Modelling wind signatures in the OIR spectrum of XRBs

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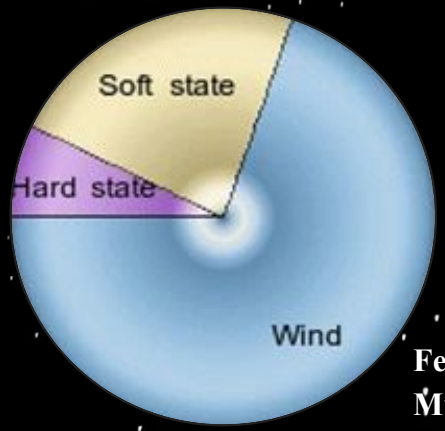
James Matthews

MQW XI

Image Credit: DESY, Science Communication Lab

Mass loss via winds

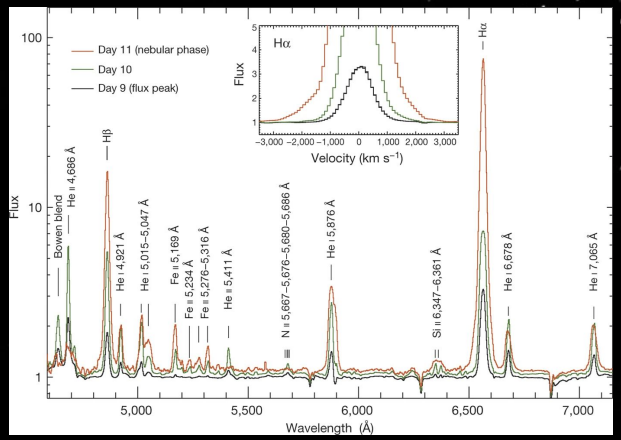
Scaling arguments



Fender &
Muñoz-Darias, 2016

$$\dot{M}_{wind} \sim \dot{M}_{acc}$$

Observations



V404 Cygni;
Muñoz-Darias+
2016

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Mass loss via winds

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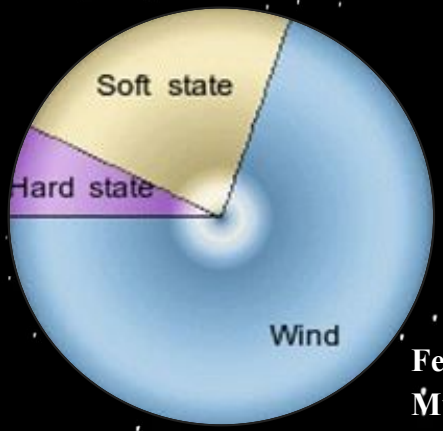


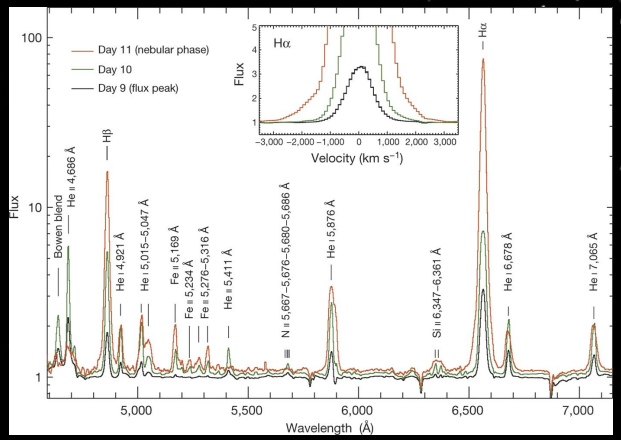
Fender & Muñoz-Darias, 2016

$$\dot{M}_{wind} \sim \dot{M}_{acc}$$

Winds are a key ingredient of accretion

1) Can we model them?
2) Do models predict such high mass outflow rates?

Observations



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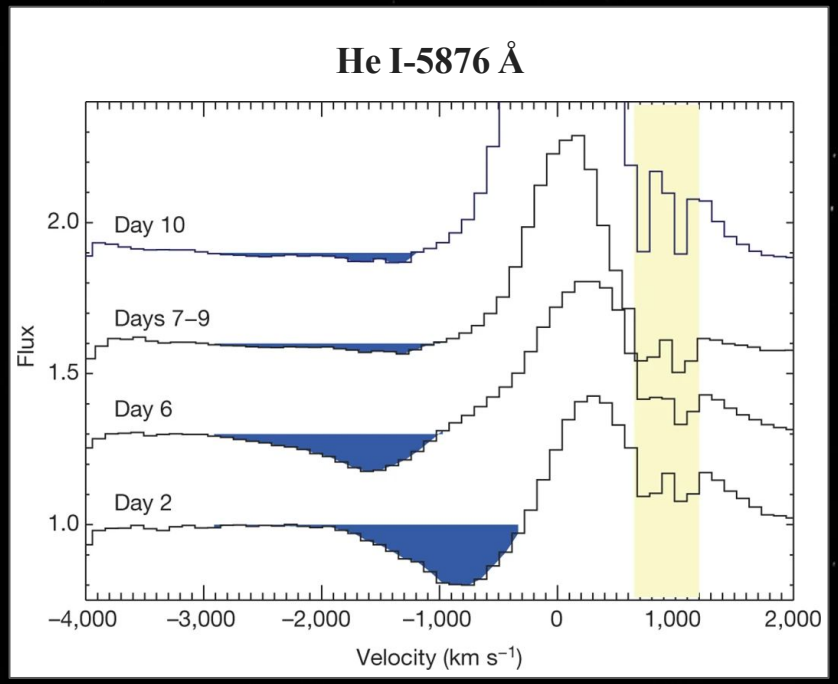
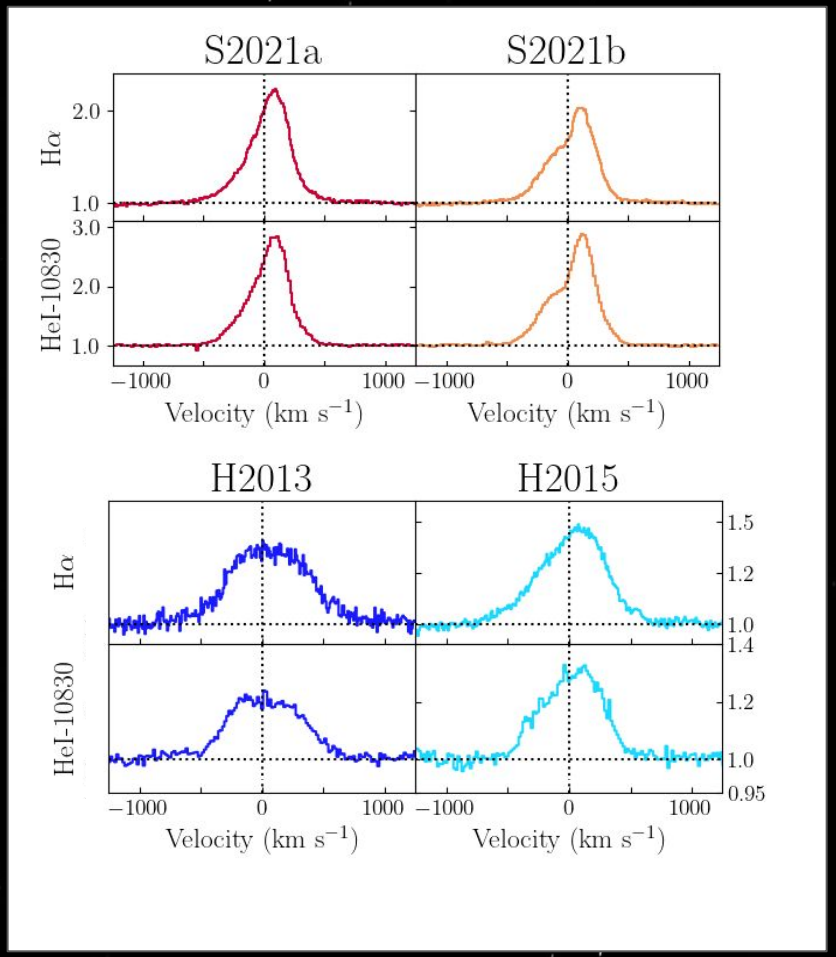
Wind spectral signatures in the OIR



V404 Cyg, Muñoz-Darias et al. 2016



GX 339-4, Ambrifi et al. 2025

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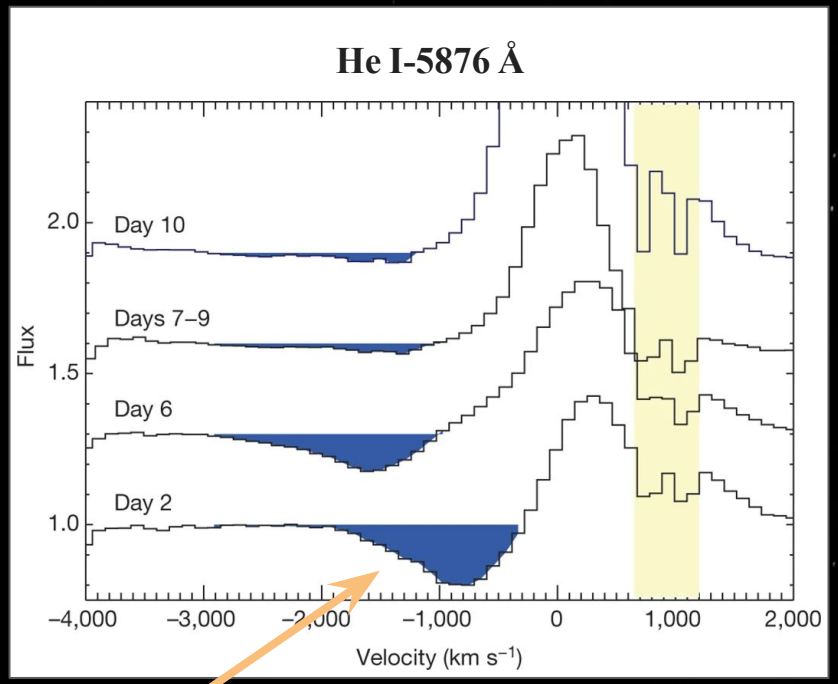
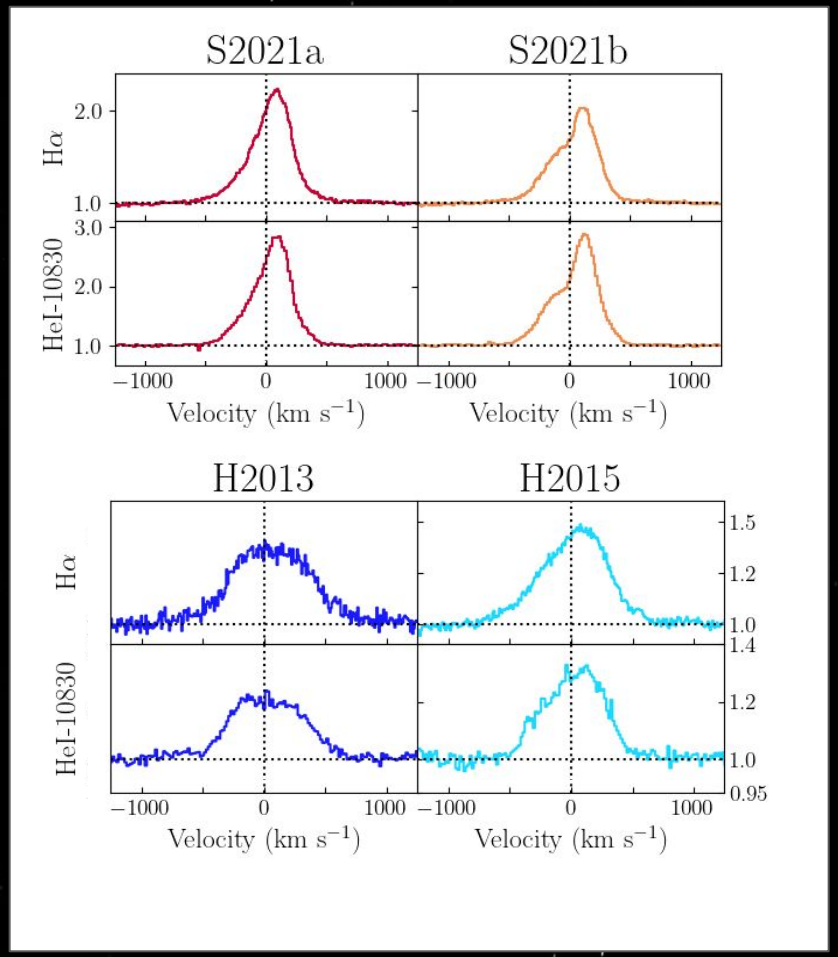


V404 Cyg, Muñoz-Darias et al. 2016

P-Cygni profiles



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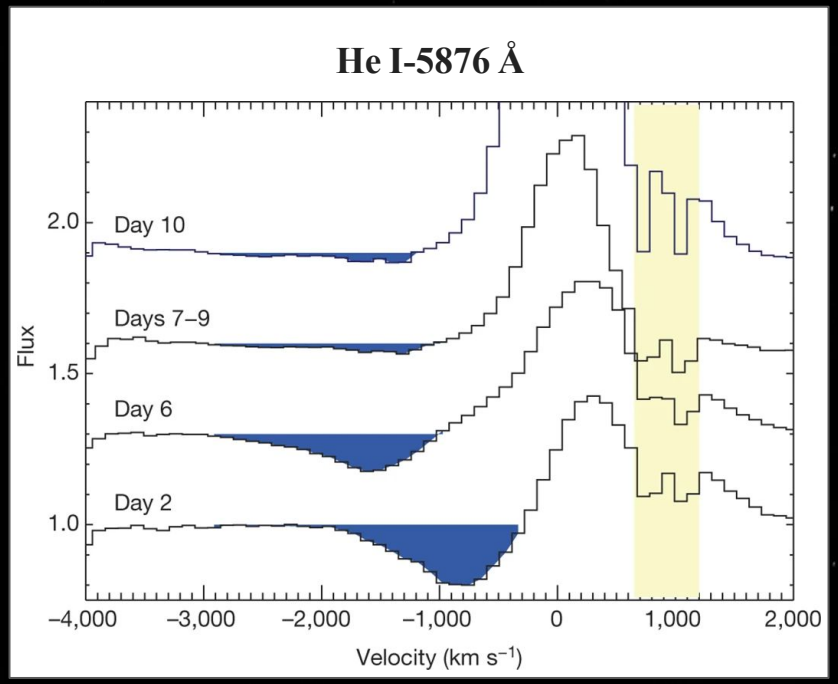

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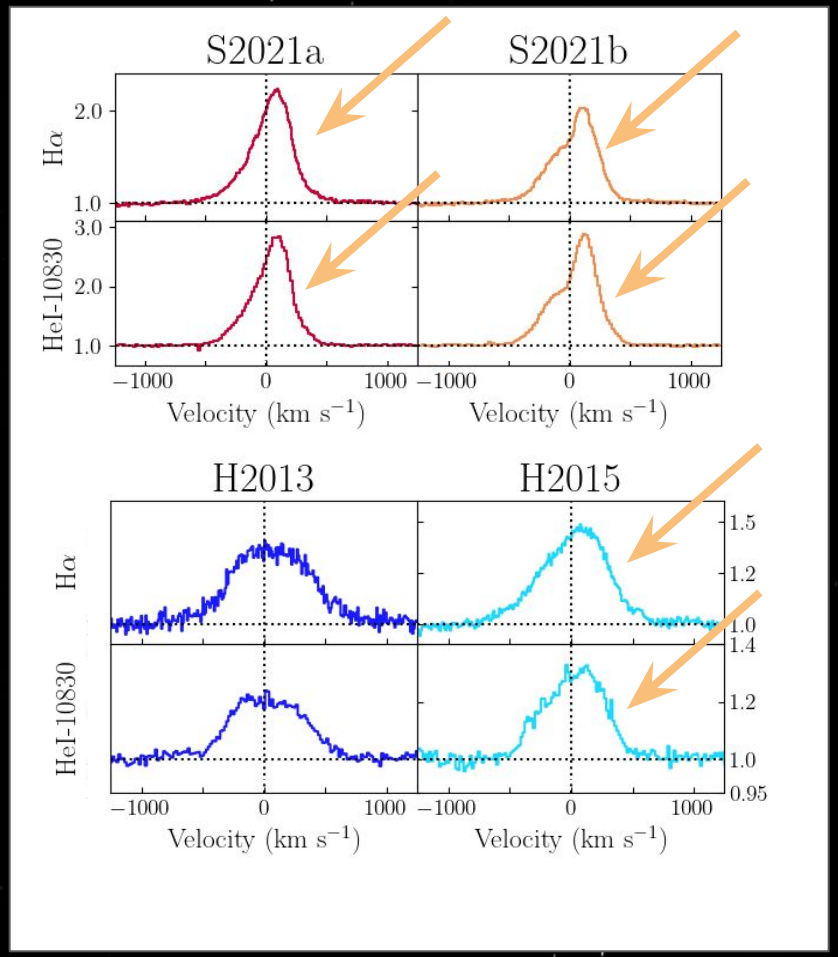
P-Cygni profiles
Asymmetric red-skewed lines



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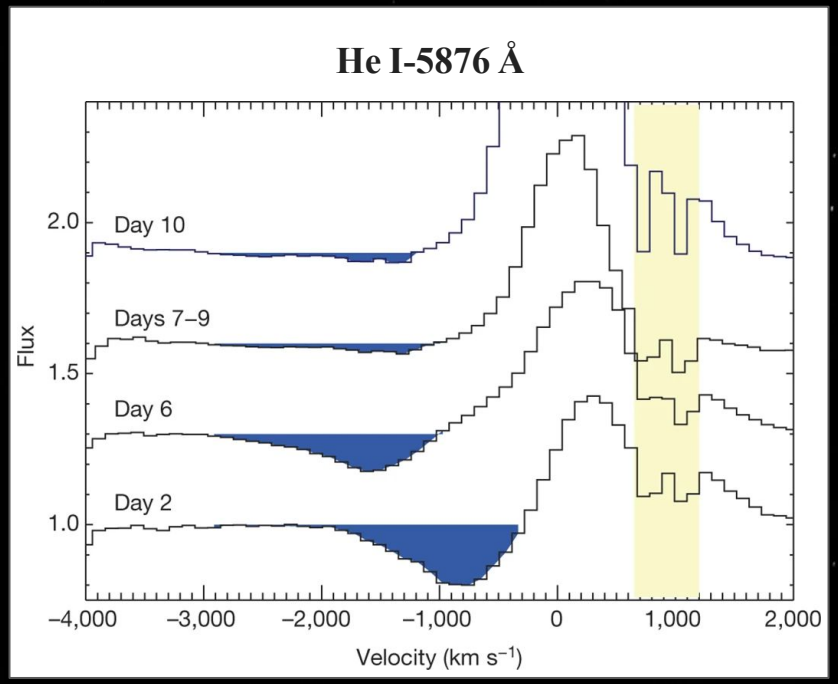

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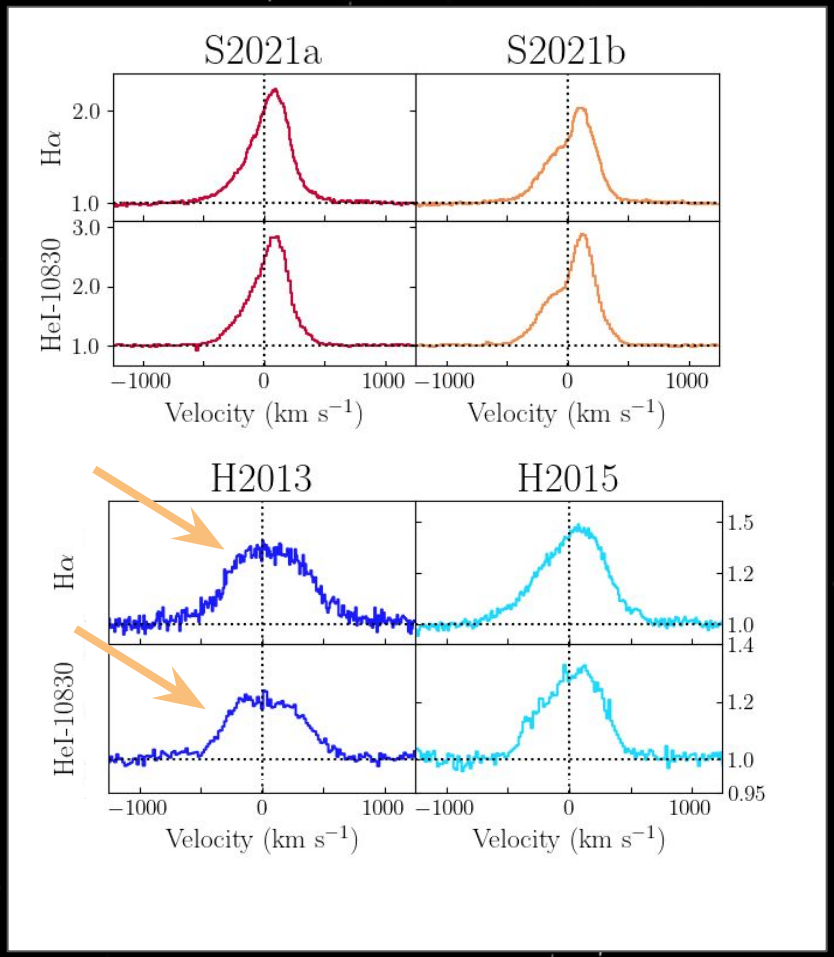

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P-Cygni profiles
Asymmetric red-skewed lines
Flat-top profiles

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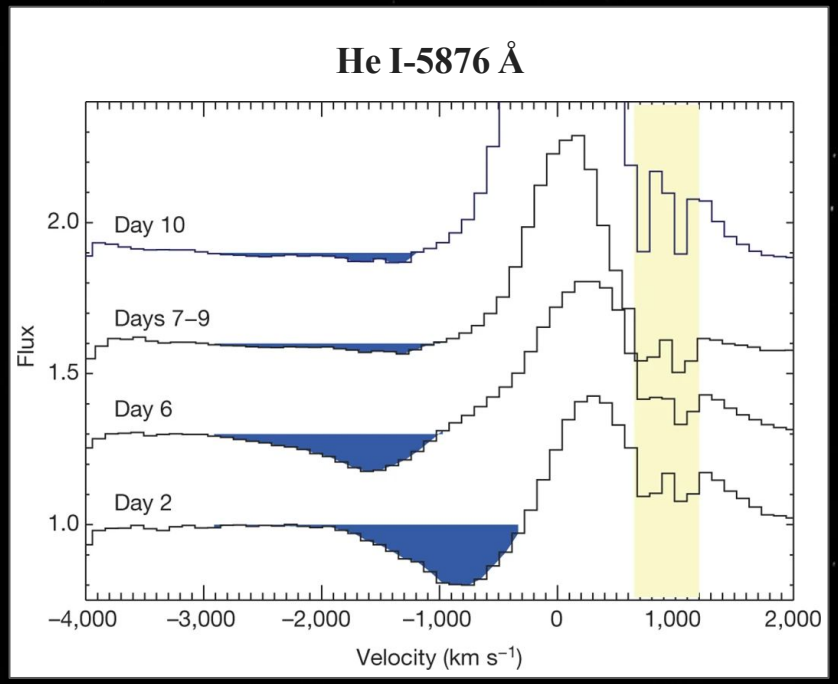
Wind spectral signatures in the OIR



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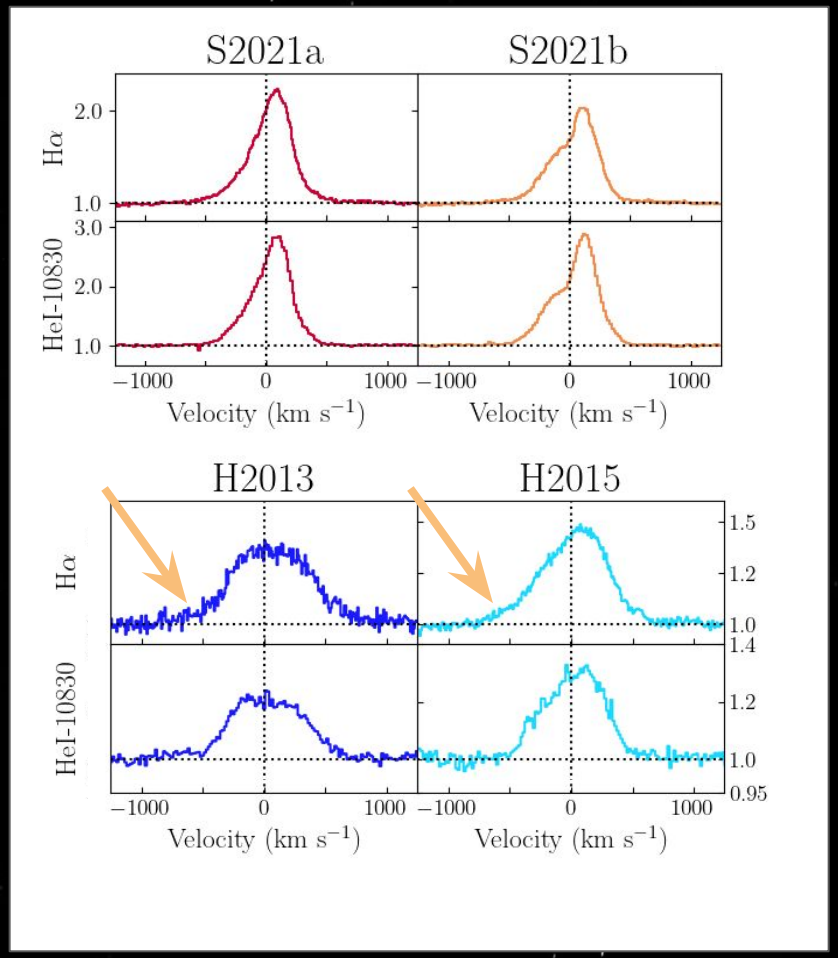
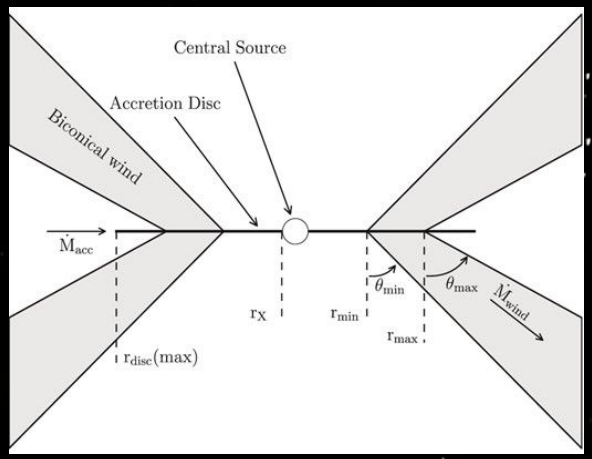


GX 339-4, Ambrifi et al. 2025

- P-Cygni profiles
- Asymmetric red-skewed lines
- Flat-top profiles
- Broad line wings

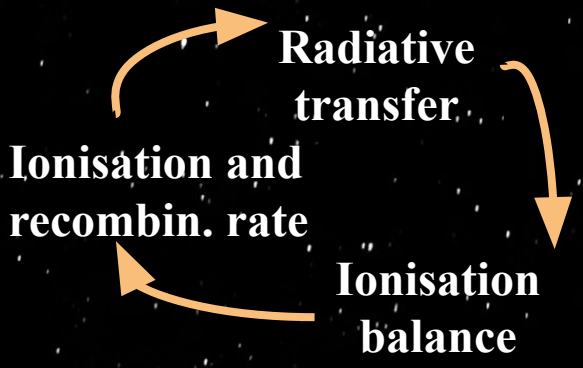
Simulating OIR wind signatures with SIROCCO

Parametric approach

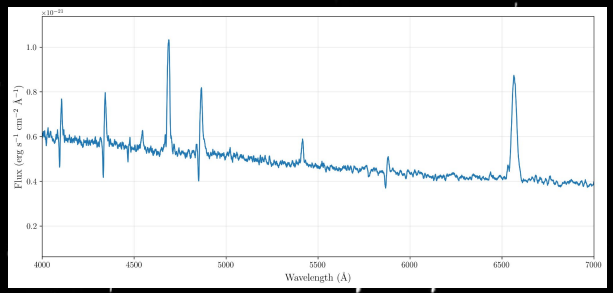


Shlosman & Vitello, 1993

Ionisation cycles



Spectrum synthesis



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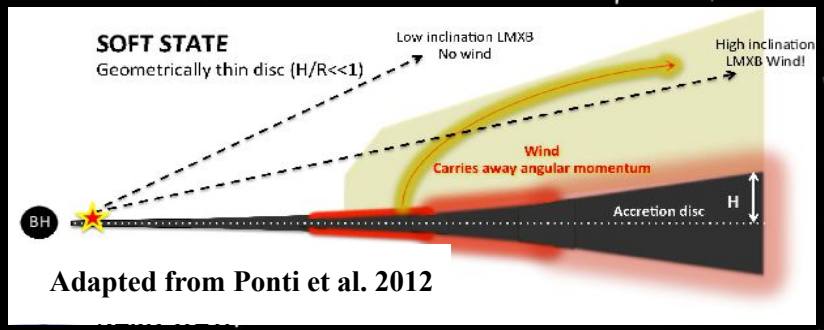
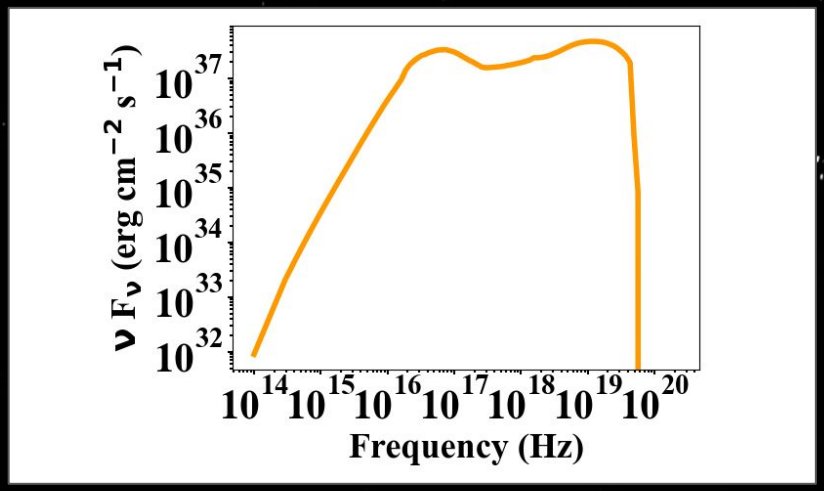
Simulating OIR wind signatures with SIROCCO

Geometry: equatorial



Adapted from Ponti et al. 2012

Irradiating spectrum: MAXI J1820+070



Typical velocities

(a) OIR wind detections

LMXB	Object	i (°)	P (h)	Wind features	Vel. (km s^{-1})[a]
GX13+1	NS	60–80	589	P-Cygni	~2400
V404 Cyg	BH	60–70	155.3	P-Cygni Broad wings	1500–3000 ~3000
V4641 Sgr	BH	60–70	67.6	P-Cygni Broad wings	900–1600 ~3000
Swift J1357.2-0933	BH	≳80	2.8	P-Cygni	1600–4000
MAXI J1820+070	BH	67–81	16.4	P-Cygni Broad wings Blue-shifted abs.[b]	1200–1800 ~1800 1200–1800
Swift J1858.6-0814	NS	Dipping/eclipsing	21.8	P-Cygni	1700–2400
GRS1716-249	BH	?	?	P-Cygni Flat-top, asymmetries	~2000 -
MAXI J1803–298	BH	Dipping	7–8	P-Cygni	~1250
MAXI J1348–630	**BH**	**Mid-to-low**	**?**	**Broad wings** **Blue-shifted abs.** **Flat-top, asymmetries**	**1500–1700** **500–900** -

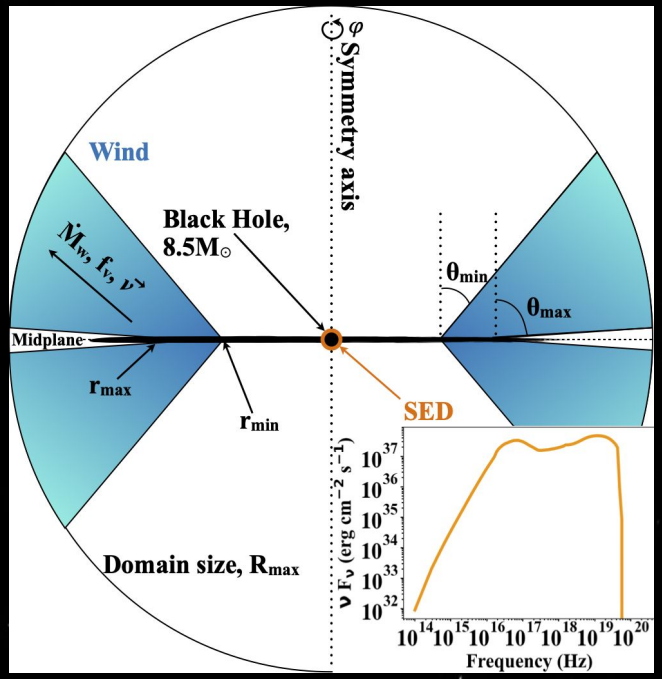
(b) Tentative OIR wind detections

LMXB	Object	i (°)	P (h)	Wind features	Vel.(km s^{-1})[a]
Sco X-1	NS	<40	18.9	P-Cygni	~2600
GRO J1655–40	BH	67–70	62.9	Flat-top, asymmetries	-
GX339–4	BH	37–78	42.2	Broad wings	?
Aql X-1	NS	23–53	18.7	Broad wings	800

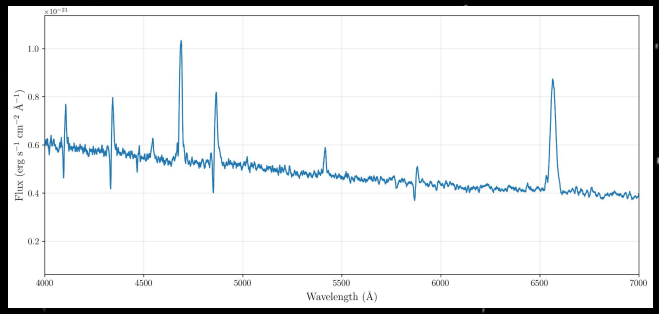
Adapted from Panizo-Espinar et al. 2022

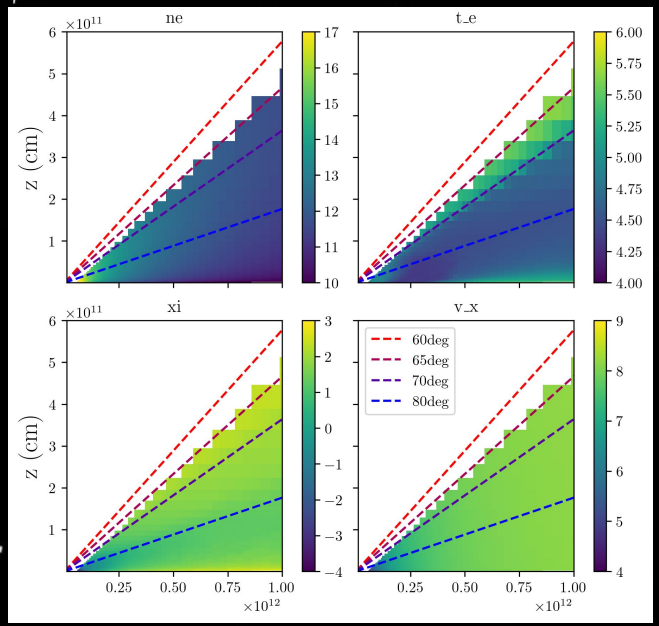
Simulating OIR wind signatures with SIROCCO

CAUTION
WORK IN PROGRESS



MCRT





Parameter	Grid Point Values
$\dot{M}_{\rm wind}$ ($\dot{M}_{Edd}$)	0.05, 0.17, 0.5, 1.7
log $f_{\rm V}$	0, −1, −2, −3

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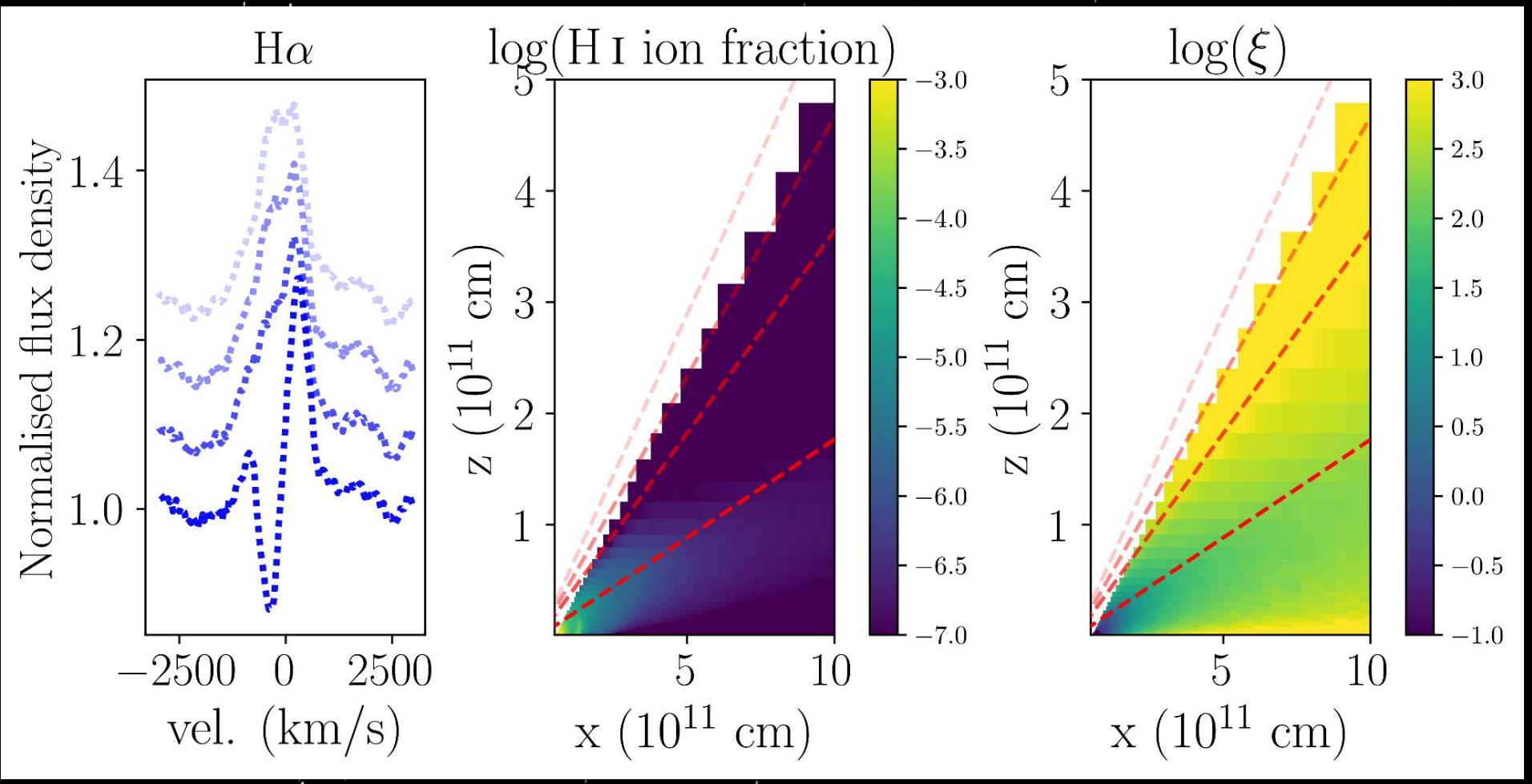
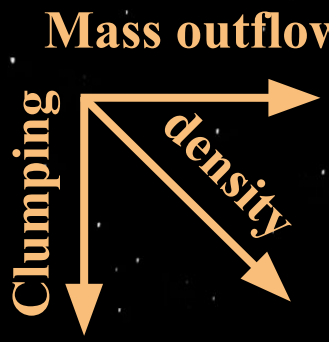
Results: P-Cygni profiles at high inclination



i = 80° i = 65°

i = 70° i = 60°

Optical results: need of extreme condition



❐ No P-Cygni
❐ P-Cygni

... Hα
— He I-5876

Optical results: need of extreme condition

Mass outflow rate

Clumping

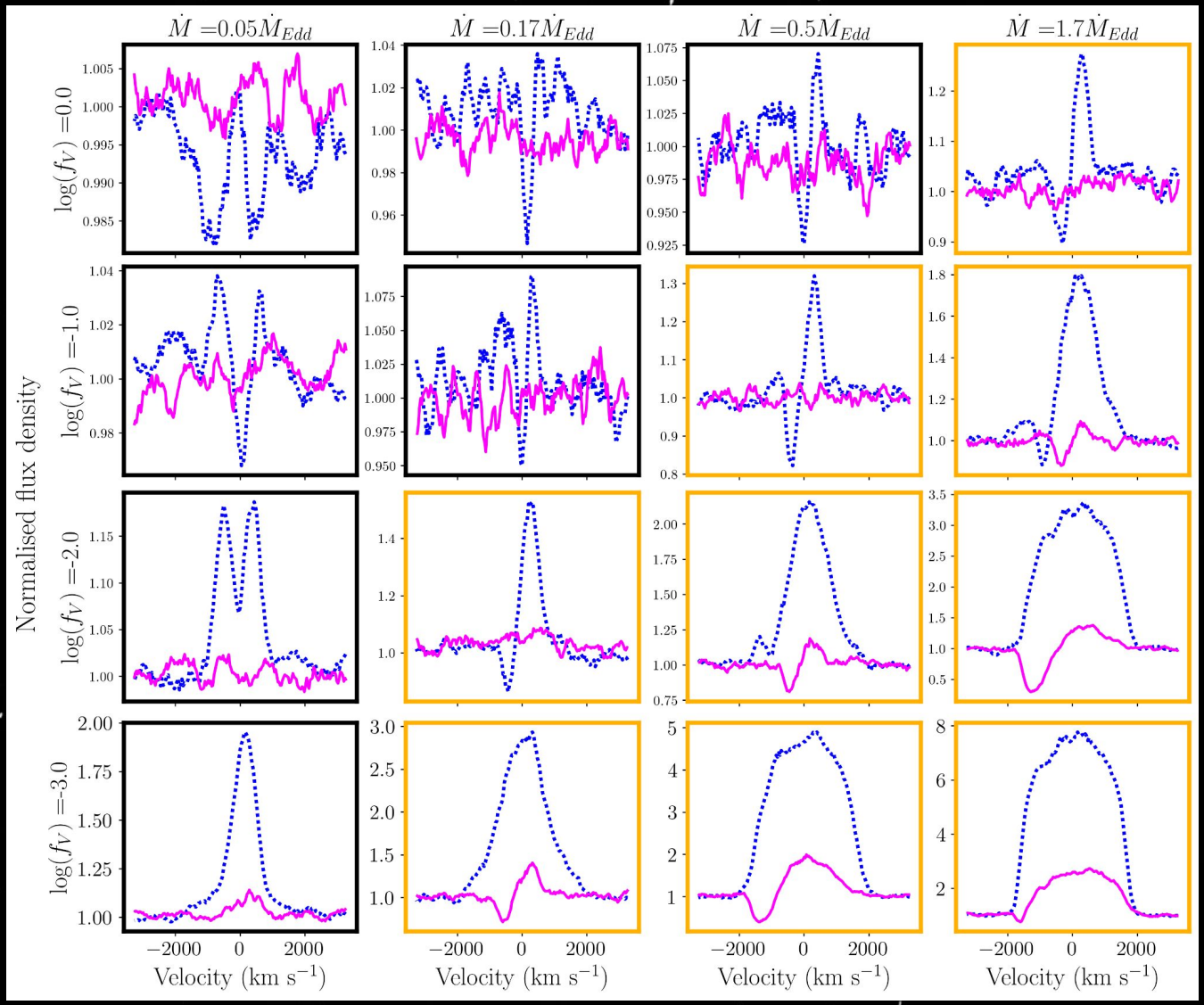
density

No P-Cygni

P-Cygni

Hα

He I-5876



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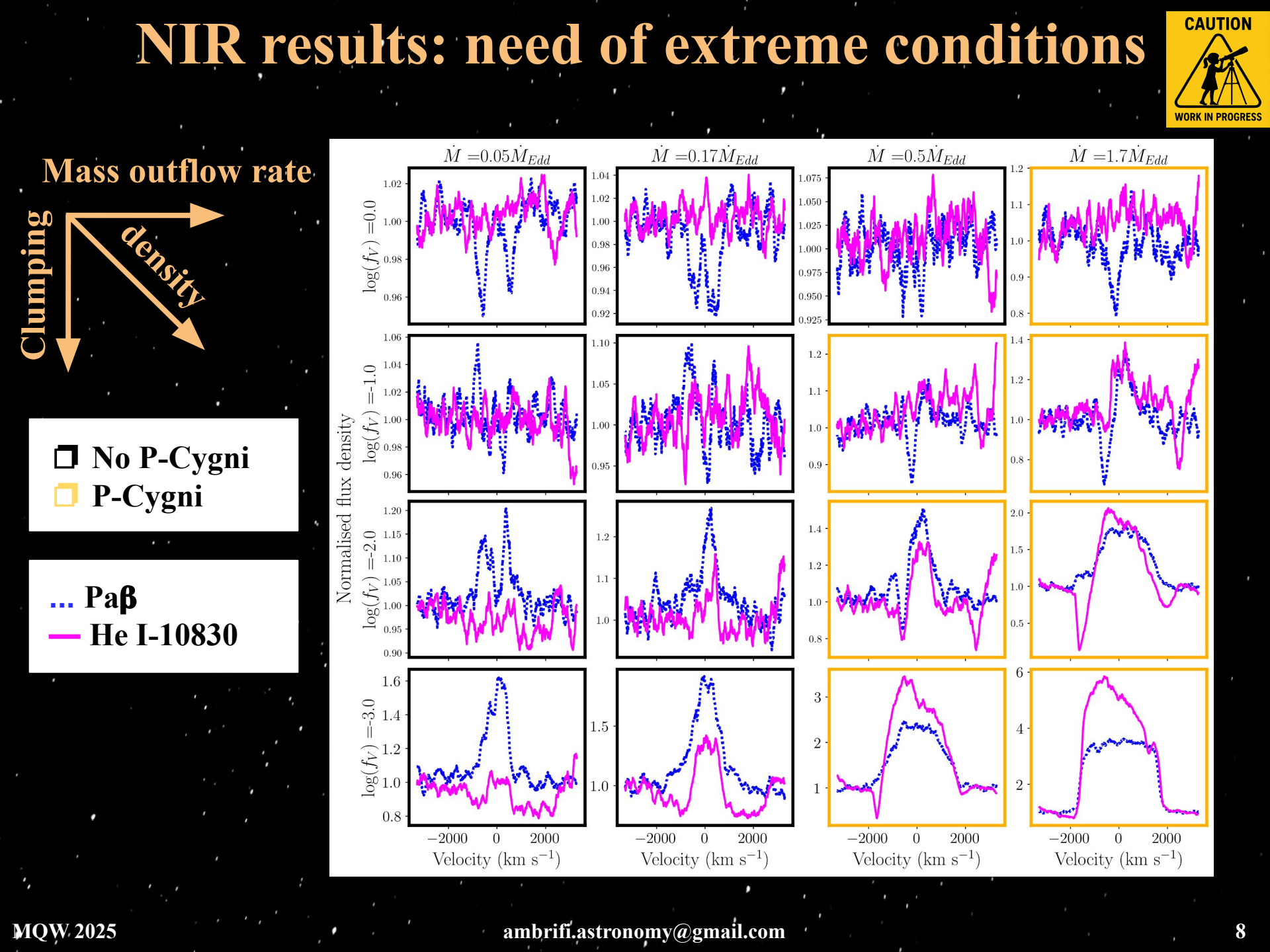
NIR results: need of extreme conditions



Mass outflow rate

Clumping

density

No P-Cygni

P-Cygni

Paβ

He I-10830

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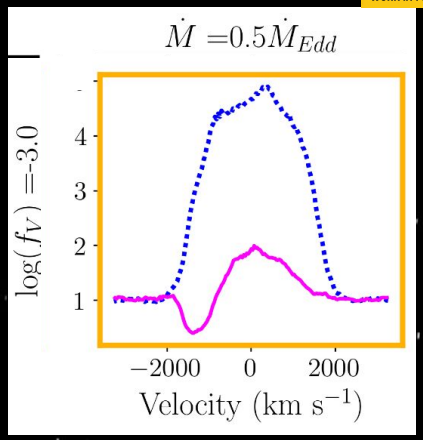
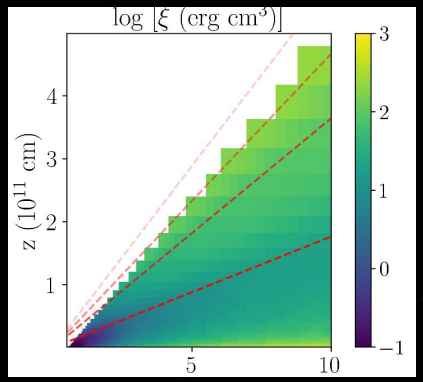
Implications

- High $\dot{M}_{wind}$ are needed to reproduce OIR wind signatures. Winds extract a significant amount of mass and angular momentum

- Low ξ reached in models reproducing wind features. Clumping is needed.

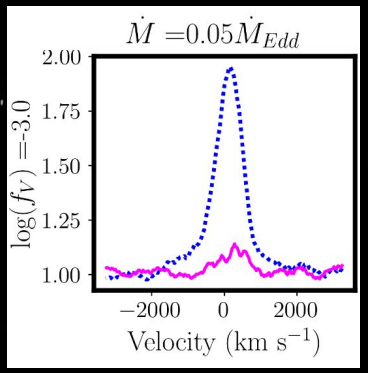
- Wind driving: combination of mechanisms?





Implications

- Weaker wind signatures can be reproduced at lower $\dot{M}$ and $i \rightarrow$ such features should be considered in observational studies



Take home messages

- OIR wind signatures can be reproduced, but extreme conditions ($\dot{M} \gtrsim 10\% \dot{M}_{Edd}$ and/or $f_v \lesssim 10\%$) are needed
- High $\dot{M}_{wind}$ indicates that winds can play a role in the accretion process
- Their clumpy structure has implications for the wind launching mechanism

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