Gabi A. Matzeu

PhD supervisor: Dr James Reeves

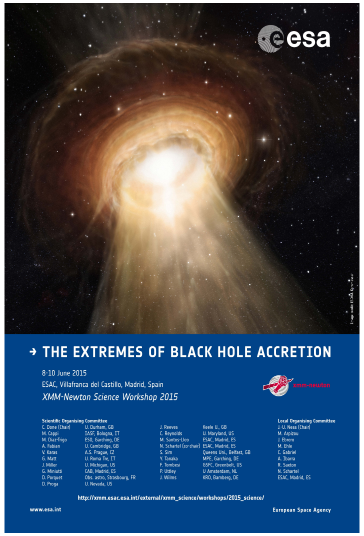
Collaborators - The PDS 456 team including: James Reeves, Emanuele Nardini, Valentina Braito, Michele Costa, Francesco Tombesi, Martin Ward, Paul O'Brien

Broad-band short term X-ray spectral variability of quasar PDS 456

Keele University

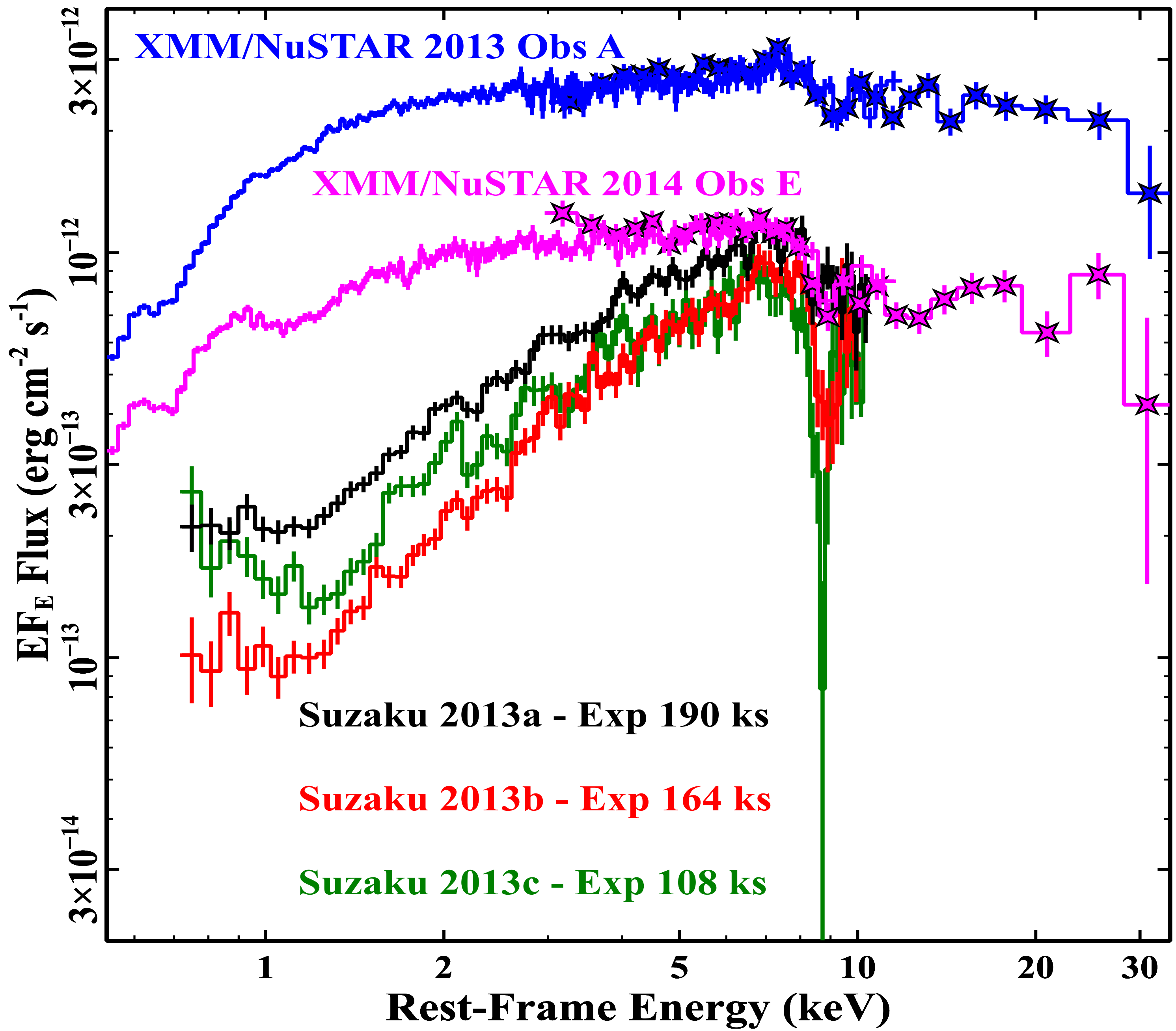
The Extremes of Black Hole Accretion : 8 – 10 June 2015

European Space Astronomy Centre (ESAC)
Villafranca del Castillo
Madrid

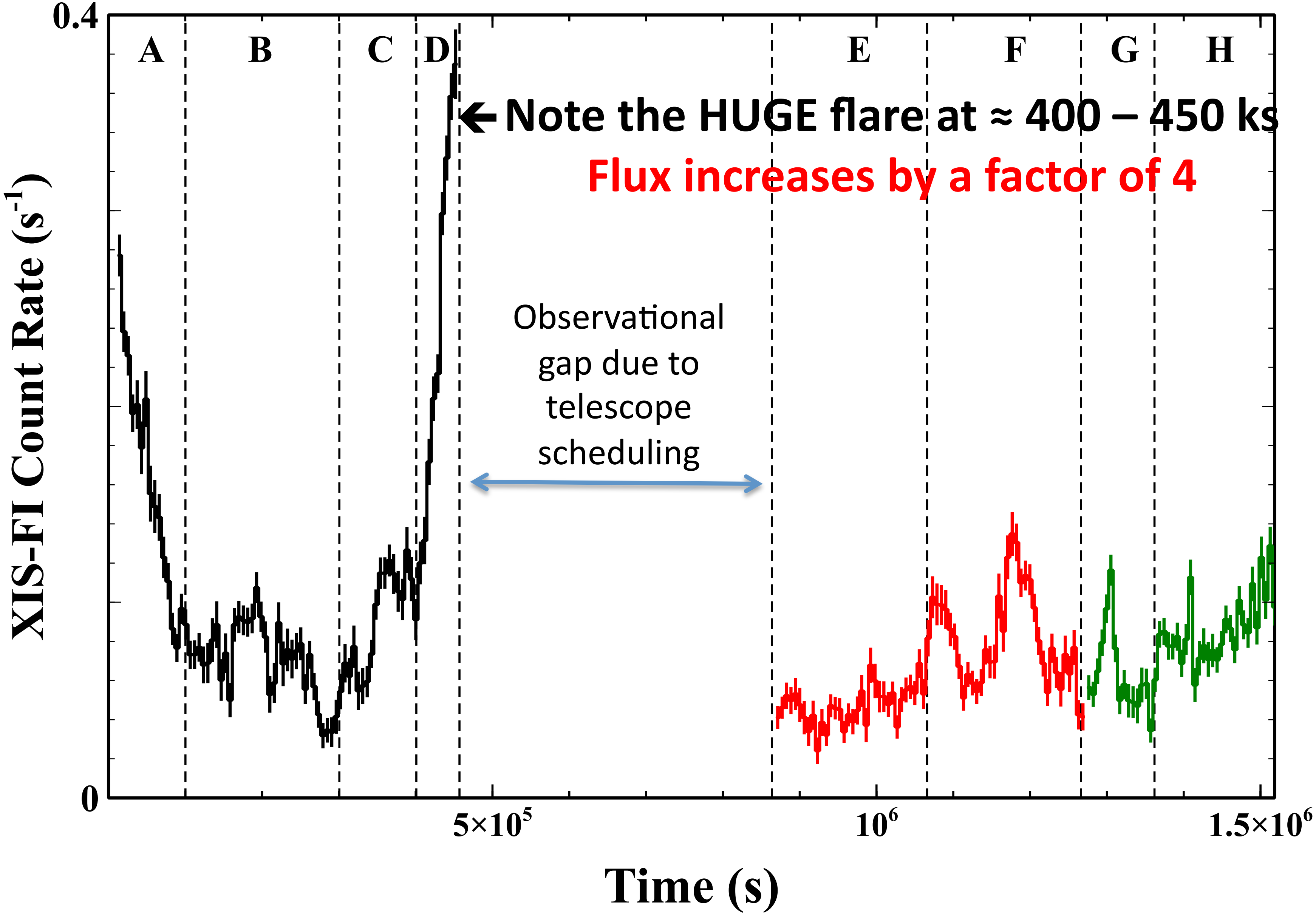


PDS 456 – 500 ks net exposure *Suzaku* campaign in early 2013

Total Duration ≈ 20 days



PDS 456 – 2013 lightcurve



PDS 456 – Short time scale X-ray variability of the Fe K absorption feature

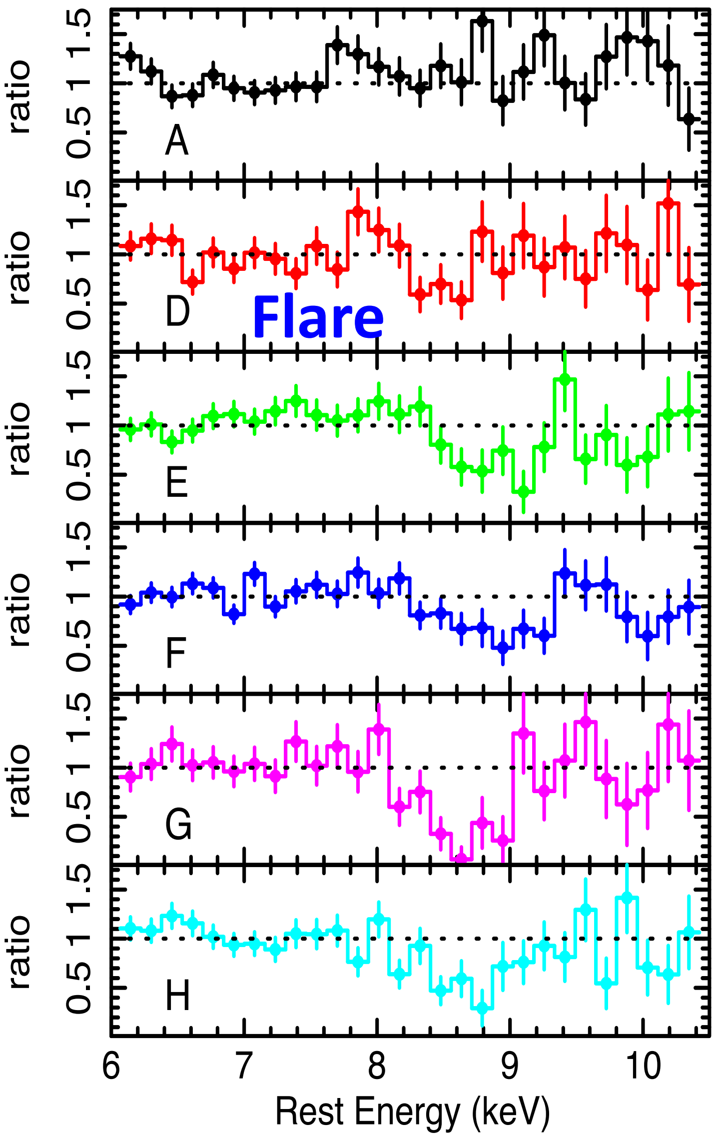
Slice A: EW < 70 eV and $N_H < 5.0 \times 10^{22}$ cm^{-2}

Slice G: EW ≈ 550 eV and $N_H \approx 1.0 \times 10^{24}$ cm^{-2}

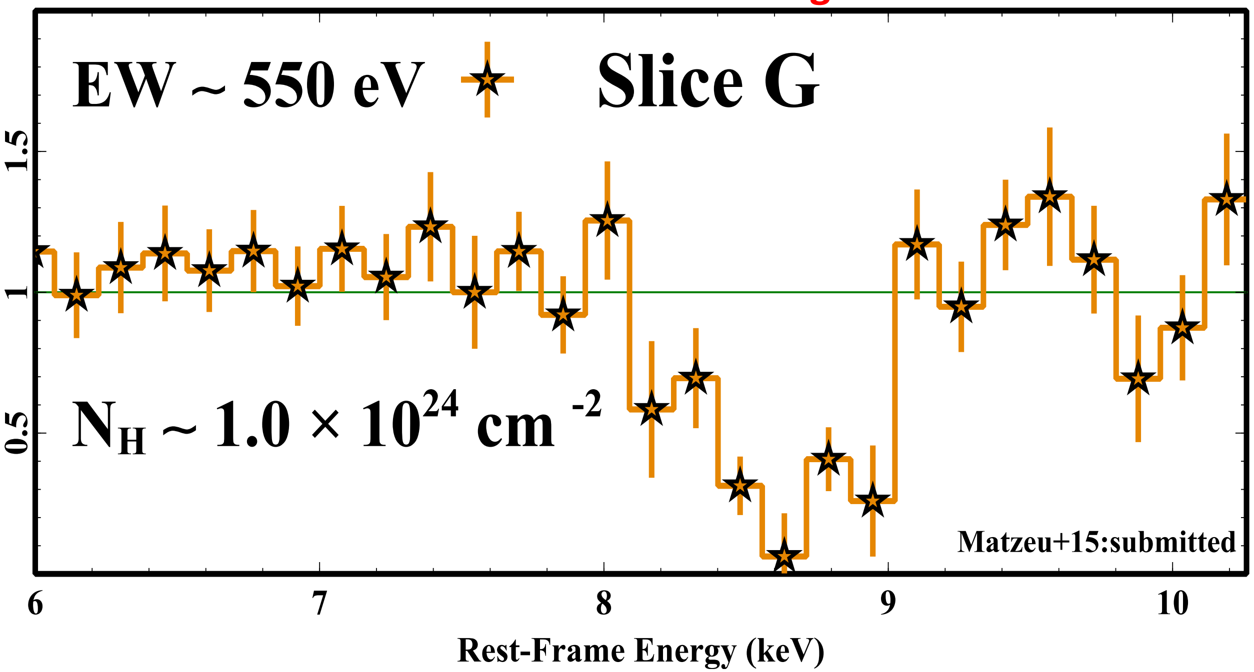
V_{out} ranging from (0.22±0.02)c to (0.26±0.01)c

$\Delta R_{cloud} = v_{out} \Delta t$ Δt (From E to G) = 400ks

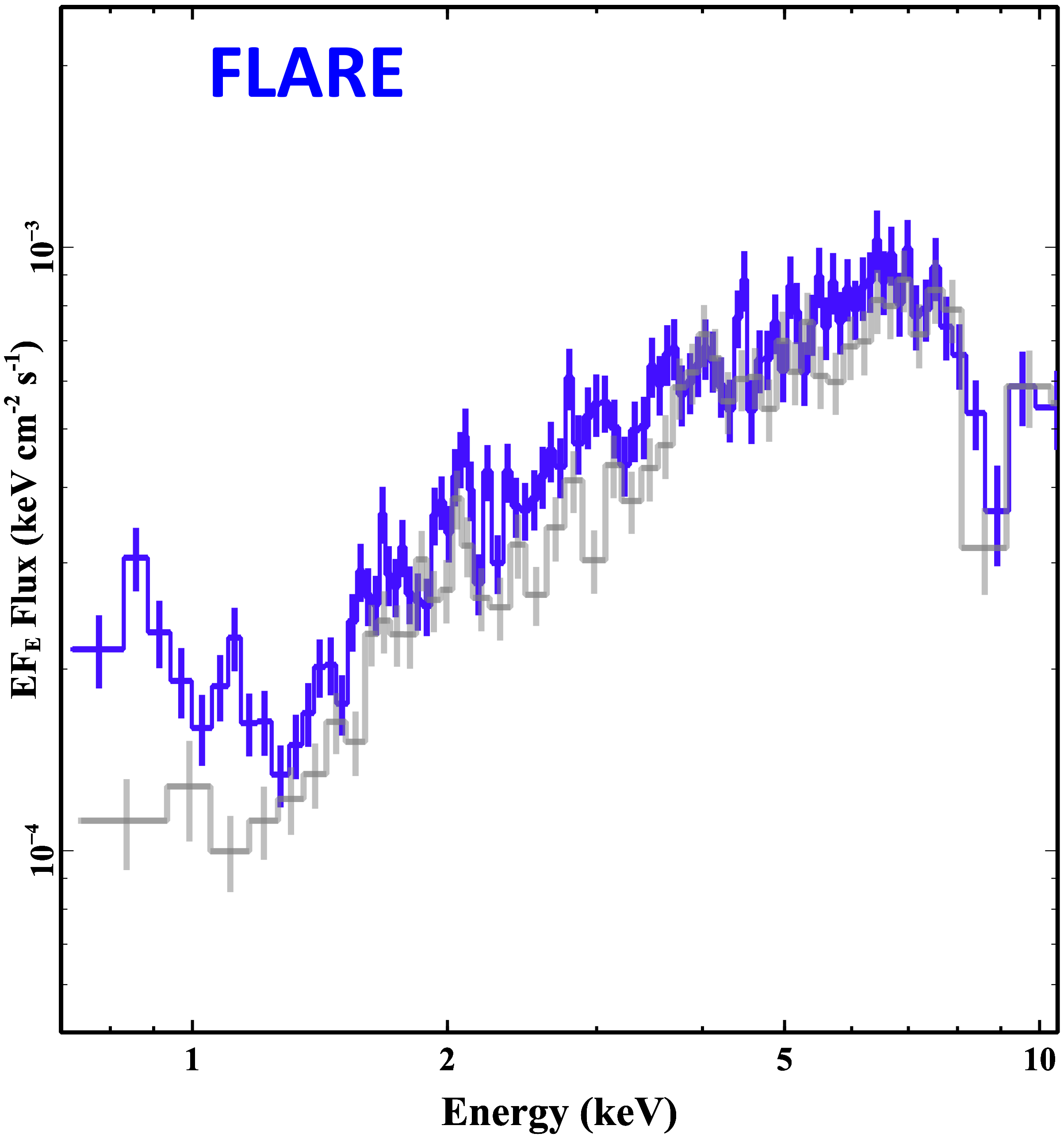
$\Delta R_{cloud} \approx 3 \times 10^{15}$ cm ≈ 20 R_g in PDS 456



Gofford et al. 2014



PDS 456 Broad-band Analysis – Partial Covering Variability



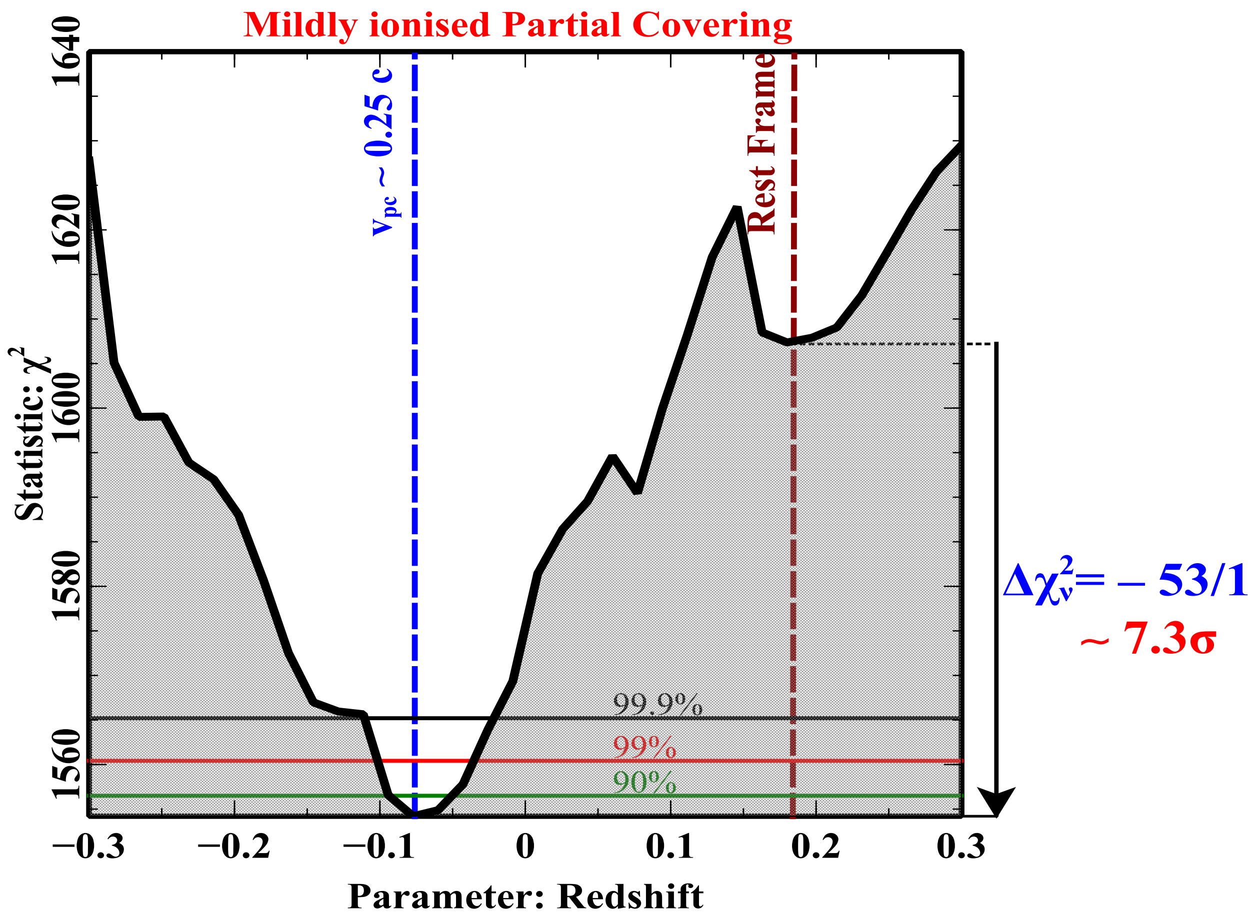
	Low Column pc $\log(N_H/cm^{-2})=22.3\pm0.1$ $f_{cov,low}$ (%)	High Column pc $\log(N_H/cm^{-2})=23.2\pm0.1$ $f_{cov,high}$ (%)
Slice A	75^{+4}_{-6}	59^{+6}_{-7}
Slice B	78^{+4}_{-5}	66^{+5}_{-6}
Slice C	72^{+5}_{-7}	60^{+7}_{-8}
Slice D	85 ± 3	47^{+9}_{-11}
Slice E	82^{+4}_{-5}	72^{+4}_{-5}
Slice F	84^{+3}_{-4}	69 ± 5
Slice G	84^{+3}_{-4}	61^{+6}_{-8}
Slice H	80^{+4}_{-6}	55^{+7}_{-8}

Matzeu+2015:submitted

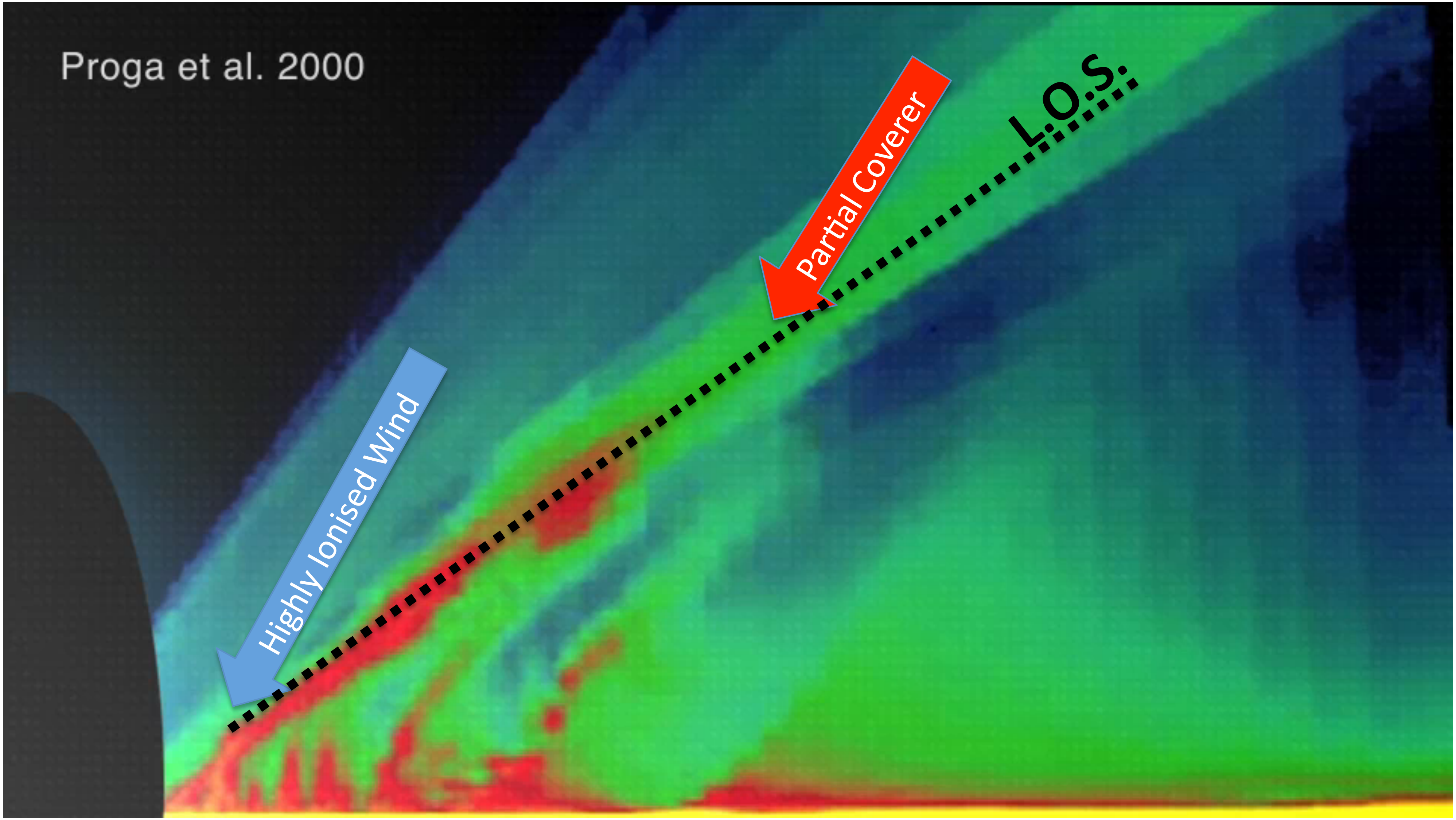
PDS 456 - Properties of The Partial Covering

The global minima indicates that the pc layers are outflowing at $v_{pc} \approx 0.25c$ at least 99.9% confidence level.

This suggests that the pc may be the less ionised and more dense clumpy component of the same wind.

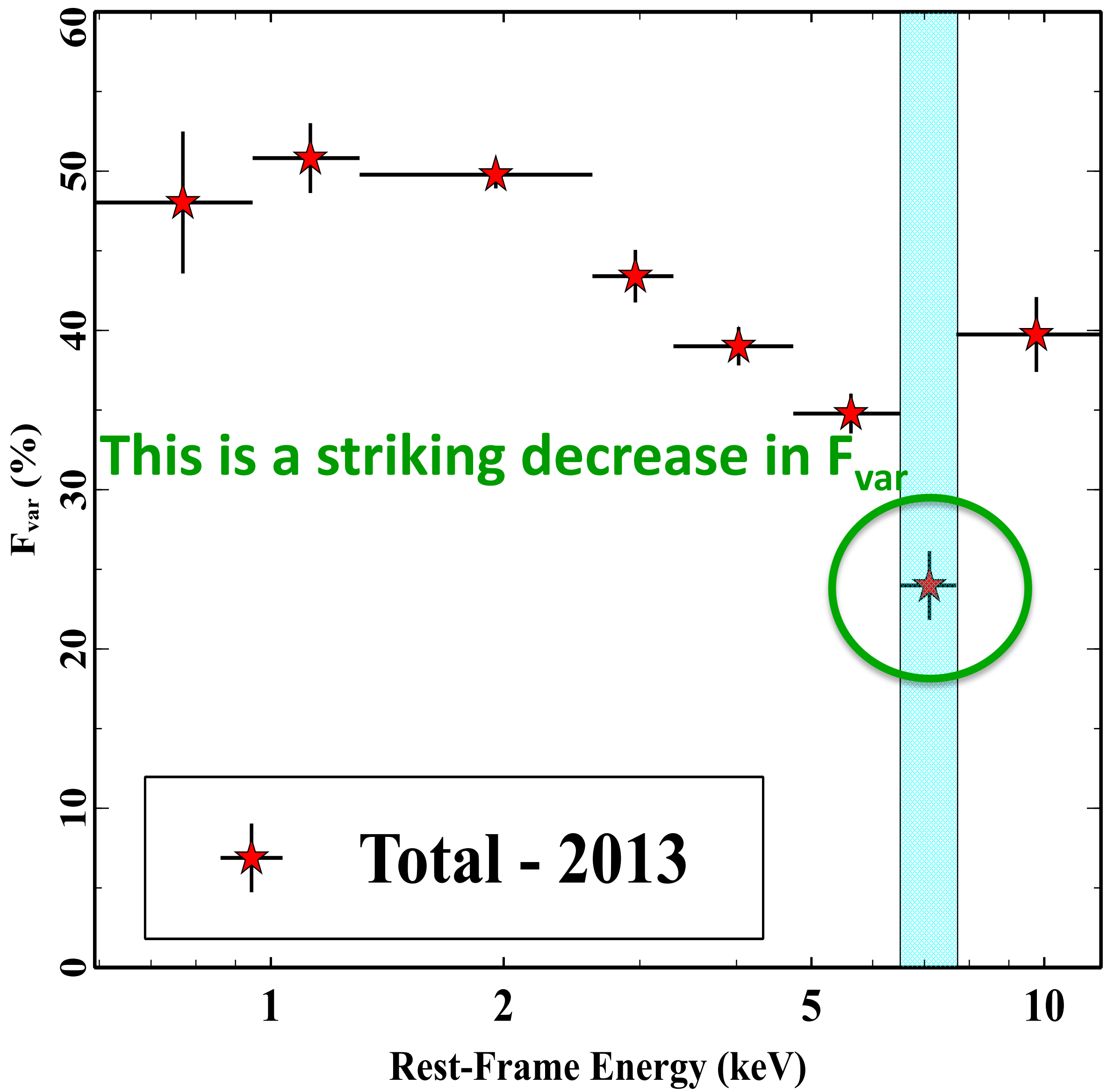


Matzeu+15:submitted



Proga et al. 2000
Partial Coverer
L.O.S.
Highly Ionised Wind

PDS 456 – Fractional Variability



Matzeu+2015: submitted

The Fe K line flux is less variable than the continuum or is not varying on the same short timescale i.e. ≈ 100 ks

We tested two scenarios:

(i) Fe K emission line flux fixed

(ii) Fe K emission line flux vary with constant EW

Scenario (ii) produced a worse fit

$$\Delta\chi^2/\Delta\nu = 100/8$$

PDS 456 - Can the Flare Drive The Outflow?

$$\dot{p}_{\rm w} = \dot{M}_{\rm w} v_{\rm w} = \tau \frac{L_{\rm flare}}{c}, \quad \tau \sim 1 \text{ when } N_{\rm H} \sim 10^{24}\ {\rm cm}^{-2}$$

where $\dot{p}_{\rm w}$ **is the momentum rate of the wind**

$\dot{M}_{\rm w}$ **is the mass outflow rate of the wind**

$v_{\rm w}$ **is the outflow velocity** $v_{\rm w} \sim 0.25\ c$

$$\dot{E}_{\rm w} = \frac{1}{2}\dot{M}_{\rm w} v_{\rm w}^2 = \left(\frac{v_{\rm w}}{2c}\right) L_{\rm flare}, \xrightarrow{\text{integrating}} E_{\rm w} = \left(\frac{v_{\rm w}}{2c}\right) E_{\rm flare}.$$

$$\dot{E}_{\rm w} \sim 0.15\ \dot{E}_{\rm flare}$$

Theoretical prediction suggests that
only 15 % of the radiative power of the flare is transferred directly to the wind.

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Theoretical prediction suggests that
only 15 % of the radiative power of the flare is transferred directly to the wind.

From the best fit model we estimated $L_{\rm flare(1\text{-}1000Ryd)} \approx 10^{46}$ erg s^{-1}

We assume the flare is symmetric with total duration ≈ 100 ks

The Radiative energy of the flare is ≈10^{51} erg.

PDS 456 - Can the Flare Drive The Outflow?

$$\dot{M}_w = \Omega m_p N_H v_w R_{in}$$

$\Omega = 2\pi$ sr – from Nardini+15

$N_H = 7.9 \times 10^{23}$ cm^{-2} – the average column density between slices E – H

$R_{in} > 32\ R_g$ – launch radius (conservative)

$v_w \approx 0.25$ c – the average outflow velocity between the observations.

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We estimated that $\dot{M}_{\rm w} \gtrsim 0.5 \dot{M}_{\rm Edd}$

It follows that the kinetic luminosity of the outflow is > 1.5×10^{46} erg s^{-1}

Δt of the outflow is at least 700 ks

The mechanical energy of the outflow is at least $\approx 10^{52}$ erg.

PDS 456 - Can the Flare Radiatively Drive The Outflow?

The Radiative energy imparted by the flare is ≈ 10^{51} erg

The mechanical energy of the outflow is at least ≈ 10^{52} erg

The mechanical energy deposited in the wind in at least one order of magnitude higher than the radiative energy imparted by the flare.

Thus the answer is probably NOT!

PDS 456: Summary

- **Following an obscuration event** in slice G, we could constrain the size of the X-ray emitting region which cannot be larger than **≈ 20 R_g**

- **The Fractional Variability suggest that the Fe K emission is less variable compared to the continuum on short time-scale i.e ≈ 100 ks implying that the origin of Fe K emission may be from the outer disc or ≥ 100 R_g if associated with the wind!**

- The model suggests that the **pc may be the less ionised more dense component of the SAME wind** i.e. **$v_{pc} \approx v_w \approx 0.25$ c at 99.9% confidence level**

- We found **that the radiative power from the flare may NOT be sufficient enough to drive the wind**, so other physical mechanism may be also involved e.g., magnetically driven wind.

Thank you for listening!