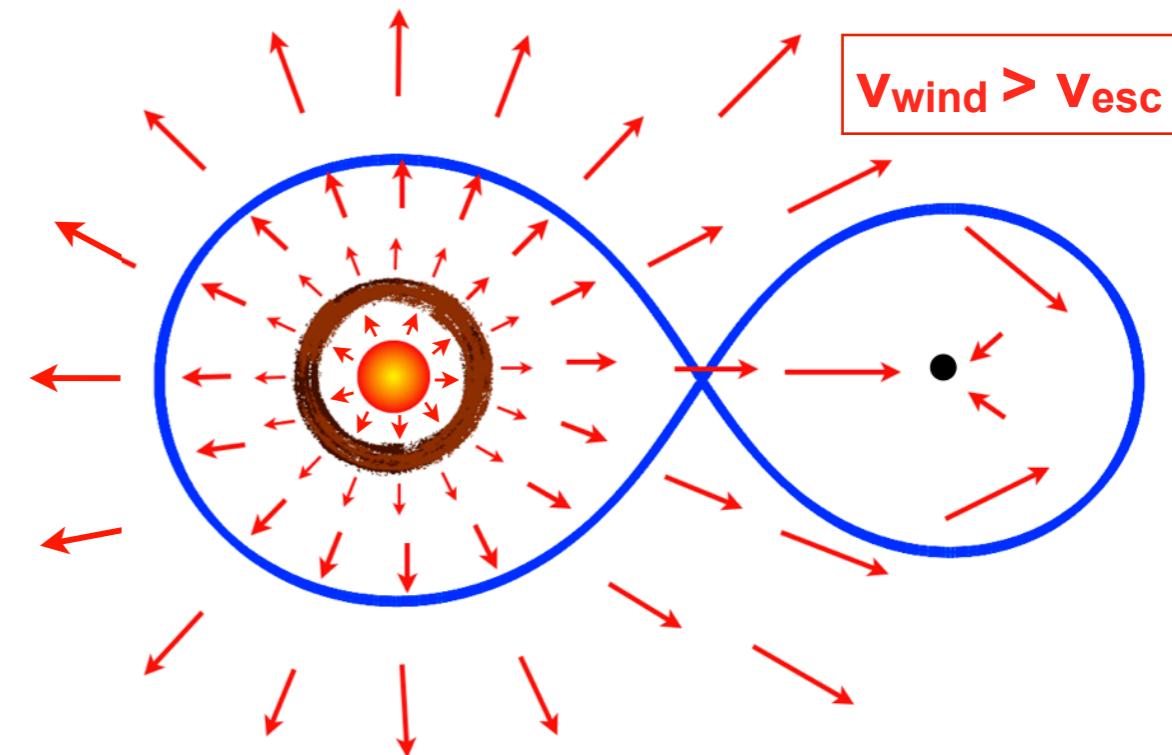
# Binary interaction in Mira?



# Wind Roche-lobe Overflow: “Case D” mass transfer



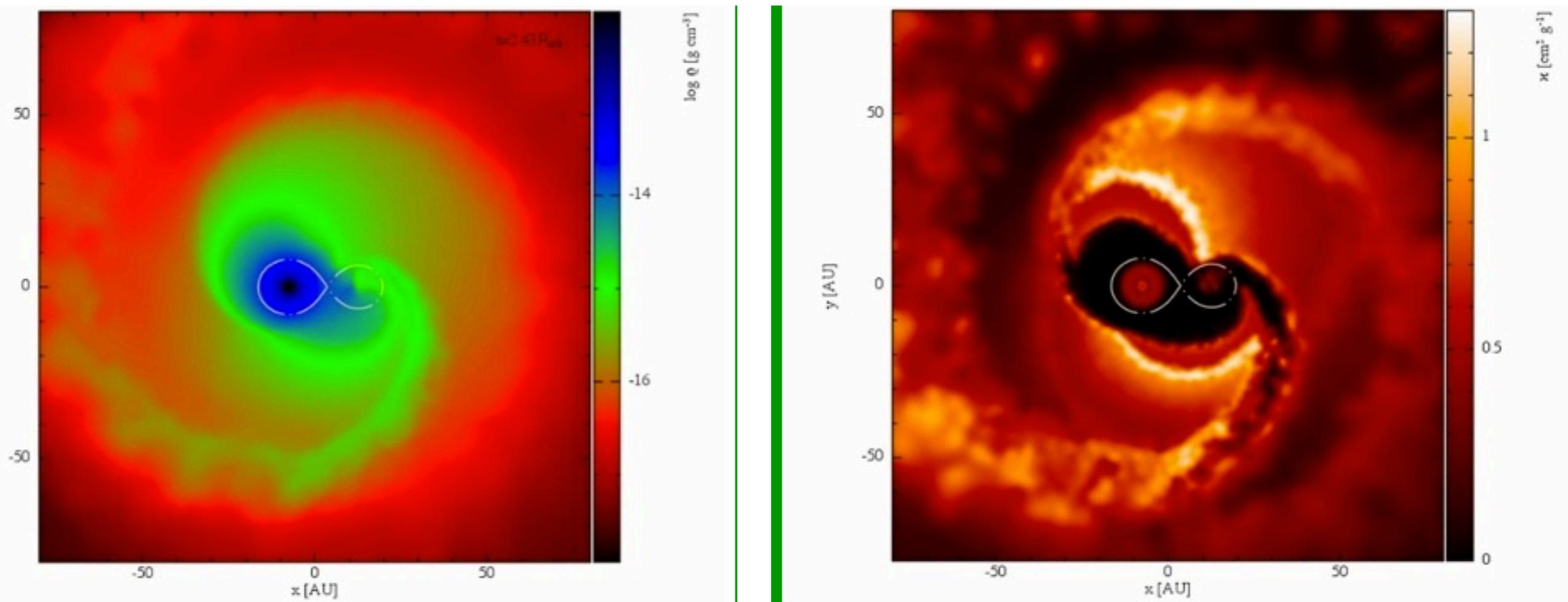
- Velocity of the wind at the  $R_L$  depends on the amount of dust acceleration and the dust formation radius





# Wind Roche-lobe Overflow

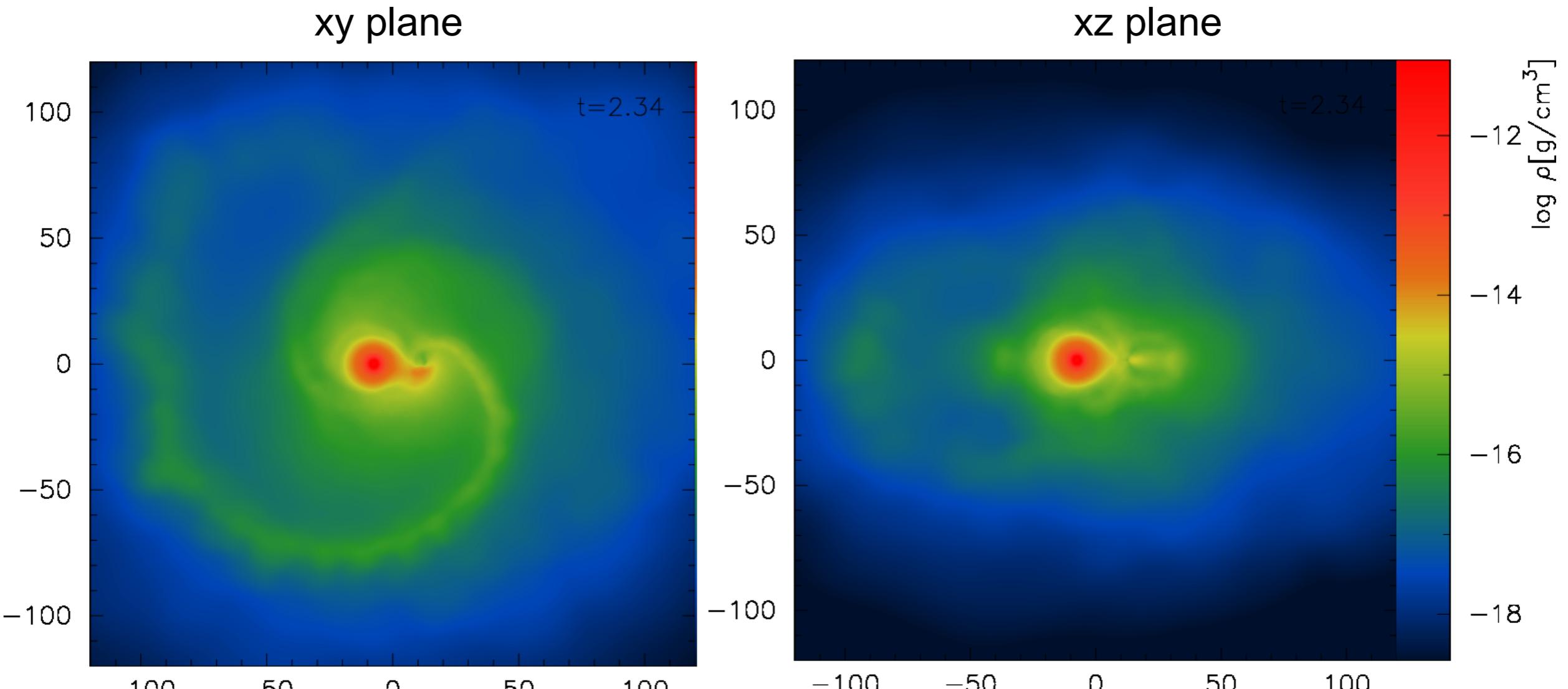
(WRLOF, Mohamed+Podsiadlowski, 2007; 2012)



- Accretion rates are greater than expected wind accretion

# Wind Roche-lobe Overflow

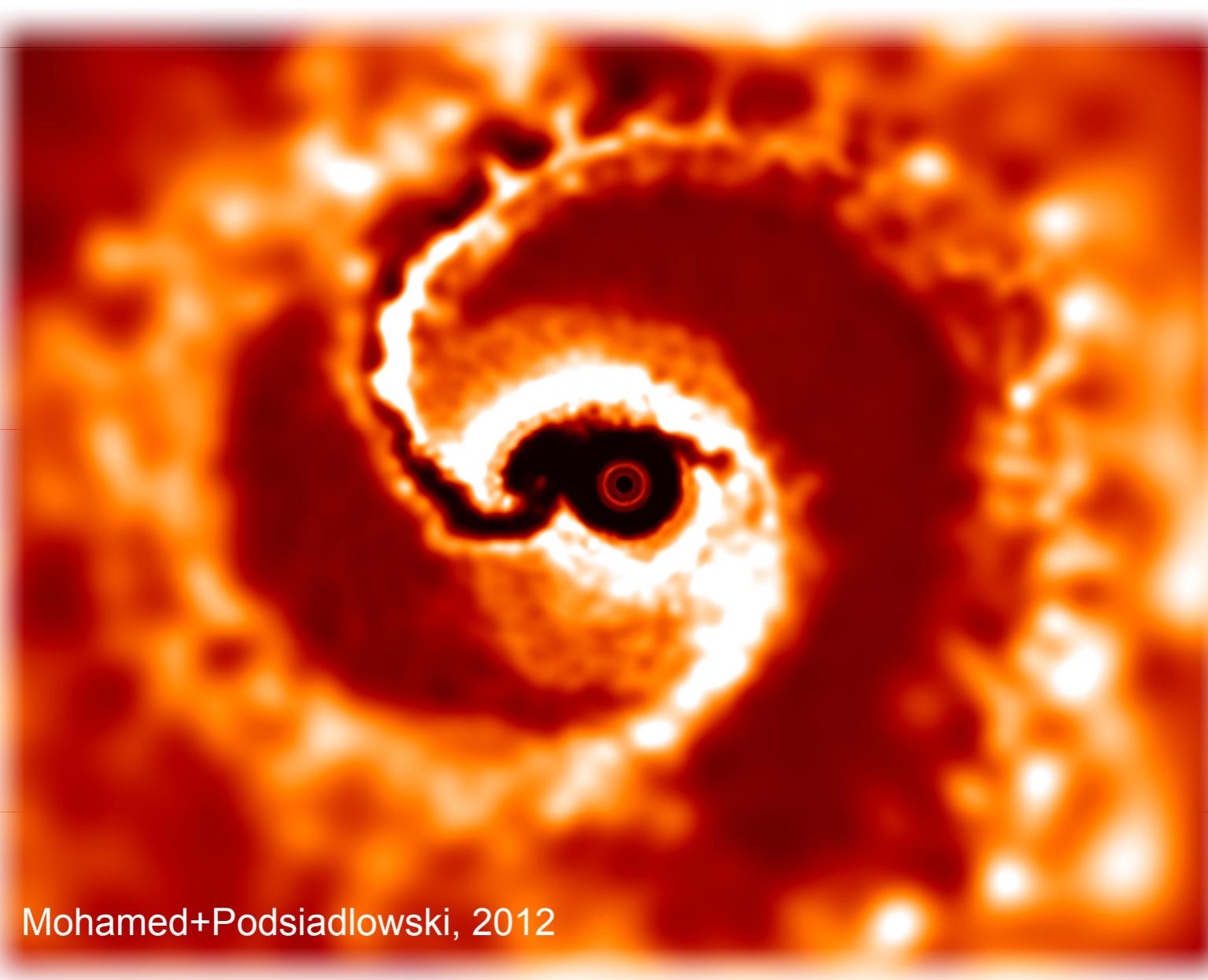
(WRLOF, Mohamed+Podsiadlowski, 2007; 2012)



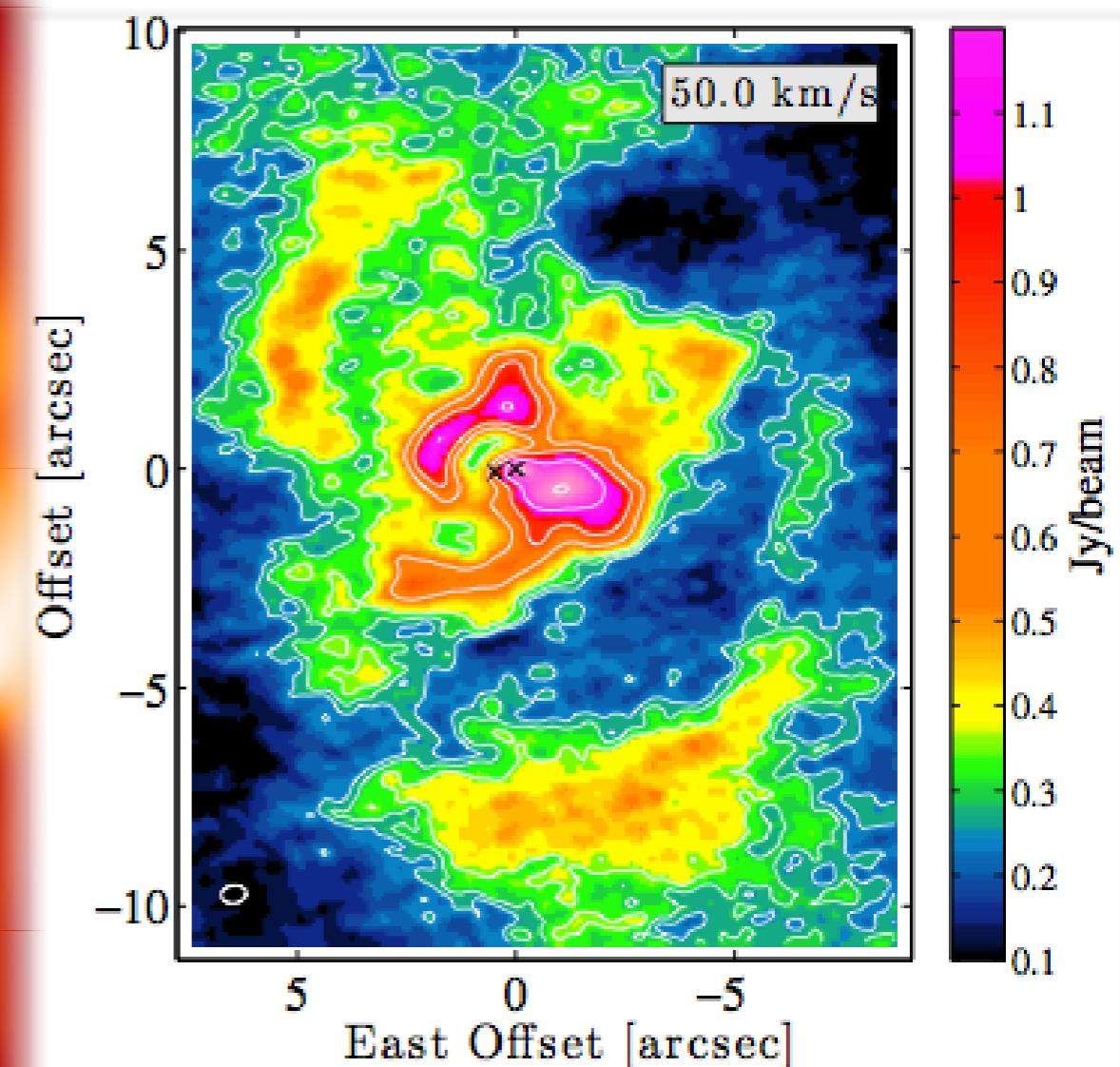
Equatorial enhancements even for binaries with  $a \sim 20$  AU

# Mira with ALMA

(Ramstedt et al. 2014)

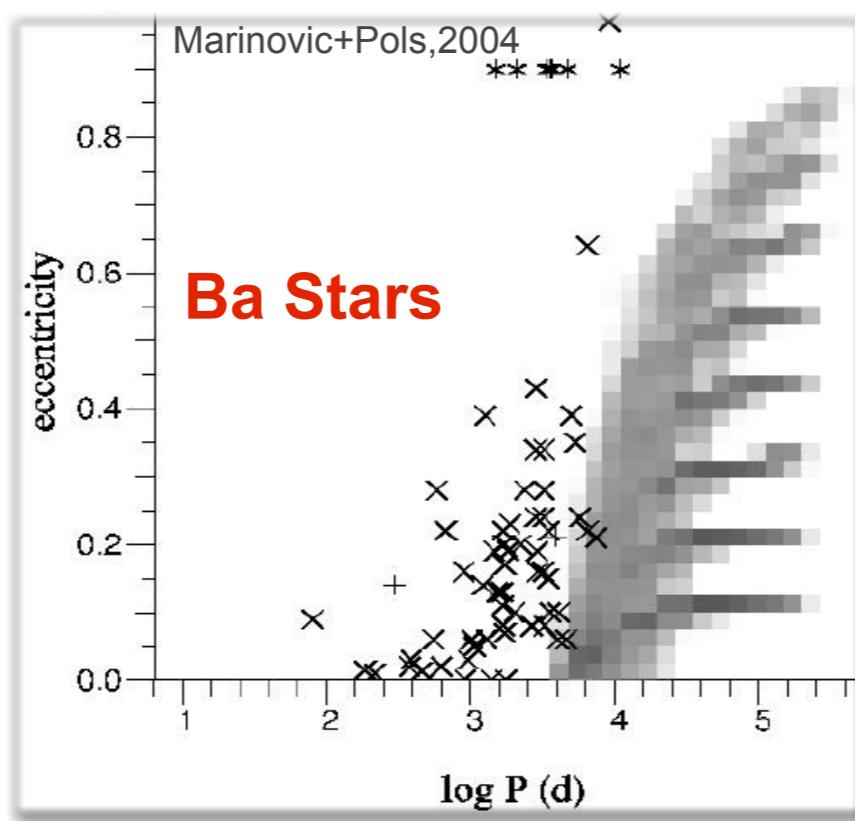
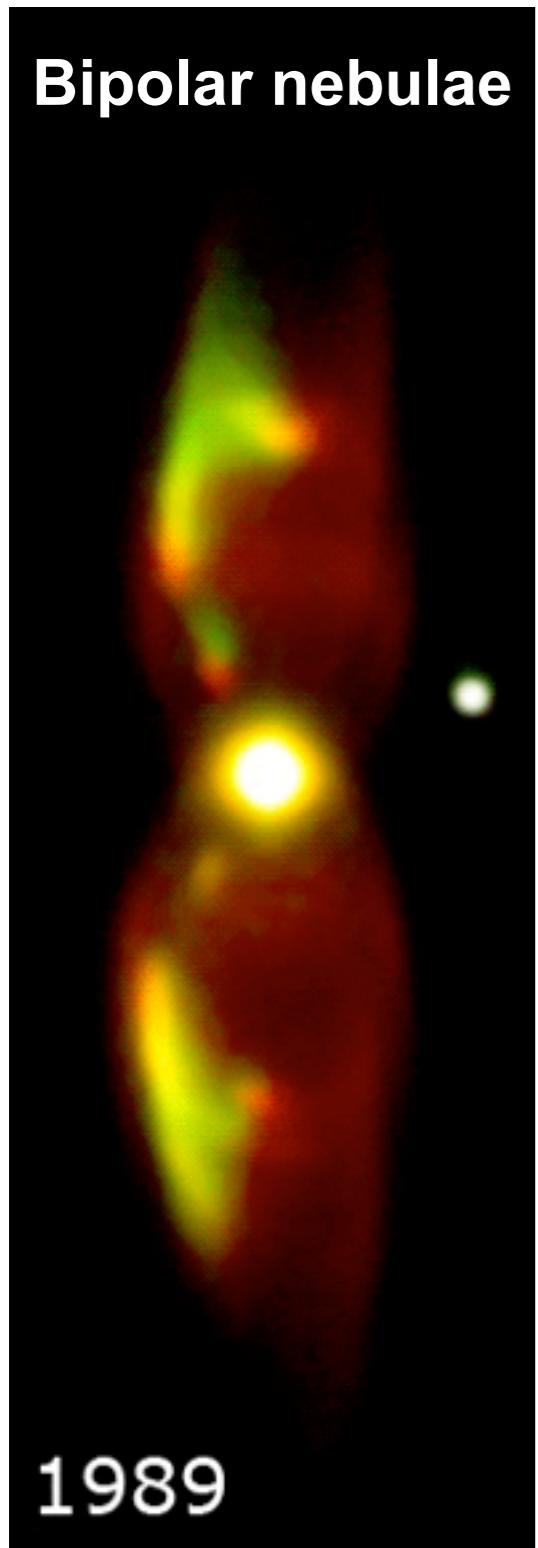


Mohamed+Podsiadlowski, 2012



# Related systems

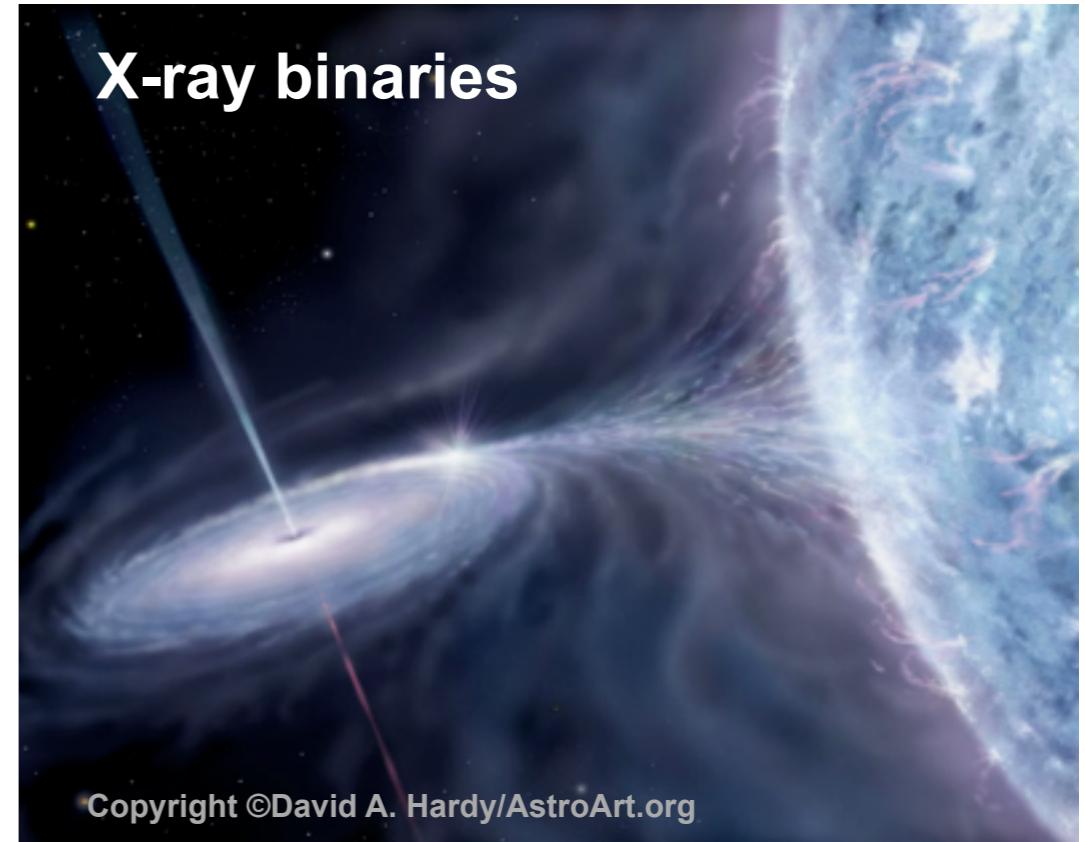
# Bipolar nebulae



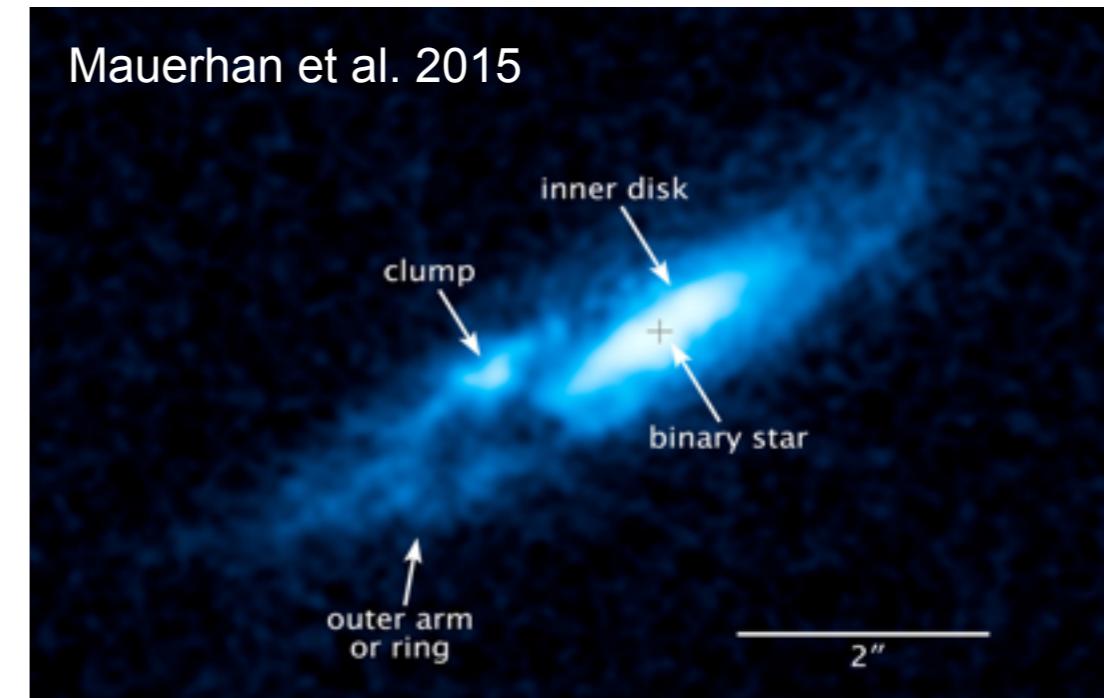
# Unusual supernovae: SN 2002ic

Credit: Wang

# X-ray binaries

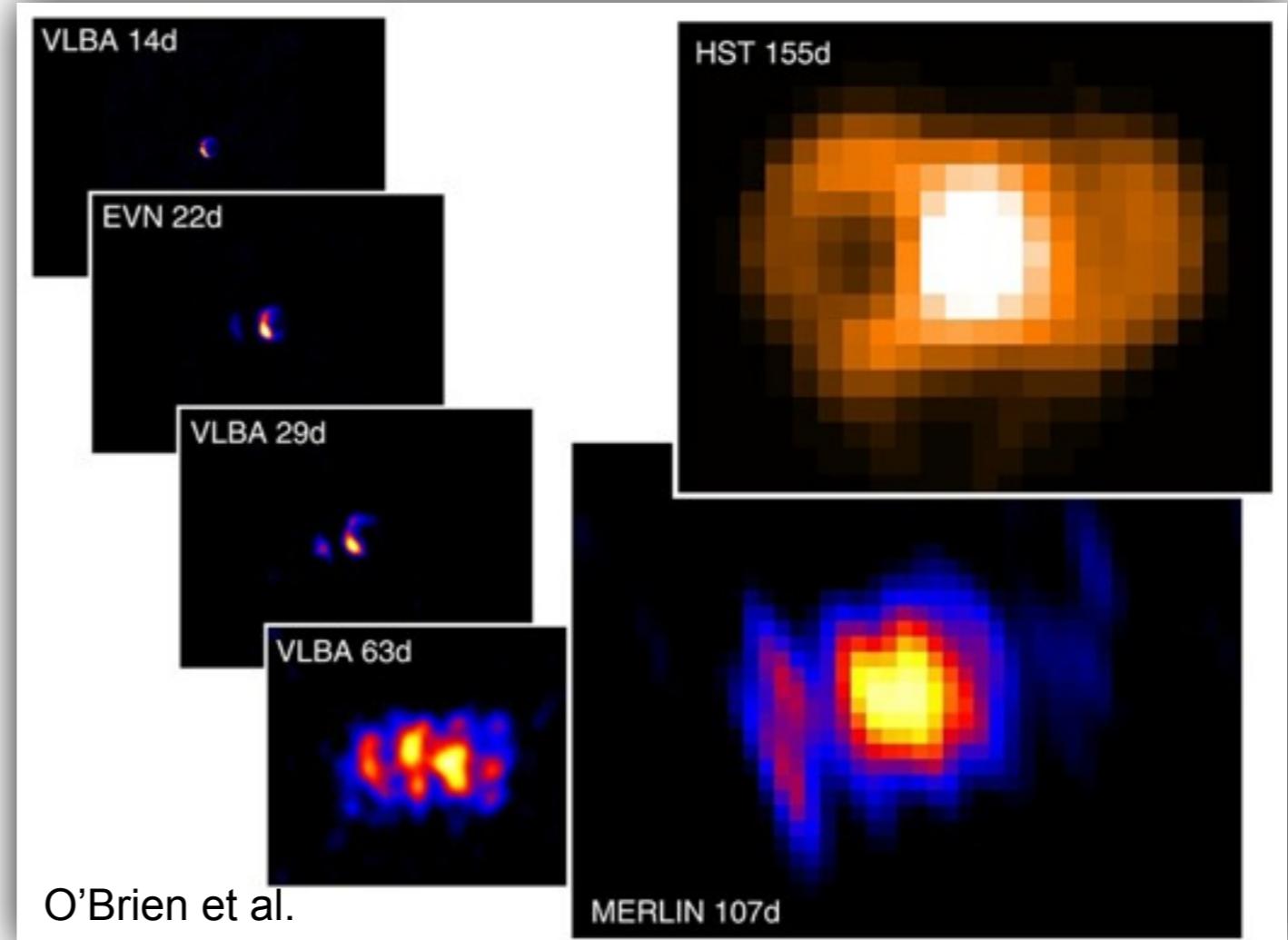


Mauerhan et al. 2015

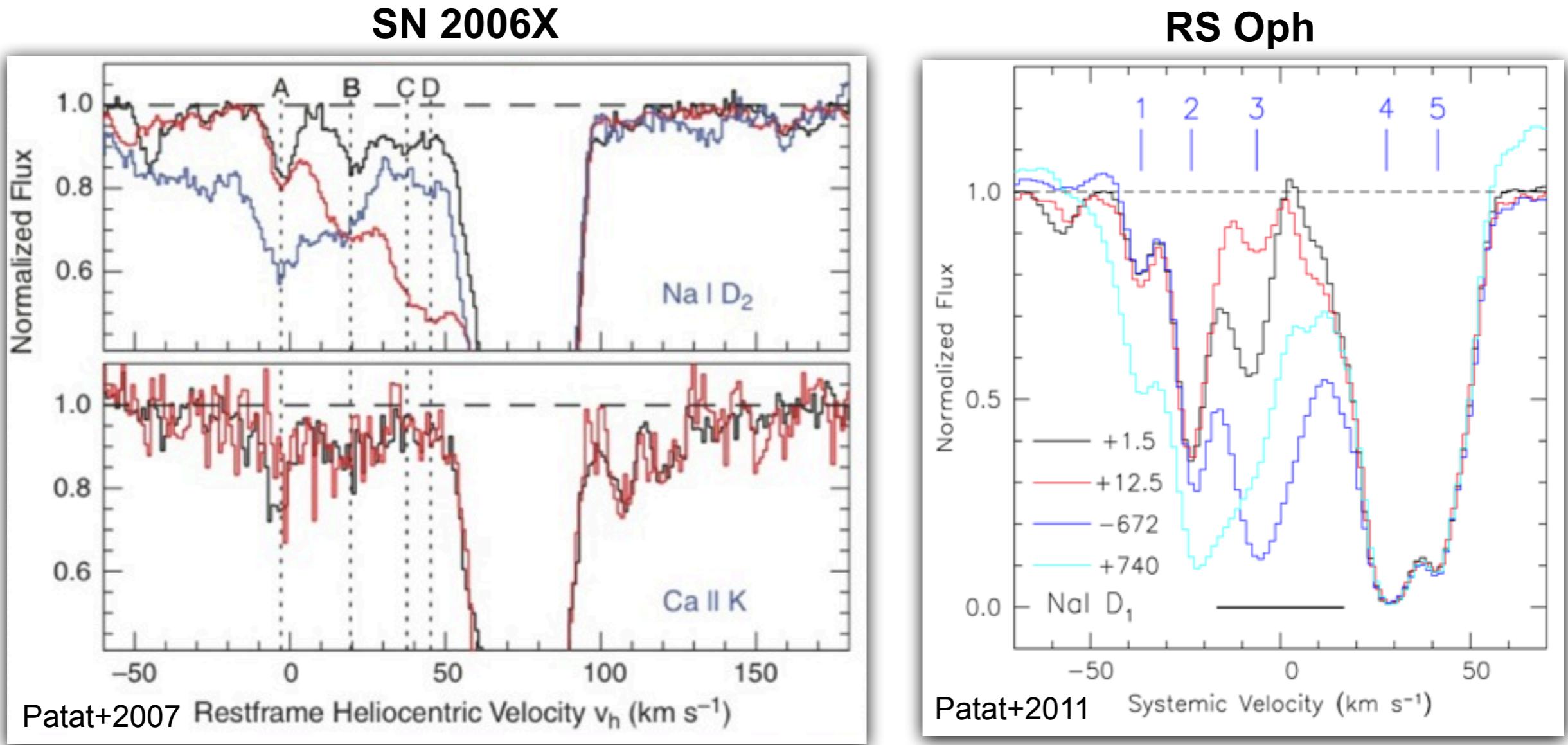


# RS Oph: Symbiotic recurrent nova

- Red giant:  $0.6 - 0.8 M_{\text{sun}}$   
White dwarf:  $1.2 - 1.4 M_{\text{sun}}$   
 $P_{\text{orb}} \sim 455 \text{ days}$  (Brandi+2009)
- Multiple nova outbursts every  $\sim 20$  yrs since 1898
- Bipolar ejecta (Ribeiro+2009)
- Novae are fast: Massive WD (Starrfield et al 1985, Yaron et al 2005).
  - $M_{\text{ejecta}} \sim 10^{-7} M_{\text{sun}}$
  - $v_{\text{ej}} \sim 4000 \text{ km/s}$  (Buil 2006).

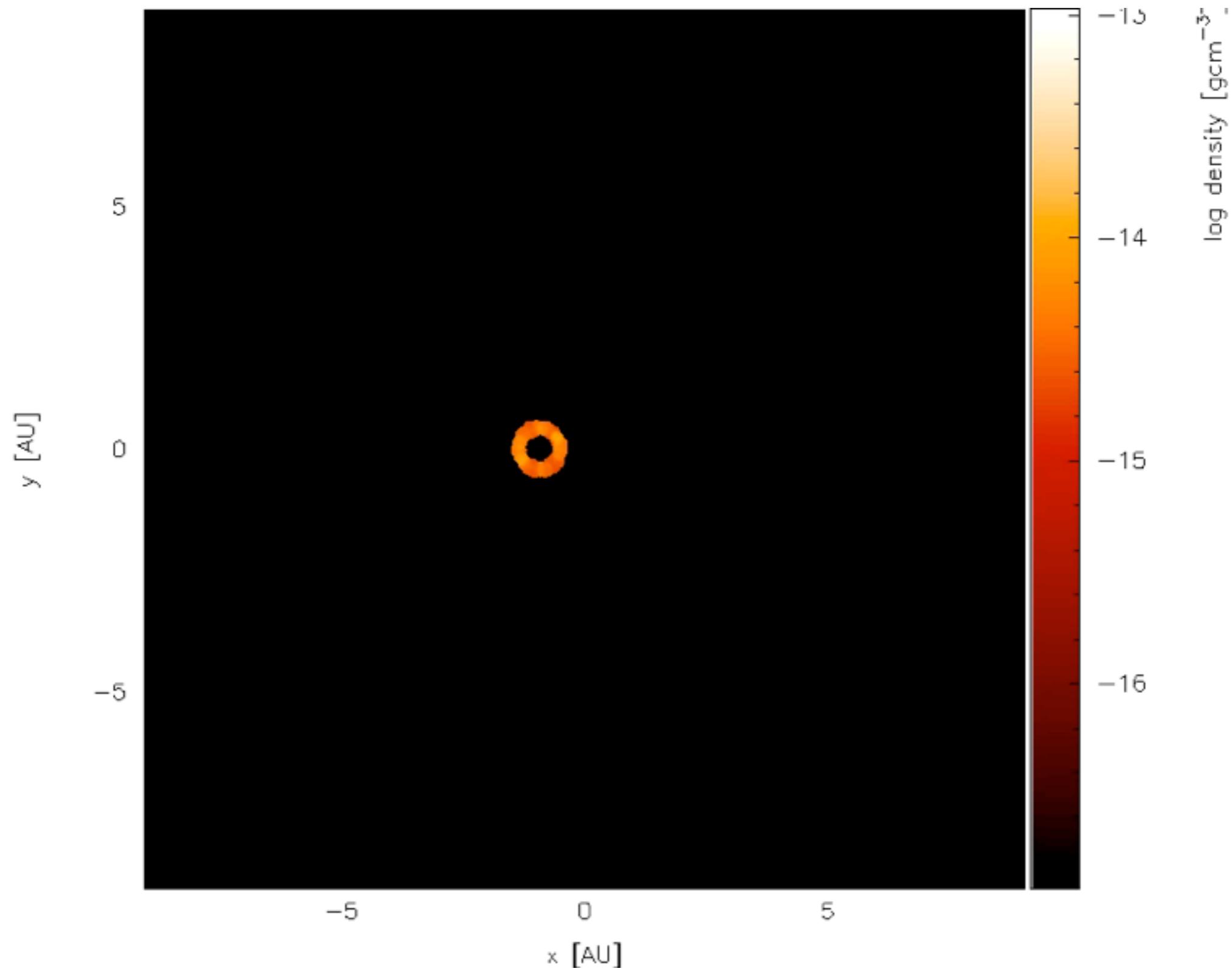


# RS Oph: Variable Na ID lines

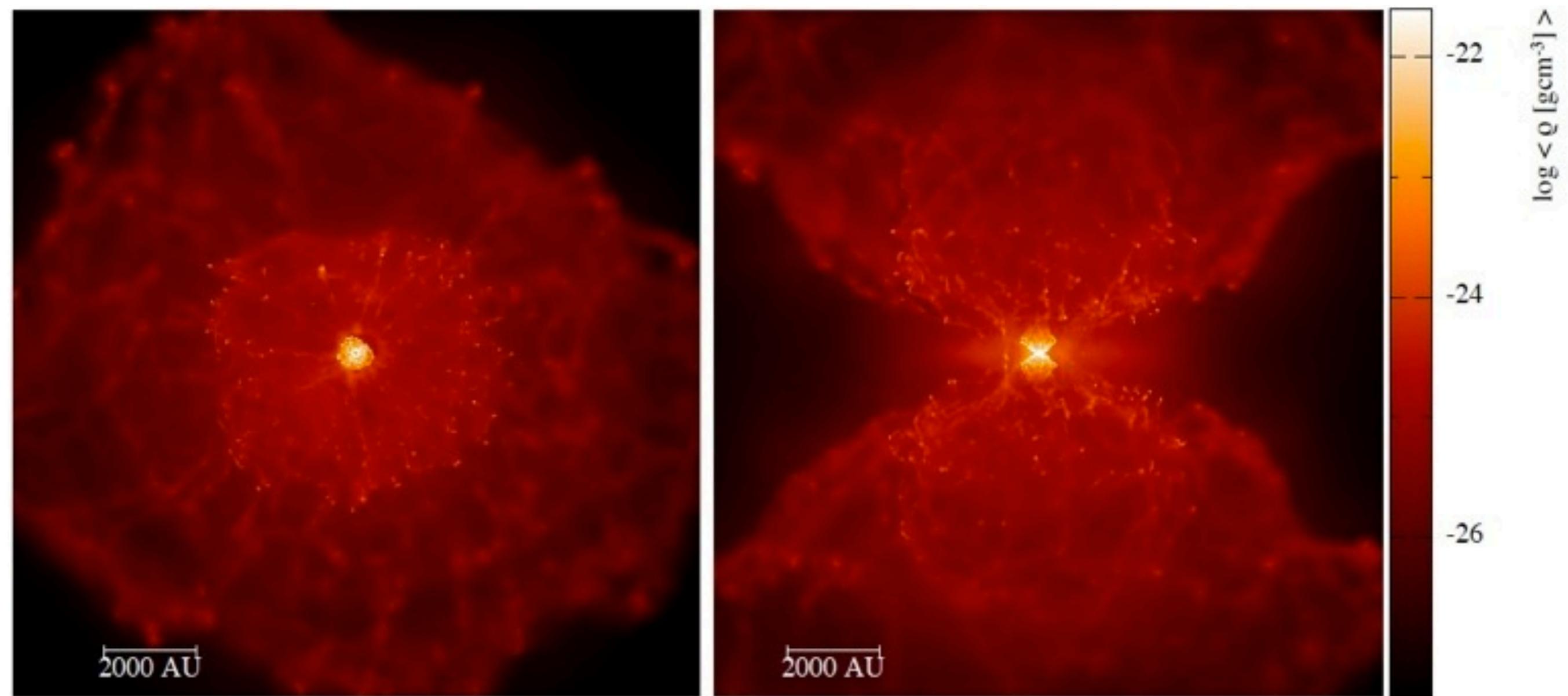


- Variations due to interaction of ejecta and radiation with dense CSM
- Similar variations in some (~20%, Sternberg+11) Type Ia supernovae, e.g. SN 2006X , SN 2007le, PTF 11kx (Patat+2007, Simon+2009, Dilday+2012)

# RS Oph: Circumstellar model



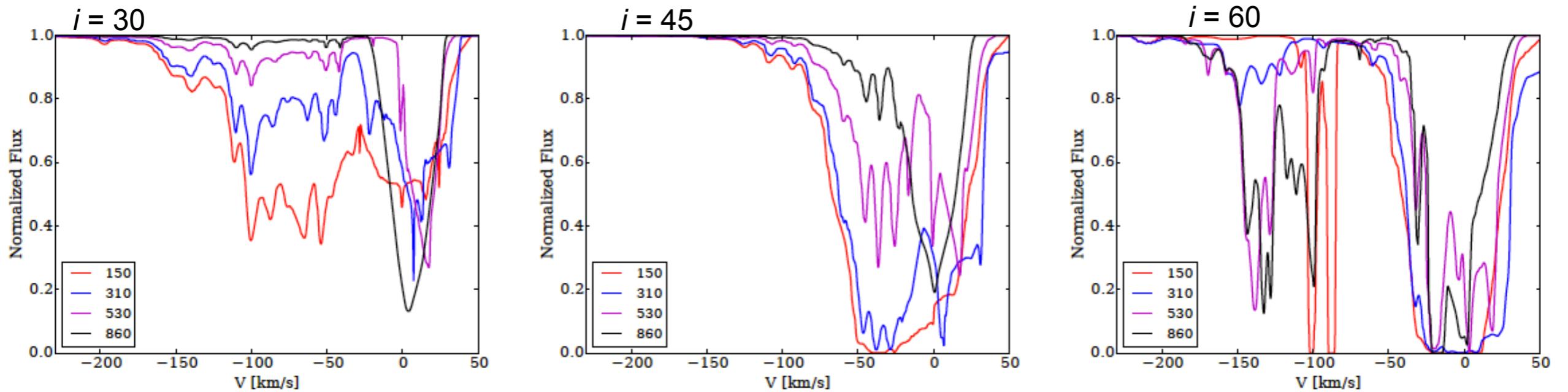
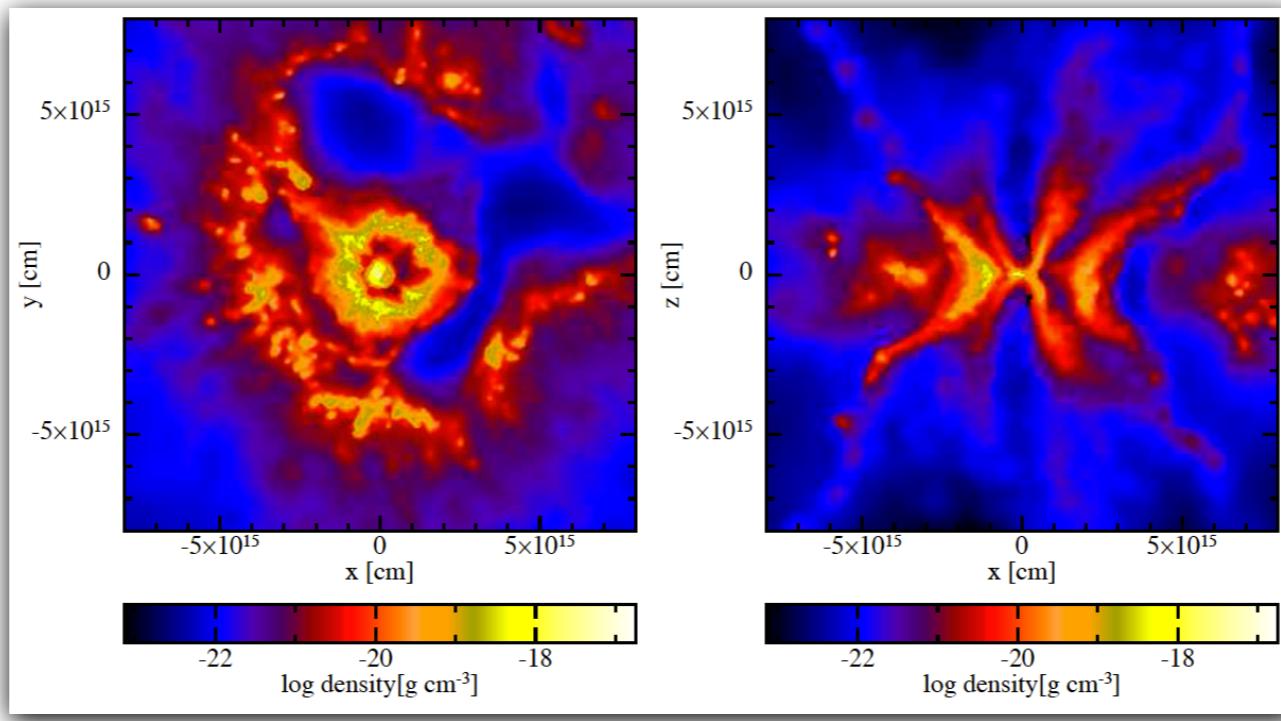
# RS Oph: Multiple novae



- Bipolar outflow geometry
- Total CSM mass  $6 \times 10^{-6} M_{\odot}$ ; Column density  $\sim 10^{17} \text{ cm}^{-2}$

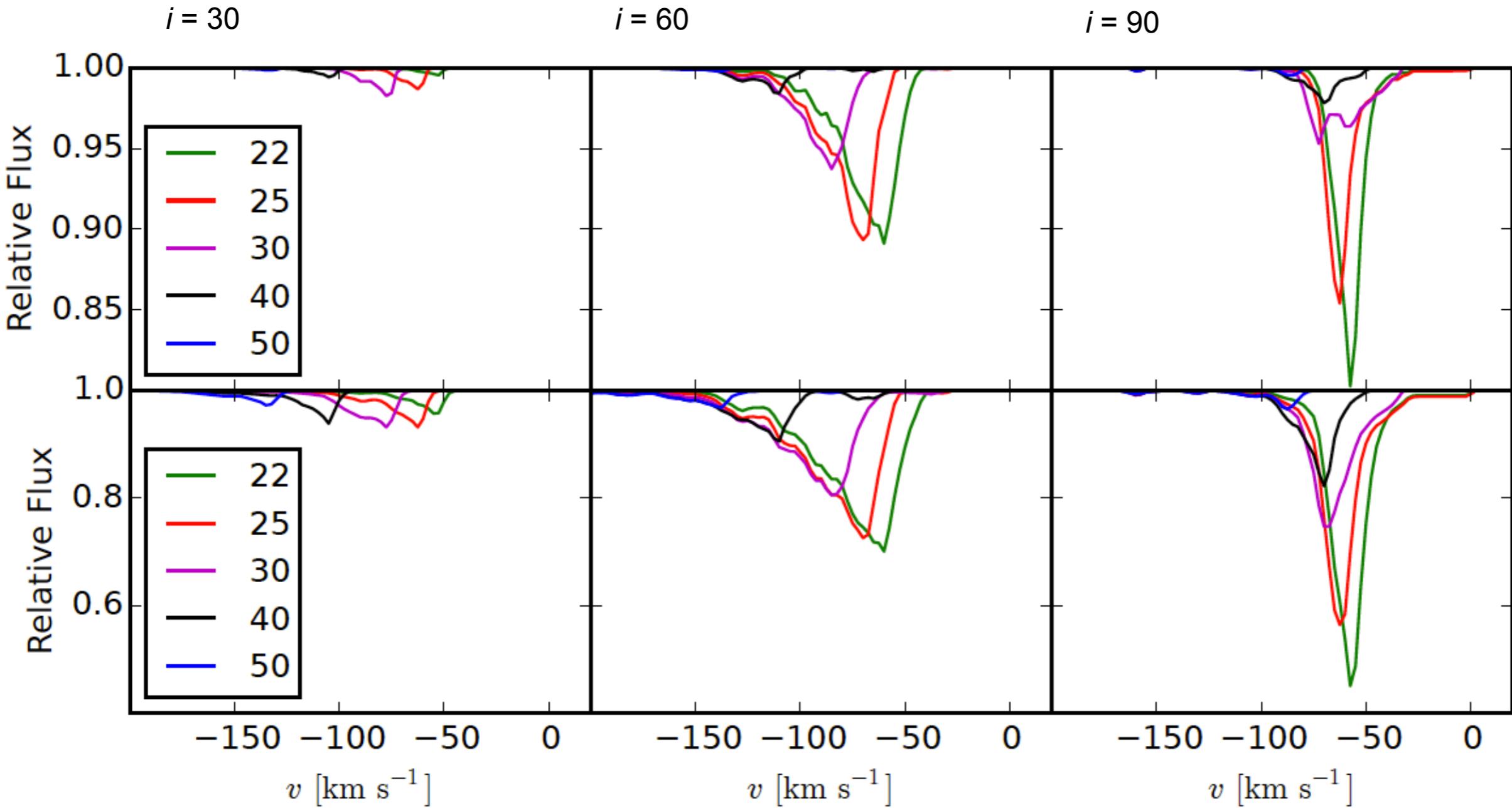
# RS Oph: Variable Na ID lines

(Booth, Mohamed, Podsiadlowski, submitted)

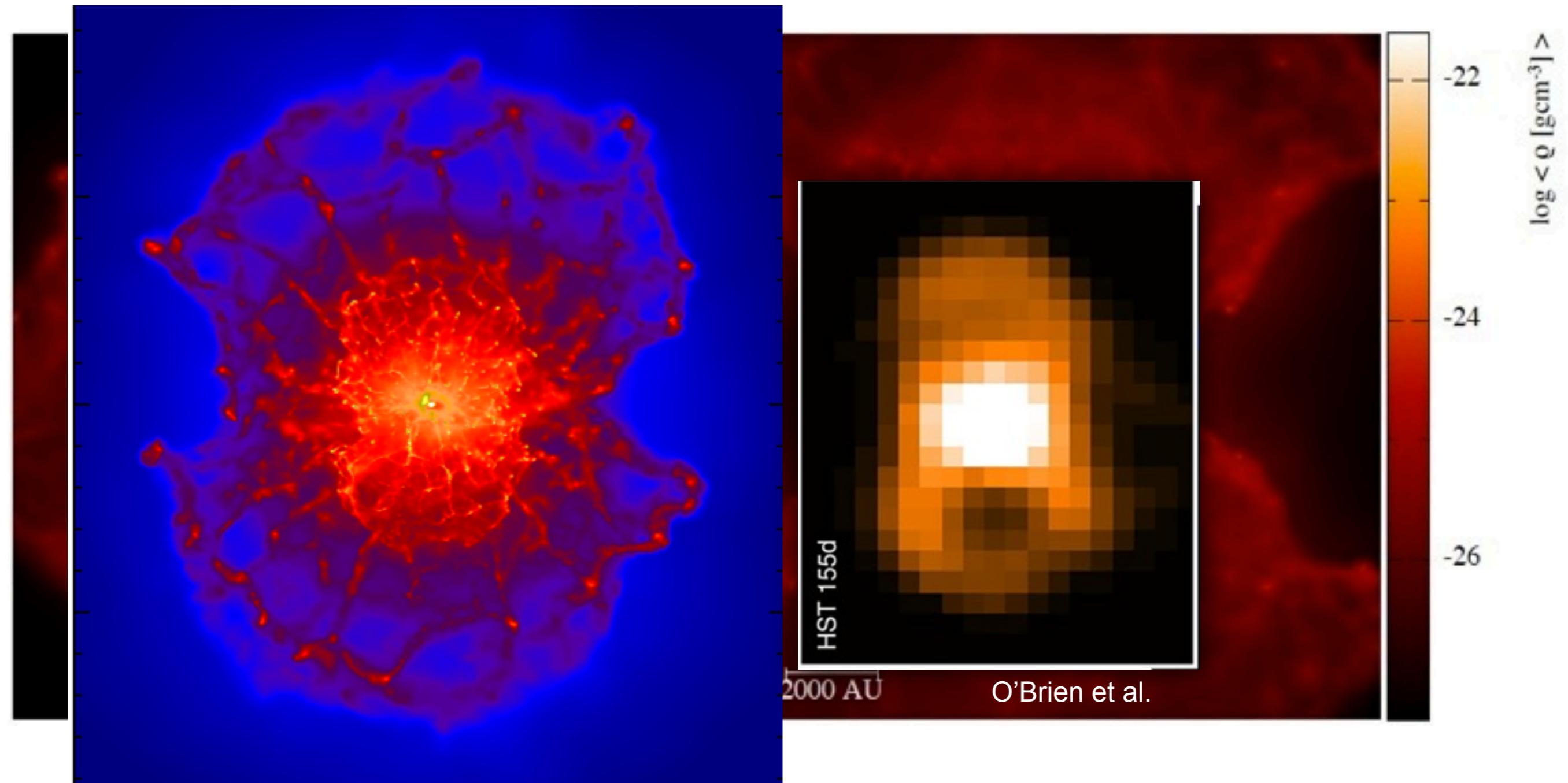


# RS Oph-SN: Variable Na ID lines

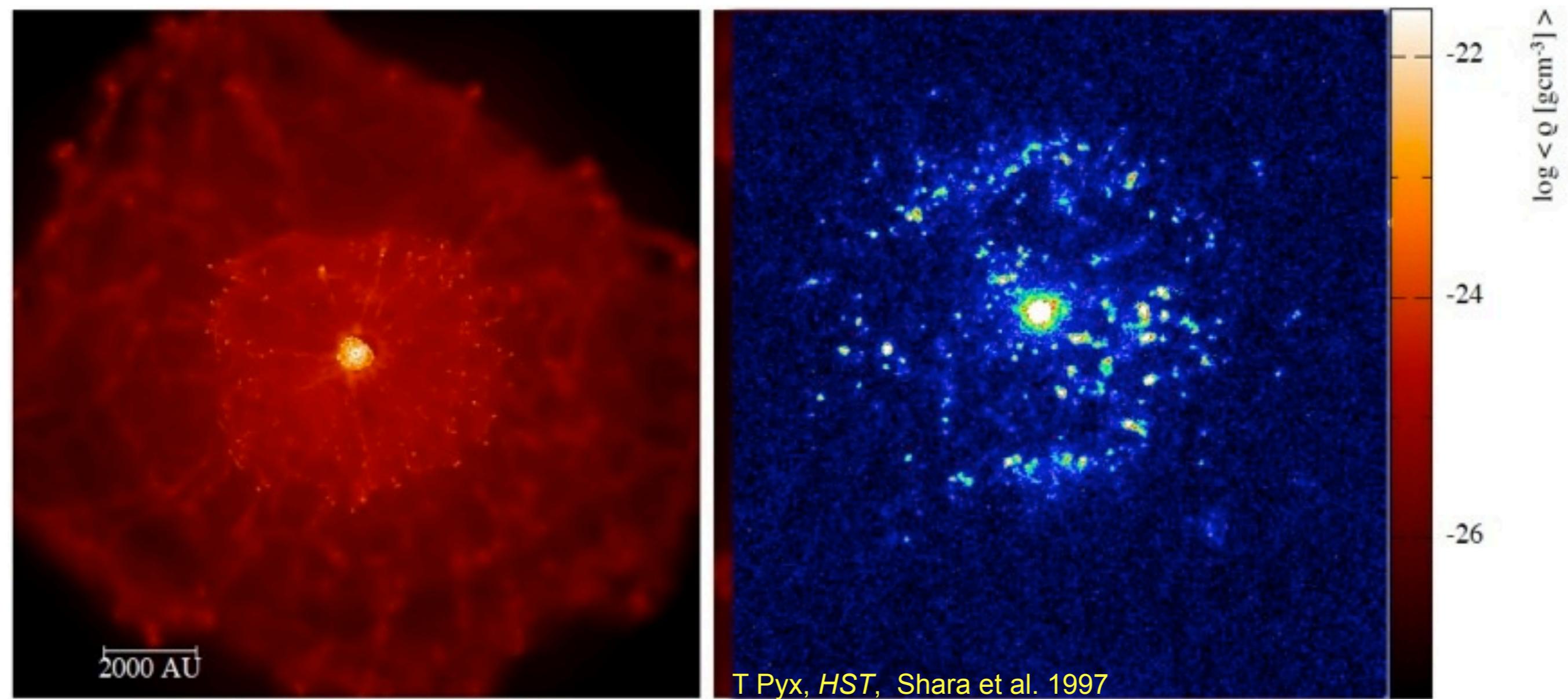
(Booth, Mohamed, Podsiadlowski, submitted)



# RS Oph: Multiple novae



# RS Oph: Multiple novae



Chesneau+2011, “The 2011 outburst of the recurrent nova T Pyxidis. Evidence for a face-on bipolar ejection”

# Summary

- Wind Roche-lobe overflow (WRLOF) in symbiotic binaries leads to complex envelope morphologies
  - spirals, arcs, cavities, shells, accretion disks and equatorial outflows
- and high mass-transfer rates
- Implications for a wide range of systems, e.g., bipolar nebulae, chemically polluted stars, X-ray binaries and supernova progenitors

