# Multiwavelength observations of NaSt1 (WR 122) : Equatorial mass loss and X-rays from an interacting Wolf-Rayet binary

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## 【Abstract】


- NaSt1 (WR122)の研究.
- コンパクトなdusty coreを[NII] emission nebulaが取り囲んでいる. →eta Carinae like
- Optical～X-rayに渡る多波長観測.
  →空間分解イメージ、物理状態.
  →個体の素性を明らかにする.
  →大質量星の形成・進化.


## 【観測と結果】

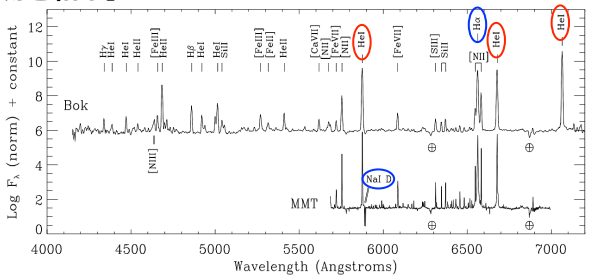


Figure 3. Optical spectra of NaSt1 from Bok (upper spectrum) and MMT (lower spectrum). The most prominent nebular features have been marked (see CS99 for a comprehensive list of all emission lines).

**Fig.3** ●可視分光
- ＊Bok 2.3m Kitt Peak (low reso.)
- ＊MMT 6.5m (mid reso.)
- ＊nebula + HII region.
- ＊NaI D → circumstellar absorption
- ＊Hα Lorentzian wing → ～2000km/s → scatter → high optical depth region

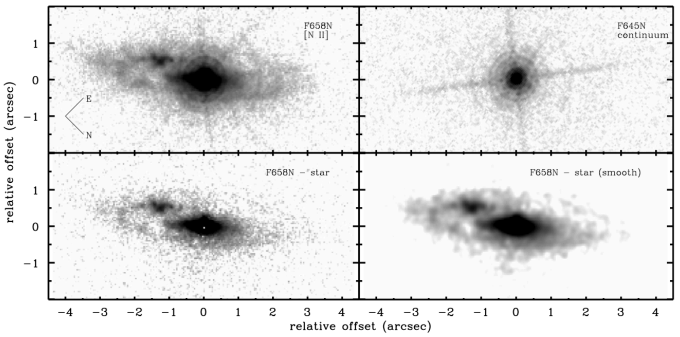


Figure 1. *HST*/WFC3 narrowband images of NaSt1 through F658N and F645N filters (logarithmic stretch), corresponding to the [N II] emission line and adjacent continuum, respectively (upper panels). The lower panels show the F658N image with the central point source removed, and a 3-pixel smoothed version.

**Fig.1** ●可視撮像
- ＊HST/WFC2
- ＊edge-onから12°傾いたdisk-likeな形.
- ＊clumpy ringに囲まれた回転楕円体.

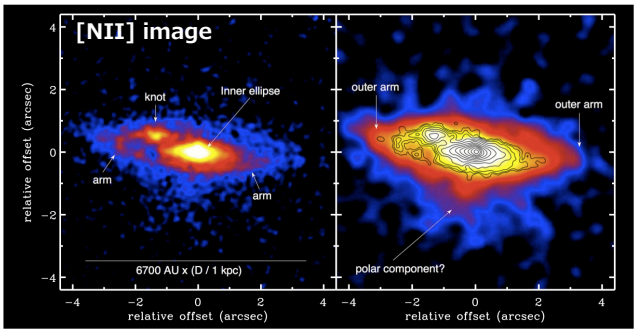


Figure 2. *Left*: star-subtracted 3-pixel smoothed F658N image of NaSt1 (logarithmic stretch), displayed in false color to enhance the nebular structure. *Right*: same as above with 9-pixel smooth and more extreme stretch to enhance the faint outer nebula. Flux contours of the brighter central regions from the 3-pixel smoothed image are overlaid for reference. The orientation of the images is the same as

**Fig.2** ＊幾何中心と輝度中心のずれ→one-armed spiral

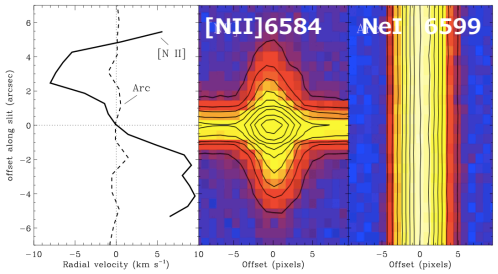


Figure 4. Radial velocity of the [N II] λ6584 profile (left panel, solid curve) as a function of position along the slit (middle pa was approximately aligned with the major axis of the nebula, and the same for an arc line of Ne I ≈ 6599 Å (right panel). Rea motion for the outer nebula of NaSt1 is apparent. Note that velocity measurements for offsets < 2″ are dominated by emissi central point source, and are not reliable.

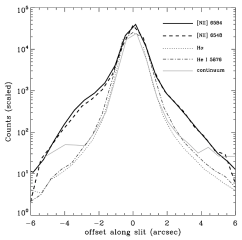


Figure 5. *Top*: spatial profile of selected emission lines along the spectrograph slit, which was tilted near the long axis of the nebula

**Fig.4** ●可視分光
- ＊slit ~ major axis
- ＊[NII]：軸の左右で±10km/sの速度差→回転運動
  →outflow gas
- ＊単なるディスクの膨張（リング形状）ではない.
- ＊Hα,HeIはそのような速度構造は見られない.

**Fig.5**
- ＊確かに[NII]のみ広がっている.

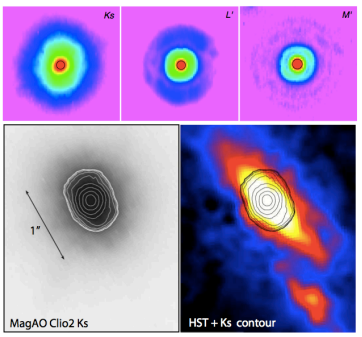


**Fig.6** ●赤外AO imaging w/ MagAO+Clio2
- ＊M′：unresolved (PSF~5.96pix~164mas)
- ＊L′：marginally resolved (FWHM=142mas)
- ＊Ks：ellipsoidal structure.
  (axis 171mas > FWHM=123mas)
  →700~2100AU.

**Fig. 7**
- ●赤外分光：VLT/SPIFFI, R~4000, 0.1″pix, 3.2″FOV
  - ＊HeI 2.06um profile → ±2500km/s (~ Hα)
- ◎extended Ks emission → HeI 2.06um

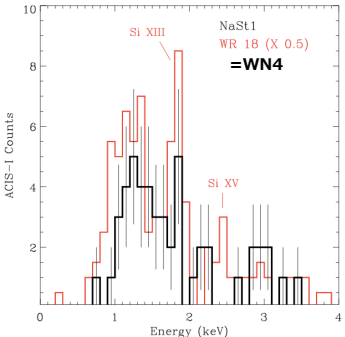


Table 1. Basic X-ray parameters for NaSt1

| Name | CXO J18521753+0059446 |
|---|---|
| $F_{\rm broad}$(0.5–7.0 keV) | $2.9^{3.7}_{2.2} \times 10^{-14}$ |
| $F_{\rm soft}$(0.5–1.2 keV) | $4.8^{8.3}_{2.5} \times 10^{-15}$ |
| $F_{\rm med}$(1.2–2.0 keV) | $1.1^{1.4}_{0.7} \times 10^{-14}$ |
| $F_{\rm hard}$(2.0–7.0 keV) | $1.3^{2.1}_{0.7} \times 10^{-14}$ |
| $HR_{med-soft}$ | $0.15 \pm 0.14$ |
| $HR_{hard-med}$ | $0.18 \pm 0.17$ |
| $\langle E \rangle$ | $1.8 \pm 0.3$ keV |
| $N_{\rm H}$ (ISM) | $1.2 \times 10^{22}$ cm$^2$ |
| $L_{\rm X}$ | $\sim 10^{32}$–$10^{33}$ erg s$^{-1}$ |
| $L_{\rm X}/L_{\rm bol}$ | $\sim 10^{-8}$–$10^{-5}$ |

**Fig.8 & Table.1**
- ●Chandra / ACIS
  - ＊SiXIII line → hot plasma (logTmax=7.0K)
  - ＊連星系におけるcolliding起因の超音速stellar windによるshock
  - ＊Av = 6.5mag → $N_H$ = 1.2 x $10^{22}$ cm$^2$

**Others (w/ open Q)**
- ＊hot dustの要因：最近WN→WCへ進化？
- ＊一時的なdust生成：eccentric orbitのせい？
- ＊NaSt1は結構earlyなWR星の可能性を支持.