Two massive stars possibly ejected from NGC 3603 via a three-body encounter

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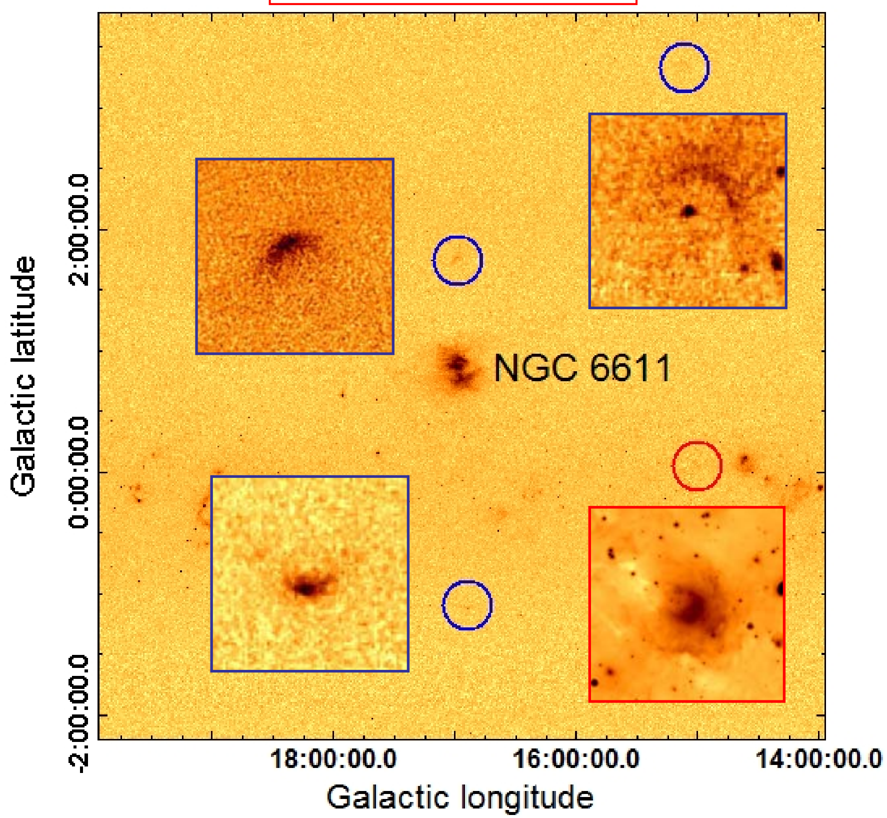
Introduction

- Star clusters lose their massive stellar content at the very beginning of their dynamical evolution
- Peculiar velocities range from ~1o km s^{-1} to several hundreds of km s^{-1}
- About 20% of high-velocity (>30 km s^{-1}) stars produce observable bow shocks, which can be detected in the optical, infrared, radio, and X-ray wavebands
- Detection of bow shock around star clusters allows us to reveal OB stars running away from these clusters, which provides useful constraints on modelling of dynamical evolution of young star clusters

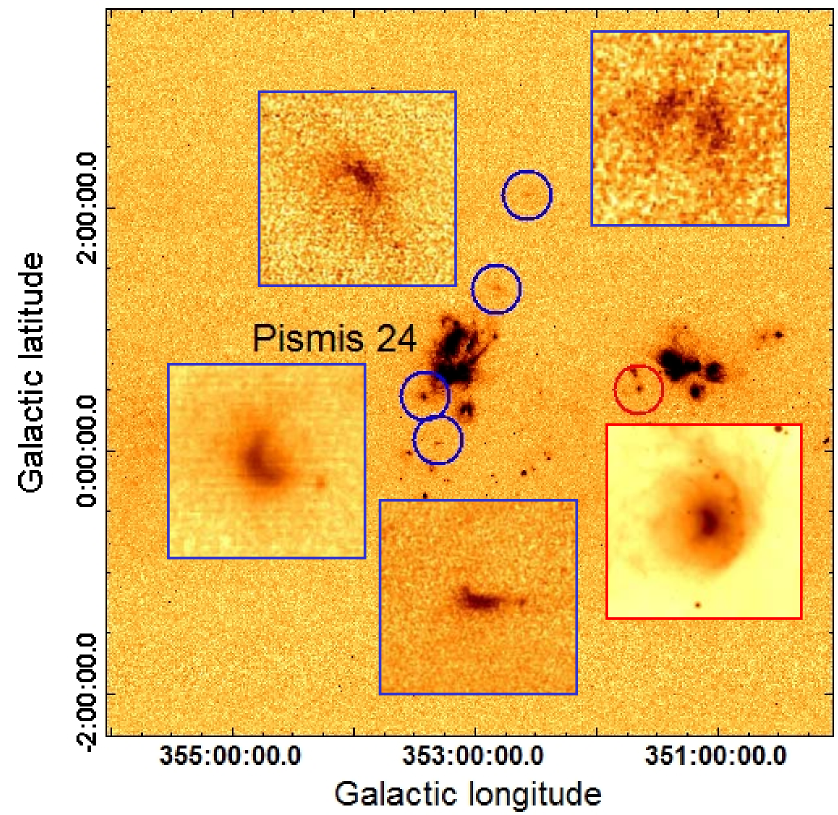
Search for bow shocks around young massive star clusters

NGC 6611



(Gvaramadze & Bomans 2008)

Pismis 24



(Gvaramadze et al. 2011)

NGC 3603

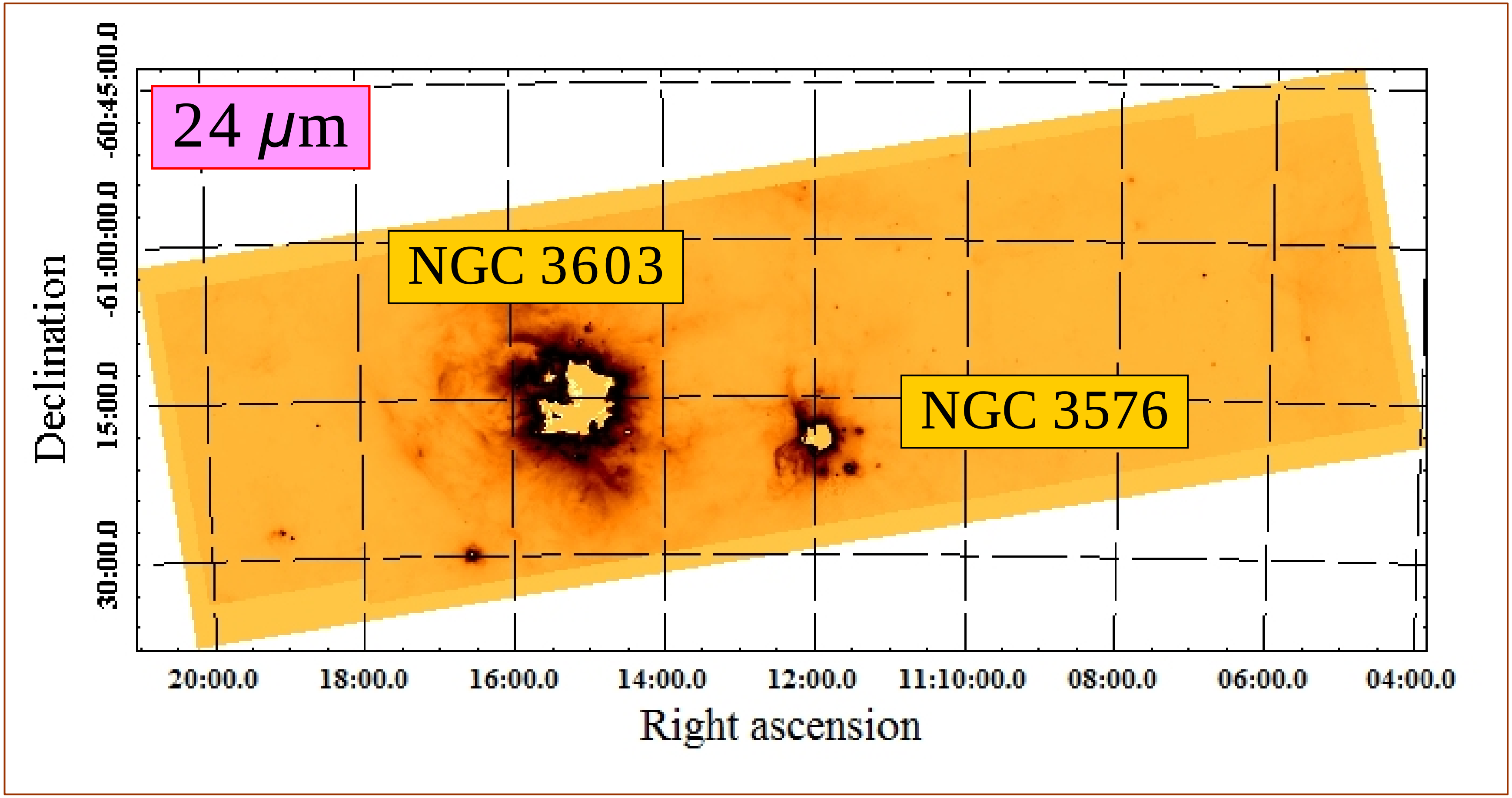
NGC 3603

- Age $\simeq$ 2 Myr (Kudryavtseva et al. 2012)
- Mass ~ 10^4 $M_\odot$ (Harayama et al. 2008)
- Distance $\simeq$ 7.6 kpc (Melena et al. 2008)
- Numerous O-type stars + 3 WN-type stars (Moffat et al. 1994; Schnurr et al. 2008)
- WN-type stars: initial mass $\simeq$ 140-170 $M_\odot$ (Crowther et al. 2010); two of the are short-period ($\simeq$ 4-9 d) binary systems (Schnurr et al. 2008)
- Core radius $\simeq$ 0.2 pc (Harayama et al. 2008)

=> effective in producing massive runaways!

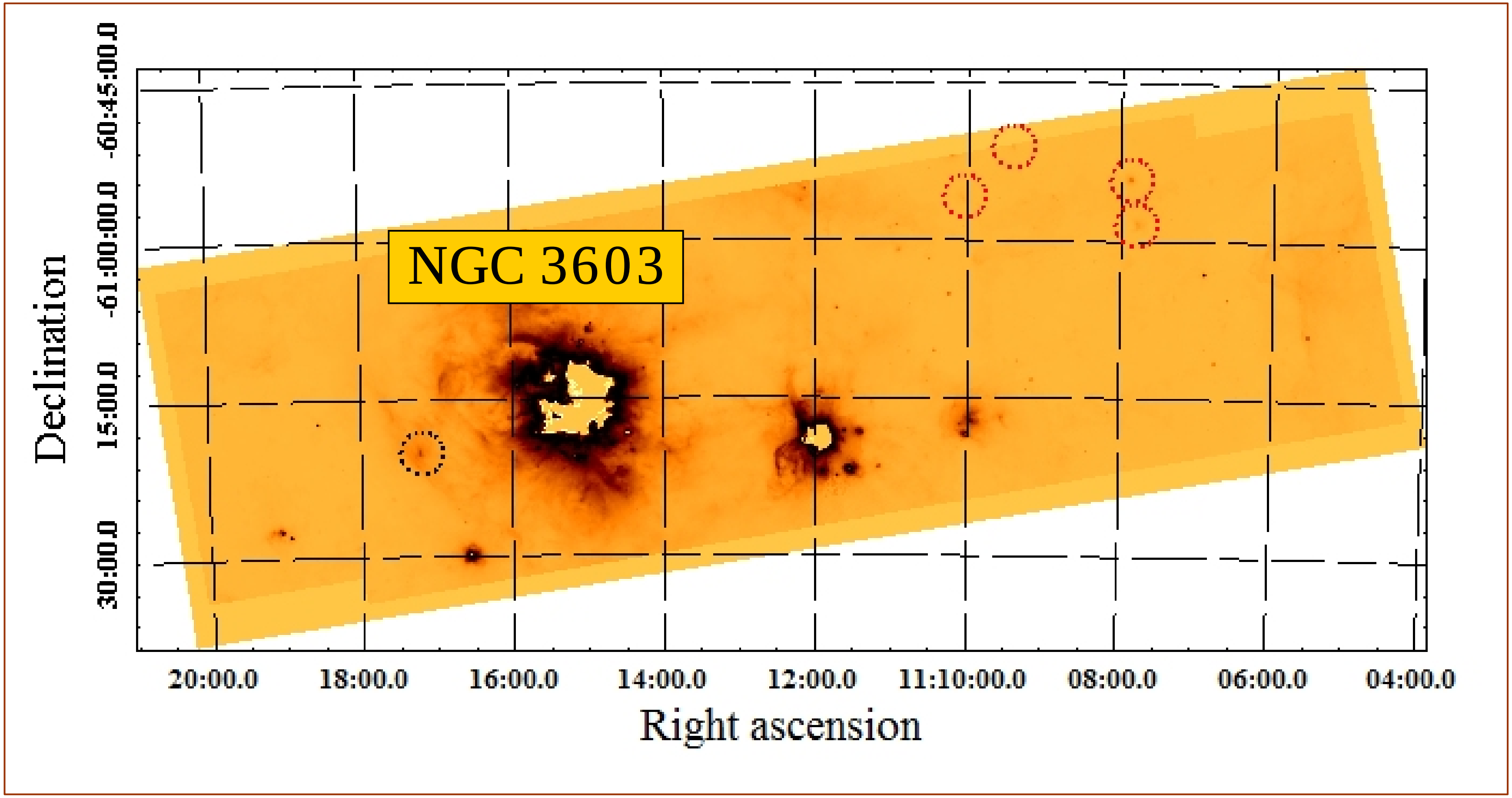
NGC 3603 and its environments as seen by *Spitzer Space Telescope*

(Multiband Imaging Photometer for *Spitzer*; MIPS)

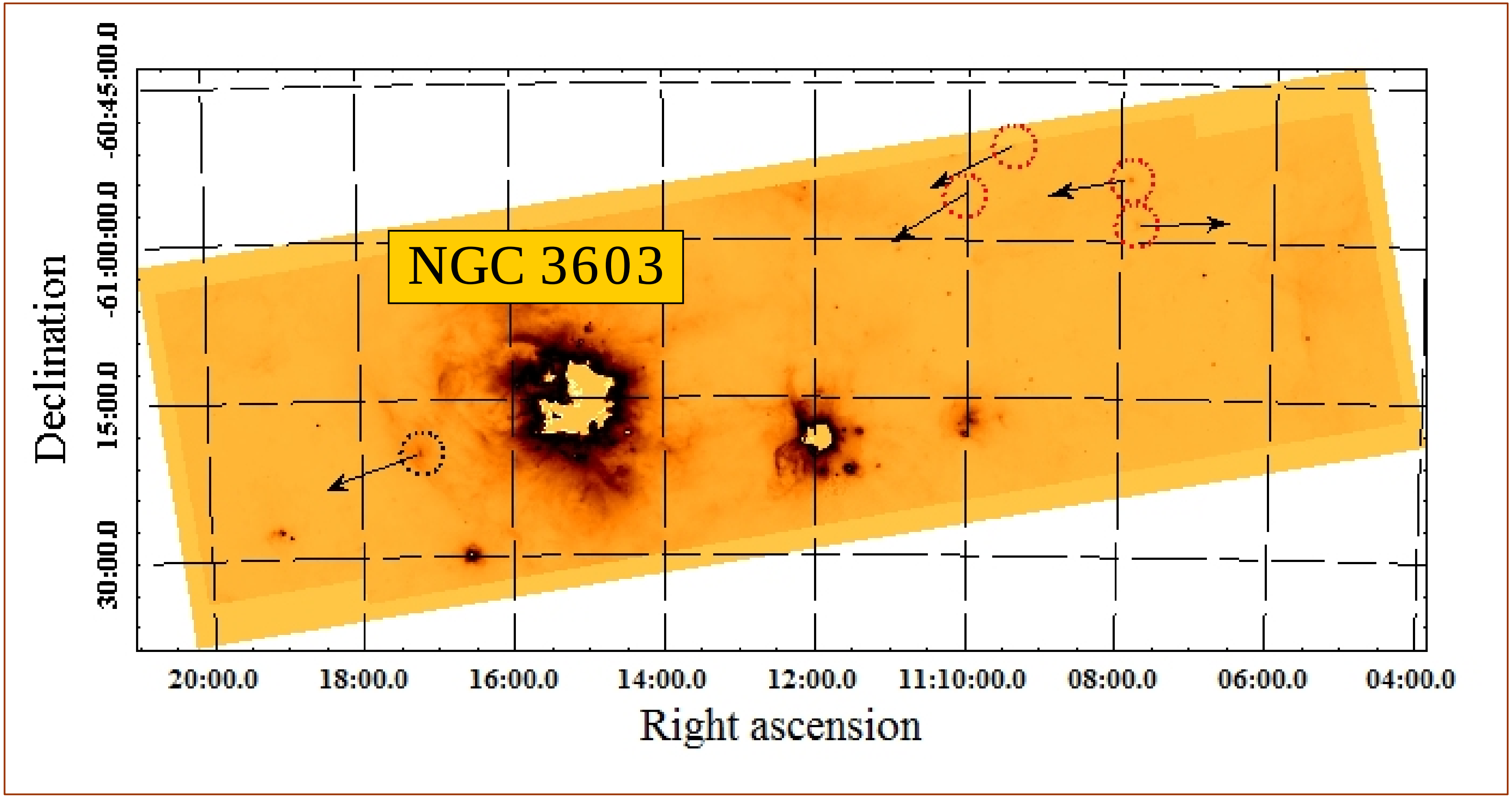


(Program Id.: 41024, PI: L. Townsley)

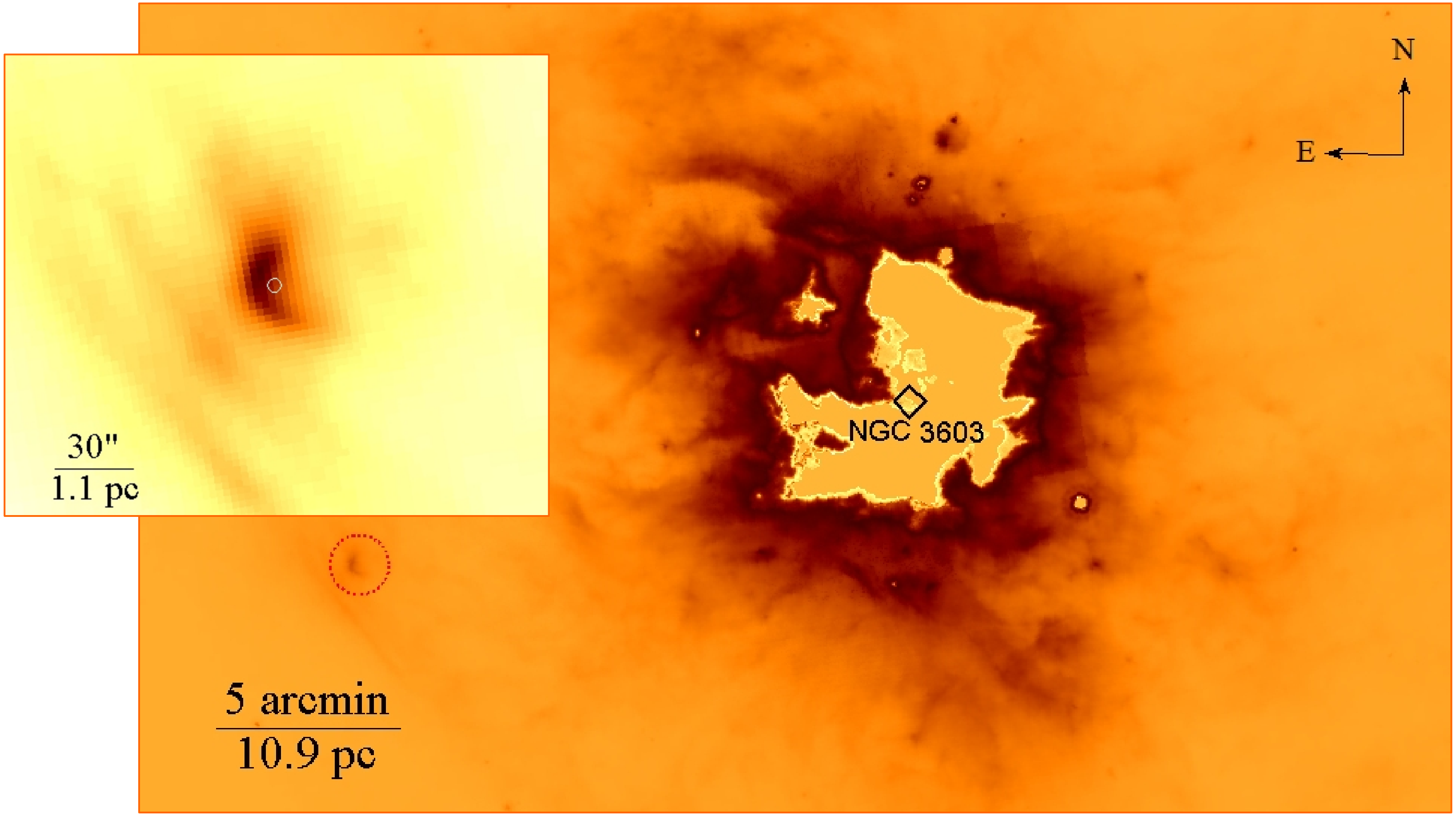
NGC 3603 and its environments as seen by *Spitzer Space Telescope*



NGC 3603 and its environments as seen by *Spitzer Space Telescope*

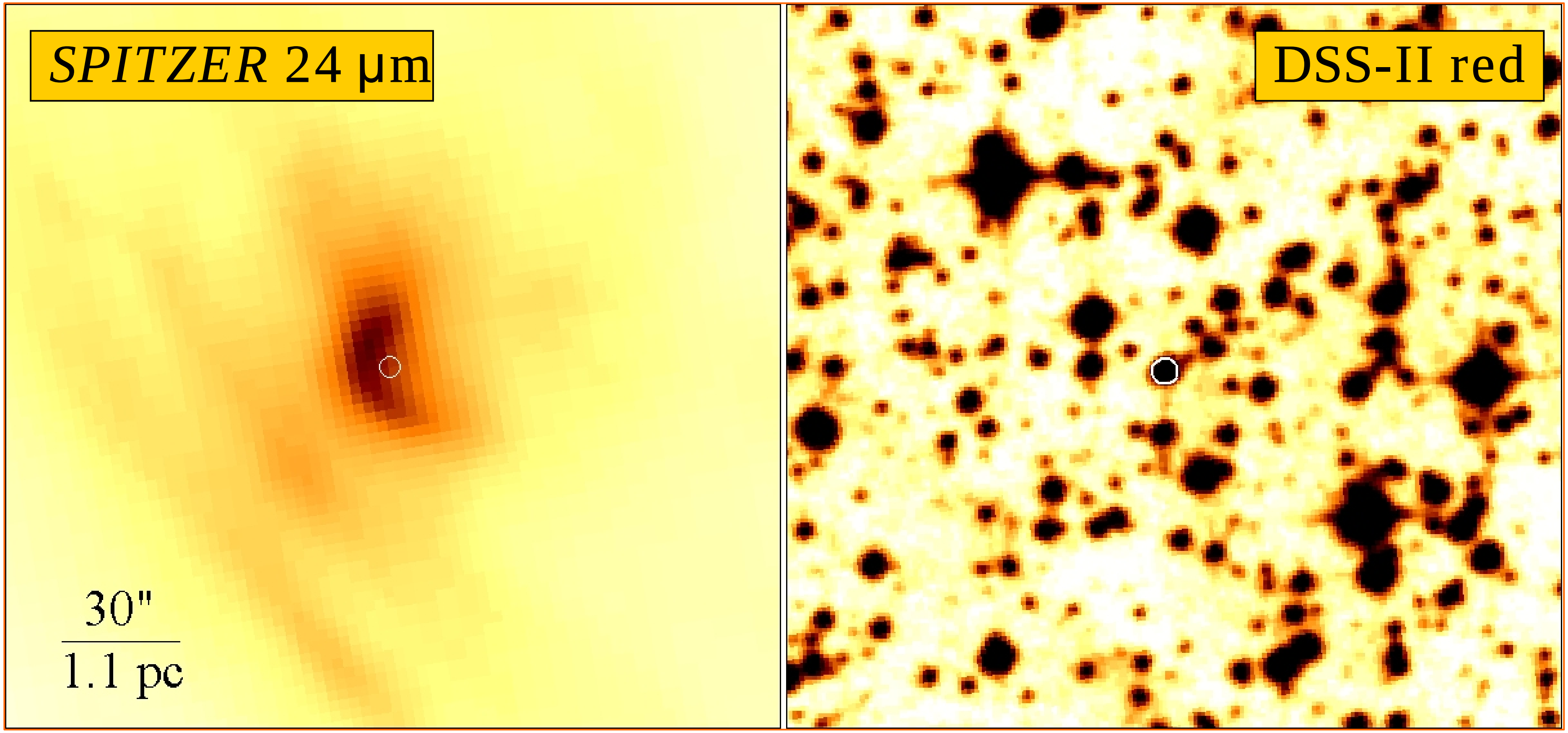


NGC 3603 and its environments



≃ 20 arcmin (or ≃ 44 pc in projection) from NGC 3603

Bow-shock-producing star 2MASS J11171292-6120085

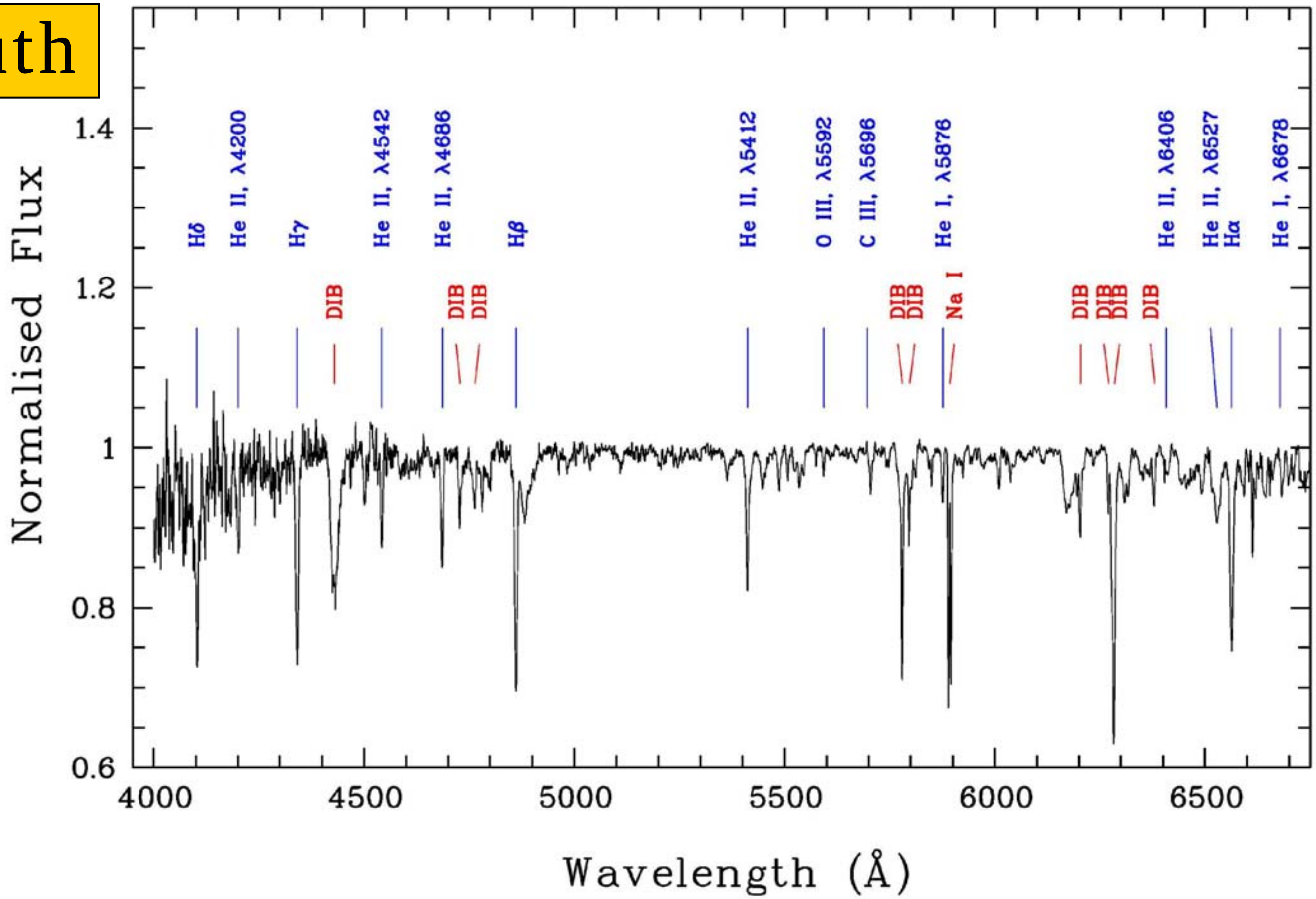


$V \simeq 15\text{-}16$ mag

Follow-up spectroscopy of J1117-6120

Gemini-South

O6 V



Distance to J1117-6120

- J=11.79±0.03 mag, K_s=10.92±0.02 mag (2MASS; Cutri et al. 2003)
- O6 V: M_{K_s}=-4.13 mag, $(J\text{-}K_s)_0$=-0.21 mag (Martins & Plez 2006)

=> A_{K_s}=0.71±0.02 mag, DM=14.34 mag

=> $d = 7.4_{-0.5}^{+0.9}$ kpc

NGC 3603 is the parent cluster of J1117-6120!

J1117-6120: a runaway star from a few-body dynamical encounter?

- The young age of NGC 3603 (~ 2 Myr) implies that J1117-6120 was ejected dynamically, either because of a binary-binary or binary-single encounter in the cluster's core

J1117-6120: a runaway star from a few-body dynamical encounter?

Binary-binary encounter:

- exchange of the more massive binary components into a new (eccentric) binary
- ejection of the less massive stars with high velocities
- the trajectories of the ejected stars make an arbitrary angle with each other

J1117-6120: a runaway star from a few-body dynamical encounter?

Binary-single encounter:

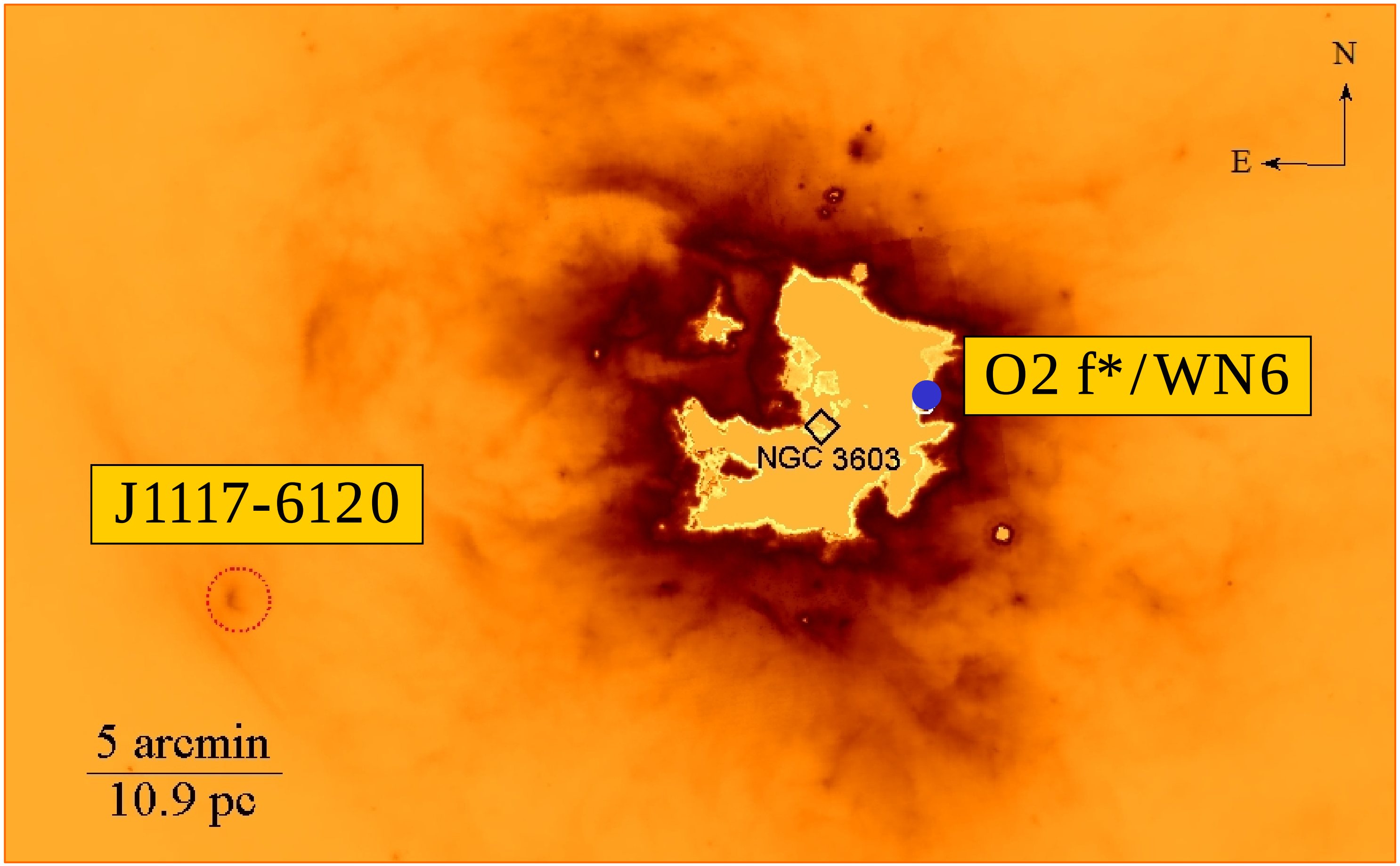
- single star (usually the lowest mass star among the stars participating in the encounter) is ejected with a high velocity
- binary system is recoiled in the opposite direction to the single star
- post-encounter binary could merge into a single star if its orbit is compact

J1117-6120: a runaway star from a few-body dynamical encounter?

Binary-single encounter:

If J1117-6120 was ejected via a three-body encounter then a massive binary or a single merged star should exist on the opposite side of NGC 3603

J1117-6120: a runaway star from a three-body encounter?

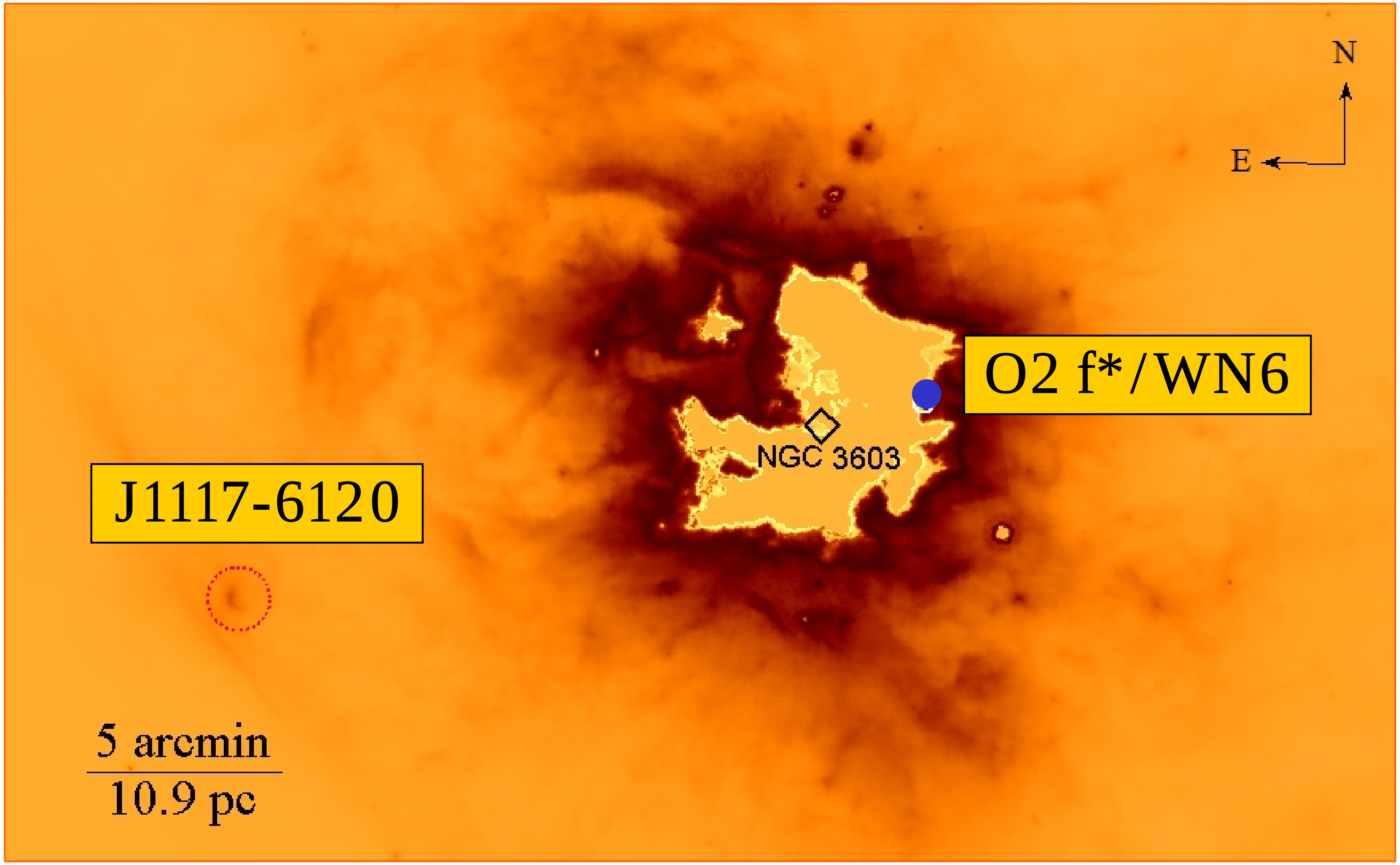


O2 f*/WN6 (Ramon-Lopes 2012)

O2f*/WN6

- WR42e (Ramon-Lopes 2012)
- $L_{\mathrm{bol}} \sim 3\mathrm{x}10^{6}\,\mathrm{L}_{\odot}$, mass > 100 $\mathrm{M}_{\odot}$
- $L_{\mathrm{X}}=2.3\mathrm{x}10^{32}$ erg s^{-1}
- $L_{\mathrm{X}}/L_{\mathrm{bol}} \sim 5\mathrm{x}10^{-8}$ – typical of single stars
- WR42e – a single star (dynamically ejected from NGC 3603 via a three-body encounter)

J1117-6120: a runaway star from a three-body encounter?



WR42e as a merged binary star

- WR42e – a merged binary star (recoiled from NGC 3603 in the course of a three-body encounter ~ 1 Myr ago)
- WR42e: $\theta_1 \simeq 0.045^\circ$; J1117-6120: $\theta_2 \simeq 0.262^\circ$
- conservation of the linear momentum

  => $M_1 = (\theta_2/\theta_1) M_2$, for $M_2 = 30\ M_\odot$, one has

  $M_1 \simeq 175\ M_\odot$

WR42e as a merged binary star

- during the merger process the binary system loses ~10% of its mass (Suzuki et al. 2007) => ~20 $M_\odot$
- during the subsequent 1 Myr the star additionally loses ~ 20-30 $M_\odot$ in the form of stellar wind
  => current mass ≃125-135 $M_\odot$
  => $\log(L/L_\odot)\simeq 6.3\text{-}6.5$
- J=10.18 mag, K_s=9.04 mag (2MASS), $(J\text{-}K_s)_0$=-0.21 mag (Martins & Plez 2006)
  => M_{K_s}=-6.25 mag
- O2-3 f*/WN5-6: BC_{K_s}=-(4.4÷5.2) mag (Crowther & Walborn 2011) => $\log(L/L_\odot)\simeq 6.2\text{-}6.5$

Observational test

- peculiar radial velocity of WR42e should be about six time smaller than that of J1117-6120
- J1117-6120: $v_{\rm hel} \simeq 21.4$ km s^{-1}

=> $v_{\rm rad} \simeq -4.8$ km s^{-1}

WR42e: $v_{\rm rad} \simeq 0$ km s^{-1}

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  => $v_{\rm rad} \simeq -4.8$ km s^{-1}

  WR42e: $v_{\rm rad} \simeq 0$ km s^{-1}

Radial velocity measurements for WR42e are of crucial importance for testing our proposal

Thank you!