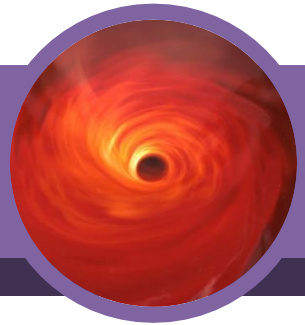


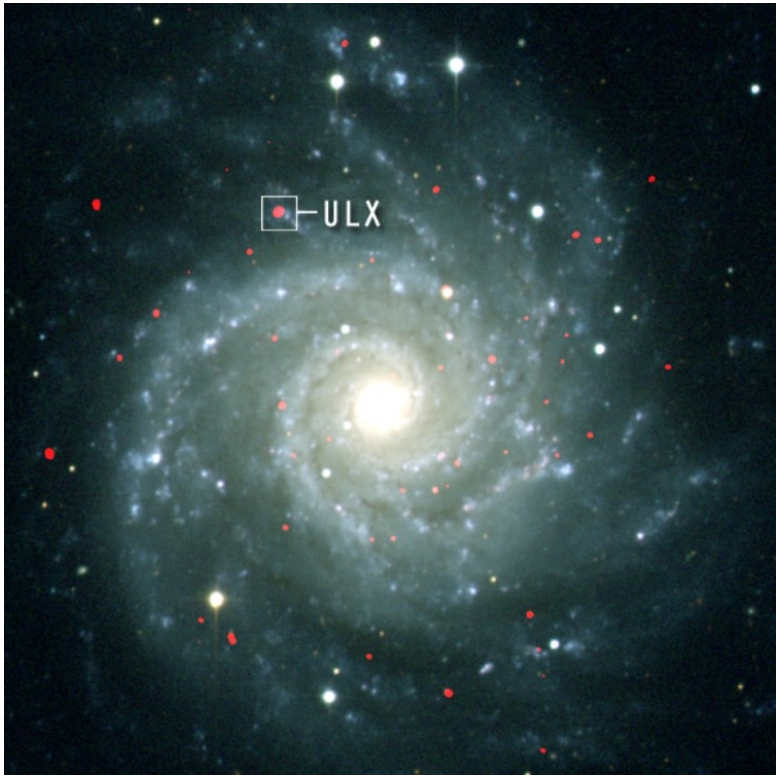
32nd Texas Symposium on Relativistic Astrophysics

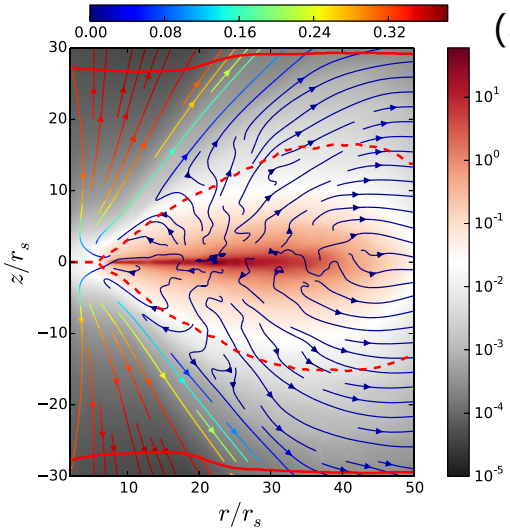
Supercritical Accretion onto Compact Objects and Massive Disk Winds

Hua Feng 冯 骅
hfeng@tsinghua.edu.cn

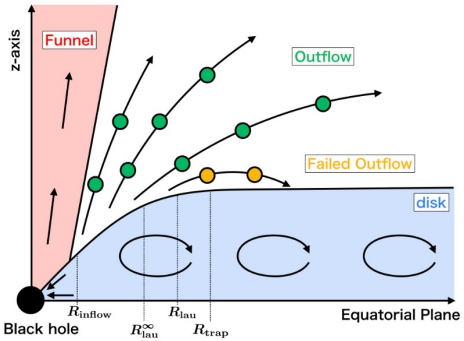
2023.12.13 • Shanghai

ULXs and supercritical accretion





(Jiang et al. 2014)



(Kitaki et al. 2021)

Supercritical accretion

Disk spherization and winds (Shakura & Sunyaev 1973)

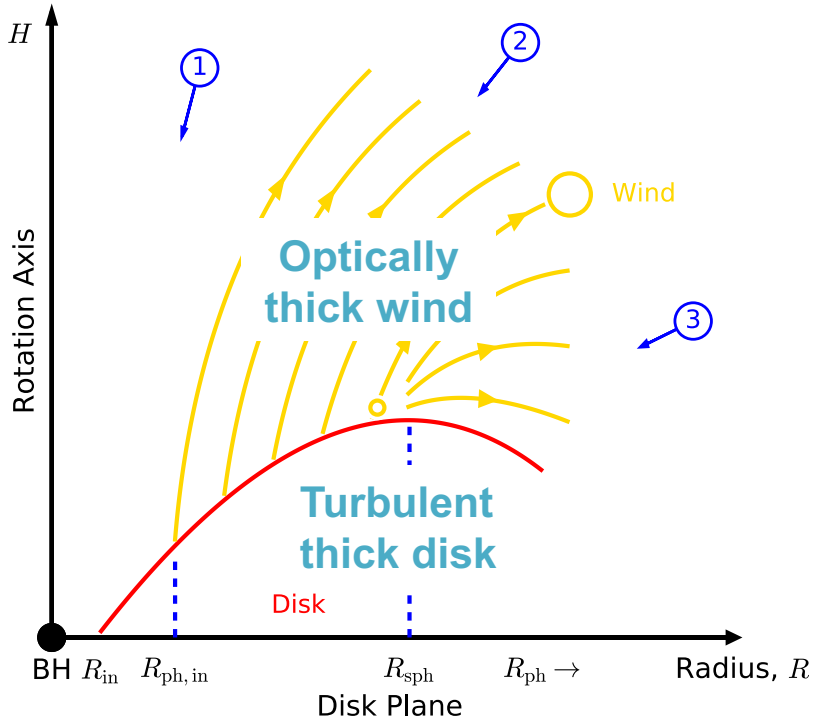
$$r_{\rm sp} \approx \frac{9}{4}\dot{m} \qquad (7.1)$$

Massive, optically thick winds

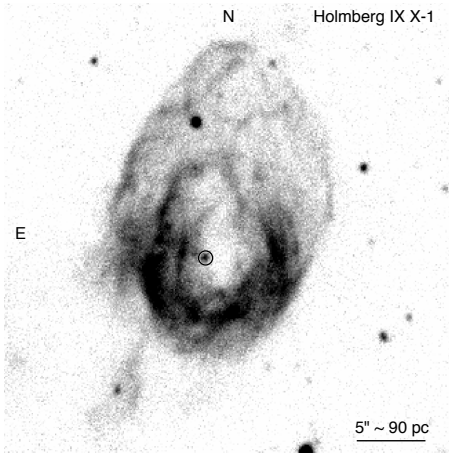
(King+2003, Poutanen+2007, Shen+2016)

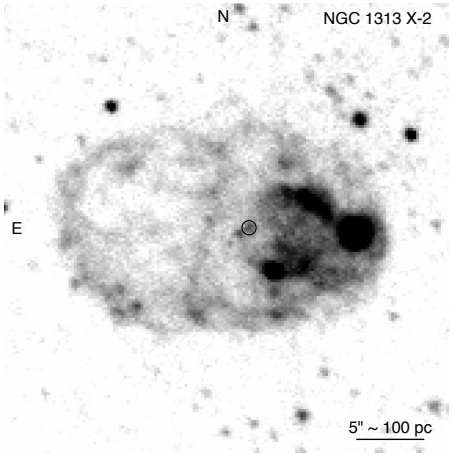
A standard picture

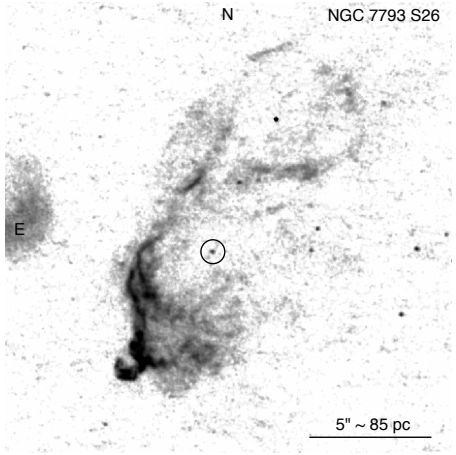
(Kaaret, Feng, Roberts 2017)

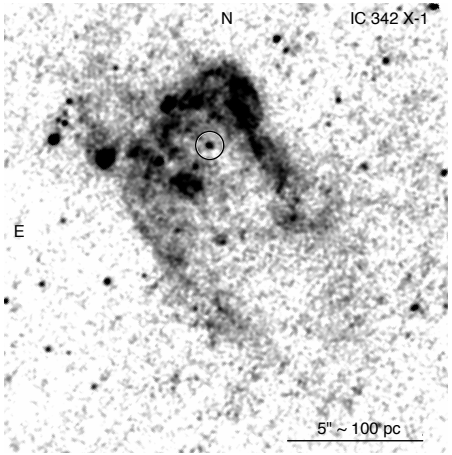


Wind interaction with environment









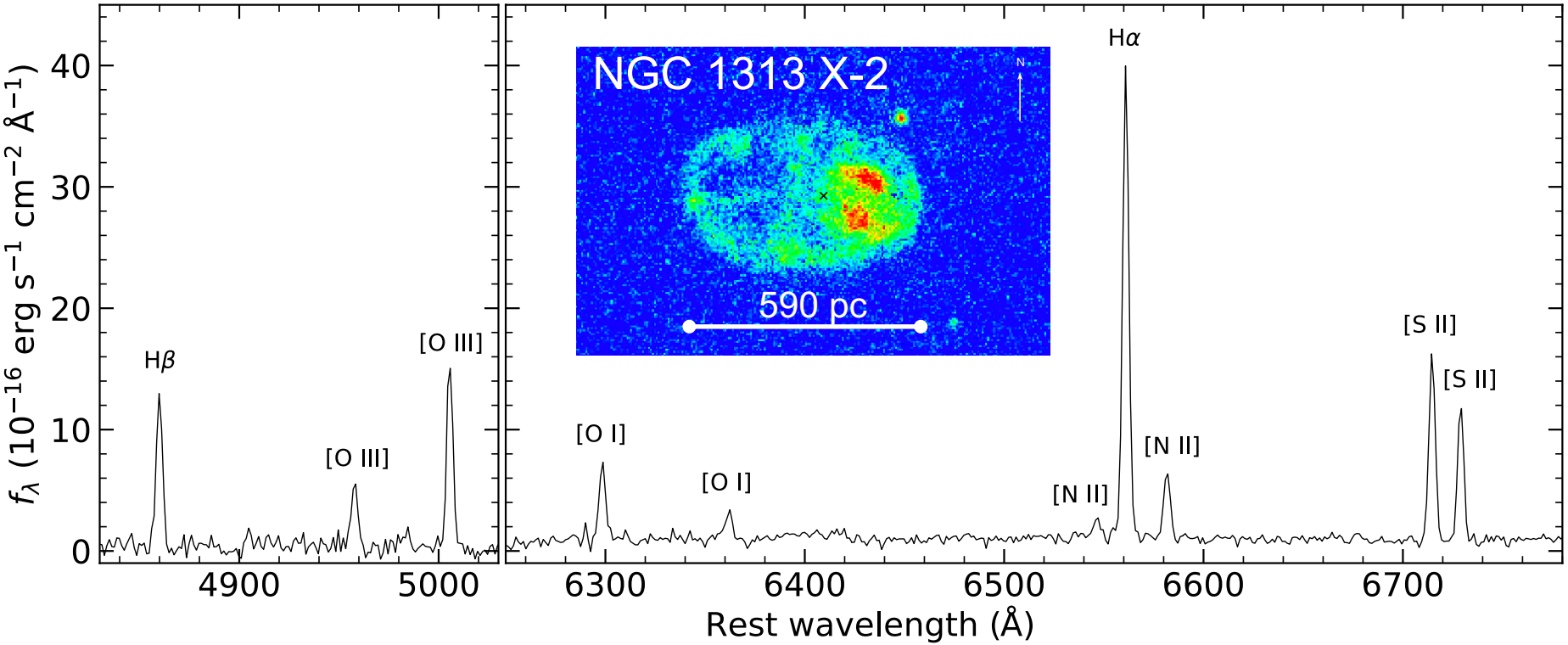
Shock-ionized bubble nebulae surrounding ULXs

(Pakull & Mirioni 2002, 2003; Pakull et al. 2006; Pakull & Grisé 2008; Ramsey et al. 2006; Abolmasov et al. 2007; Abolmasov & Moiseev 2008; Russell et al. 2011; Cseh et al. 2012; Urquhart et al. 2018; Soria et al. 2021; Gúrpide et al. 2022; Zhou et al. 2022; Guo et al. 2023).

Targets with VLT MUSE

NGC 1313 X-2	A canonical ULX with a typical bubble nebula (Zhou, Bian, Feng, et al. 2022, ApJ, 935, 38)
NGC 247 ULX-1	A supersoft/soft ULX (Zhou, Feng, Bian, 2023, ApJ, 947, 52)
NGC 55 ULX-1	A supersoft/soft ULX (Zhou, Feng, Bian 2023, ApJ, 955, 61)

A typical bubble nebula



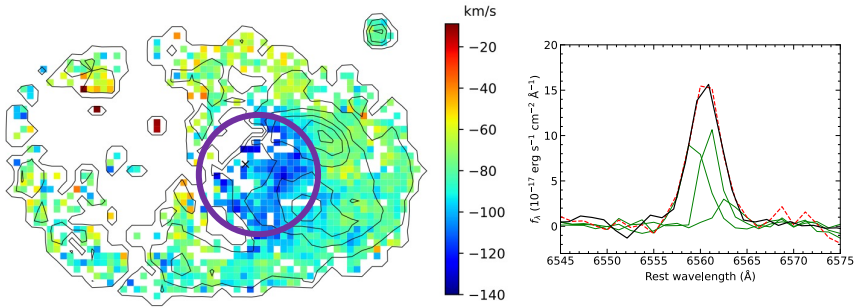
Ultraluminous mechanical output

- Comparison with MAPPINGS V simulations

Table 3
Observed and Simulated Line Flux Ratios

Line Flux Ratio	Observed	Model A	Model B
[O III] λ5007/Hβ	1.269 ± 0.079	0.004	1.092
[O I] λ6300/Hα	0.171 ± 0.005	0.018	0.201
Hα/Hβ	2.868 ± 0.138[a]	3.395	2.955
[N II] λ6583/Hα	0.154 ± 0.004	0.071	0.378
[S II] λ6716/Hα	0.400 ± 0.009	0.106	0.418

- An additional photoionization component



$$R_{\rm B} \approx 0.76\, t^{\frac{3}{5}} \left(\frac{P}{\rho_0}\right)^{\frac{1}{5}},$$

$$t = \frac{3R_{\rm B}}{5v_{\rm s}},$$

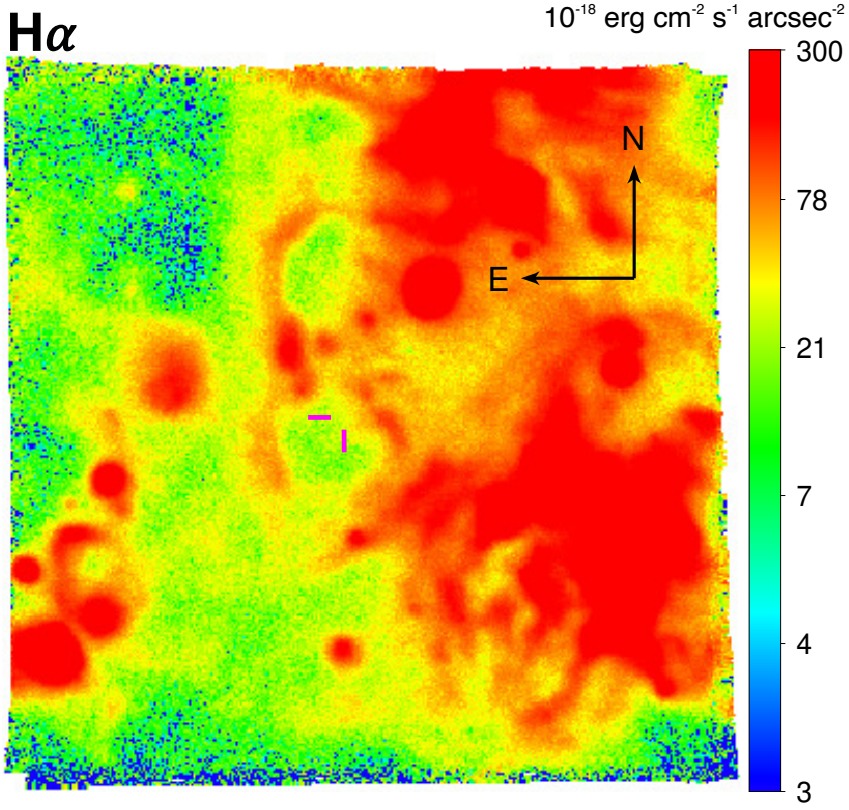
$$v_{\rm s} \approx 0.38 \left(\frac{P}{R_{\rm B}^2 \rho_0}\right)^{\frac{1}{3}},$$

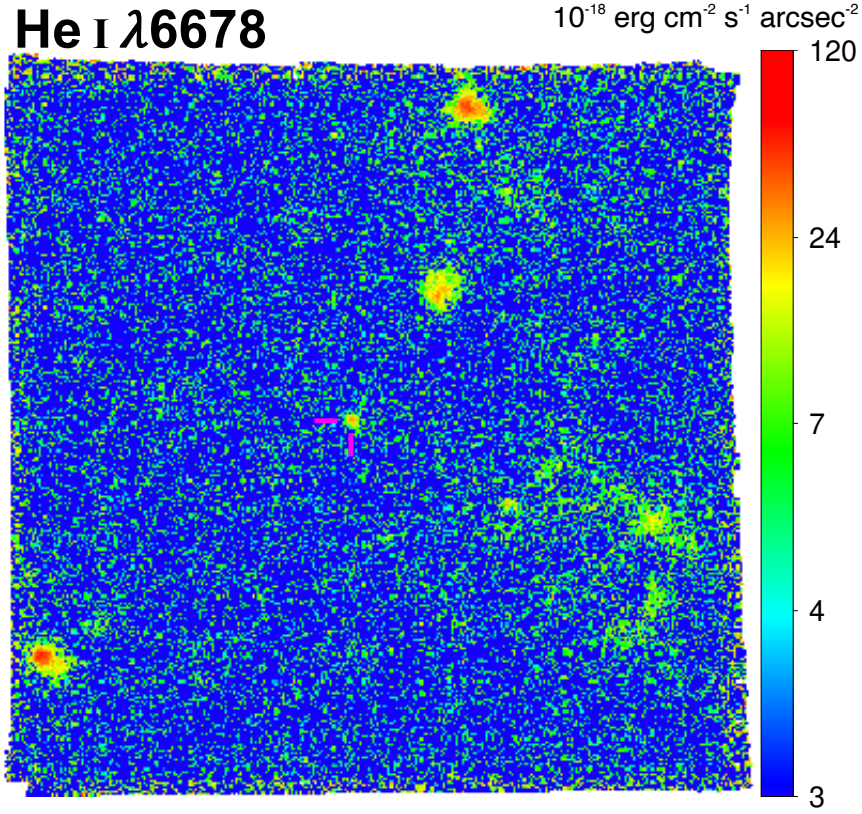
$$t \approx 2.1\ {\rm Myr},$$

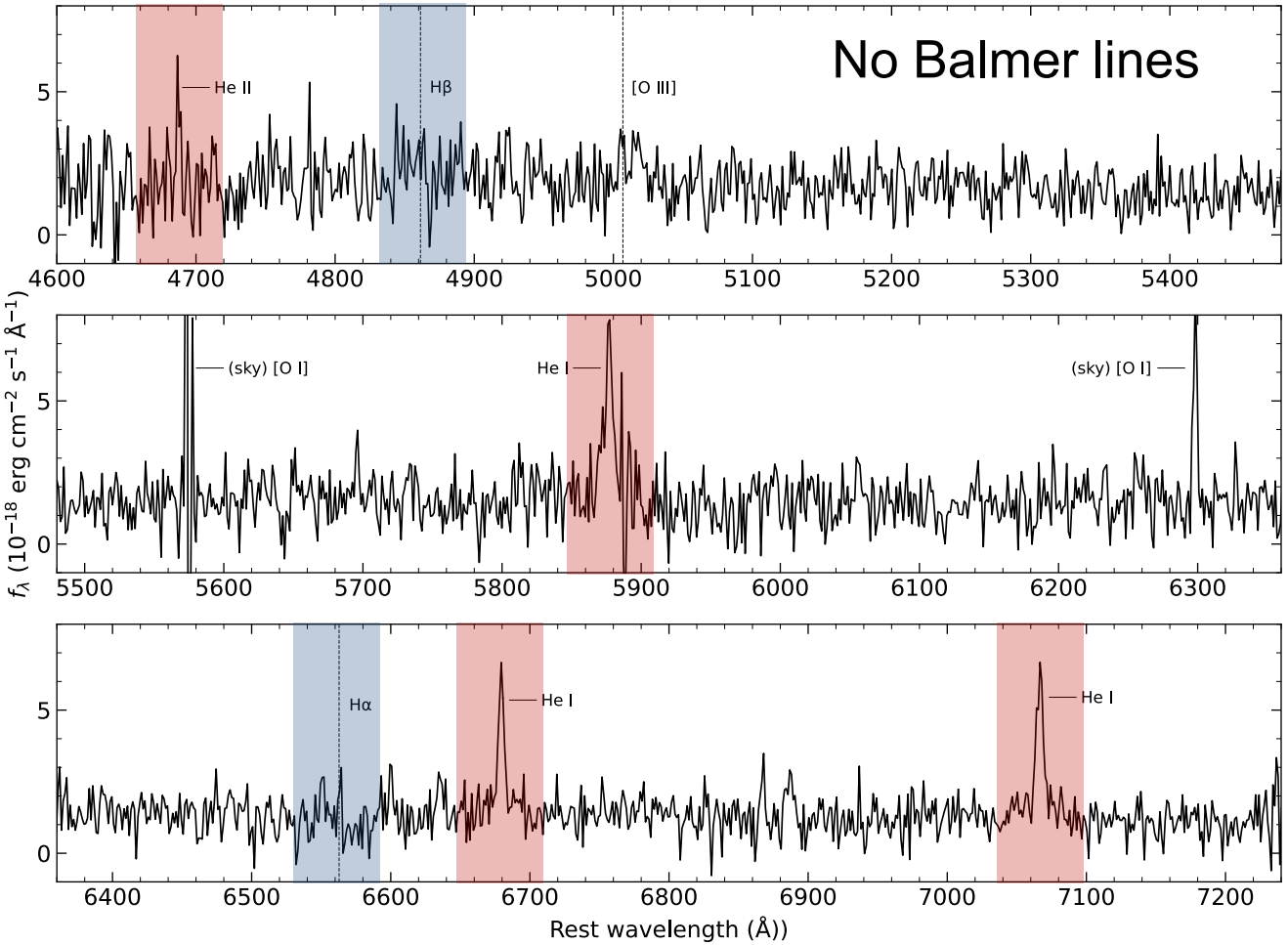
$$P = (6.5 \pm 0.3) \times 10^{39}\ {\rm erg\ s^{-1}}.$$

$$L_{\rm X} = 10^{39} - 10^{40}\ {\rm erg\ s^{-1}}$$

Optical counterpart of NGC 247 ULX-1







Donor:
A helium star

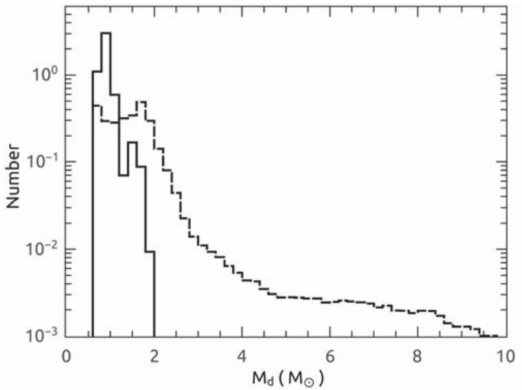
First identification of a helium donor star

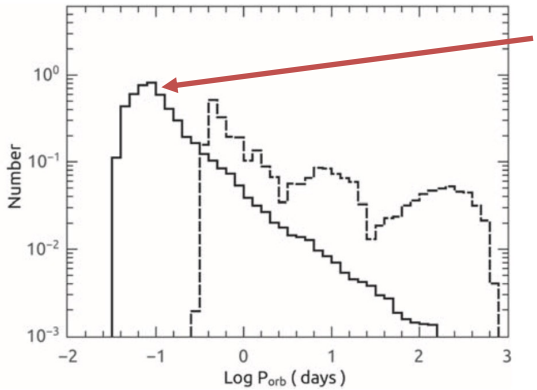
The Astrophysical Journal, 886:118 (8pp), 2019 December 1 https://doi.org/10.3847/1538-4357/ab4d50
© 2019. The American Astronomical Society. All rights reserved.

CrossMark

A Population of Neutron Star Ultraluminous X-Ray Sources with a Helium Star Companion

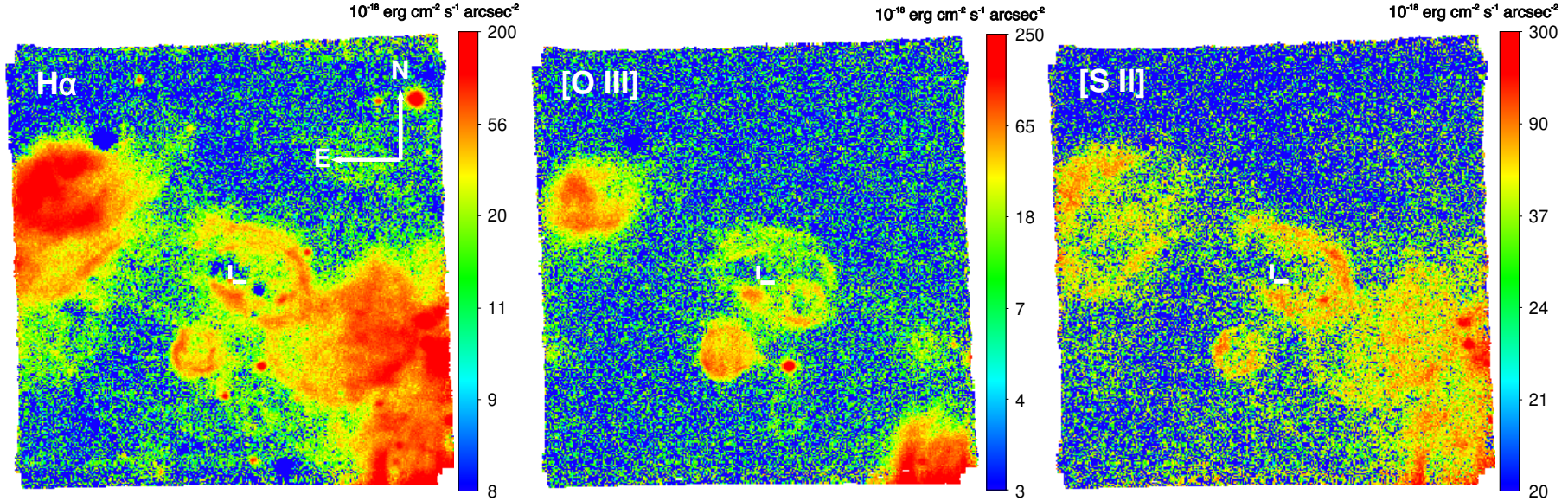
Yong Shao[1,2], Xiang-Dong Li[1,2], and Zi-Gao Dai[1,2]
[1] Department of Astronomy, Nanjing University, Nanjing 210046, People's Republic of China; shaoyong@nju.edu.cn
[2] Key Laboratory of Modern Astronomy and Astrophysics (Nanjing University), Ministry of Education, Nanjing 210046, People's Republic of China
lixd@nju.edu.cn
Received 2019 August 9; revised 2019 October 11; accepted 2019 October 11; published 2019 November 27





NS ULX with a helium donor

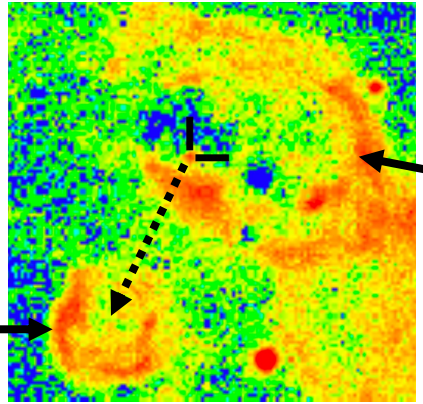
Multiple bubbles around NGC 55 ULX-1



Winds vs. jets?

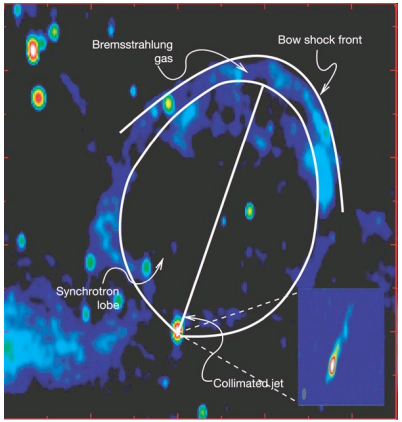
A hidden jet?

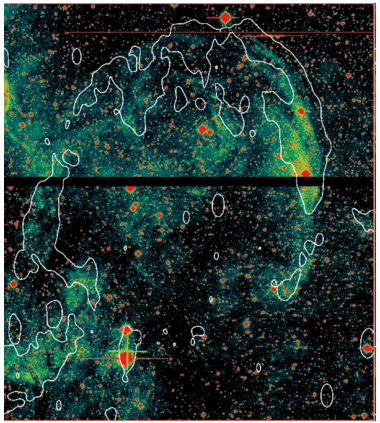
$P = 3 \times 10^{38}$ erg s^{-1}



$P = 10^{39}$ erg s^{-1}

Cygnus X-1



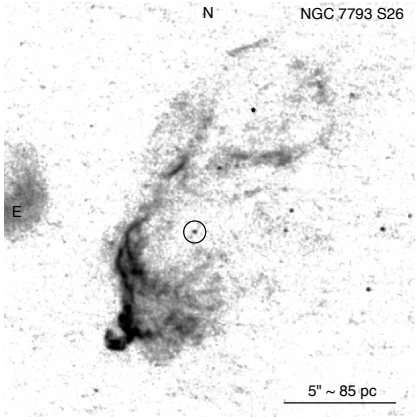


$10^{36} – 10^{37}$ erg s^{-1}

SS433/W50

$\sim 10^{39}$ erg s^{-1}

NGC 7793 S26



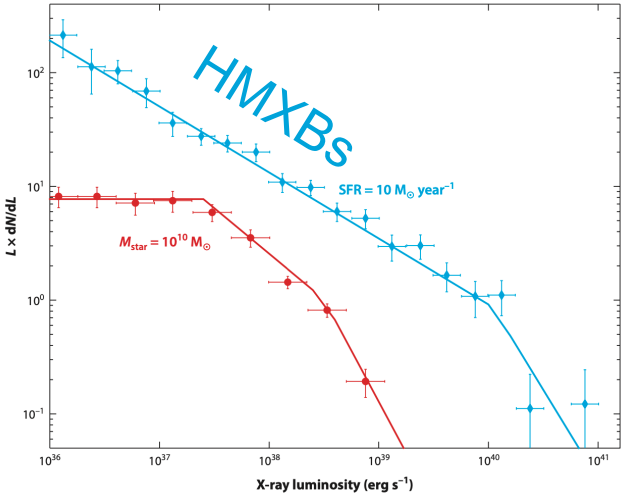
$\sim 10^{40}$ erg s^{-1}

Questions regarding supercritical accretion

- Accretion & outflow: distribution of accretion power
- History of binary evolution: how to maintain the high accretion rate in a binary
- Feedback into ISM: photoionization & shock-ionization, winds vs. jets

Discussion

- **XRB Feedback**
  - **Reionization epoch**
    - Heating source
    - Lyman escape
  - **Galaxy evolution?**
    - Mechanical output 10^{40} erg s^{-1}, 10^{7} yr → **$10^{53} \sim 10^{54}$ erg** in total
    - vs. supernova & stellar wind
  - Supercritical accretion + binary population synthesis + wind/radiative feedback



THANK YOU!