NGC 300 ULX-1: A Pulsar/Ultraluminous X-ray Source

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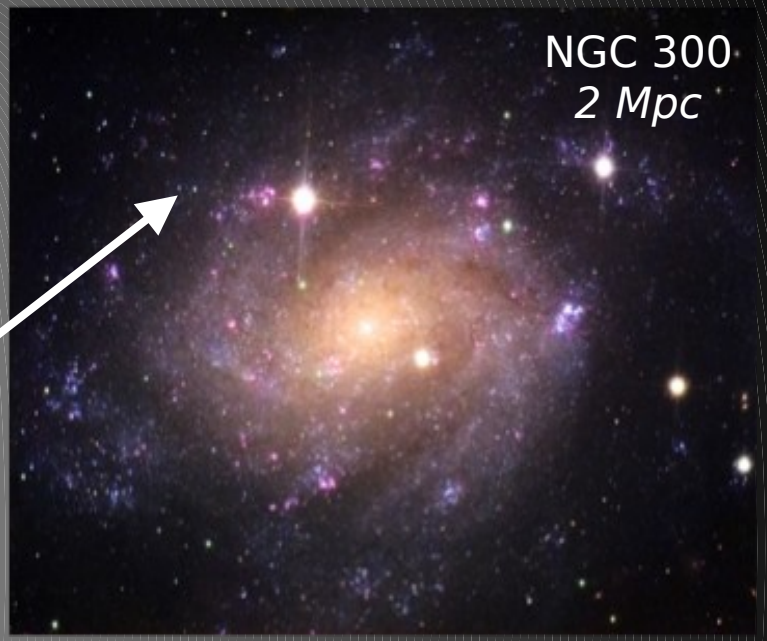
Initial Discovery

May 24, 2010
Berto Monard



A bit later: SN “impostor”

Elias-Rosa+, Immler+., Chornock & Berger, Berger & Chornock, Khan+, Brown, Bond, Laskar+, Chomiuk & Soderberg, Prieto+

What *is* SN 2010da?

Challenging the LBV-eruption interpretation:

- *Swift*, during eruption: >10^{38} erg/s *Immler et al. ATel #2639*
- *Chandra*, 4 months later: ~10^{37} erg/s *Binder et al. (2011)*

 high mass X-ray binary

Trio of papers in 2016:

- Lau et al. & Villar et al.: red/yellow supergiant donor; dust actively re-forming near binary
  - *using O/IR SED modeling, spectroscopy, light curve analysis*
- Binder et al.: *Chandra* + *Hubble* study, found recurring X-ray outbursts, <5 Myr old

Transition to ULX

Pulsar primary confirmed by *XMM-Newton*, *NuSTAR*, *Swift*

- ~31 s pulse period (Carpano et al. 2018), potential cyclotron resonant scattering feature (Walton et al. 2018)
- rapid spin-up rate: $-(1\text{-}5 \times 10^{-7}\ s^{-1})$, fastest ever observed

ATels from Carpano et al. (11158), Grebenev et al. (11174, 11228), Vasilopoulos et al. (11179), Kennea (11229), Bachetti et al. (11282)

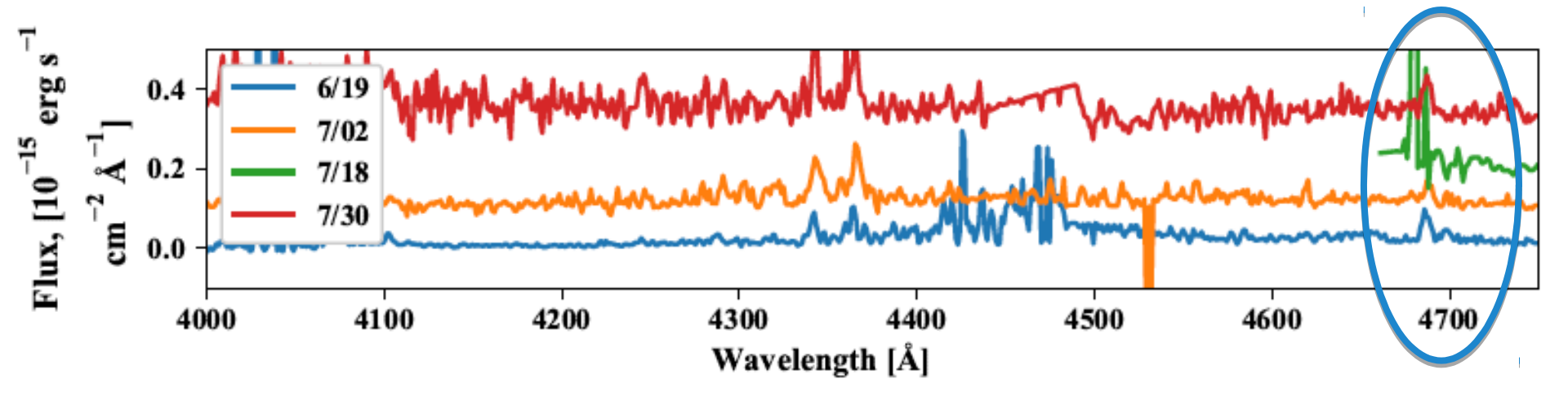
Simultaneously: increase in L_X to $\sim(2\text{-}6) \times 10^{39}$ erg/s

Carpano et al. (2018), Binder et al. (2018)

Beaming?

Is NGC 300 ULX-1 a bona fide, ultraluminous pulsar, or are we seeing the effects of geometric beaming?

He II λ4686



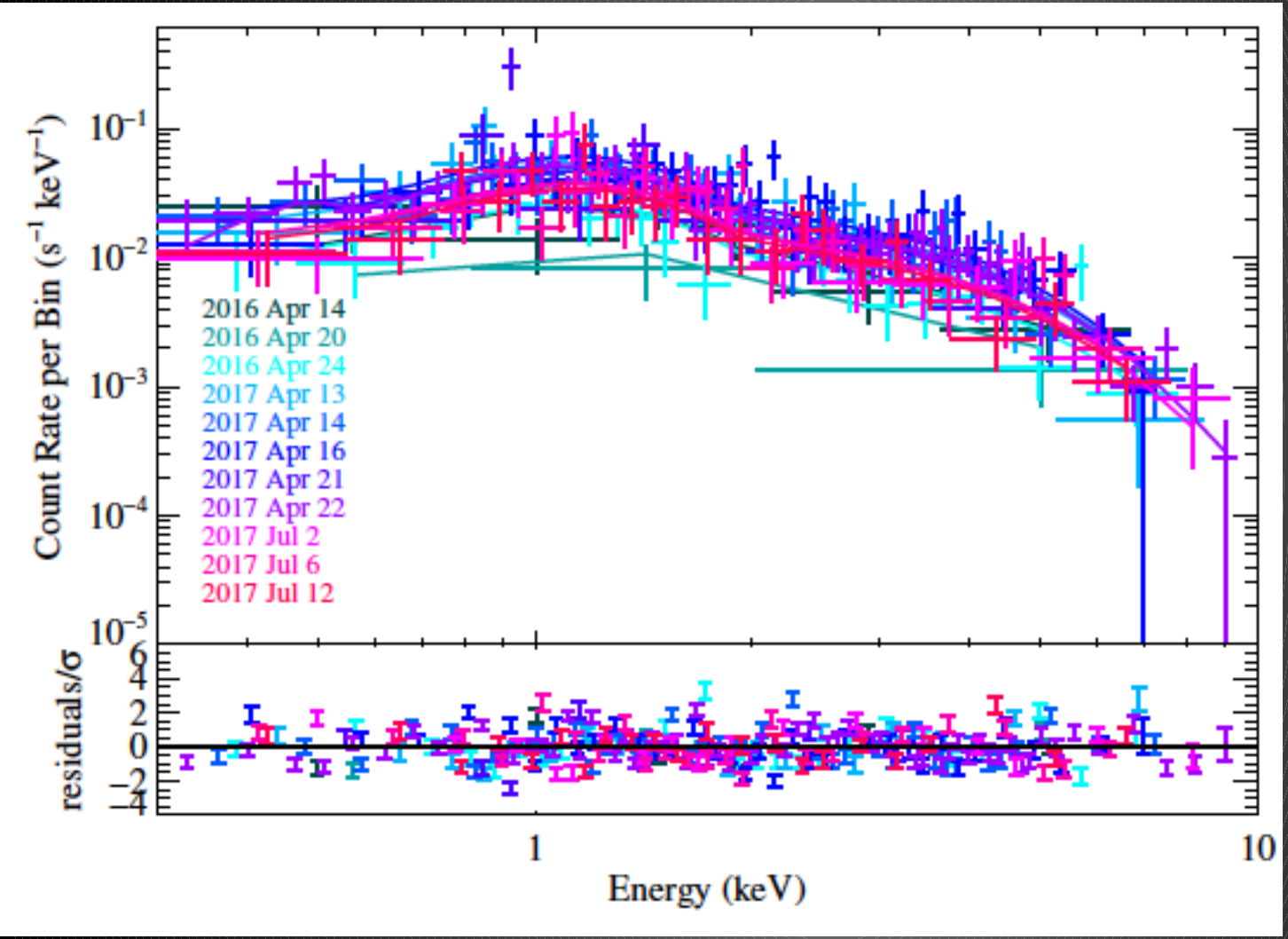
Gemini South

sensitive to 54-200 eV photons

Beaming?

Q' *absorbed* He^+ Lyman continuum photon rate	measured from	L_{4686} line luminosity
Q *emitted* He^+ Lyman continuum photon rate	measured from	*X-ray spectrum*

Beaming?



only the covering fraction was allowed to vary: 0-78%!

L_X ~ 2-6 x 10^{39} erg/s

extrapolated unabsorbed soft emission to 54-200 eV

`tbabs*pcfabs*(diskbb+nthcomp)` in XSPEC

Beaming? Probably Not

On 2017 July 2:

Q' $(1.1 \pm 0.3) \times 10^{48}$ ph s^{-1} *Gemini*

Q $(6.8 \pm 2.8) \times 10^{47}$ ph s^{-1} *Swift*

 no evidence for significant geometric beaming!

What's Next?

SN 2010da NGC 300 ULX-1

- understanding rapid spin-up rate
- optical spectroscopy to infer geometry
- how is dust re-forming?
- better understanding of ULX evolution

Thank you!

“Supercritical” Accretion

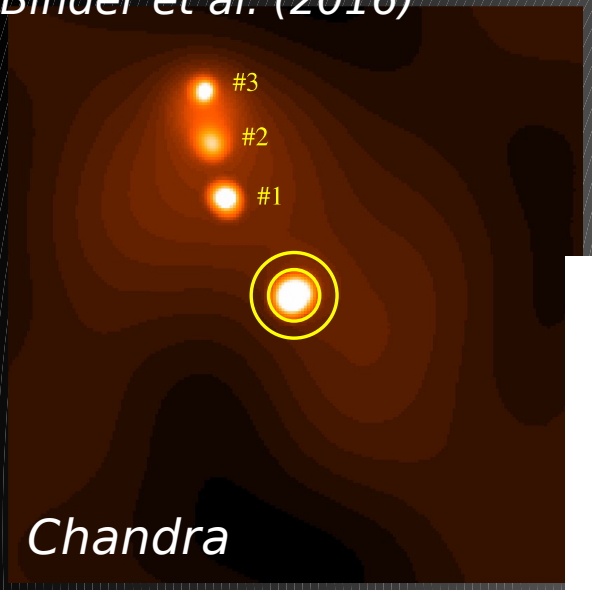
Using model of “supercritical” accretion in ULXs:
Sutton et al. (2013), Middleton et al. (2015)

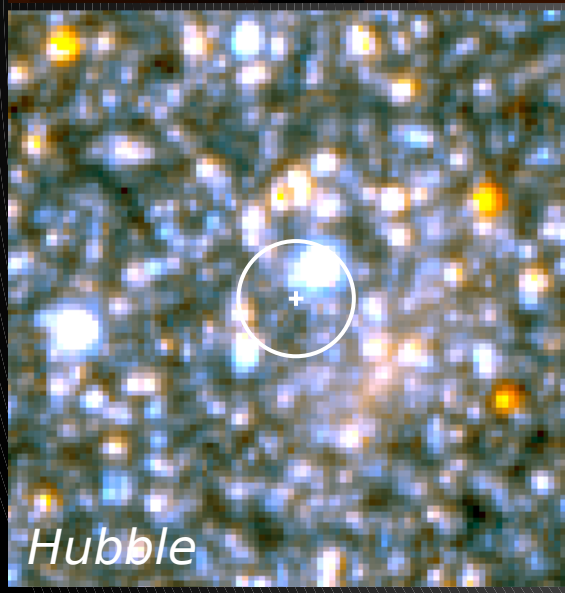
- changes in partial covering fraction: optically thick, clumpy wind that obscures central ionizing source
- high covering fraction increased inhomogeneity in winds; potential increase in mass accretion rate
- >90% of unabsorbed flux originates in soft wind component (vs. harder inner disk)

Additional evidence for a clumpy wind: Kosec et al. (2018) using *XMM-Newton*

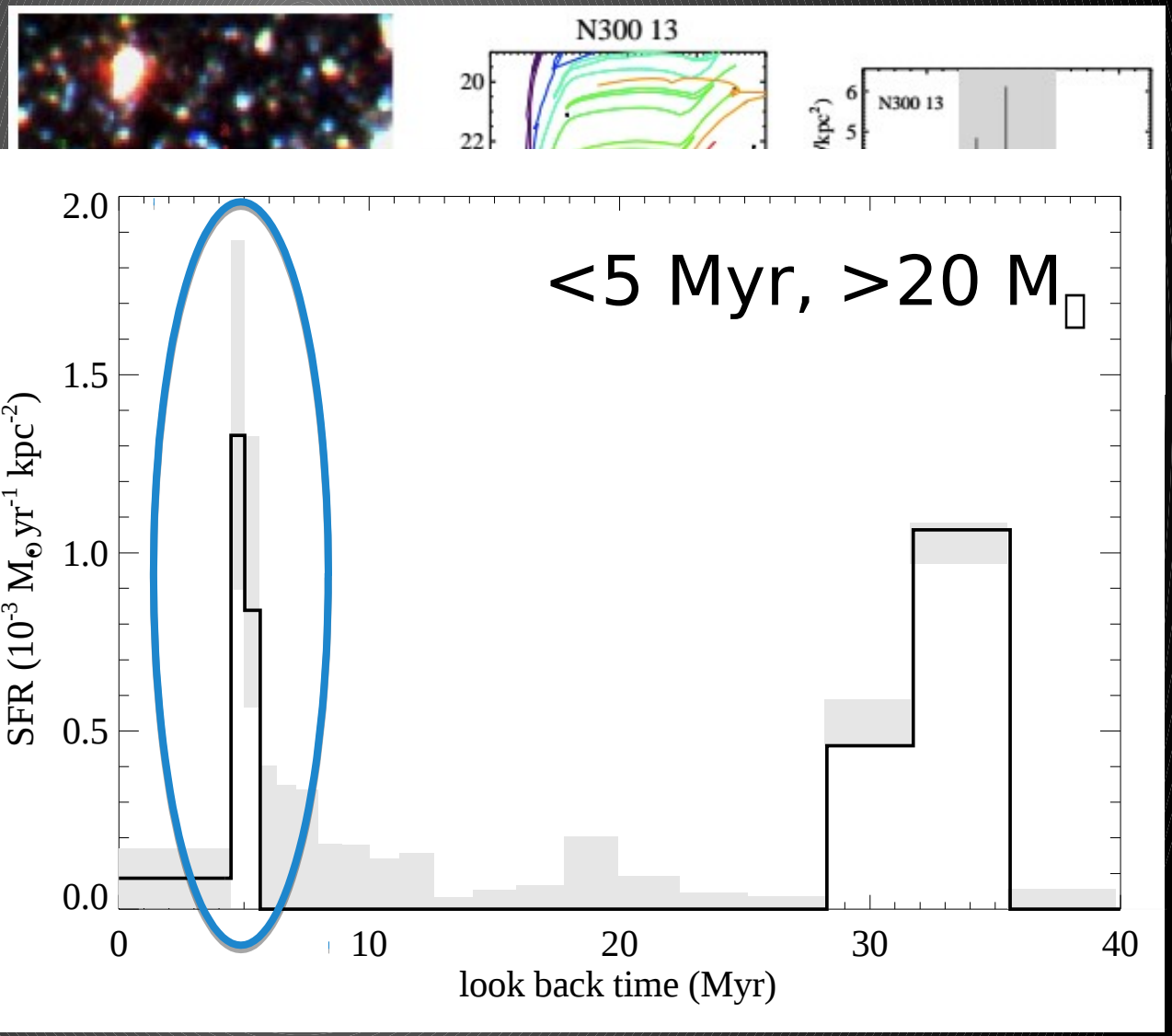
What *is* SN 2010da?

Binder et al. (2016)





Example: the age of another HMXB in NGC 300

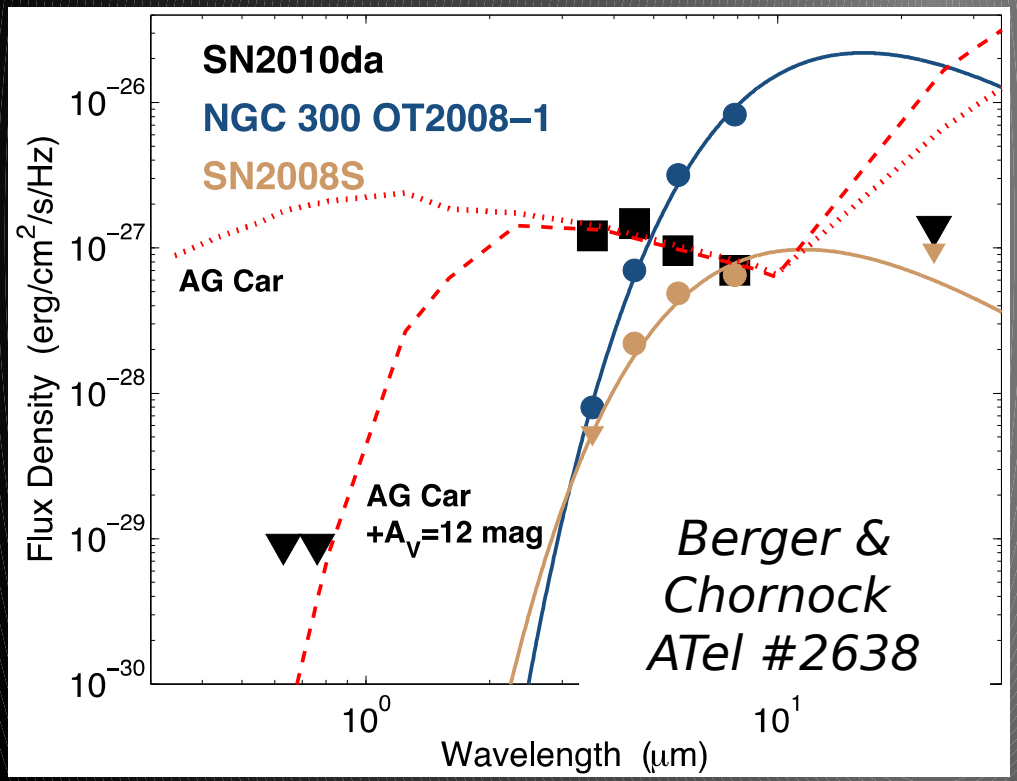


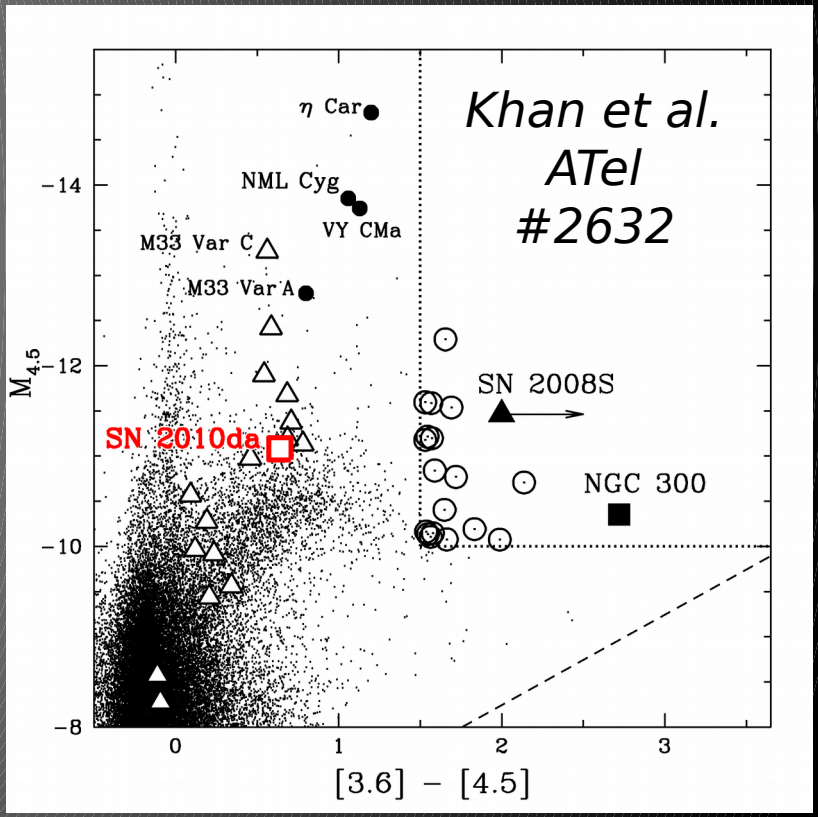
Initial Discovery

No optical progenitor detected in Magellan/Megacam images; IR progenitor found in *Spitzer*

LBV eruption?

Dusty cocoon largely destroyed





Summary

SN 2010da NGC 300 ULX-1

- *Chandra* (2011) led us to speculate a NS-HMXB origin for X-ray emission
- *Chandra* + *Hubble* (2016) constrained age to <5 Myr
- *XMM-Newton* + *NuSTAR* (2017-2018) confirmed pulsar
- with *Swift* (2016-2018), transition to ULX + evidence for clumpy winds
- X-ray + He II λ4686 emission line: no evidence for beaming – bona fide ultraluminous pulsar!