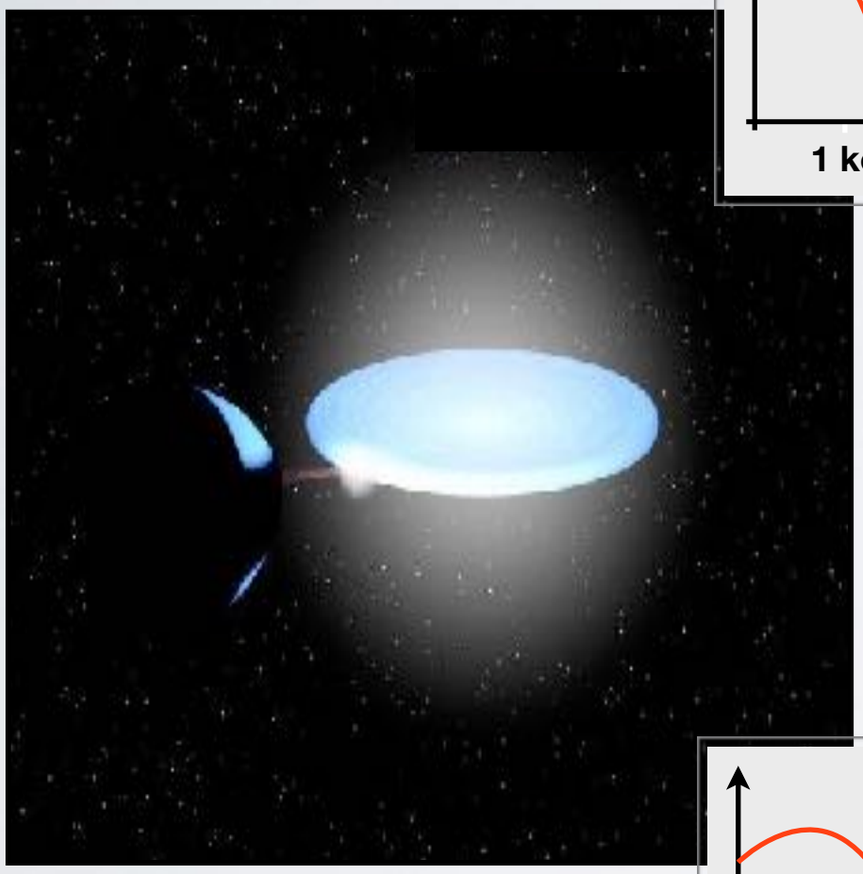
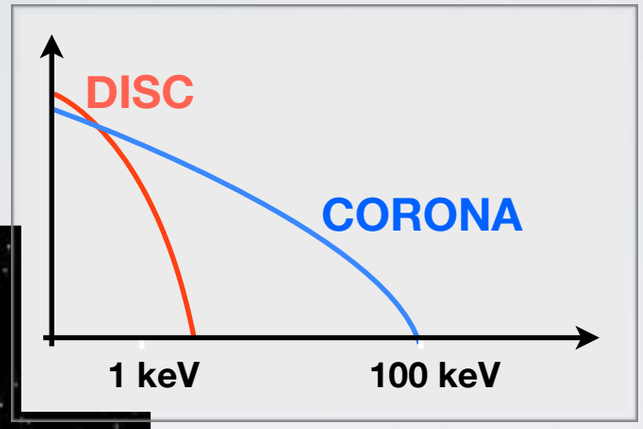
Optical Winds from accreting stellar-mass BLACK HOLES

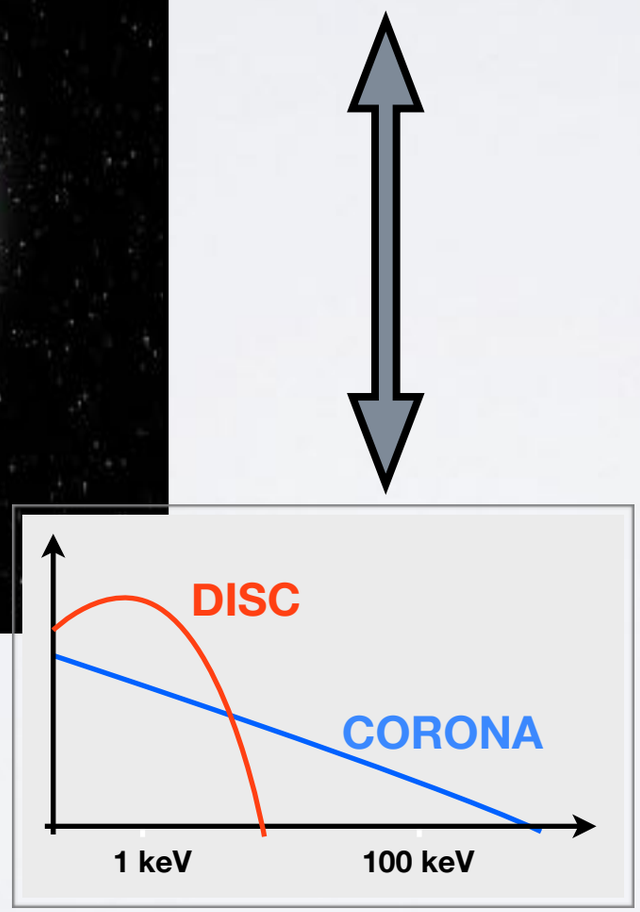
Teo Muñoz Darias

Ramón y Cajal Fellow @ IAC

DISTINCTIVE **ACCRETION/OUTFLOW** PROPERTIES

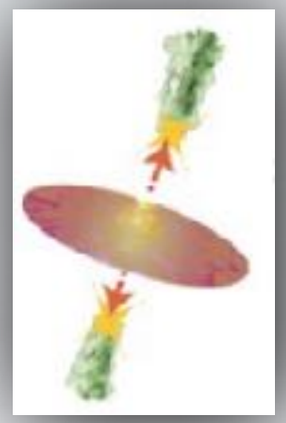






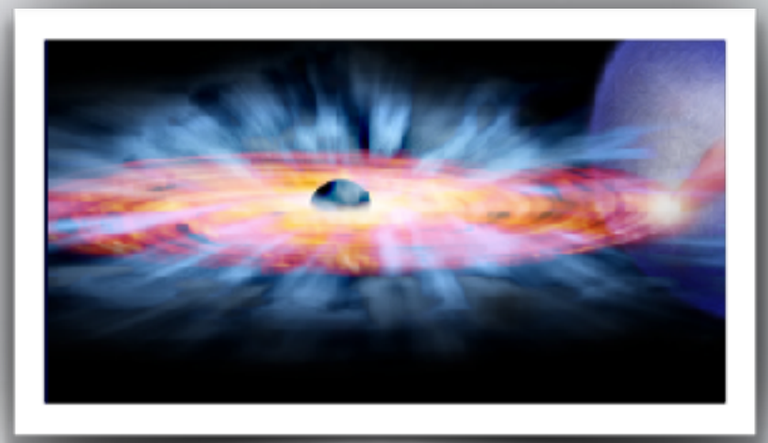
(Hard state) Radio Jets

Fender+, Corbel+, Gallo+



(Soft state) X-ray Winds

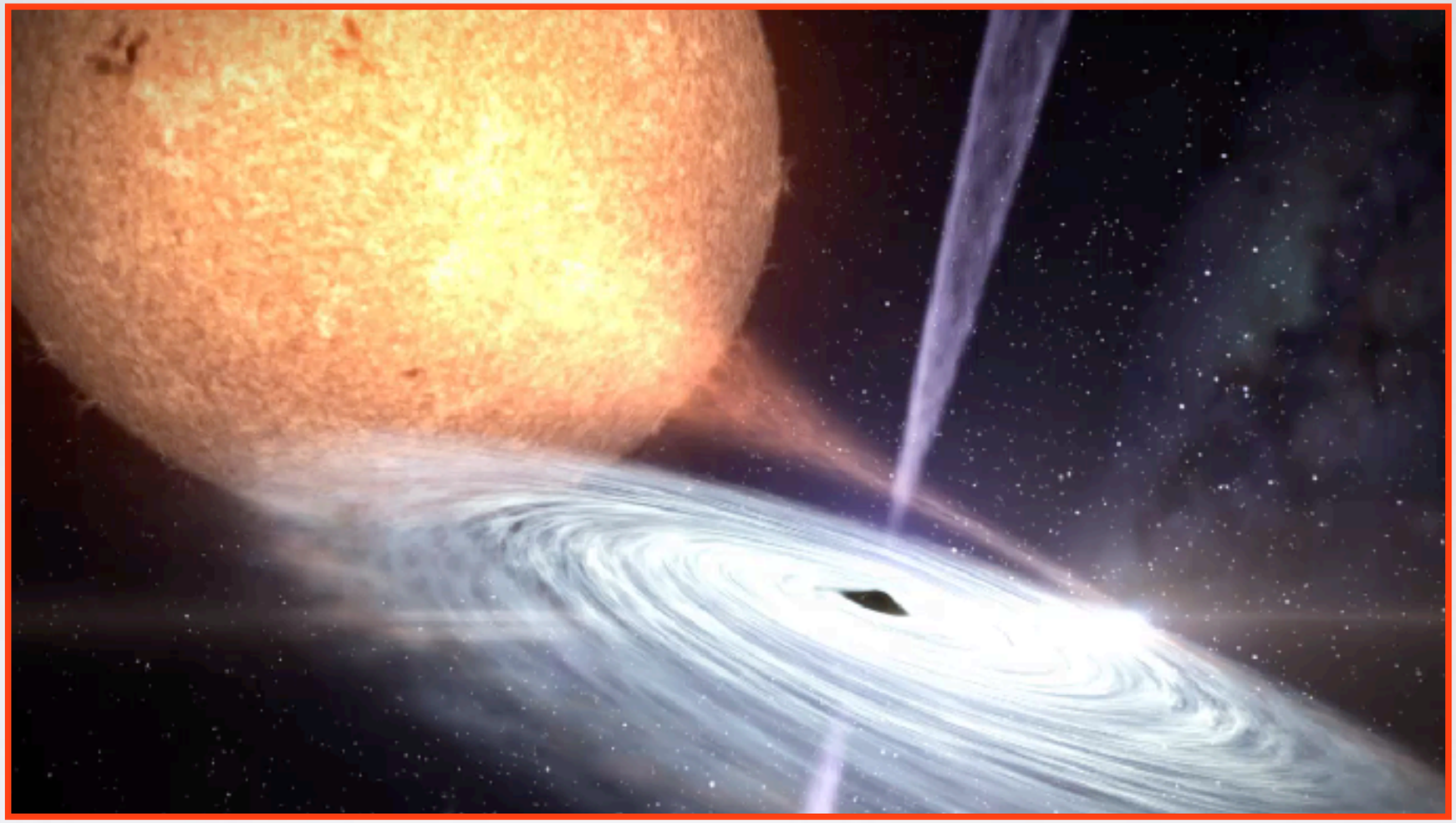
Neilsen+, Miller+, Ponti+, Díaz Trigo+,



Accretion/outflow processes

Fender & Muñoz-Darias 2016 for a review

V404 Cygni: a nearby and powerful BH transient



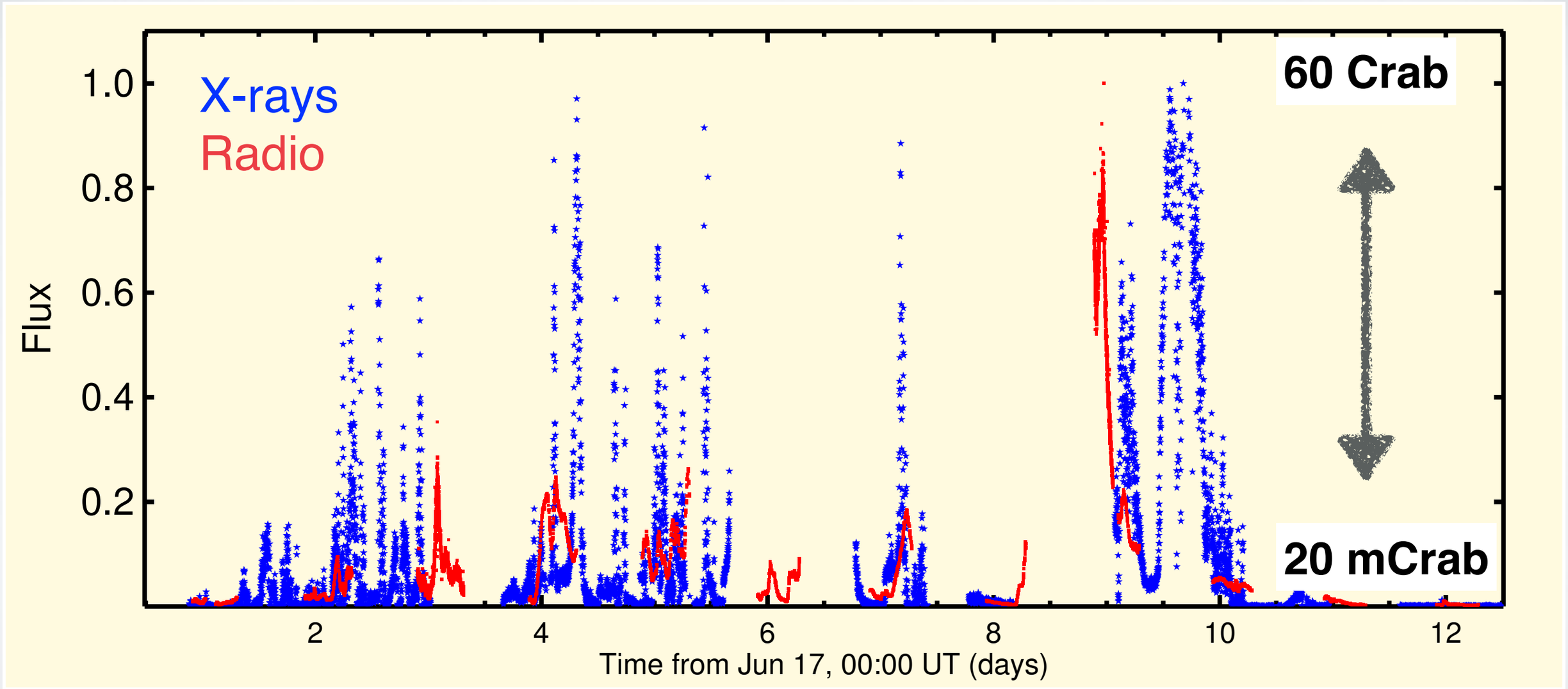
V404 Cyg is a ~10 $M_\odot$ is black-Hole in a 6.5 day orbital period at 2.4 kpc

(Casares, Charles & Naylor 1992, Nature; Miller-Jones et al. 2009)

★Very large accretion disc with R_{out} ~ 30 light seconds (9 x 10^6 km)

★In quiescence since 1989….back in outburst in June 2015

V404 Cygni: 2015 Outburst



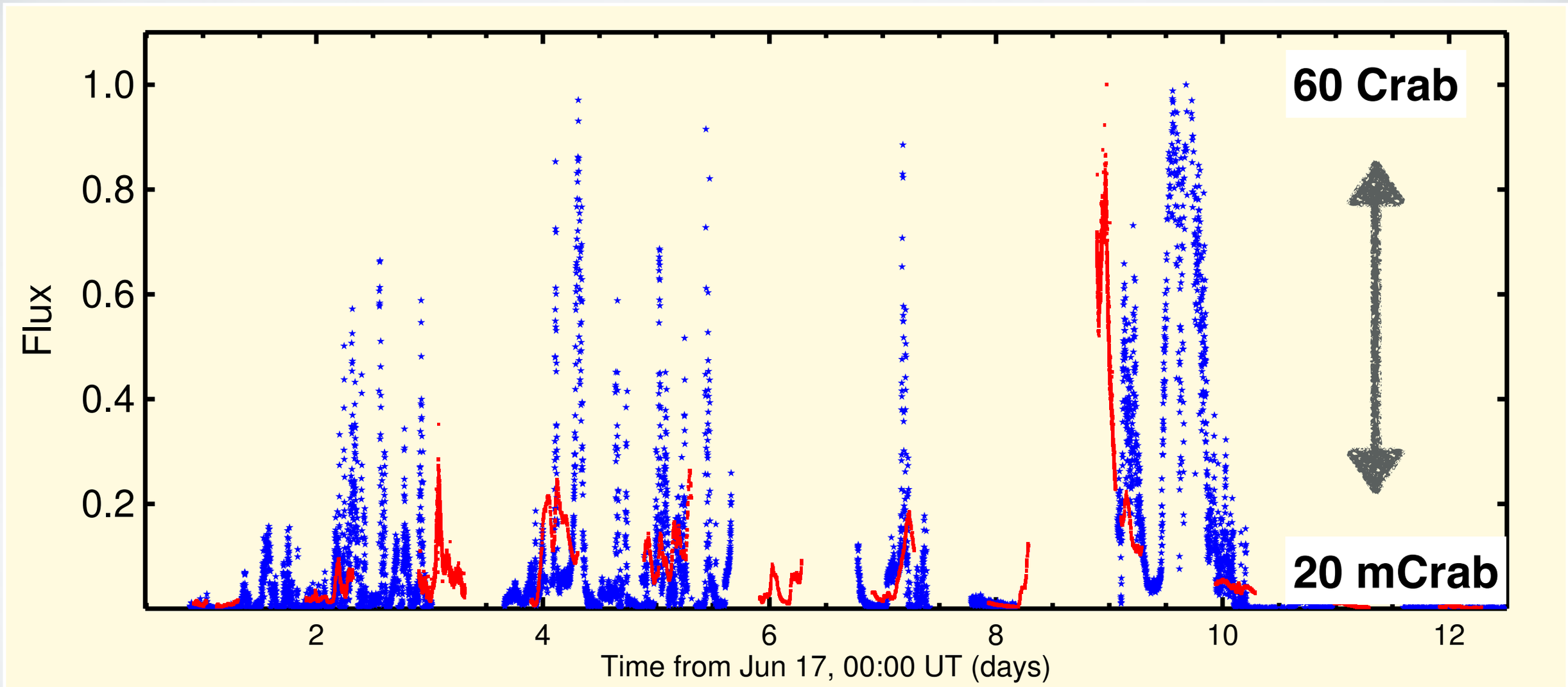
X-rays (20-200 keV): Superb INTEGRAL coverage

Rodriguez et al. 2015; Roques et al. 2015; Muñoz-Darias et al. 2016; Motta et al. 2017

Radio (16 GHz): AMI (Cambridge, UK)

Muñoz-Darias et al. 2016; Motta et al. 2017; Fender et al. in prep.

V404 Cygni: 2015 Outburst



10 + 5 days

BUT VERY SHORT…

Optical Accretion disc wind from V404 Cyg

GTC 10.4m telescope

LETTER

doi:10.1038/nature17446

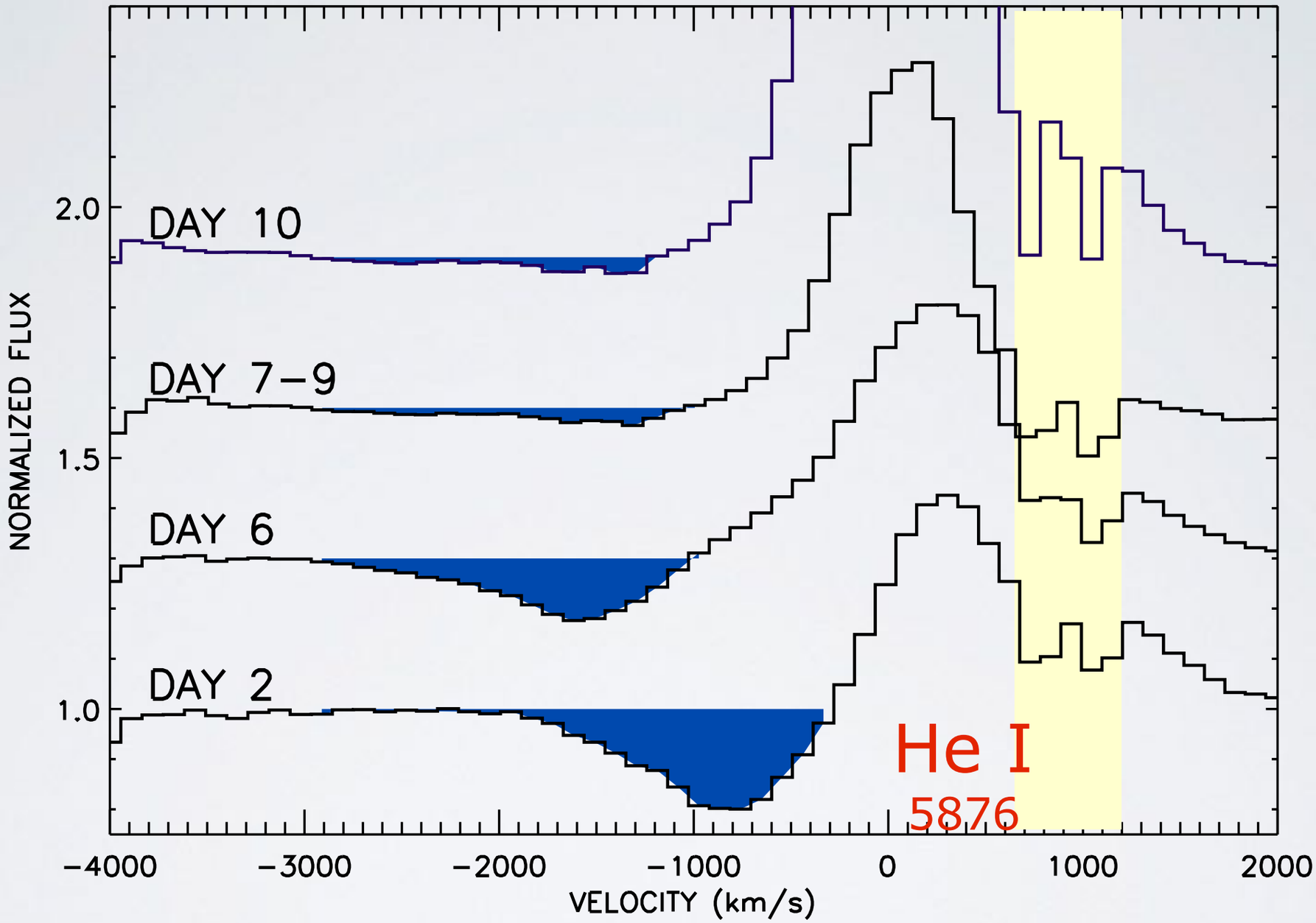
Regulation of black–hole accretion by a disk wind during a violent outburst of V404 Cygni

T. Muñoz-Darias[1,2], J. Casares[1,2,3], D. Mata Sánchez[1,2], R. P. Fender[3], M. Armas Padilla[1,2,4], M. Linares[1,2,5], G. Ponti[6], P. A. Charles[3,7], K. P. Mooley[3] & J. Rodriguez[8]

15 hrs of **ToO + DTT** with **GTC+OSIRIS**
covered the outburst with **550 spectra**
high S/N , high time resolution

P-Cyg Profiles in 12 emission lines

Muñoz-Darias et al. 2016, Nature

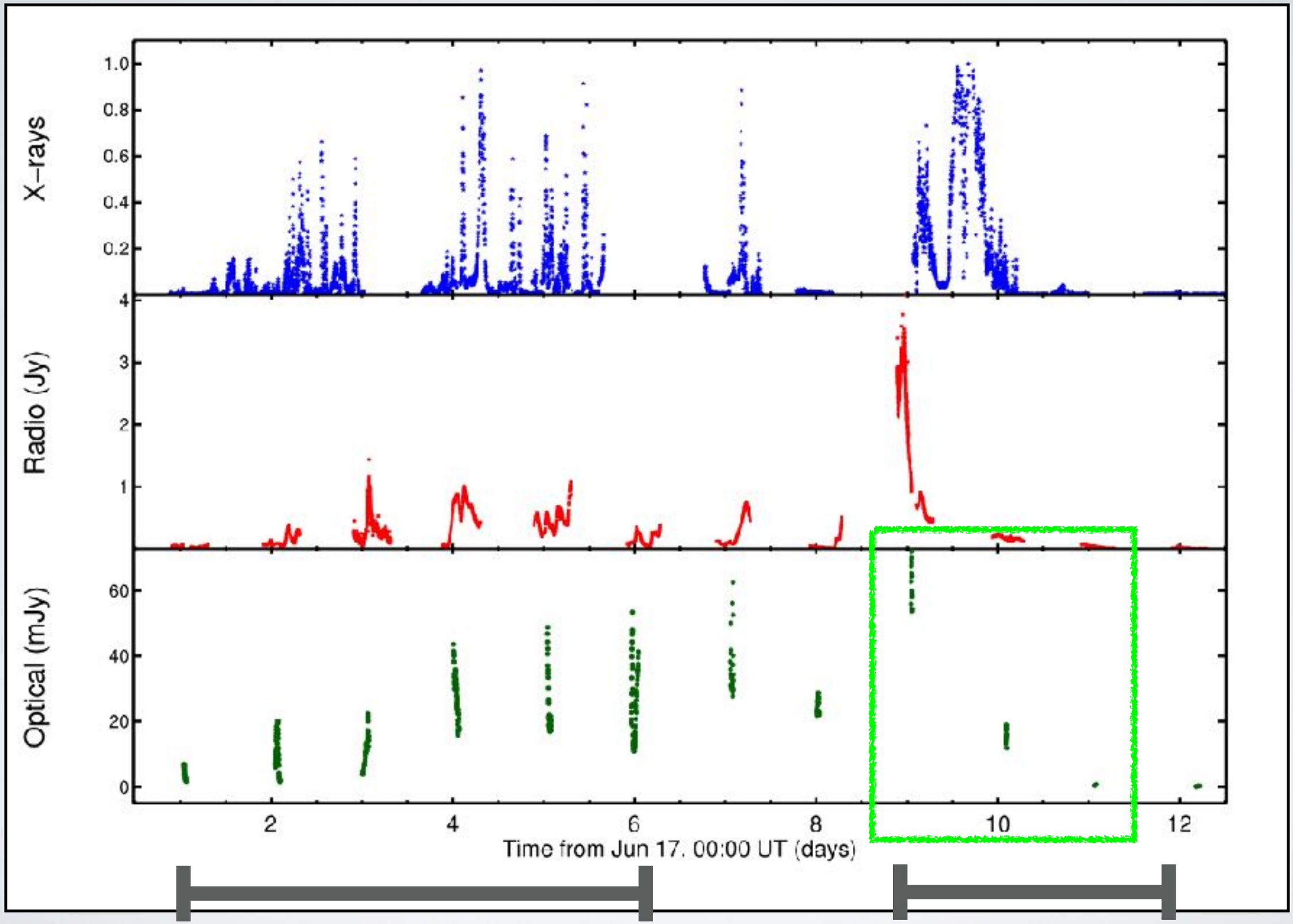


High-velocity, optical wind from the outer disc

Simultaneous with the radio jet

X-ray wind detected by Chandra King et al. 2015

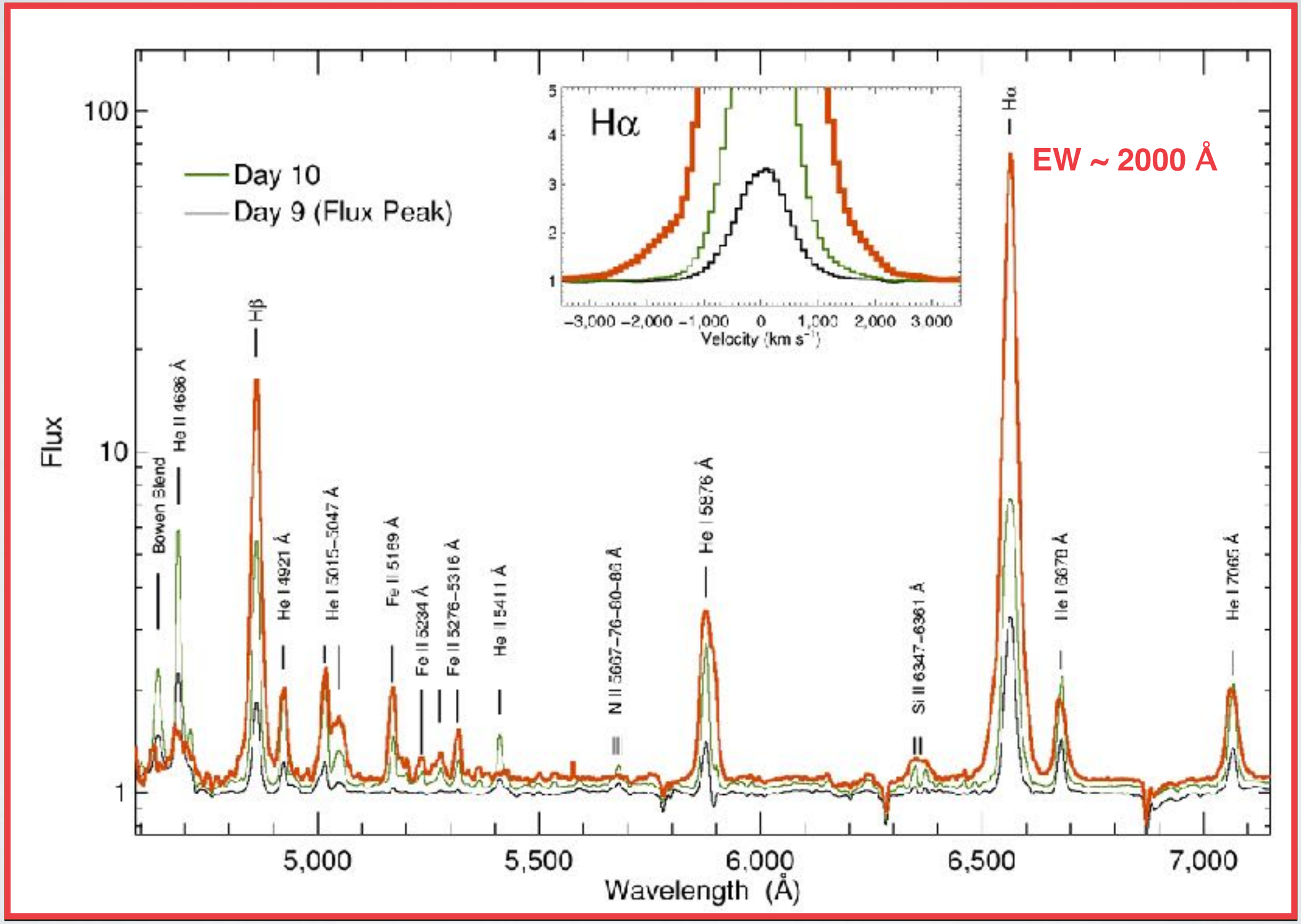
V404 Cygni: 2015 Outburst



Low Ionisation: P-Cyg Profiles

Nebular Phase

NEBULAR PHASE

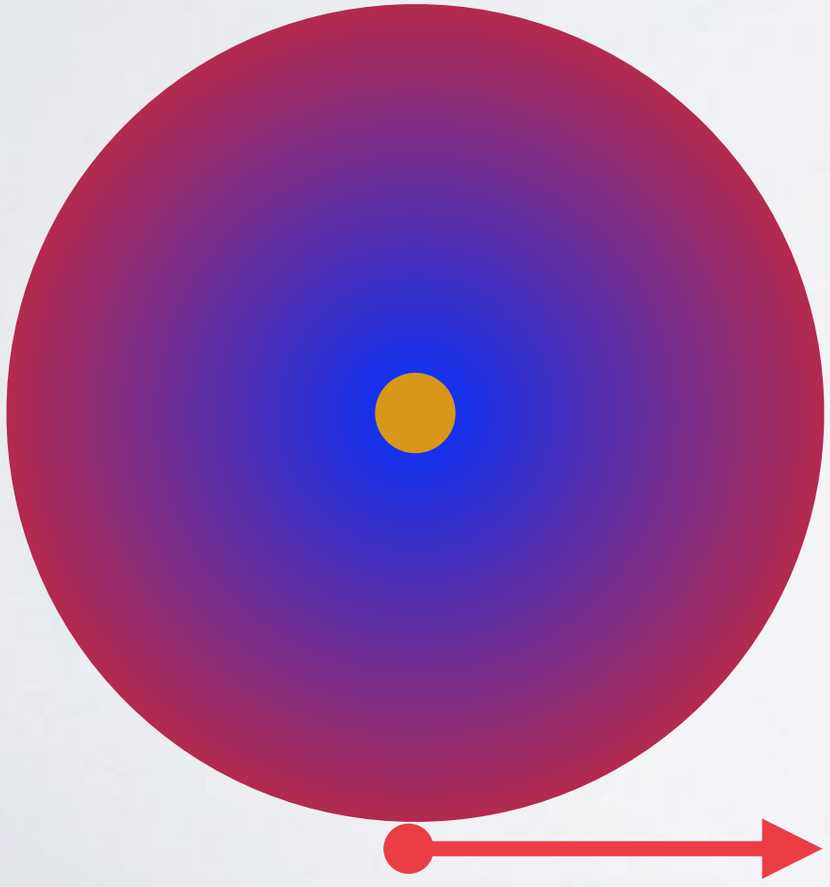


Optically thick to optically thin transition

Mass Balance (King, Kolb, Burderi 1996)

Disc contains: $\mathbf{M_{disc}} \sim 10^{-5}\ M_\odot$

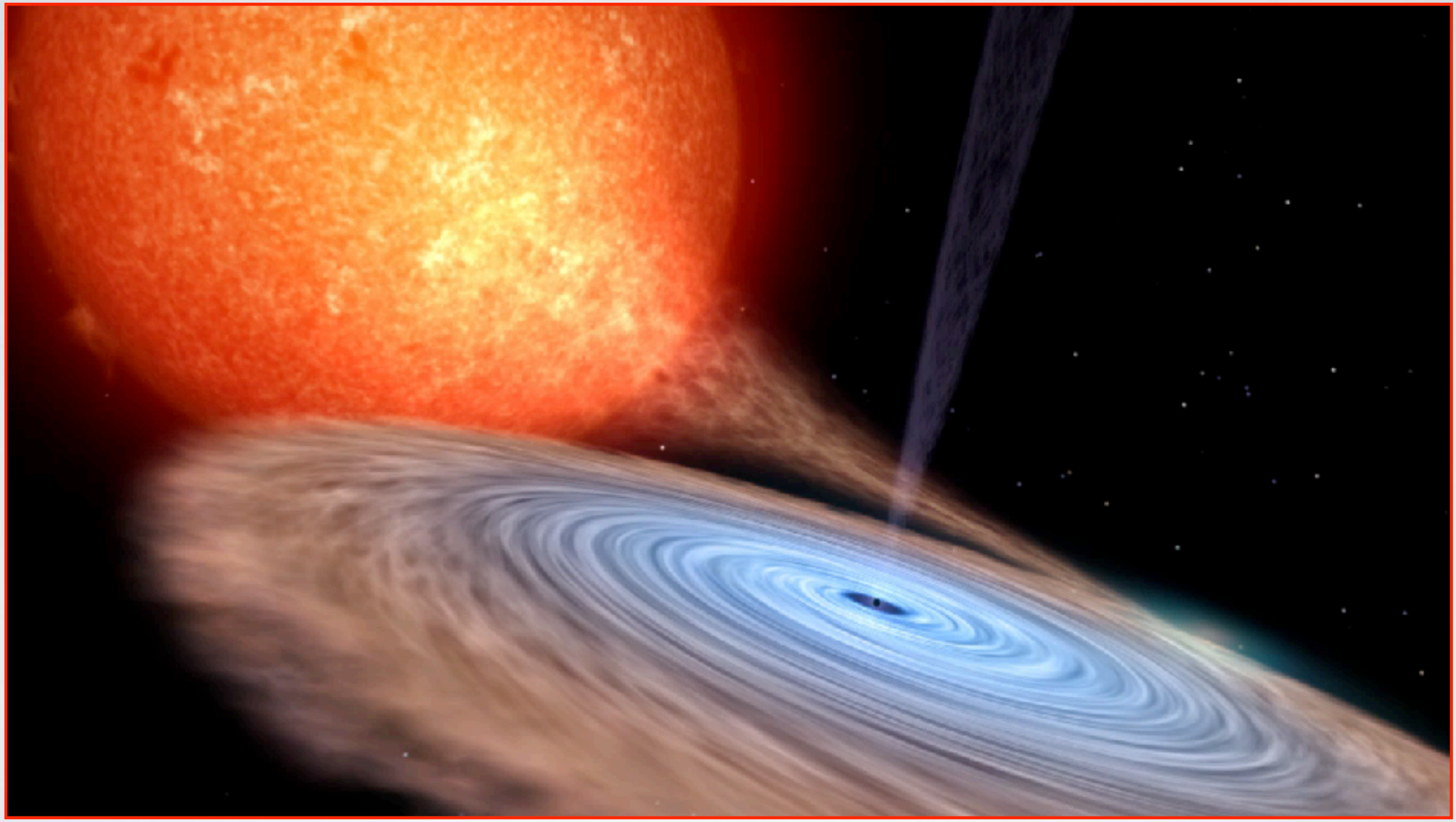
- Ejected Mass: > 0.001 $\mathbf{M_{disc}}$
- Accreted Mass: ~ 0.001 $\mathbf{M_{disc}}$
- Transferred Mass (quiescence): ~ 0.003 $\mathbf{M_{disc}}$



disc ~ 30 l.s.

Innermost 3 l.s. (Consistent with thermal wind launching radius)

The wind is regulating the outburst! (?)



Credit. G. Perez (IAC)

Are optical winds just a “peculiarity” of V404 Cygni ?

No

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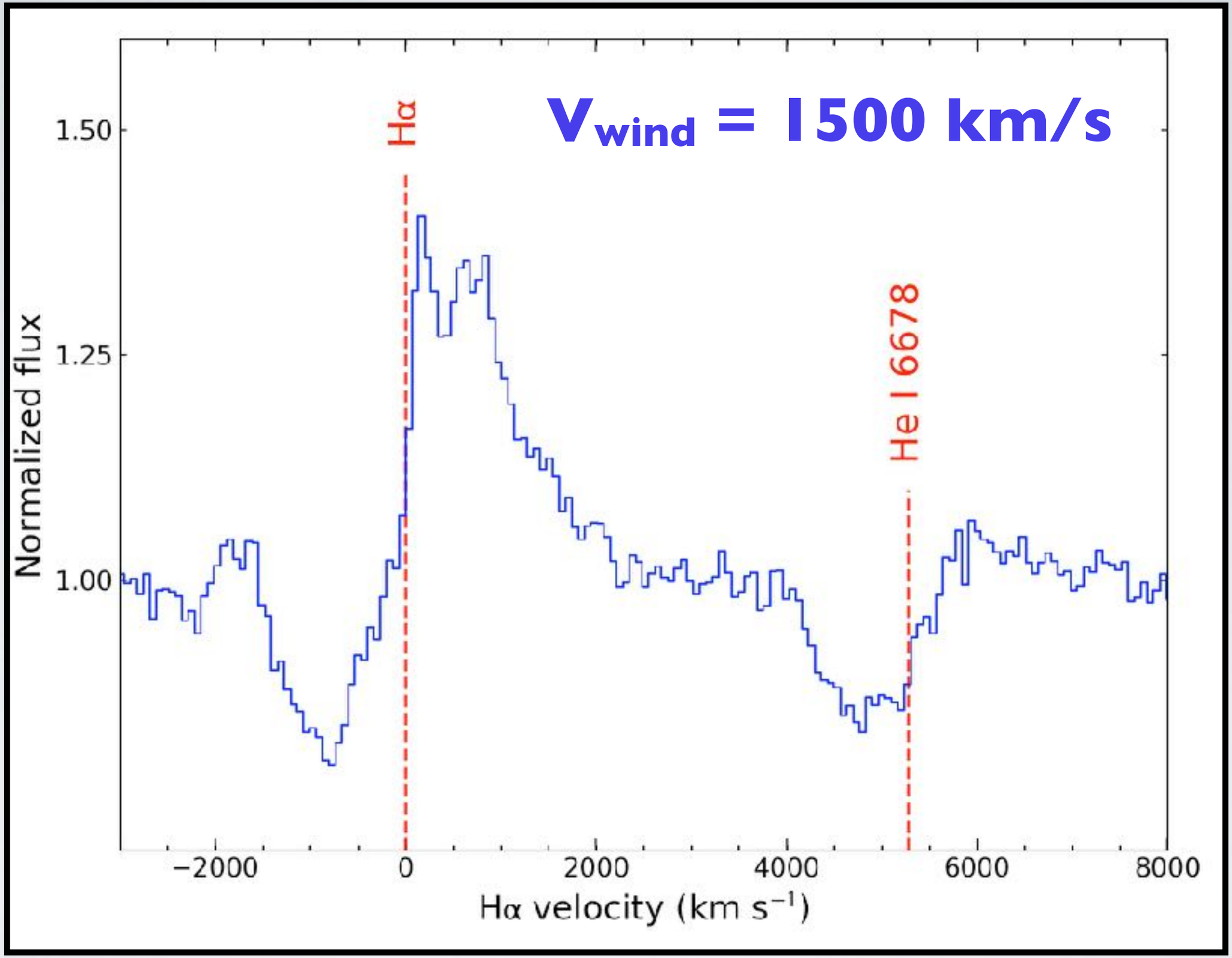
- ★ **V4641 Sagitarii:** archival search (**FLWO**). Optical winds present in every outburst Muñoz-Darias, Torres & García 2018



Optical wind simultaneous with the jet in V4641 Sgr

Muñoz-Darias, Torres & Garcia, 2018, MNRAS

Are optical winds just a “peculiarity” of V404 Cygni ?

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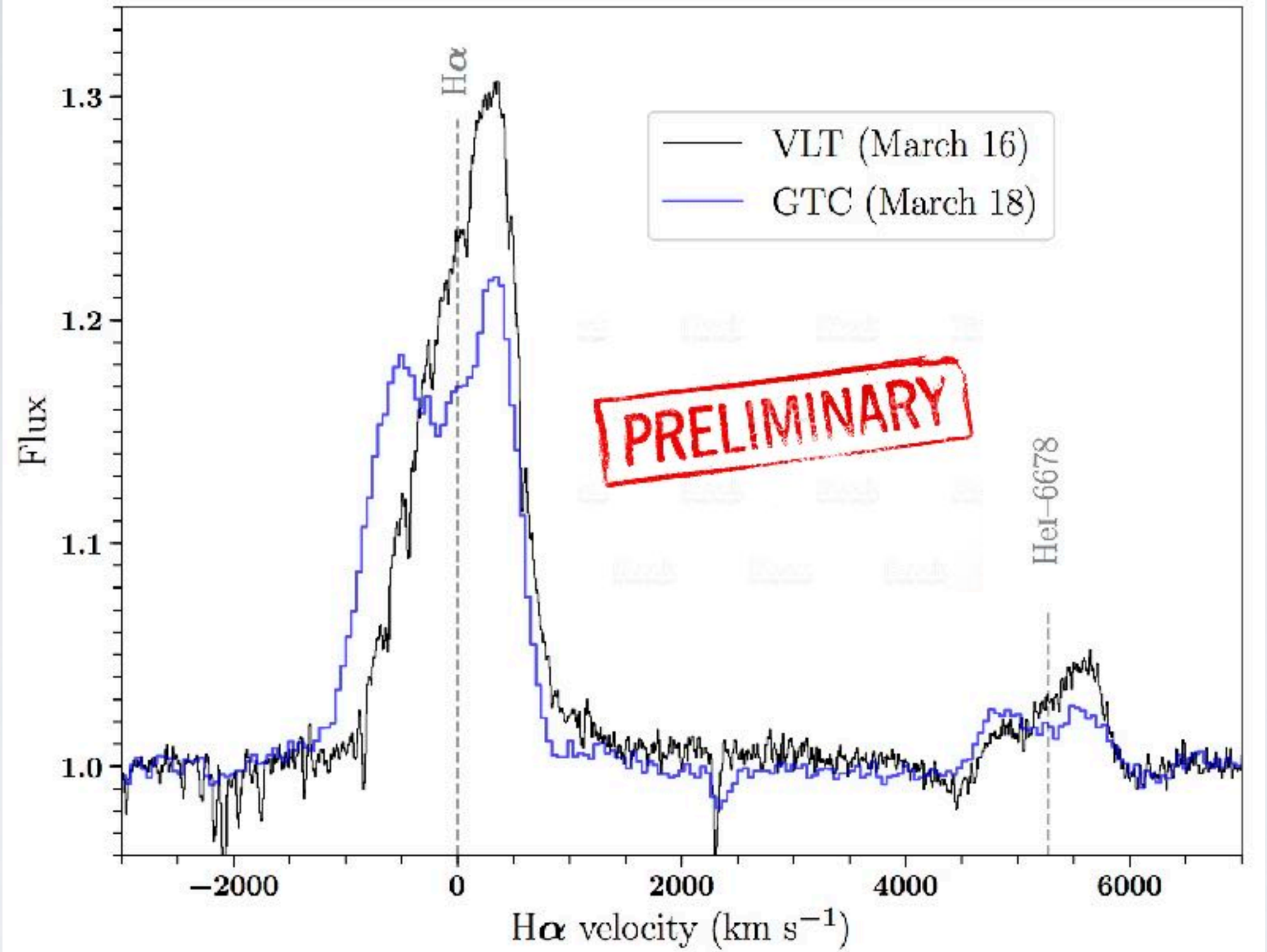
★ **MAXI J1820+070:** Black hole candidate discovered in 2018. **GTC**, **VLT** and **Keck** spectroscopy triggered. Muñoz-Darias, Jiménez-Ibarra et al. in prep.



Blak hole transient MAXI J1820+070

Muñoz-Darias, Jimenez-Ibarra et al. in prep.

Are optical winds just a “peculiarity” of V404 Cygni ?

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- ★ **Neutron Stars:**
  - Conspicuous radio Jets Migliari & Fender 2006
  - X-ray winds: Diaz-Trigo et al. 2006; Ponti, Muñoz-Darias & Fender
  - Archival search show that Infrared winds are likely present Bandyopadhyay et al. 1999; Homan et al. 2016

We have detected/discovered:

Cold **accretion disc winds** from stellar-mass black holes

Simultaneous with the **Radio-jet**

Nebular phase (1st ever)

Not only in V404 Cygni

Implications:

Wind carries as much material as that accreted

Accretion phase might be **regulated by the wind**

Are these cold winds a **fundamental property**

of black hole accretion?

We are hiring a Postdoc to work in this project for 2 years (see AAS Jobs)

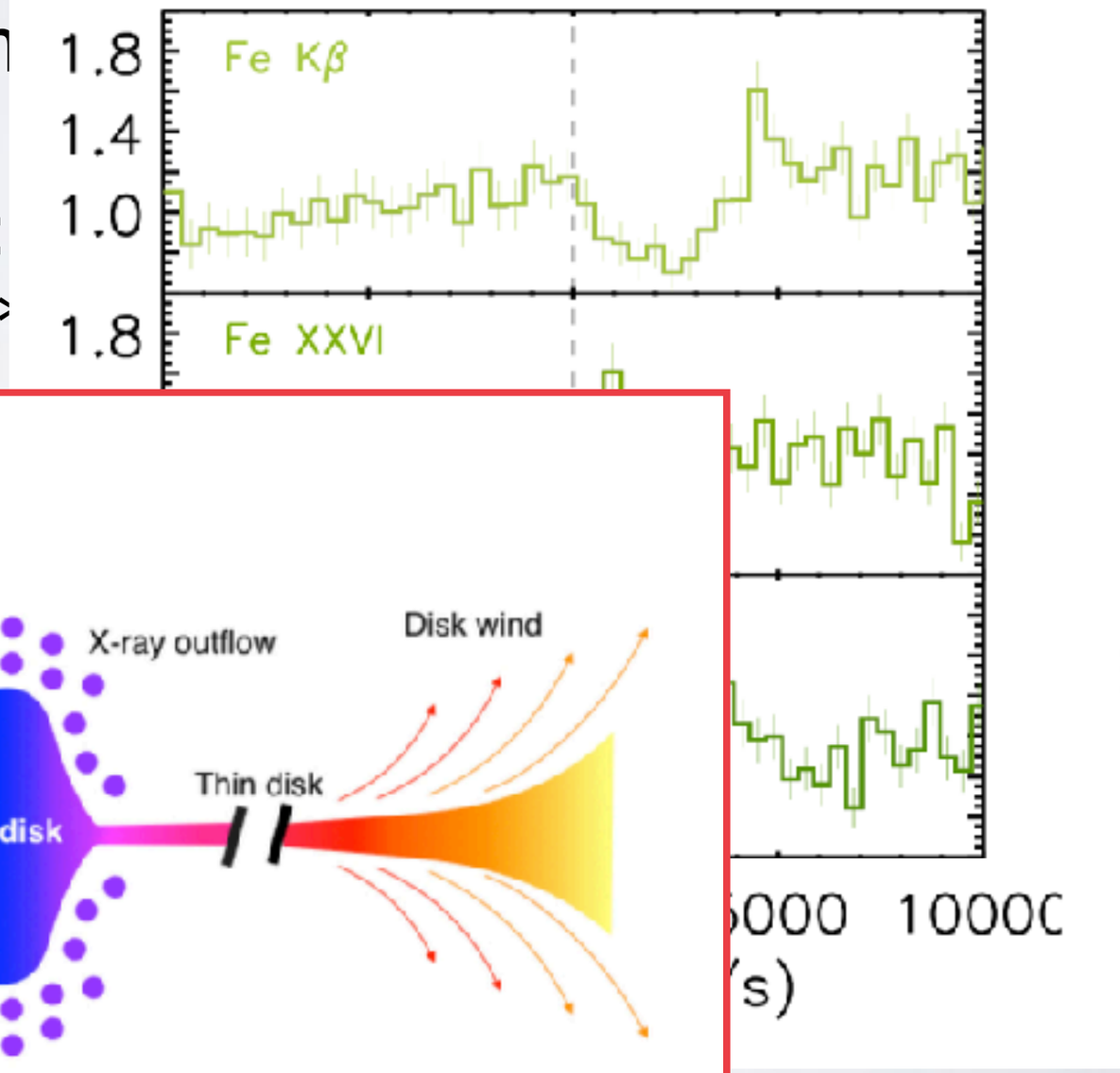
SOME NUMBERS

(Shakura & Sunyaev 1973; King et al.1996; Begelman et al. 1982)

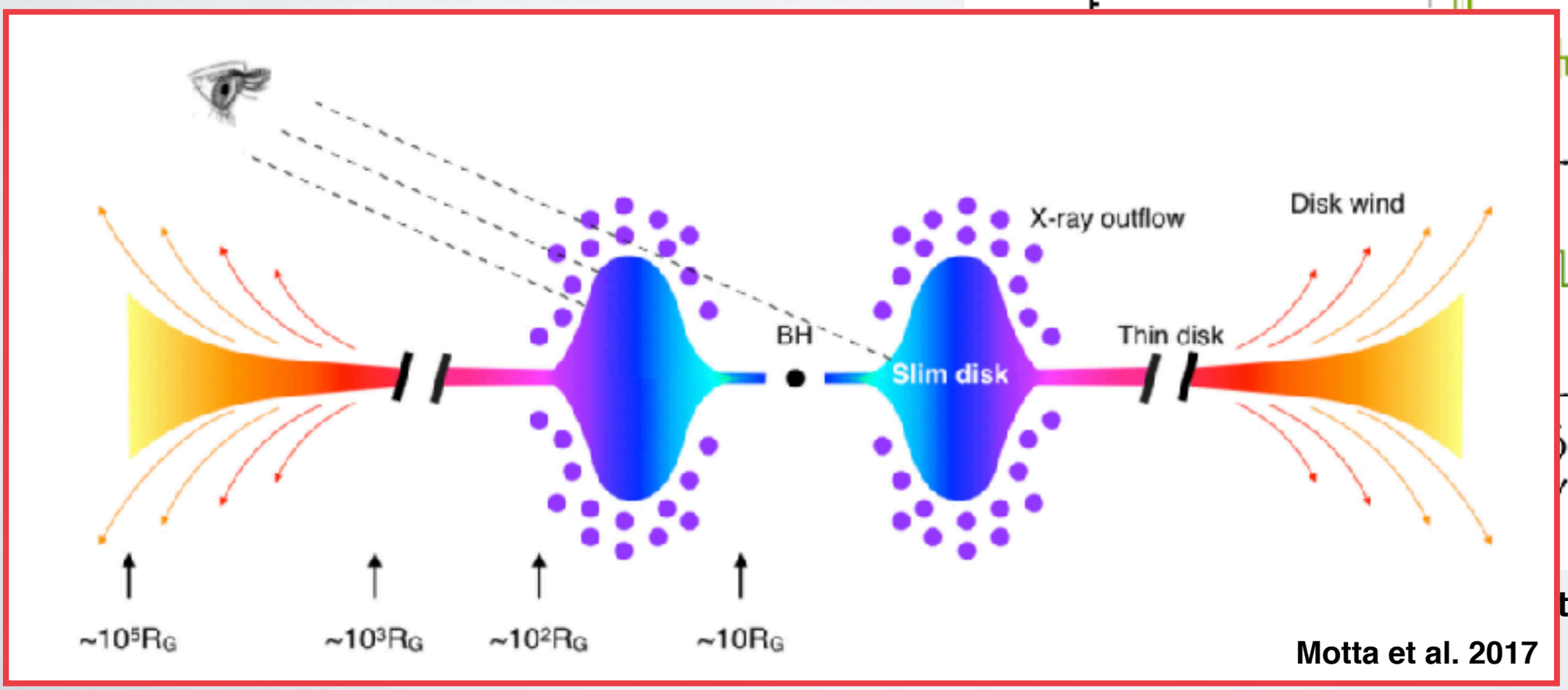
Wind Mechanism

- Wind velocity (V_T~1.5–3 x 10^3 km s^{-1}) ~ escape velocity at 0.5 – 2 l.s.
- Temperature < 3 x 10^4 K for Lun

Thermal Wind from the outer disc
Radiation Driven is probably not (



ted (King et al. 2015)



Motta et al. 2017

Summary

The 2015 outburst of V404 Cygni forces us to revisit the global picture of BH outburst:

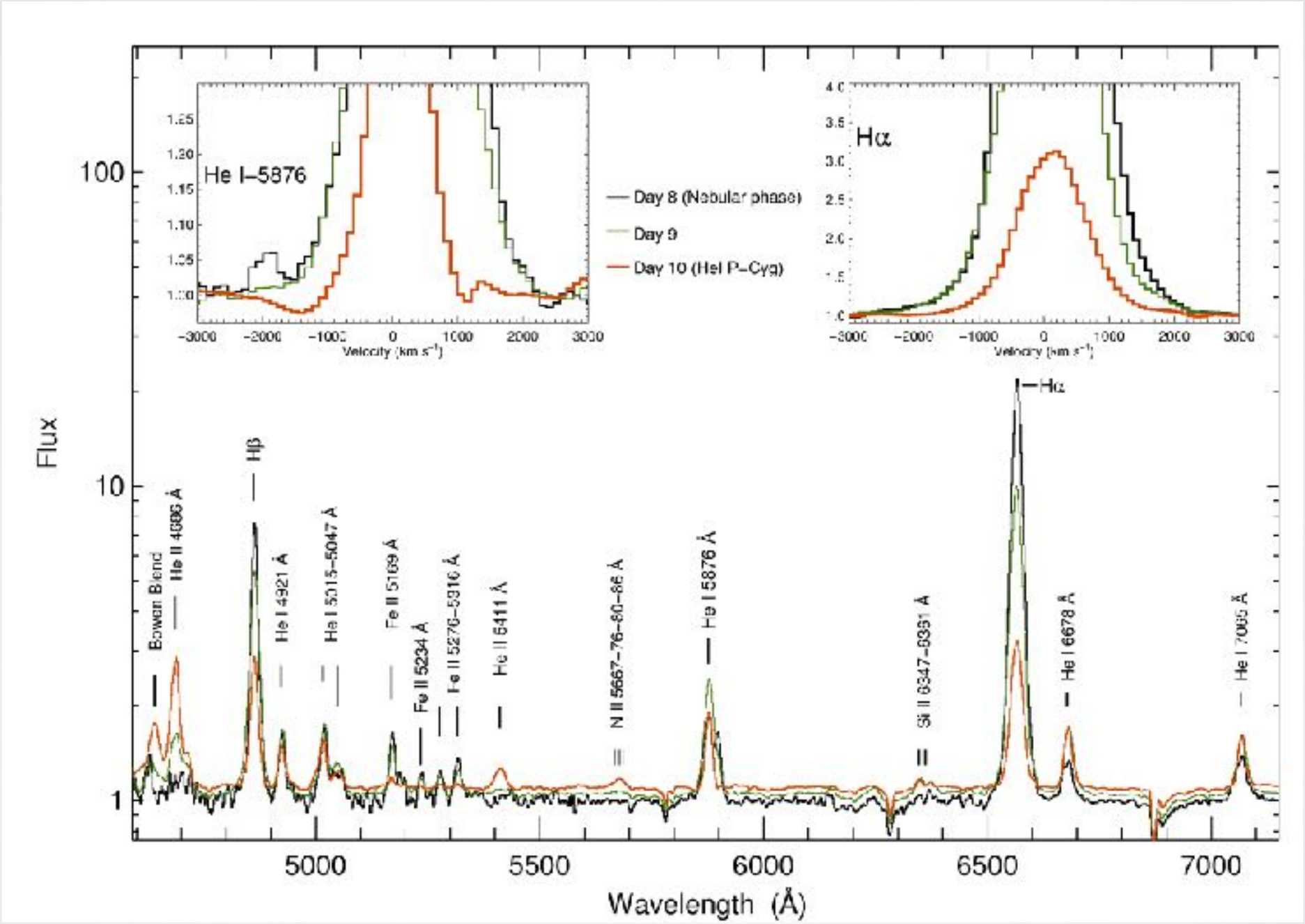
- ★ Luminous but very short outburst. No soft state
- ★ High velocity wind (3000 km s^{-1}) simultaneous with the jet. Nebular phase (1st ever)
- ★ Variable absorption. Strong flaring

- ★ Wind carries as much material as that accreted
- ★ Only the very inner disc is accreted
- ★ Accretion phase regulated by the wind?
- ★ How general is this? Is it just a matter of accretion disc size?
- ★ Do we really understand large accretion discs?

THE DECEMBER MINI-OUTBURST

We detected (again) optical wind (GTC+OSIRIS)

Radio (AMI) and X-ray (Integral, Swift) coverage and optical photometry (pt5m)



Muñoz-Darias et al. 2017, MNRAS

Many exciting results:
(~40 papers)

★**Strong variability in radio, sub-mm** (Tetarenko et al. 2017)**, Optical** (Gandhi et al. 2016) **Soft X-ray rays** (Motta et al. 2017) **and hard X-rays** (Rodriguez et al. 2015; Walton et al. 2017)

★Possible **High-energy Gamma-Ray Activity** detected by *AGILE* (Piano et al. 2017) and *Fermi* (Loh et al. 2016; Jenke et al. 2016)

★**Optical patterns** mimicking GRS 1915+105 (in X-rays) but at much lower luminosities (Kimura et al. 2016, Nature)

★Positron **annihilation signatures** (511 keV; Siegert et al. 2016 Nature; see **Thomas's Talk**)

★Variable and **X-ray absorption** (10^{22} — 10^{24} cm^{-2}). Super-Eddington luminosity (?). No soft states (Motta et al. 2017). **Radio jet** always on (e.g. Muñoz-Darias et al. 2016

★Sustained **optical accretion disc wind simultaneous with the radio jet** (Muñoz-Darias et al. 2016 Nature). **X-ray wind** (King et al. 2015)