WG3

Transient X-ray Binaries
Magnetars
ULXs

with SOXS

Piergiorgio Casella & Alexandra Veledina

on behalf of the whole WG3

WG3

20 members (Italy, Finland)
~25 ideas/proposals received

Black Hole-Transients
Accreting Millisecond Pulsars
New Transient X-ray pulsators
Transitional Millisecond Pulsars
Neutron-Star Transients
Z-sources
Magnetars
High-mass X-ray Binaries
Ultra-luminous X-ray Sources

Accretion
Strong Gravity
Dense Matter
Magnetic fields

WG3

IMMEDIATE OBJECTIVES

Accretion Physics: tracking the matter

Accretion Physics: SED evolution

Orbital Parameters

Mass Measurements

Doppler Tomography

Classification / Identification

The importance of MASSes

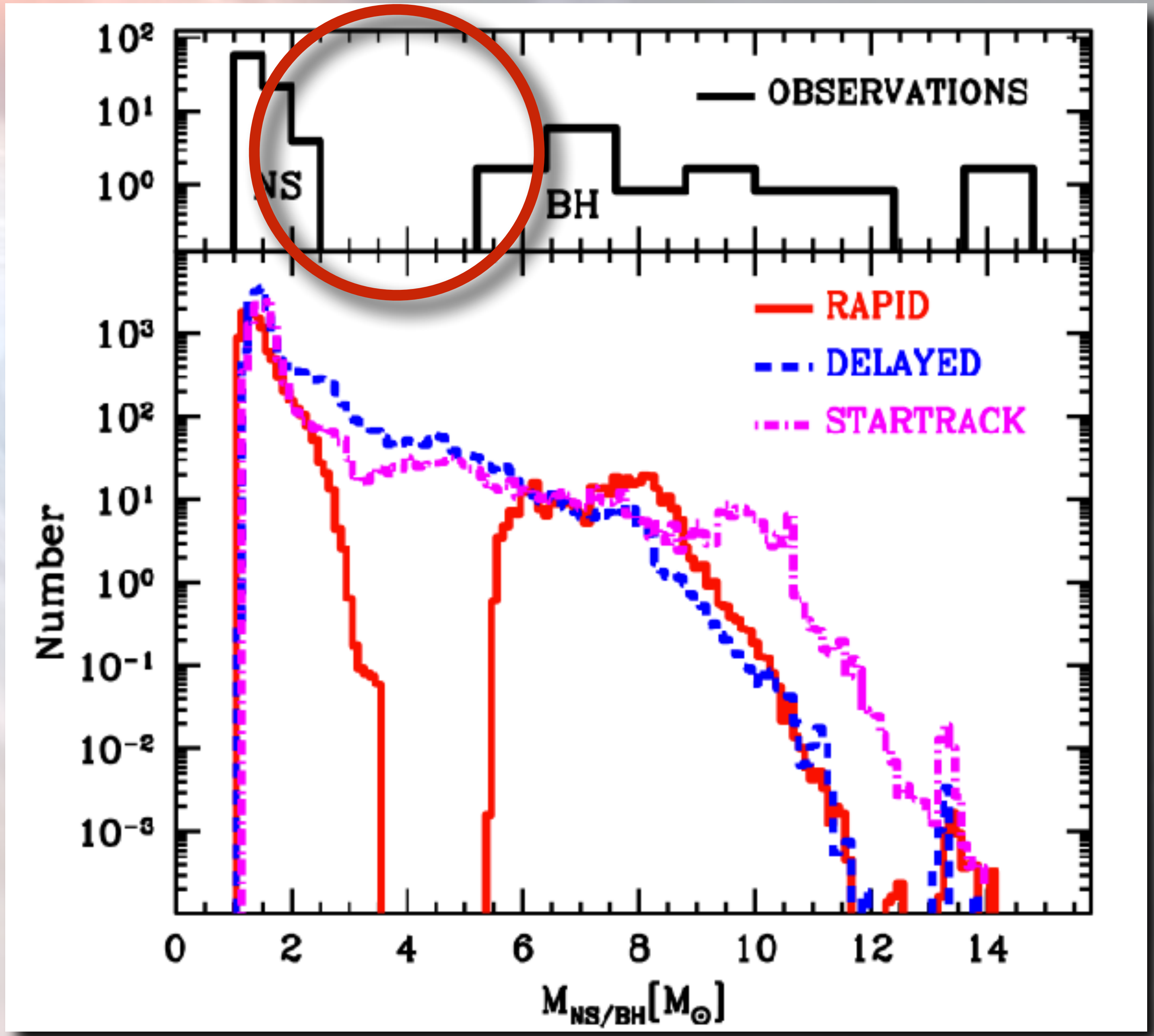
Accretion processes

SNe models

Is the gap real?

..or is it a bias?

Belczynski et al. (2012)



The importance of MASSes

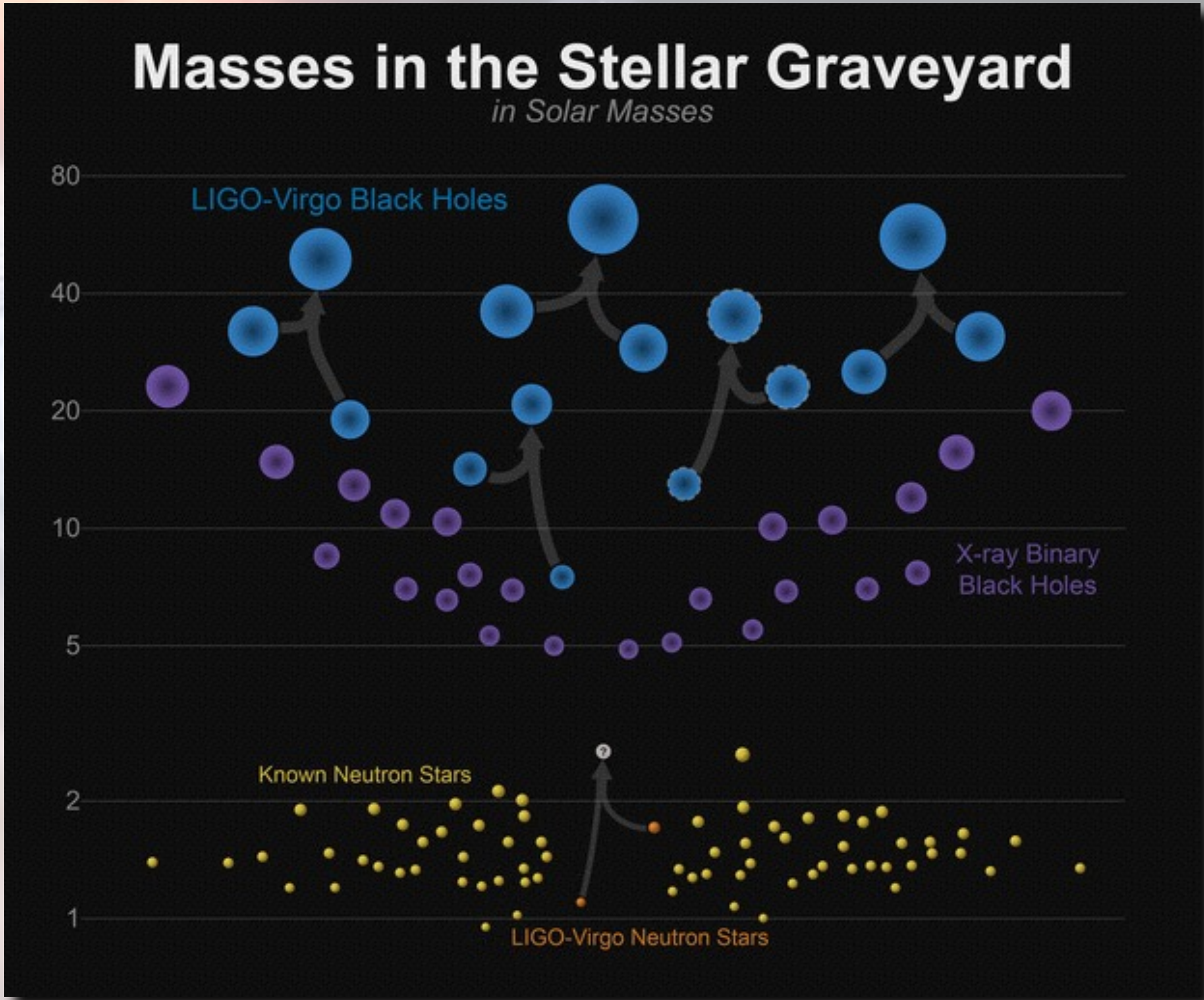
Accretion processes

SNe models

Is the gap real?

..or is it a bias?

Belczynski et al. (2012)



The importance of MASSes

HOW do you obtain a MASS?

1 You trust your X-ray spectral fitting

2 You trust your broad-band X-ray timing interpretation

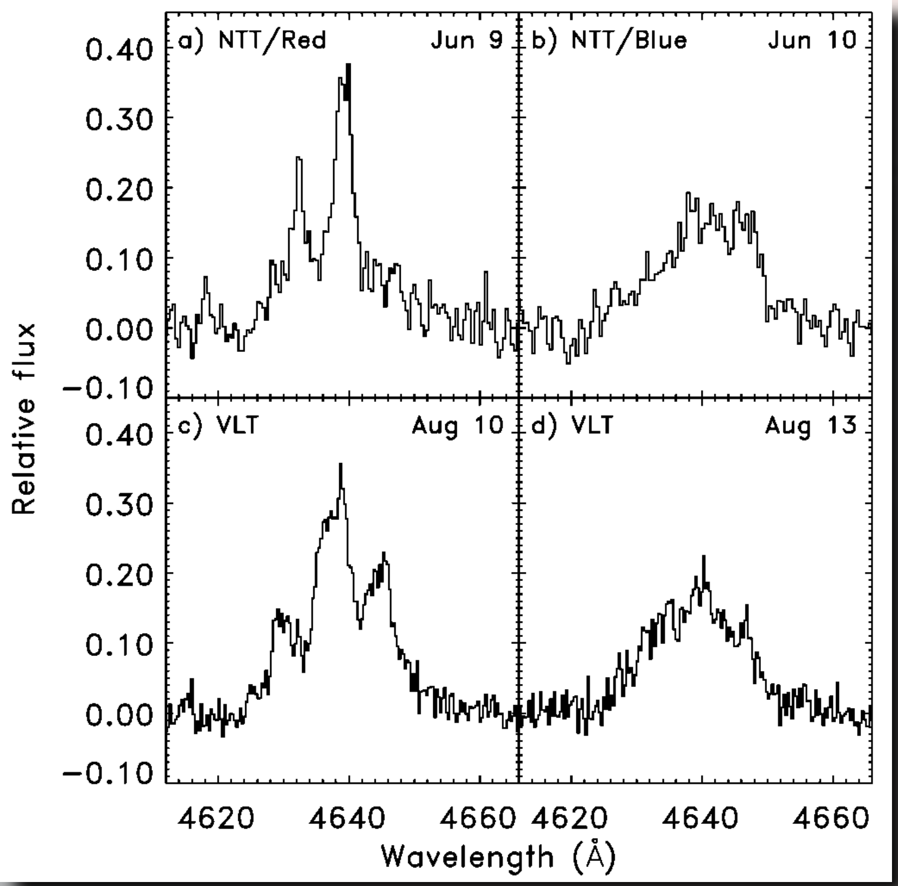
3 You measure it

$$f(M) = \frac{P_{orb} K^3}{2\pi G} = \frac{M_X \sin^3 i}{(1+q)^2}$$

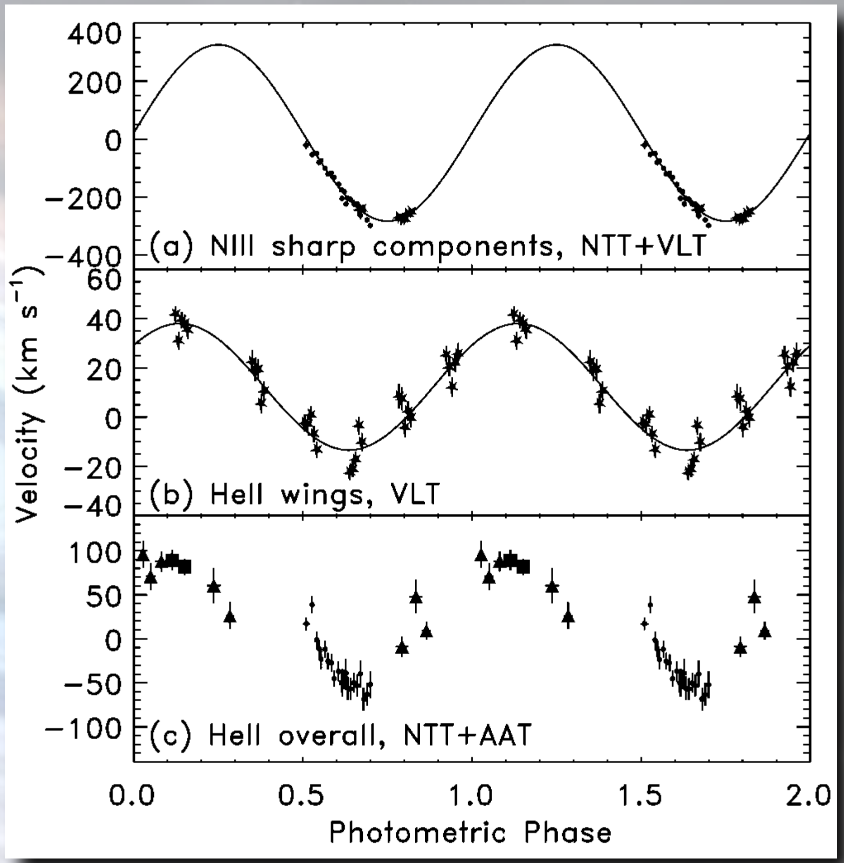
The importance of **MASSes**

Bowen blend emission lines from the irradiated donor

Outburst
(here GX 339-4 with NTT & VLT in 2002)



Hynes et al. (2003)



$$f(M) = \frac{P_{orb} K^3}{2\pi G} = \frac{M_X \sin^3 i}{(1+q)^2}$$

f(M) = 5.8 +/- 0.5 Mo

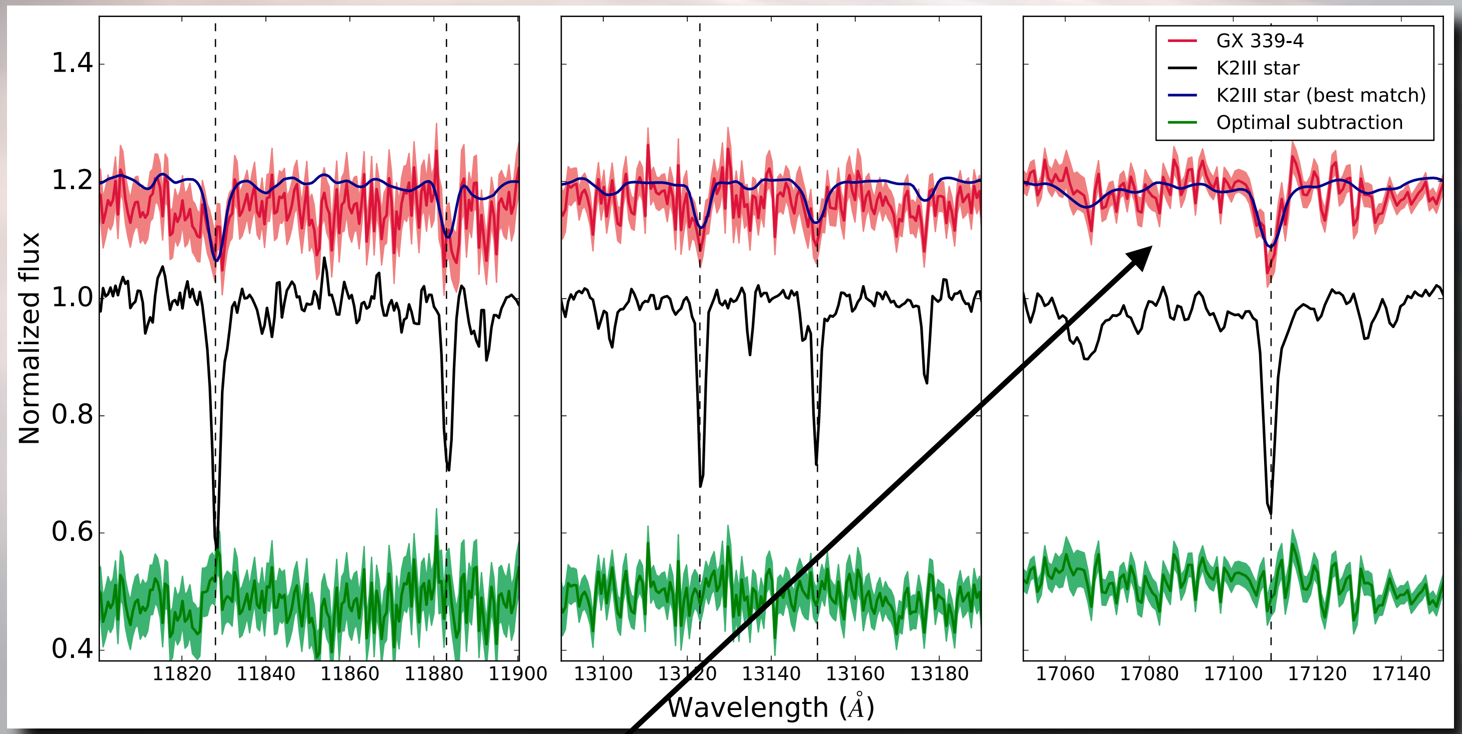
P ~ 1.76 days

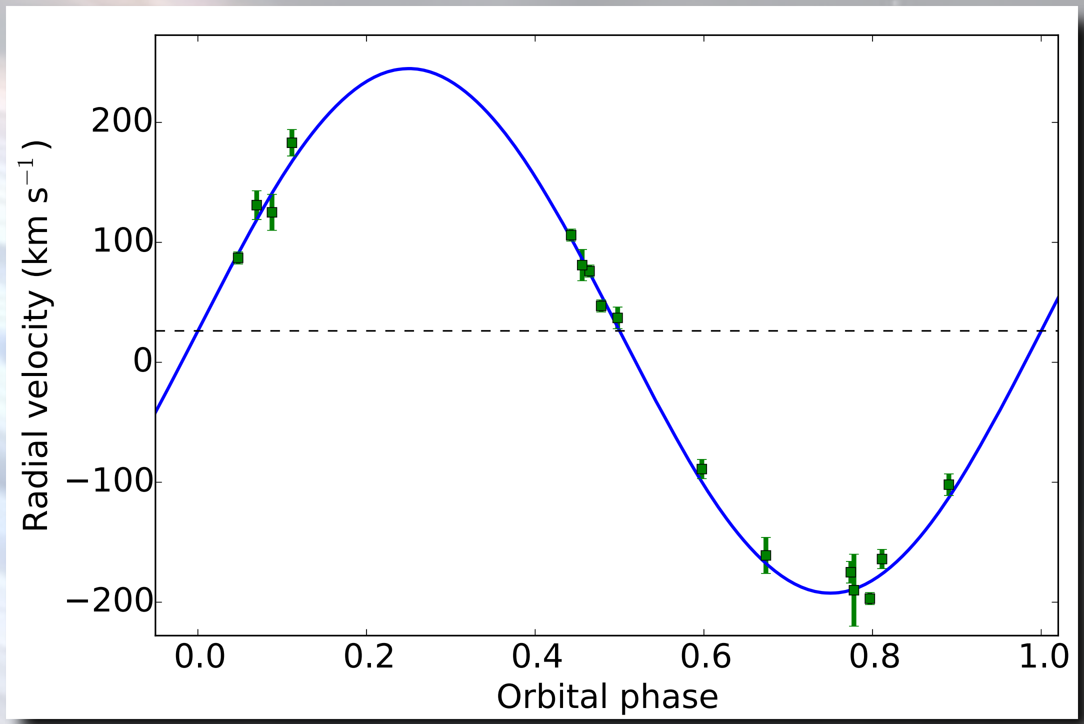
The importance of **MASSes**

absorption lines from the donor

Decay to quiescence
(here GX 339-4 with X-Shooter)

Heida et al. (2017)





better S/N in infrared

$$f(M) = \frac{P_{orb} K^3}{2\pi G} = \frac{M_X \sin^3 i}{(1+q)^2}$$

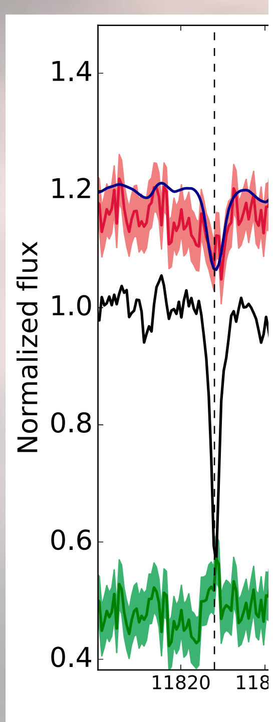
f(M) = 1.91 +/- 0.08 Mo

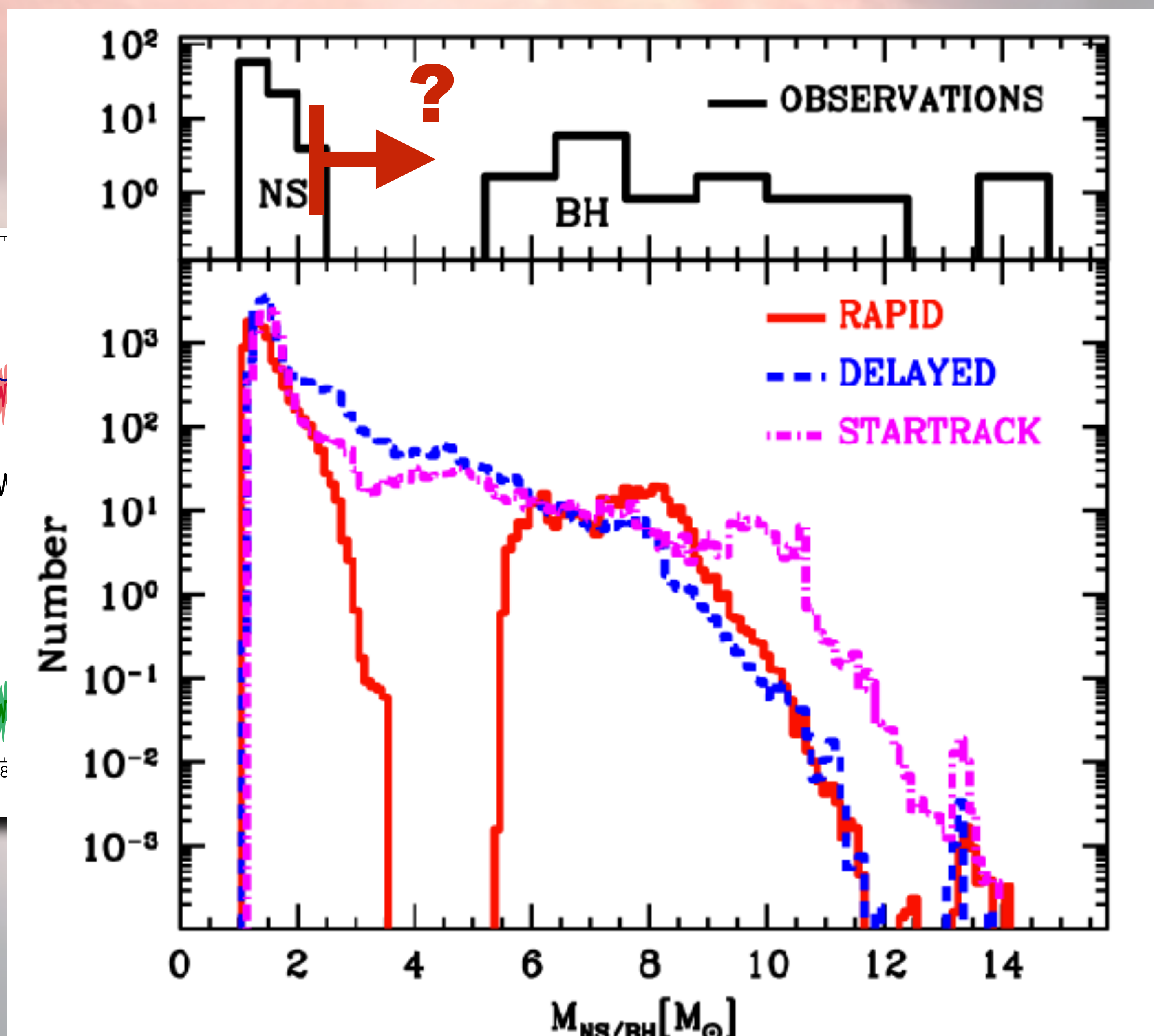
P ~ 1.76 days

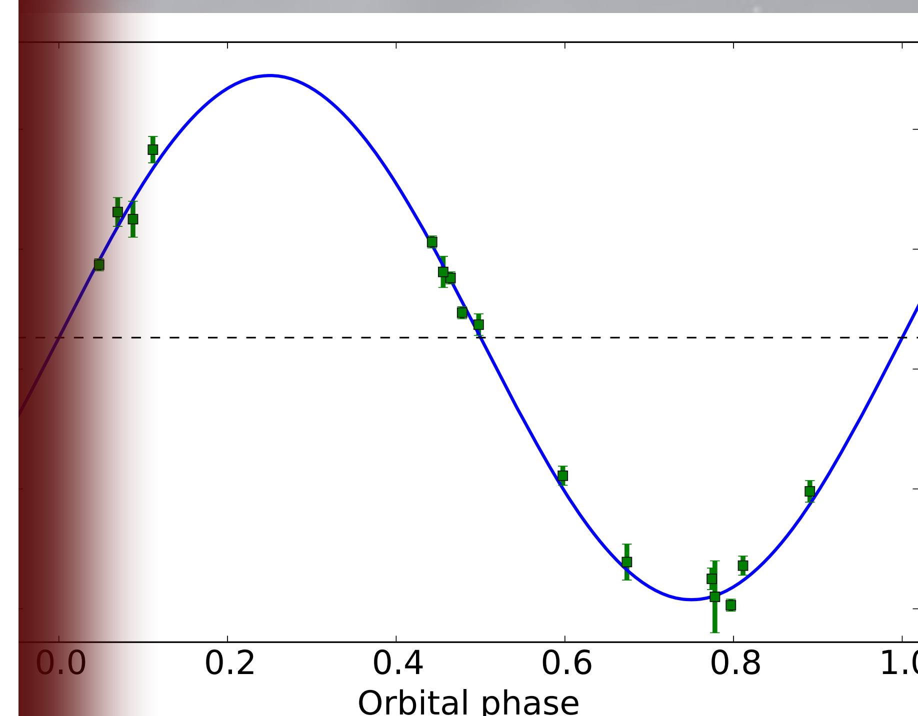
The importance of MASSes

absorption lines from the donor

ter)







f(M) = 1.91 +/- 0.08 Mo

P ~ 1.76 days

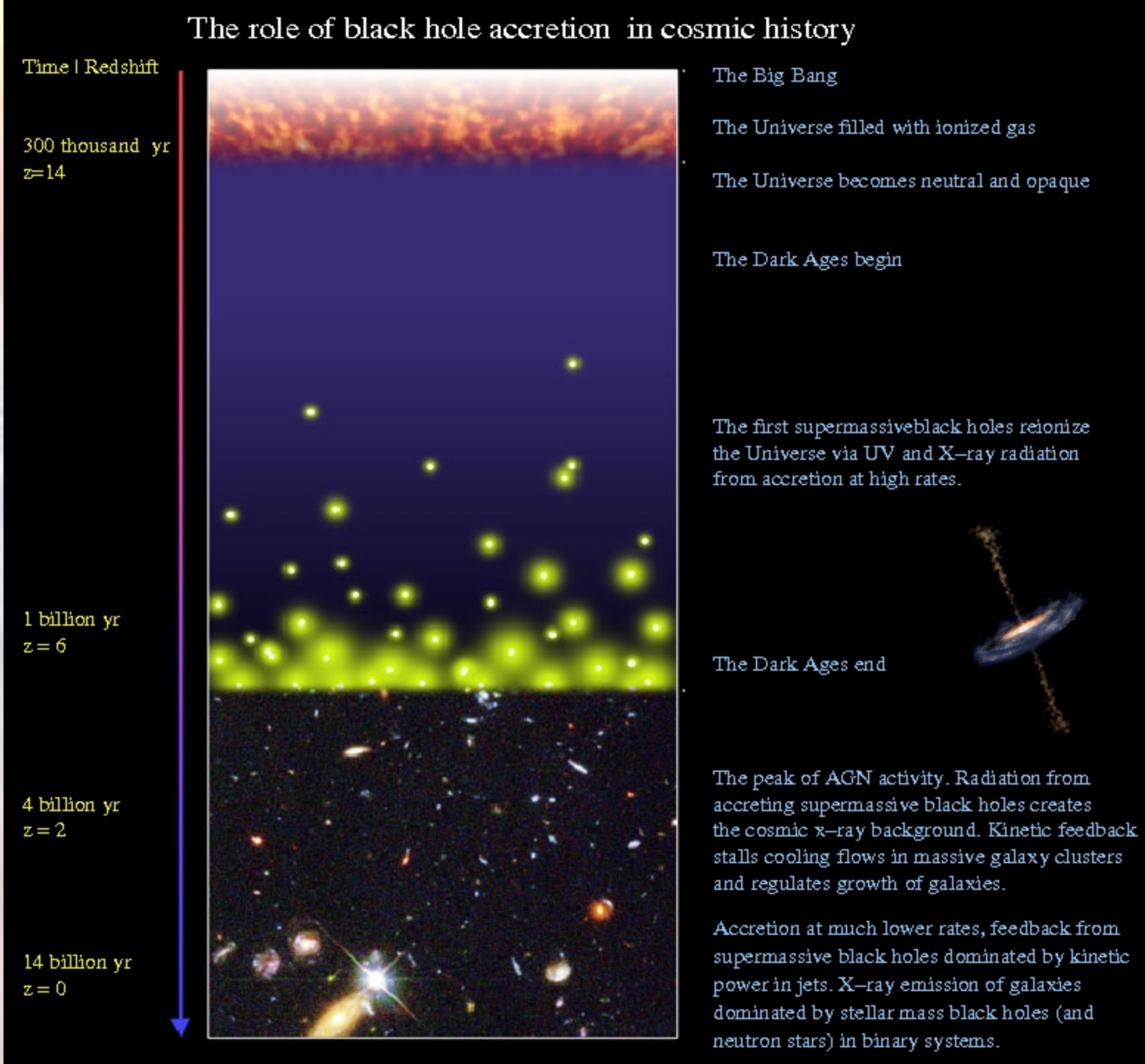
better

The importance of accretion in the Universe

6<z<14 first 'AGN' reionize universe

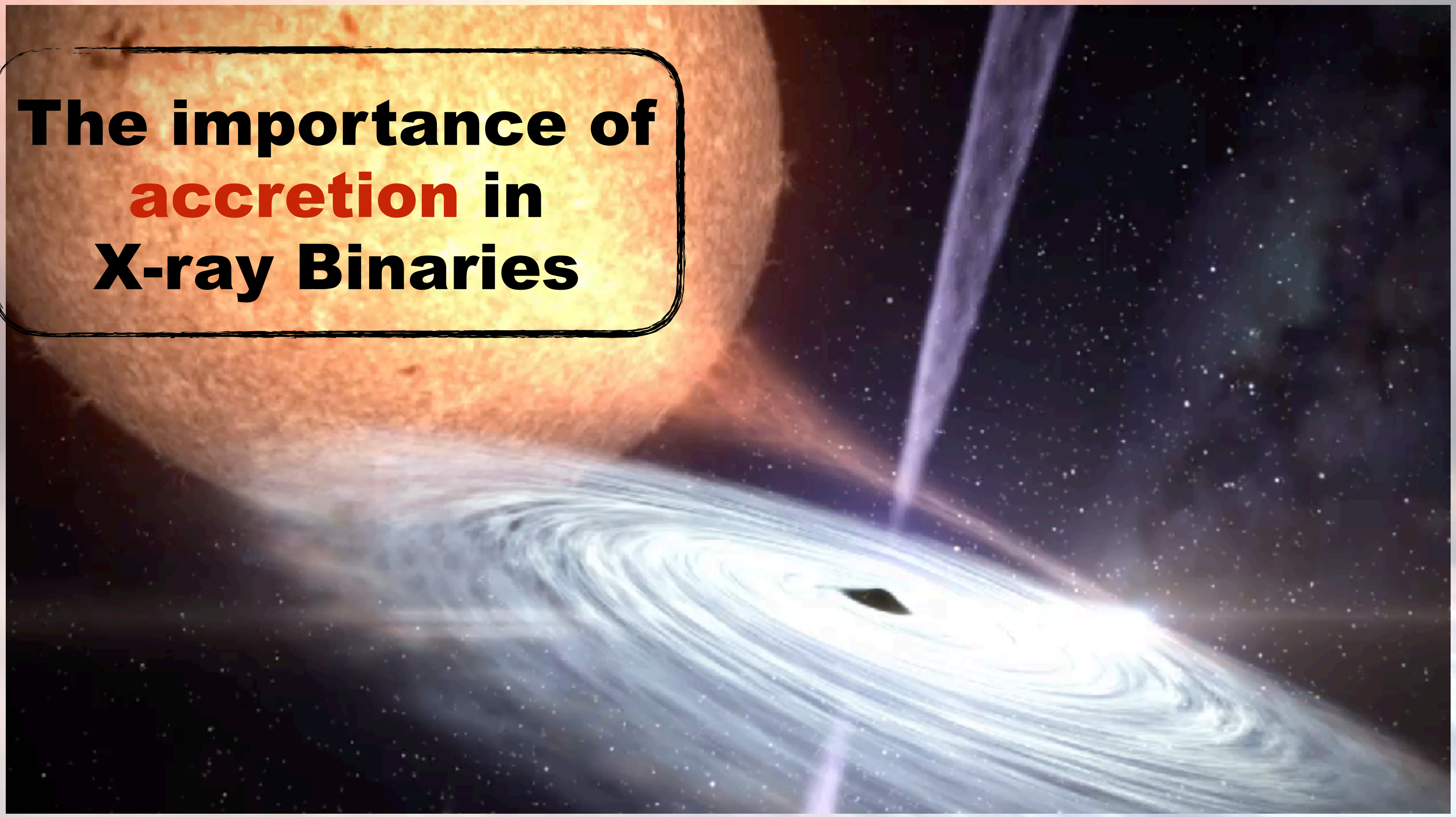
1<z<6 peak of AGN activity: feedback regulates galaxy growth, reheats cooling flows, creates X-ray background

z<1 AGN accretion rates drop, accretion luminosity of universe dominated by binaries, jets dominate radiation



courtesy of R.Fender

The importance of accretion in X-ray Binaries

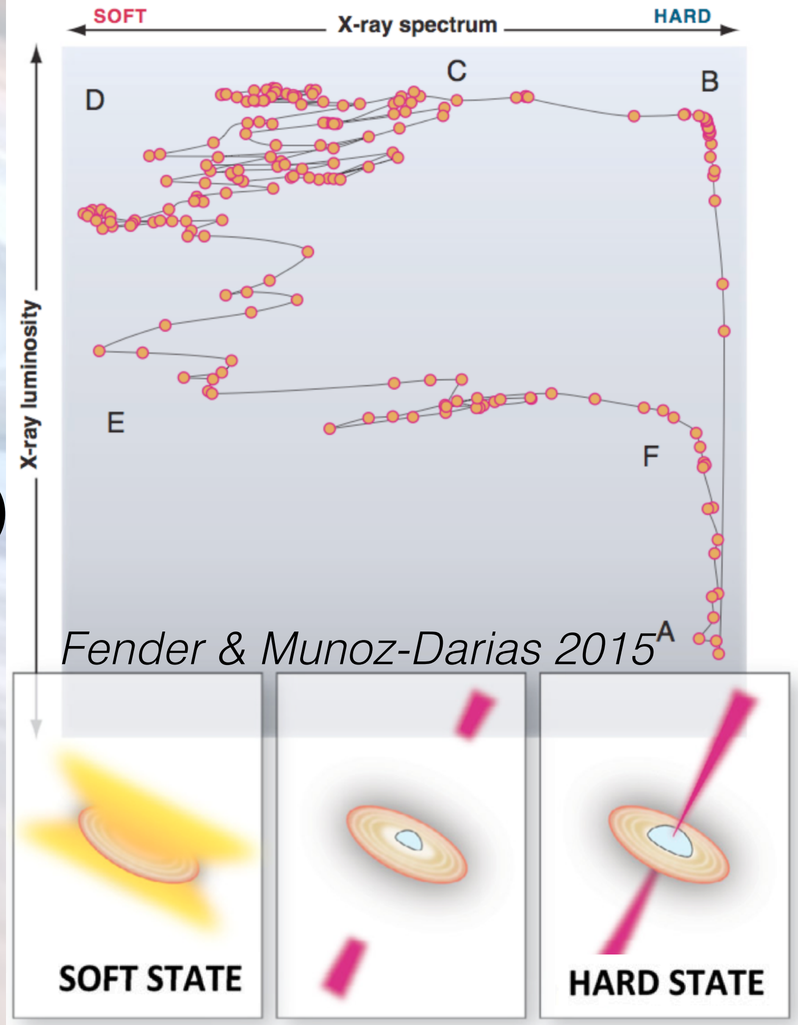


strong GRAVITY

relativistic JETS

clean ACCRETION (BH)

~dipolar B-FIELDs (NS)



Fender & Munoz-Darias 2015

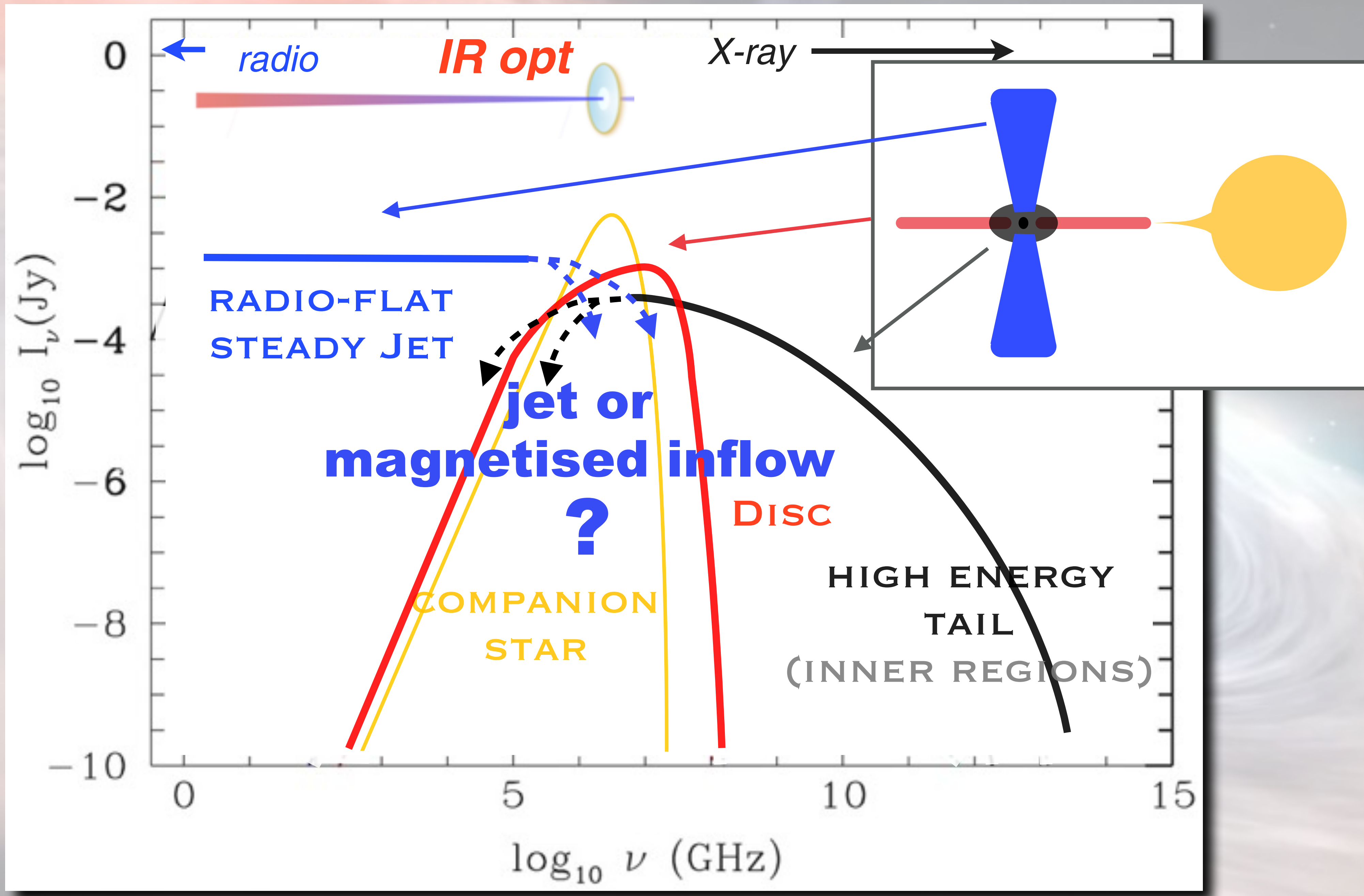
many orders of magnitude in luminosity ($10^{31} \sim 10^{39}$ ergs/s)

accessible timescales (i.e. < PhD project duration)

different accretion regimes

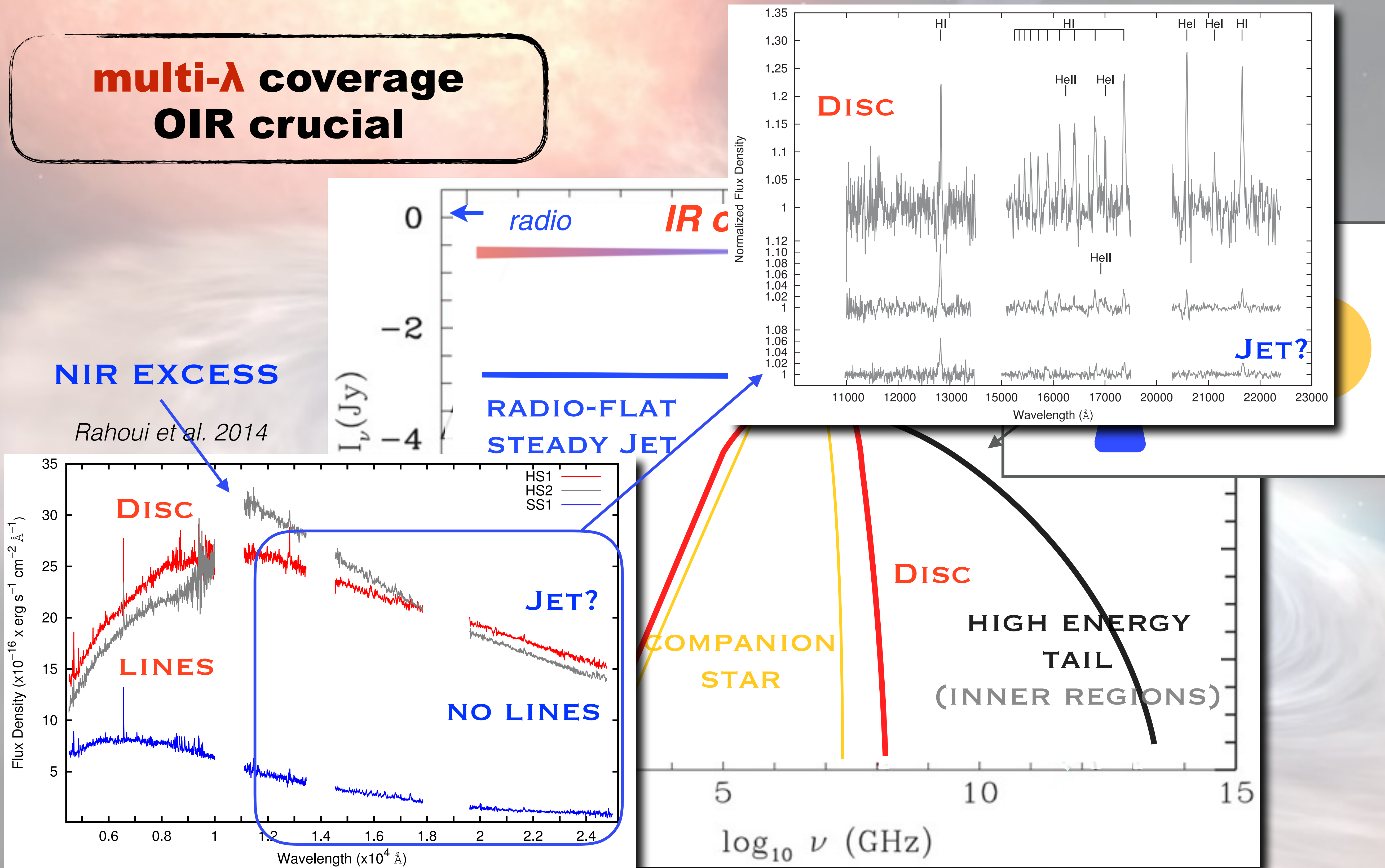
multi-λ coverage
OIR crucial

black-hole transients



Rahoui et al. 2014

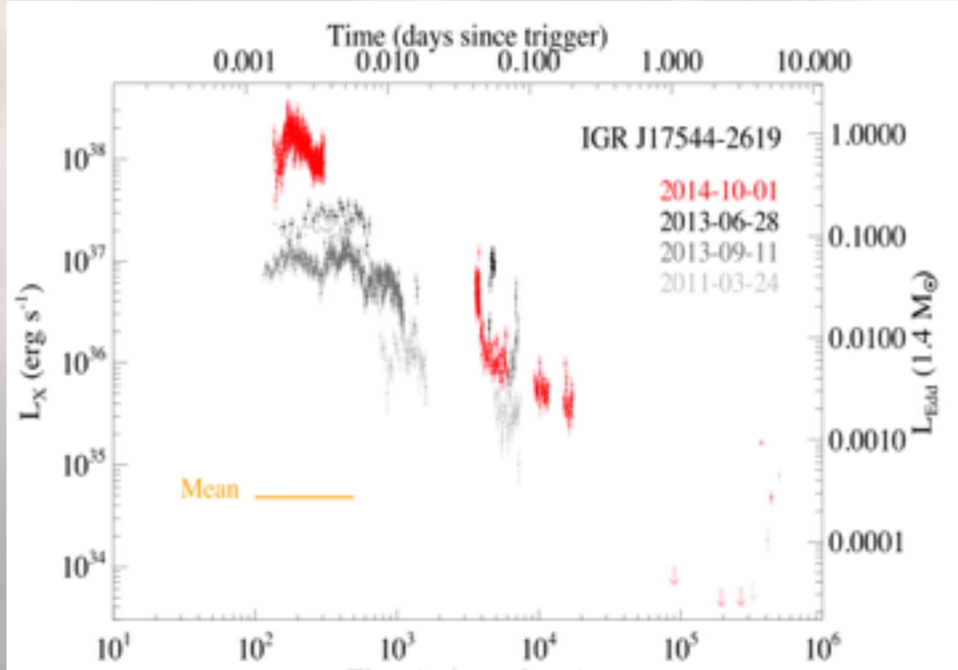
multi-λ coverage OIR crucial



DISRUPTION AND FORMATION OF DISKS — STUDYING THE ACCRETION AND EXCRETION DISKS IN TRANSIENT HMXBS DURING GIANT OUTBURSTS - PI: KOLJONEN / CO-I: TSYGANKOV, ISRAEL

DISRUPTION AND FORMATION OF DISKS DURING GIANT OUTBURSTS IN HMXBS

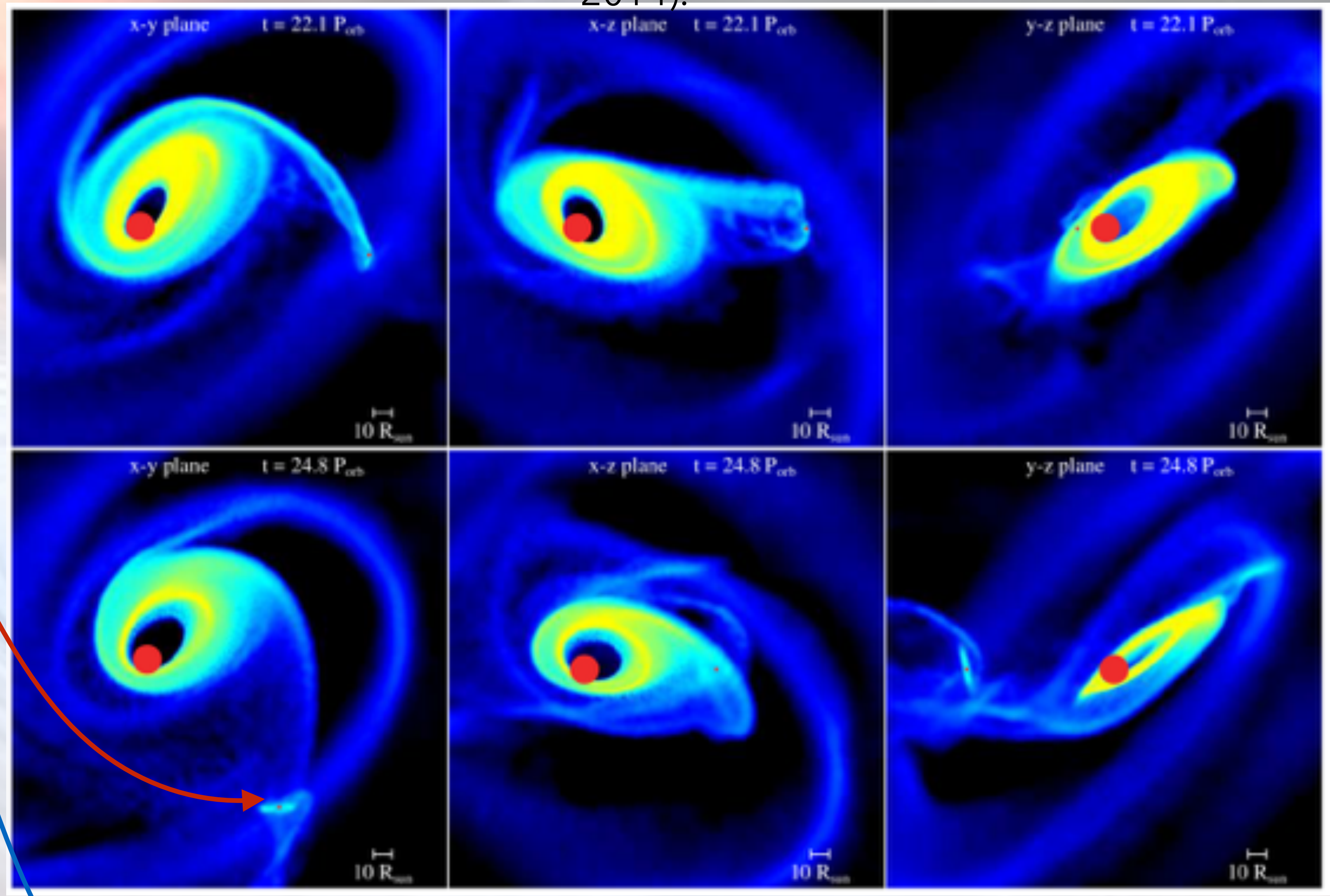
SOXS observations of transient HMXBs during the giant outbursts will allow us to track the possible formation of a transient acceretion disk, the disruption of the excretion disk in BeXRBs, and follow the impact of the outburst event to the local environment of the compact object through spectral line studies.



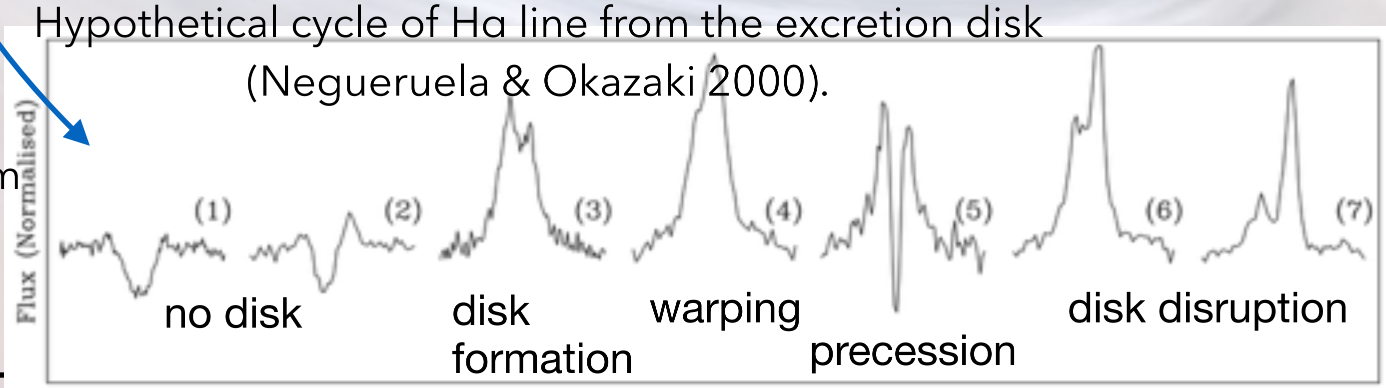
Romano et al. 2015

Giant outbursts from SFXTs are rare and fast, and the mechanism producing the transient X-ray emission is still an open issue. SOXS will probe the changing stellar wind properties that could be the driving force of the SFXT outbursts.

Simulation of the disruption of the Be-star excretion disk and formation of the accretion disk around the compact object during type II outburst (Martin et al. 2014).



Hypothetical cycle of Hα line from the excretion disk (Negueruela & Okazaki 2000).



multi-λ coverage OIR crucial

transitional MSPs

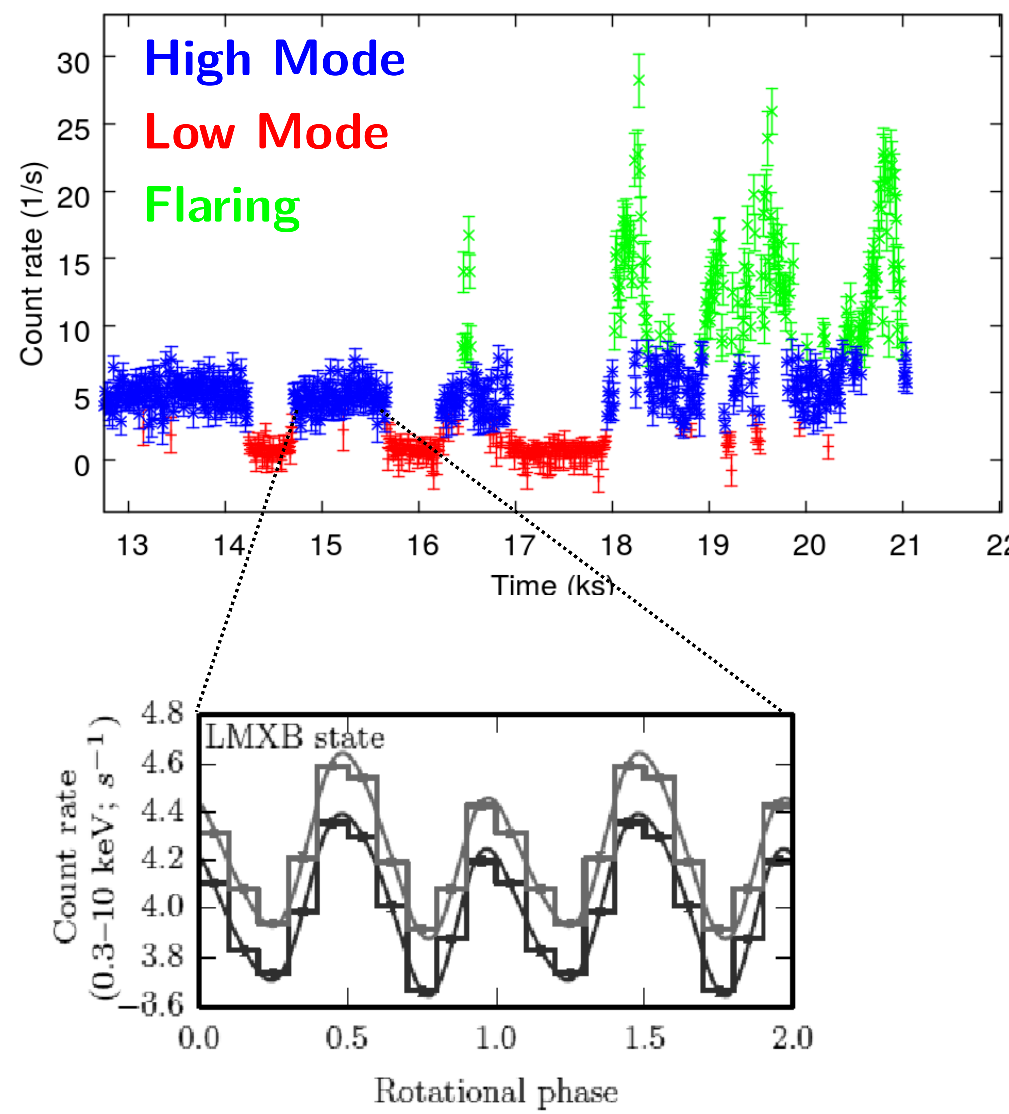
A peculiar accretion disk state

X-rays:
L~$5x10^{33}$ erg/s
Persistent (years)
Distinctive variability

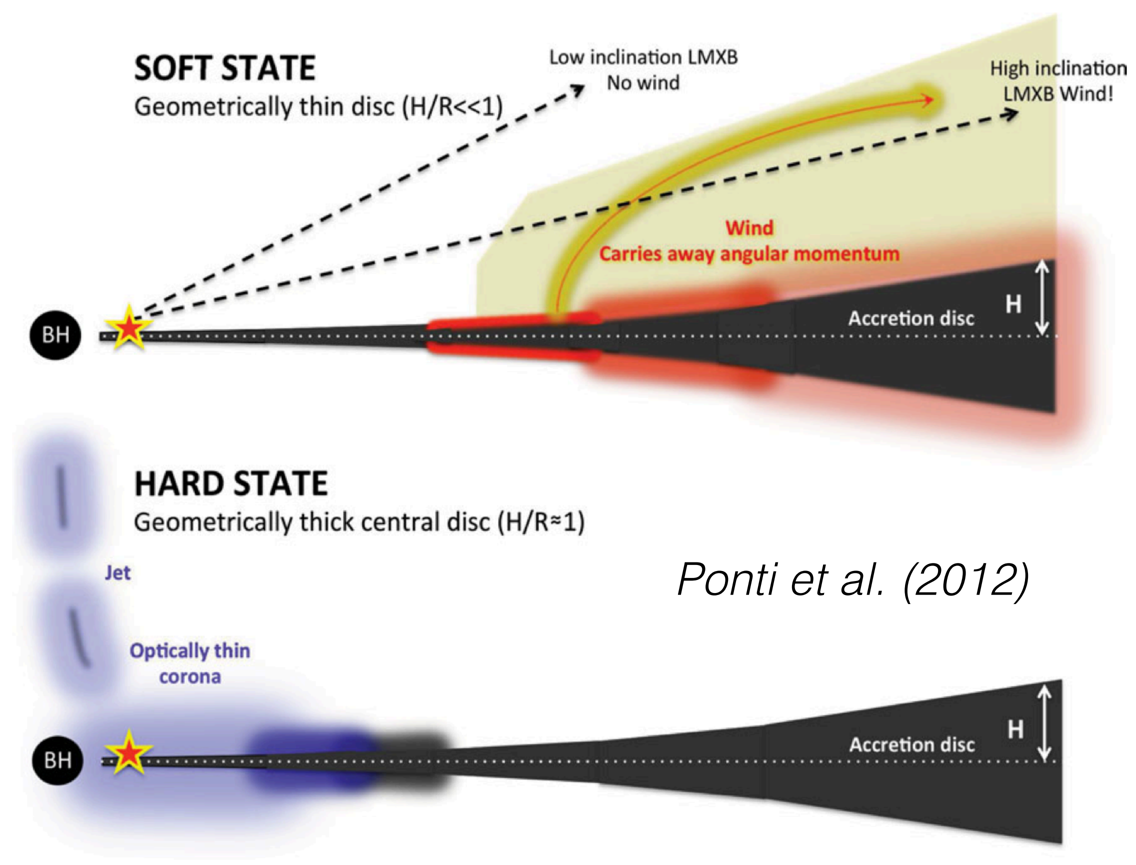
Optical:
Flares, Disk emission lines

Gamma-rays:
5x brighter than radio PSR

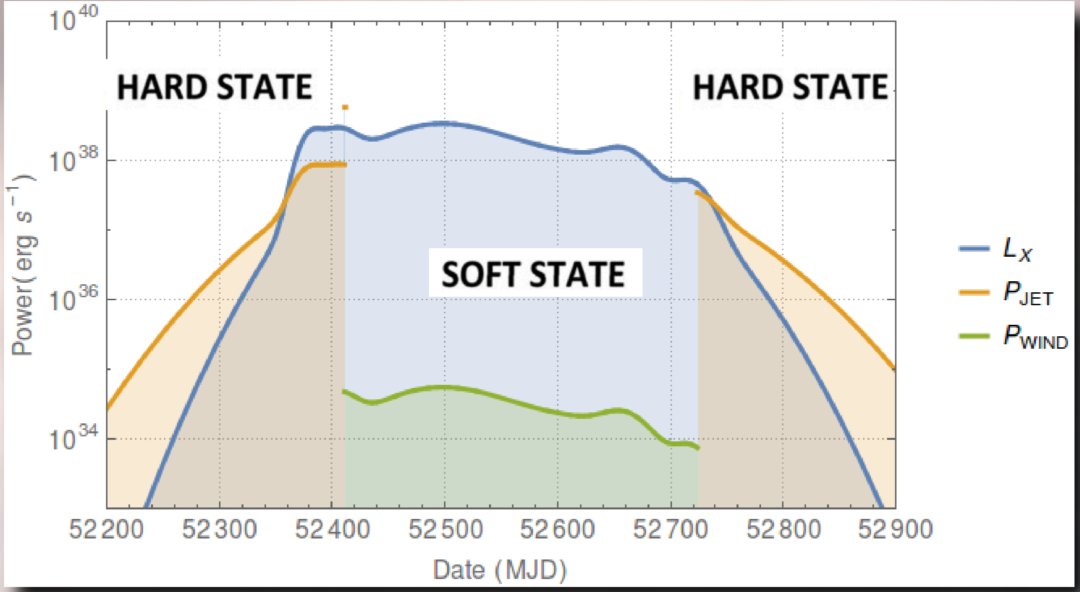
Radio:
Not pulsed
Variable jet emission



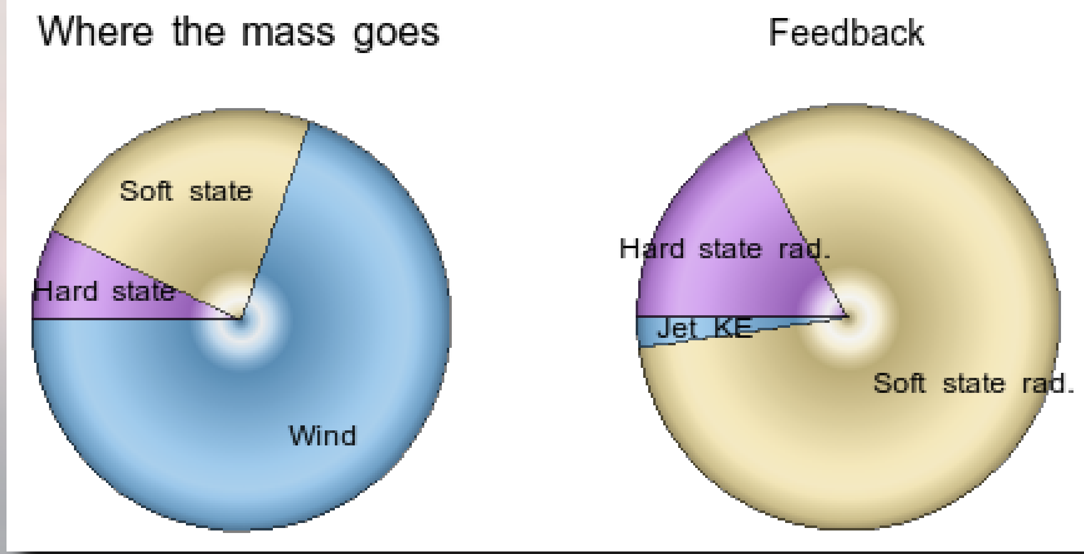
tracking the matter

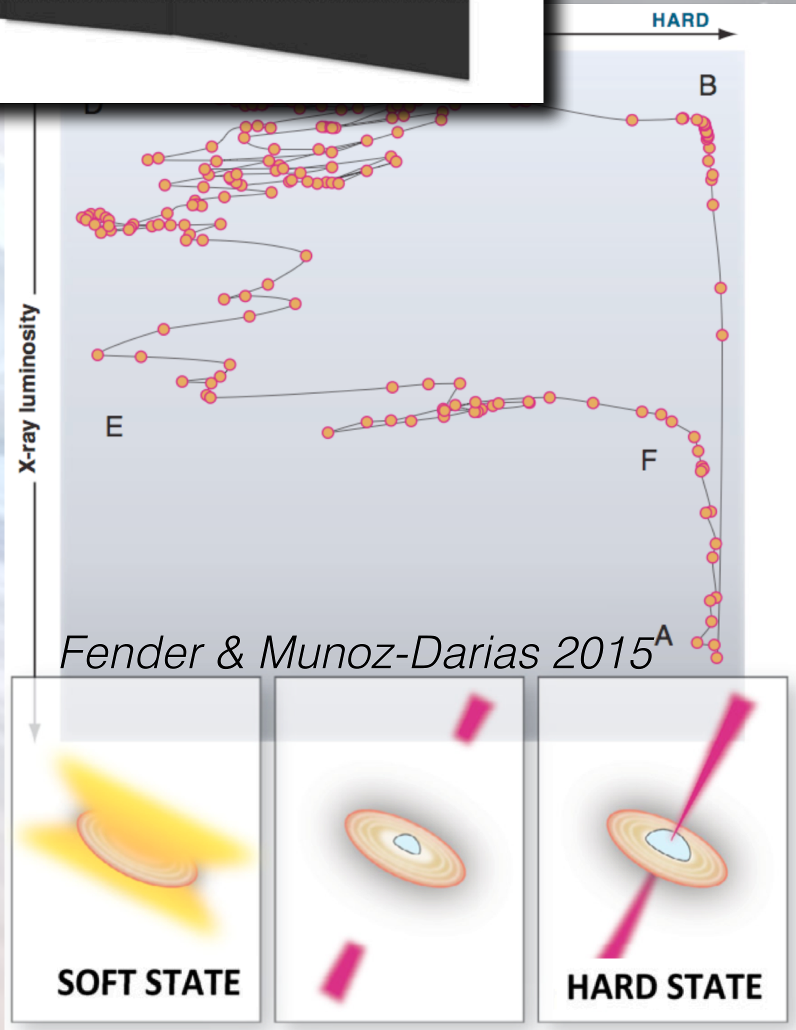


Ponti et al. (2012)



Fender & Munoz-Darias 2015





Fender & Munoz-Darias 2015

tracking the matter

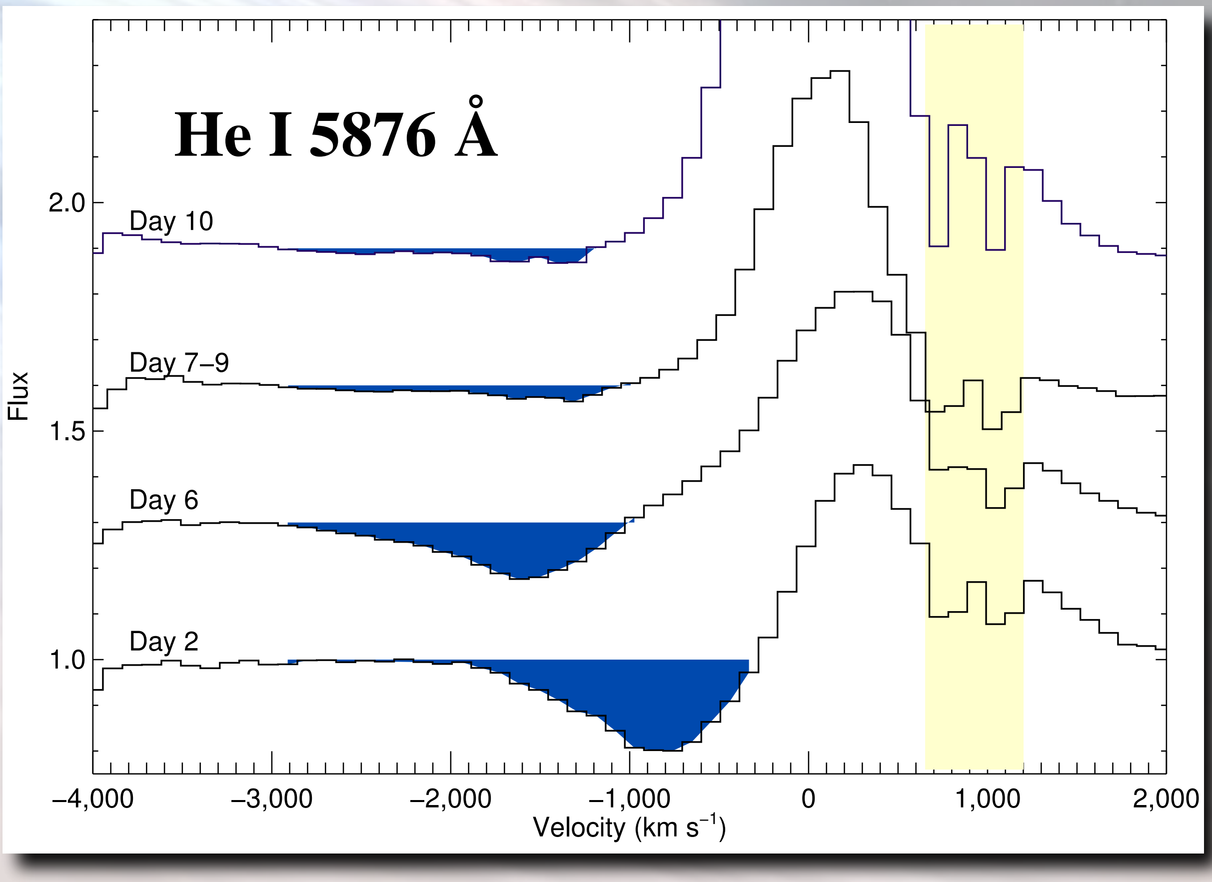
2015: extremely luminous outburst from the nearby BH V404 Cygni

short (15 days)
extreme (from 20 mCrab to 60 Crab)
reach (~50 papers - inc. 3 Nature)

P Cygni profile in 12 emission lines

—> high-velocity massive wind

Munoz-Darias et al. 2016



tracking the matter

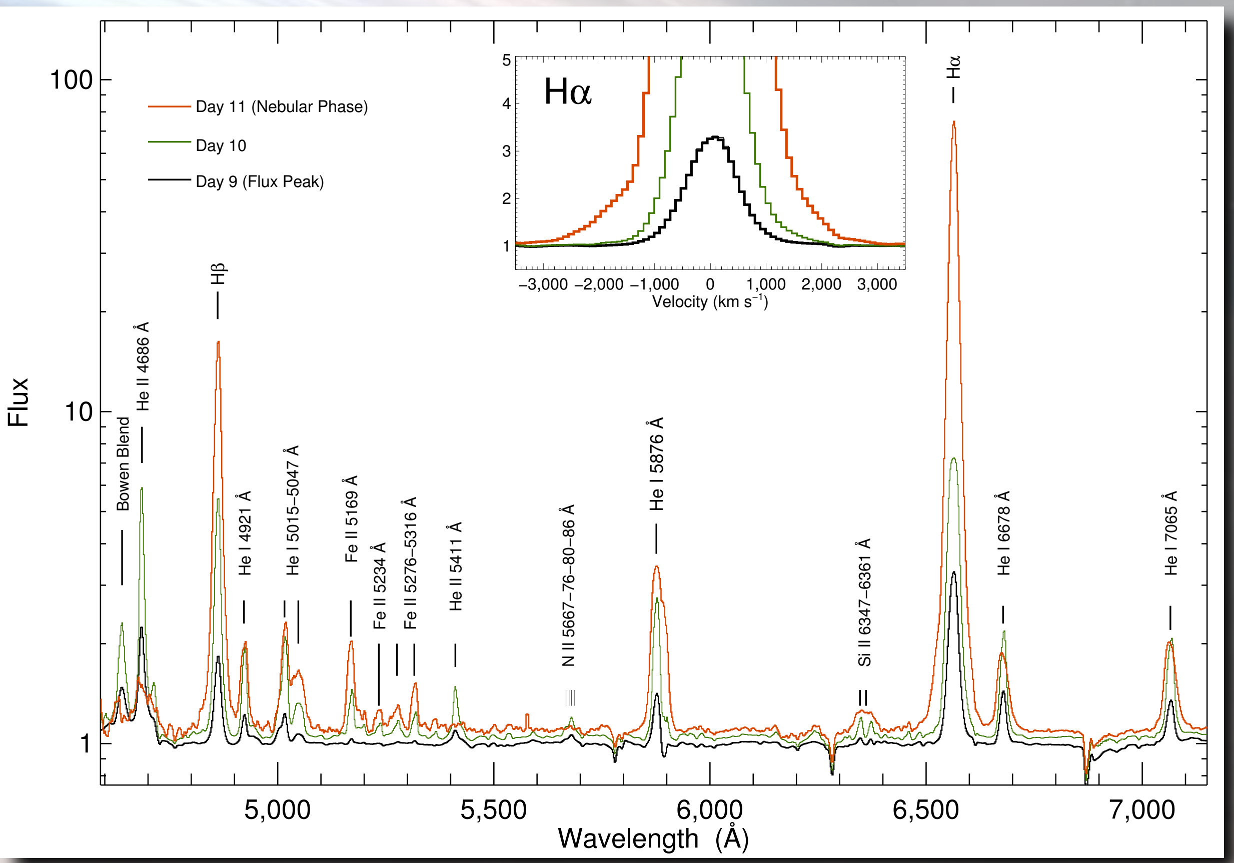
2015: extremely luminous outburst from the nearby BH V404 Cygni

short (15 days)
extreme (from 20 mCrab to 60 Crab)
reach (~50 papers - inc. 3 Nature)

followed by broad Balmer lines (up to 3000 km/s)

—> short-lived nebular phase

Munoz-Darias et al. 2016



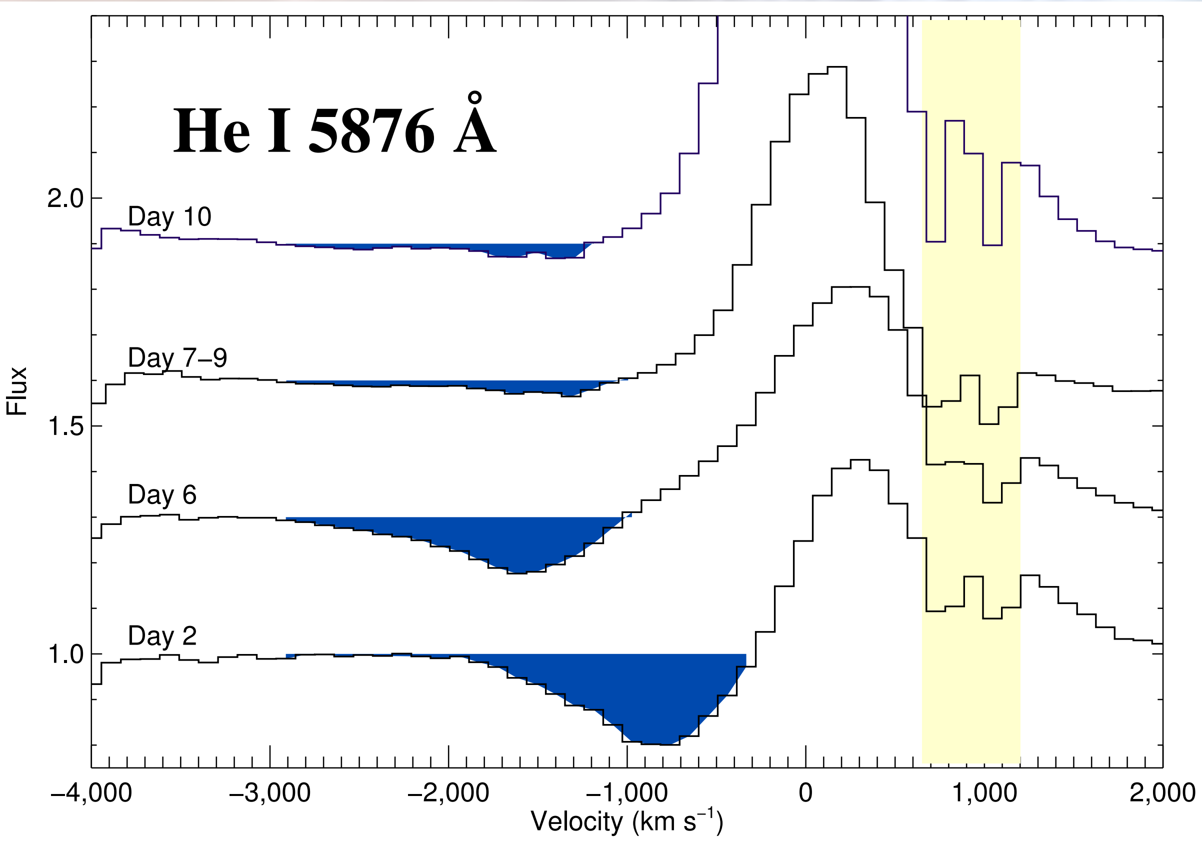
tracking the matter

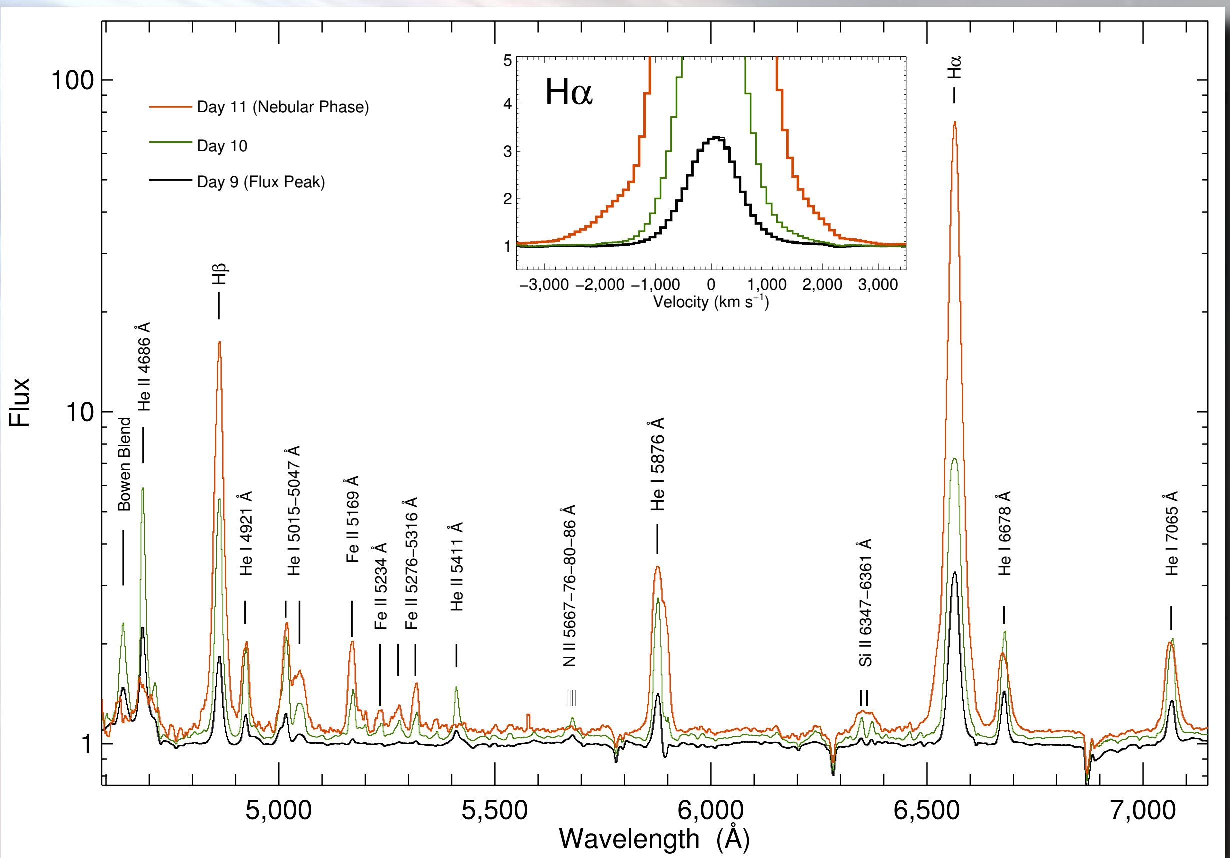
Wind velocity (V_T~1.5–3 x 10^3 km s^{-1})

(escape velocity at 0.5—2 light seconds)

Temperature < 3 x 10^4 K

Munoz-Darias et al. 2016





tracking the matter

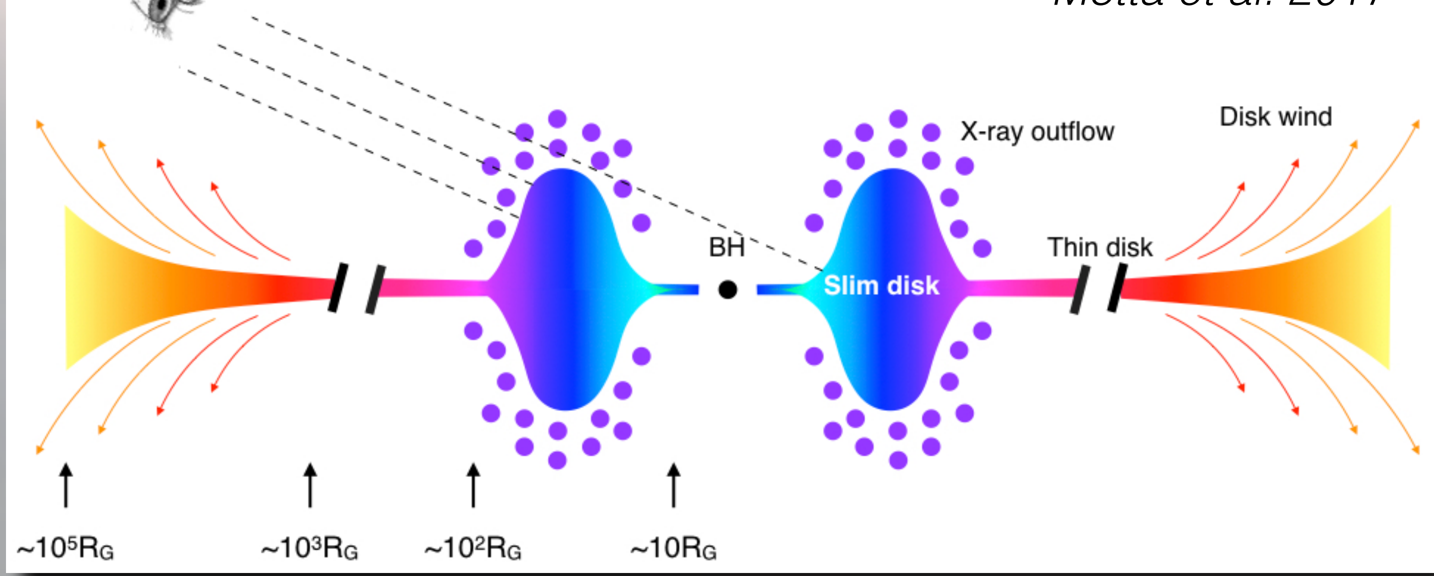
Matter transferred by the donor ~ 10^{-8} $M_\odot$

Disc contains M_{disc} ~ 10^{-5} $M_\odot$

Matter accreted onto the BH ~ 10^{-8} $M_\odot$

Matter expelled ~ 10^{-8} - 10^{-5} $M_\odot$ ← (transition time - calibrated from SNe)

Motta et al. 2017



Powerful thermal WIND

from the outer disc

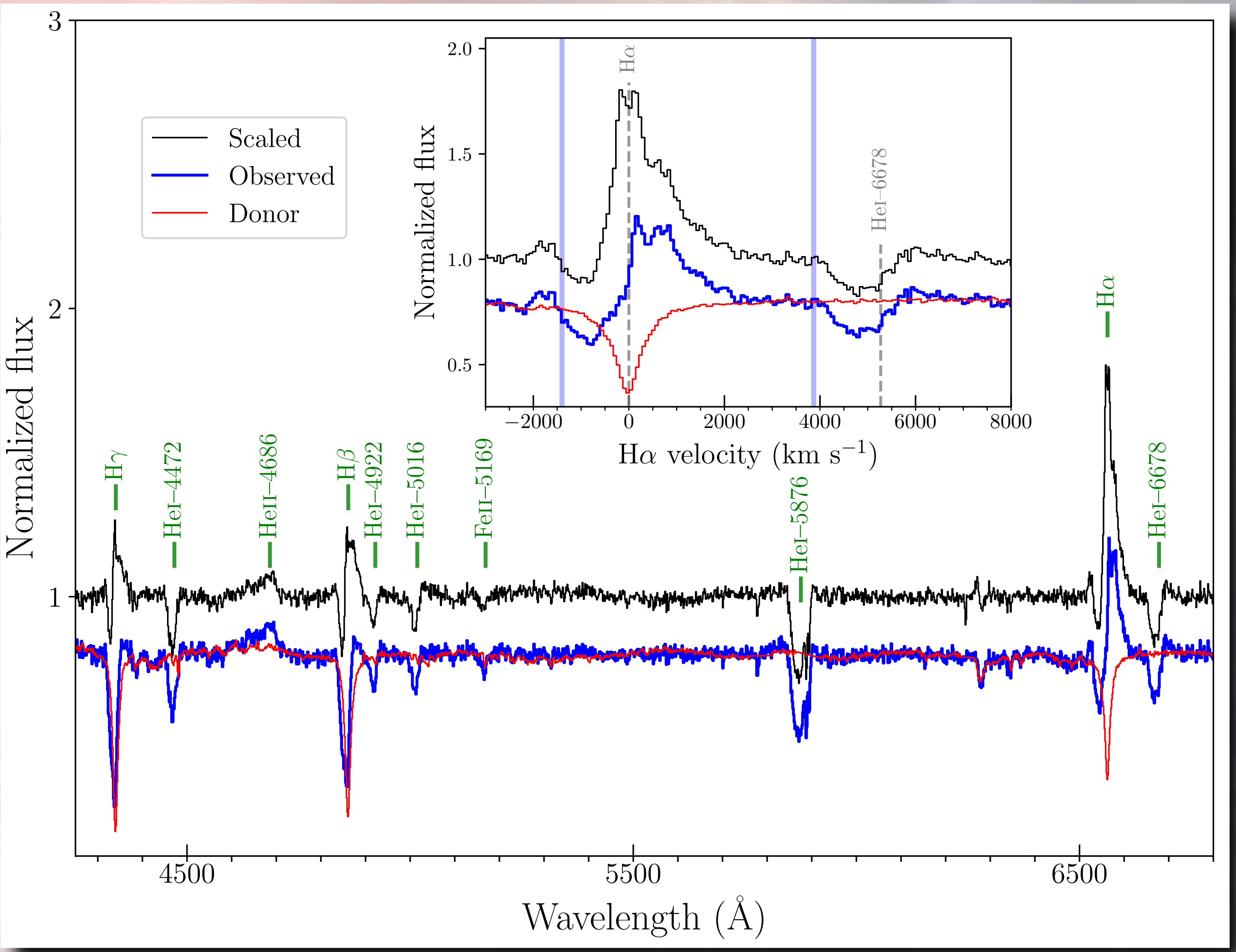
regulating the outburst

Munoz-Darias et al. 2016

several other objects e.g. V4641 Sagittari

The WIND from the outer disk is regulating the outburst

archival data



UBIQUITOUS?

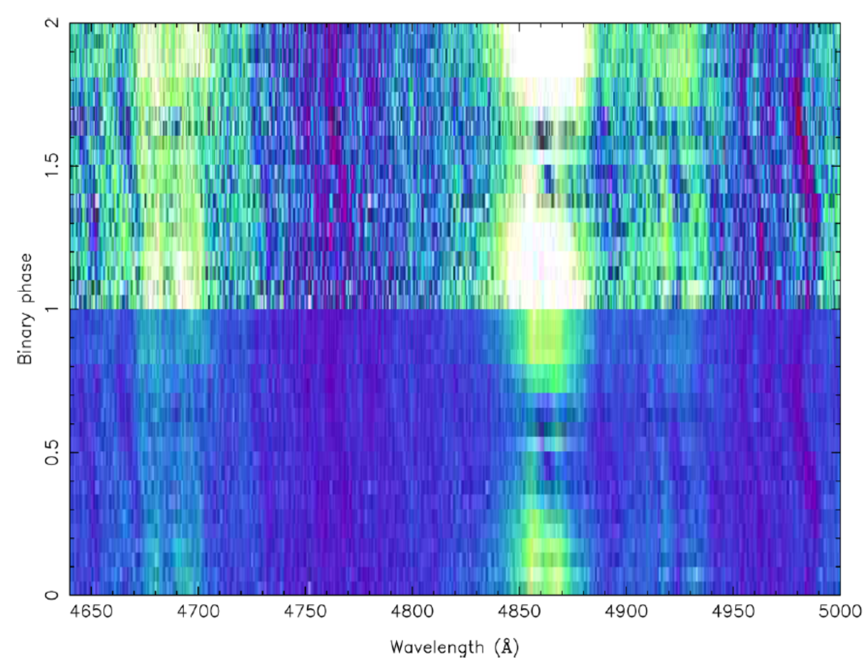
Munoz-Darias et al. 2017

this source was fainter...and was done with a 1.5m telescope

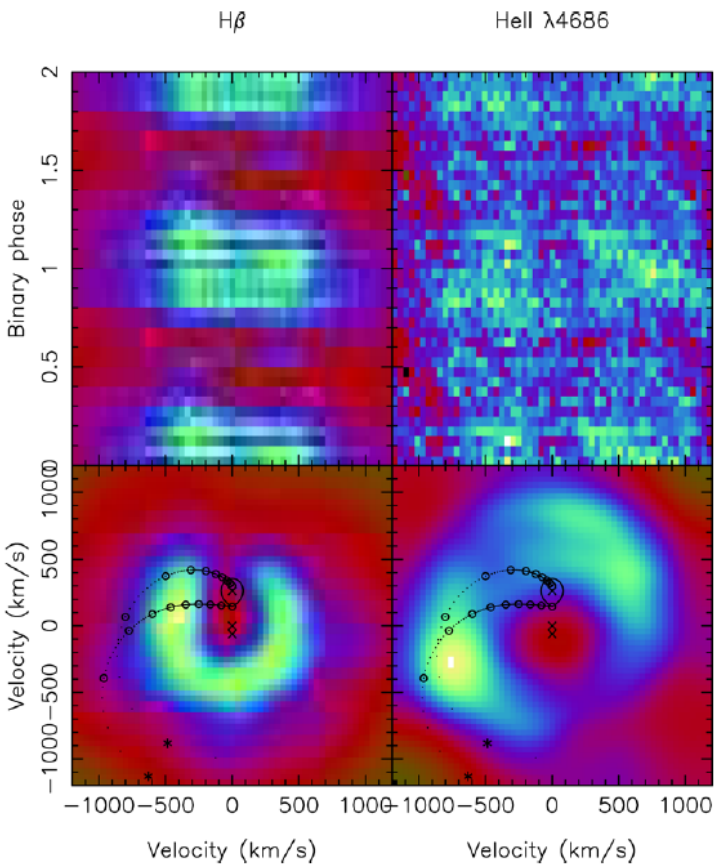
tracking the matter

transitional MSPs

Probes of the outflow



NTT/EFOSC2, SALT/RSS
de Martino+ 2014



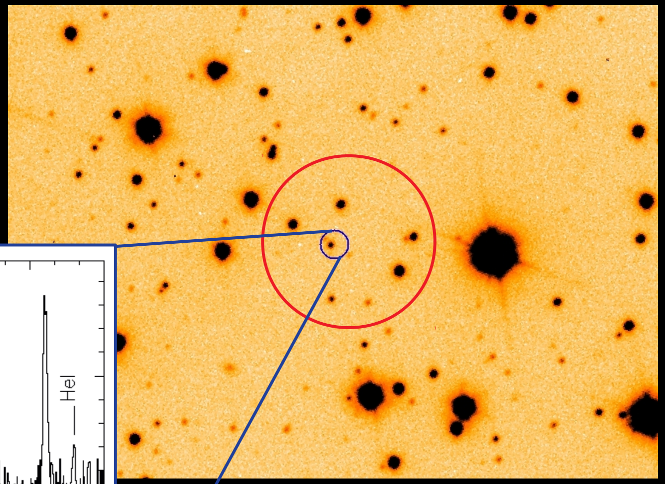
Emission lines disappear during part of the orbit

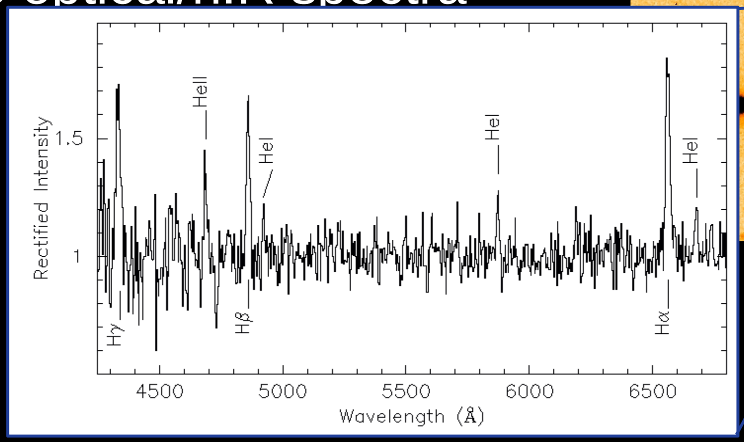
→ Evidence for matter expelled by the pulsar?

Identification & Classification

Spectroscopic identification of new X-ray pulsators and study of the signal origin (spin vs orbital)

1) Identification owing to the detection of emission lines in the optical/nIR spectra

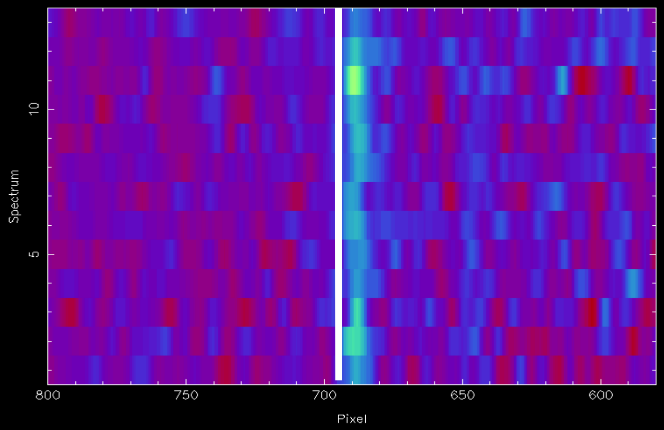




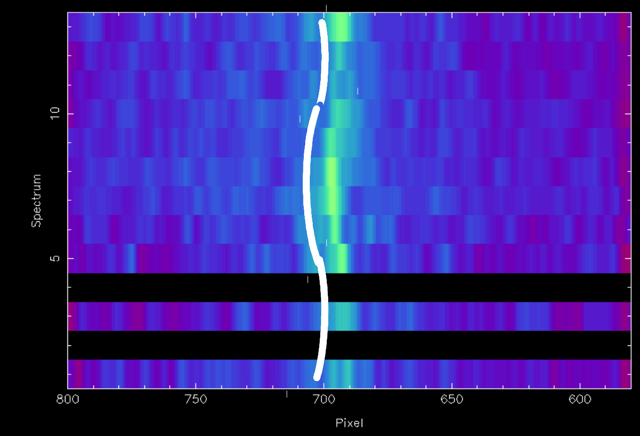
2) studying the evolution of the SED and assessing the origin of the X-ray flux modulation (spin vs orbital)

No line shift

X-ray period could be orbital or spin



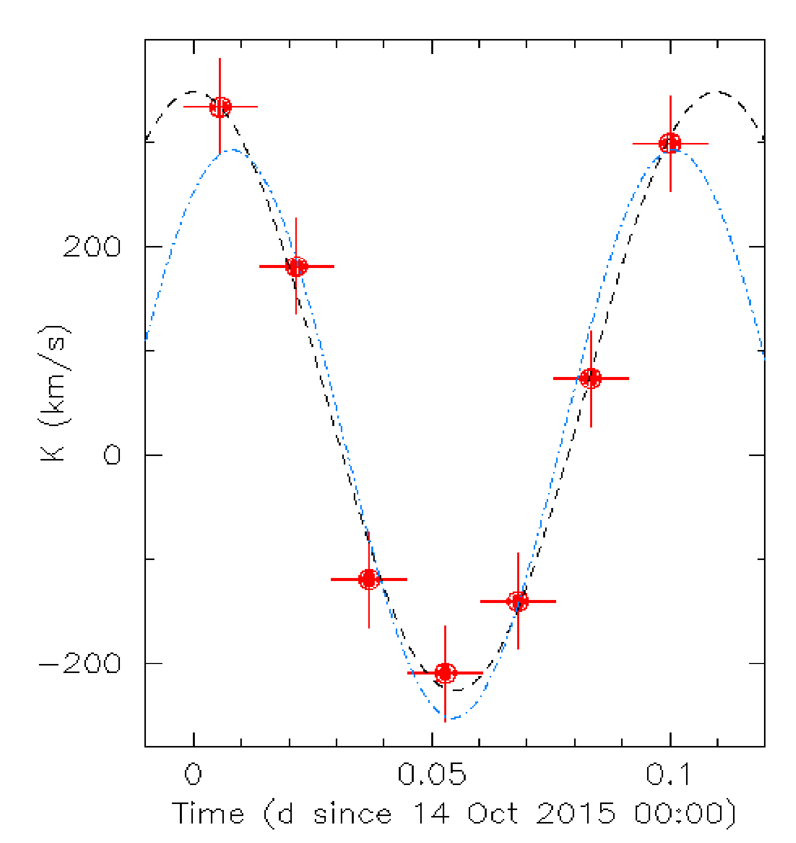
Line shift ~
X-ray period

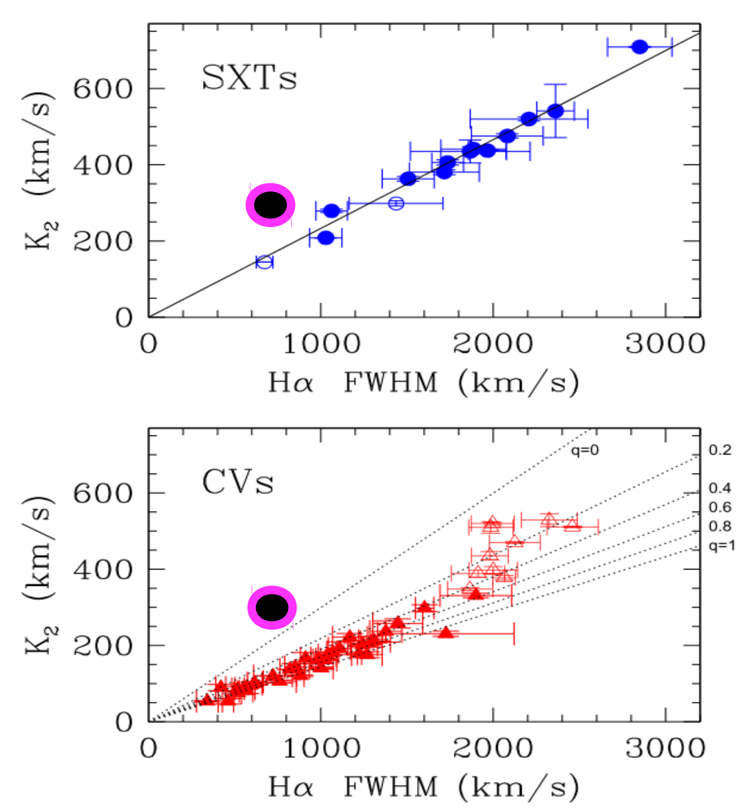


Identification & Classification

3) Classification of the binary system (if X-ray signal orbital origin)

Example:
P_x ~ 8000s
FWHM (Halpha): 15Å = 700 +\- 80 km/s
K = 290 +\- 40 km/s
EW = 41 Å





More consistent with a NS in a LMXB
(adapted from Casares 15, ApJ, 808, 80)

- **Black Hole-Transients**

- **1 outburst / semester**
- **outburst duration: few weeks - several months**
- **each spectrum: 200s - 1500s (up to 1.5 hr extreme cases)**

1 target

- 1 obs / week	4-40	full outburst long-term evolution
- 1 obs / day	3-7	initial stages (outer outflow)
- 1 obs / day	5-20	bright transition (wind onset)
- 1 obs / day	3-20	Ultra-luminous State (rare)
- 1-2 obs / week	5-20	decay transition (jet onset)

- **if short orbital period: 10-20 obs in 1 night**

over 5 years:

- **MINIMUM = 100 hr**
(very few goals on very bright targets)
- **OPTIMAL = 900 hr**
(all goals on all targets)
- **REALISTIC = 300 hr**

- **transitional MSPs**

- **3 transitions (in 5 years)**
- **each spectrum: 1 hr**

1 target

- **1-2 obs / 3-5 days**	**10-20**	**SED evolution**
- **15 obs / day**	**60**	**tomography, orbital, outflows**

over 5 years:

- **MINIMUM = 90 hr**
  (1 target, minimal coverage)
- **OPTIMAL = 312 hr**
  (3 targets, optimal coverage)

- **Accreting MSPs**

- **2-3 targets (in 5 years)**
- **outburst duration: 1-2 weeks**
- **each spectrum ~ 1 hr**

1 target

- **1 x 10**	**10**	**SED evolution, outflows**
- **5 x 5**	**25**	**tomography, orbital**

over 5 years:

- **MINIMUM = 35 hr**
  (1 target)
- **OPTIMAL = 100 hr**
  (3 targets)

- **New X-ray pulsators**

- **10 targets (in 5 years)**
- **1-5 candidates / target**
- **each spectrum: 5 min - 1.5 hr**

1 target

- 2-4 hr x 5	10-20	identification
- 4hr x 5	20	classification
- 3-8hr x 5	15-40	orbital

over 5 years:

- **MINIMUM = 40 nights**
- **OPTIMAL = 65 nights**

(assuming follow up for all 10 targets / year)

- **Z-source**

- **very rare: < 1 target / 5 year**
- **each spectrum: < 2 hr**
  - **1-2 obs / day   < 25   rise (Z phase)**
  - **2 obs / week   < 25   decay**

- **MINIMUM = ?**
- **MAXIMUM = 50 hours   (over 5 years)**

- **High-mass XBs**

- **1-2 outbursts / year**
- **each spectrum: 900 s**
  - **5 obs   1.25h**

1 target

- **OPTIMAL = 10 hr   (8 targets)   (over 5 years)**

- **NS transients**

- **1 outburst / year**
- **each outburst duration: ~ 1 month**
- **each spectrum: ~3 hours**

1 target

- **2 obs / week 30**

- **OPTIMAL = 150 hours** **(5 targets)** **(over 5 years)**

- **Magnetars**

(à la SWIFT J195509+261406)

- **very rare: 1 target / 5 year**
- **activity phase: a few days**

- **OPTIMAL = 10 hr** **(over 5 years)**

WG3

20 members (Italy, Finland)
~25 ideas/proposals received

Black Hole-Transients
Accreting Millisecond Pulsars
New Transient X-ray pulsators
Transitional Millisecond Pulsars
Neutron-Star Transients
Z-sources
Magnetars
High-mass X-ray Binaries
Ultra-luminous X-ray Sources

over 5 years:

- **MINIMUM = 750 hr**
- **OPTIMAL = 1600 hr**

The importance of OIR spectroscopy in the Universe

SOXS in 5 years CAN (for many new XBs & friends)

- **Systematically measure the mass function in outburst**
  - **Detect and study outflows (jets and winds)**
- **Provide excellent spectra to track the formation and evolution of various components**
  - **Provide Doppler tomography**
- **Identify and Classify unknown objects**