OAO 1657-415

ANALYSIS AND DISCUSSION OF THE SPECTRUM OF A NEUTRON STAR IN A BINARY SYSTEM

Group 14

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Esaminator

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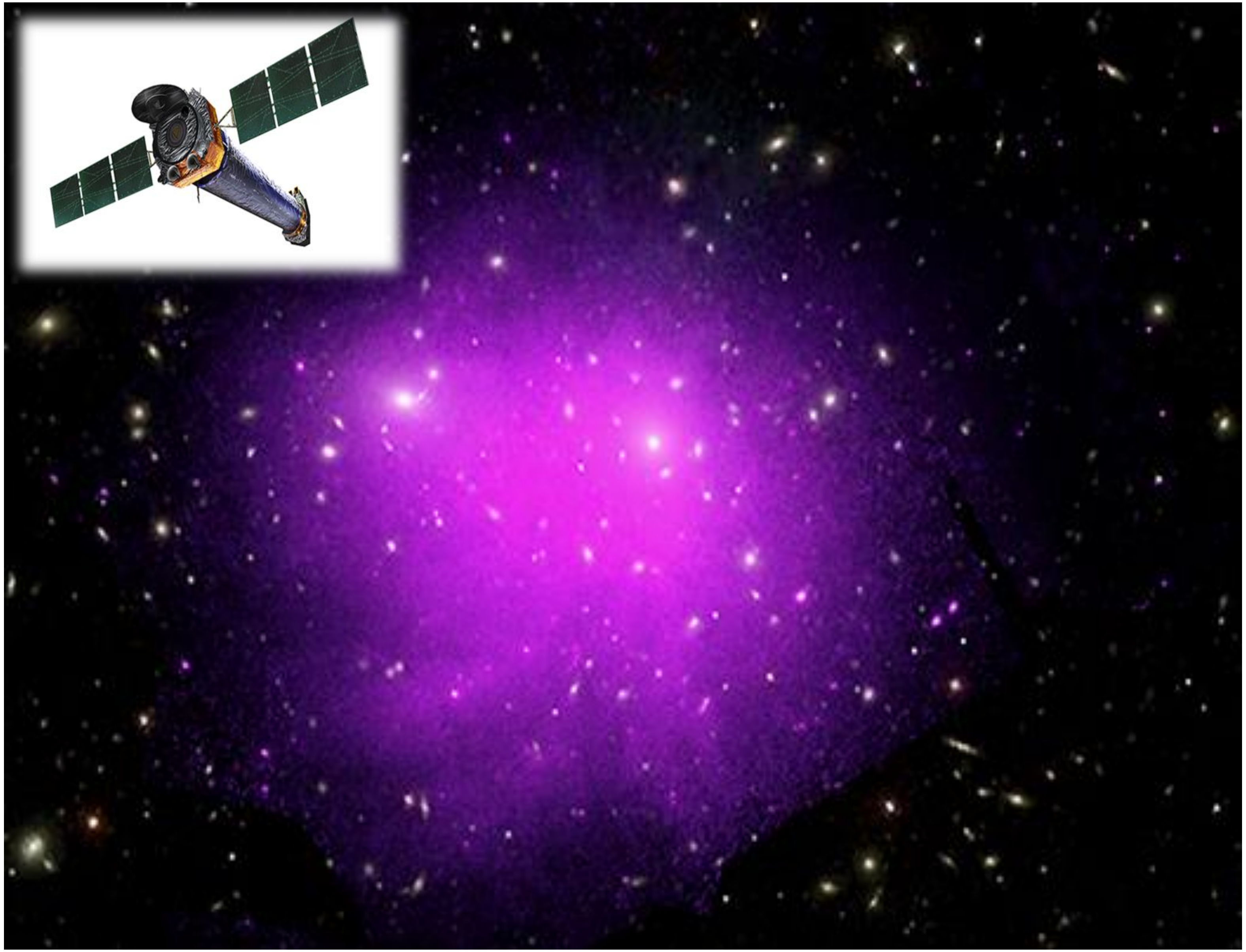


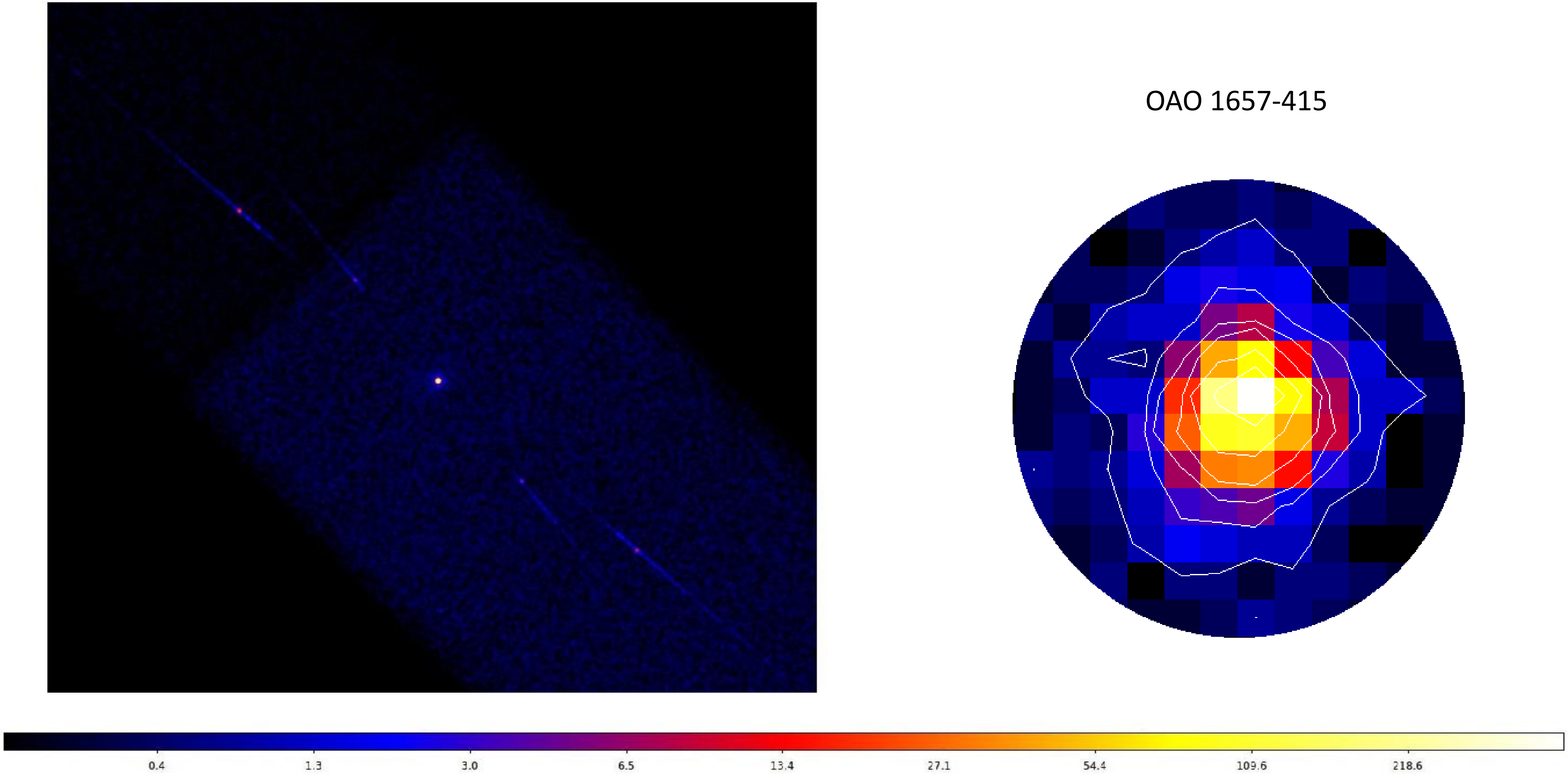
CHANDRA (1999 -)

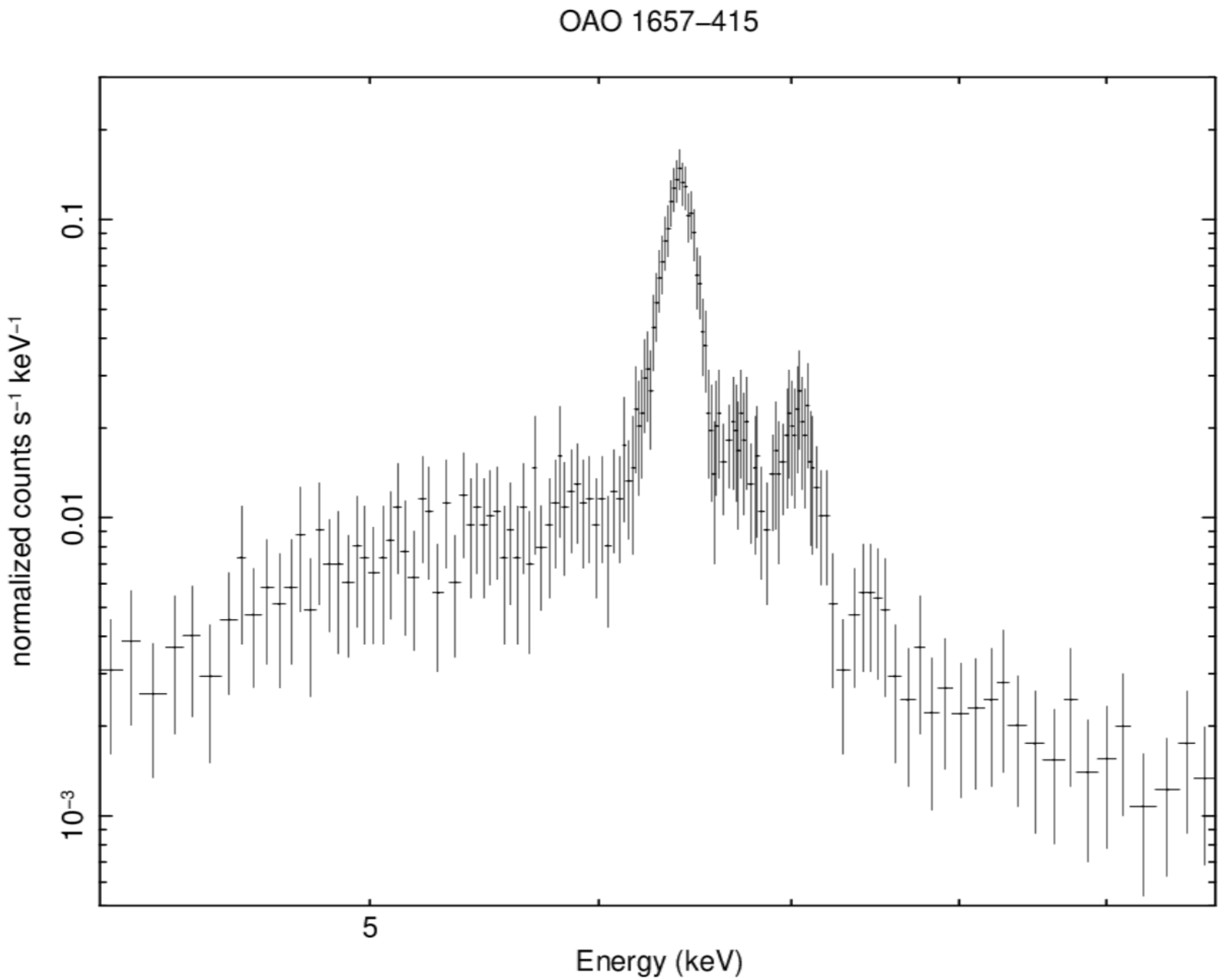
- NASA mission
- 4 pairs of mirrors
- Interval: 0.1 – 10 KeV
- Angular resolution: 0.05’’
- One of the most sophisticated X-ray observatory built to date

NASA/CXC/SAO & J.Vaughan

X-ray: NASA/CXC/Univ. of Chicago, I. Zhuravleva et al, Optical: SDSS

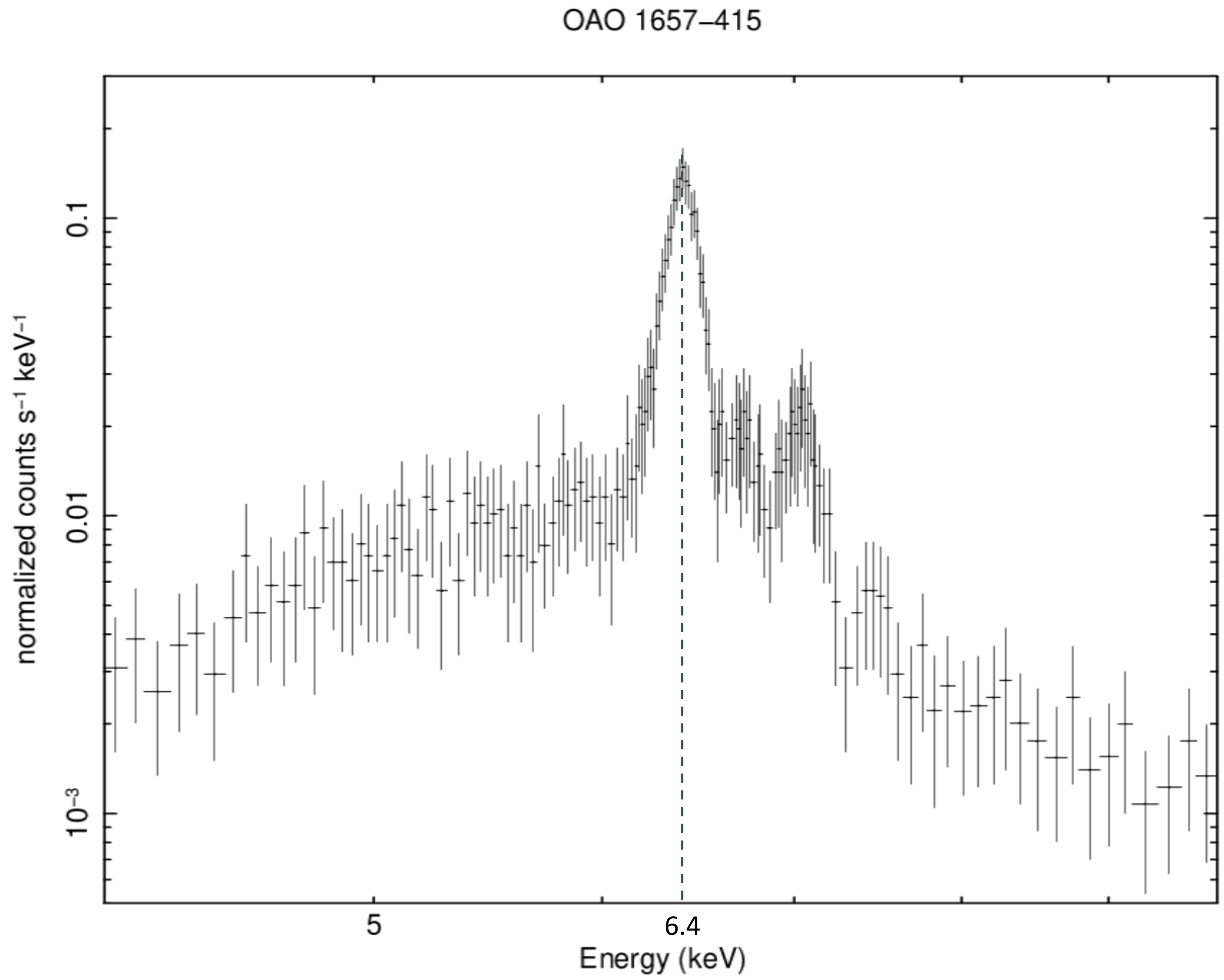
OAO 1657-415





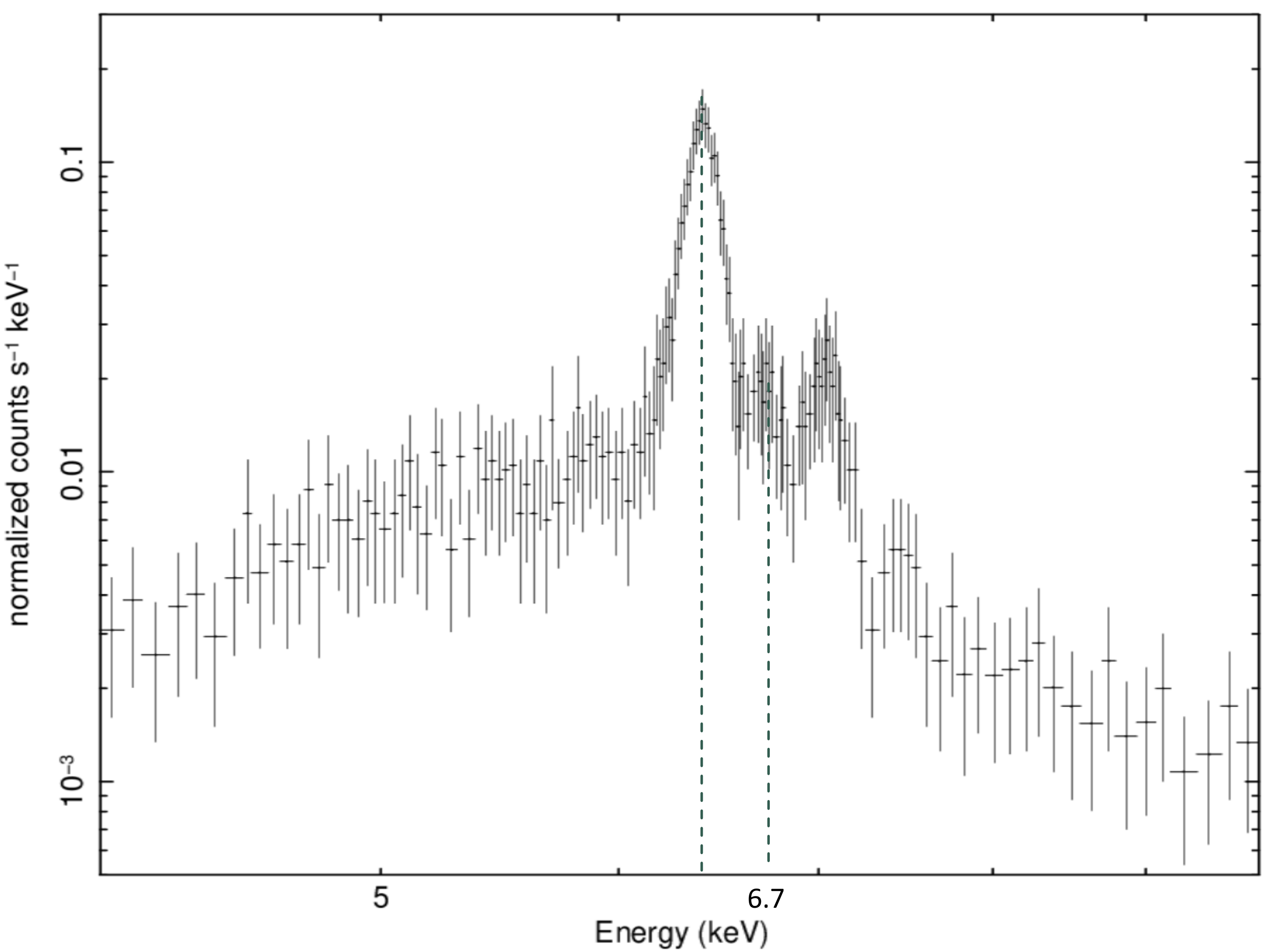
- Spectrum between 4 and 10 KeV
- Rebinned 20
- Exposure Time 4.89e4 s
- ID observation 12460

Well defined spectrum in which we can clearly distinguish some spectral lines

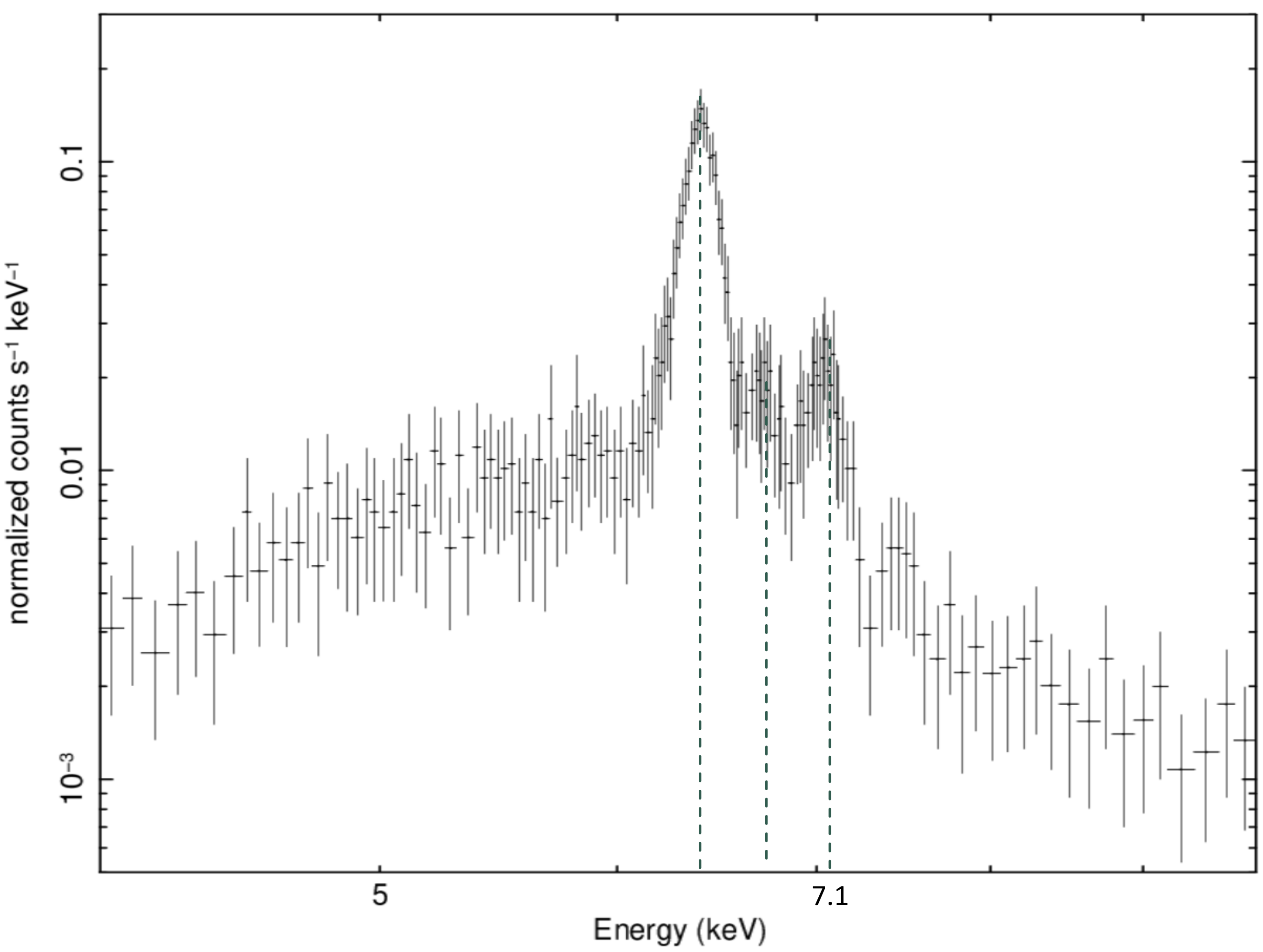


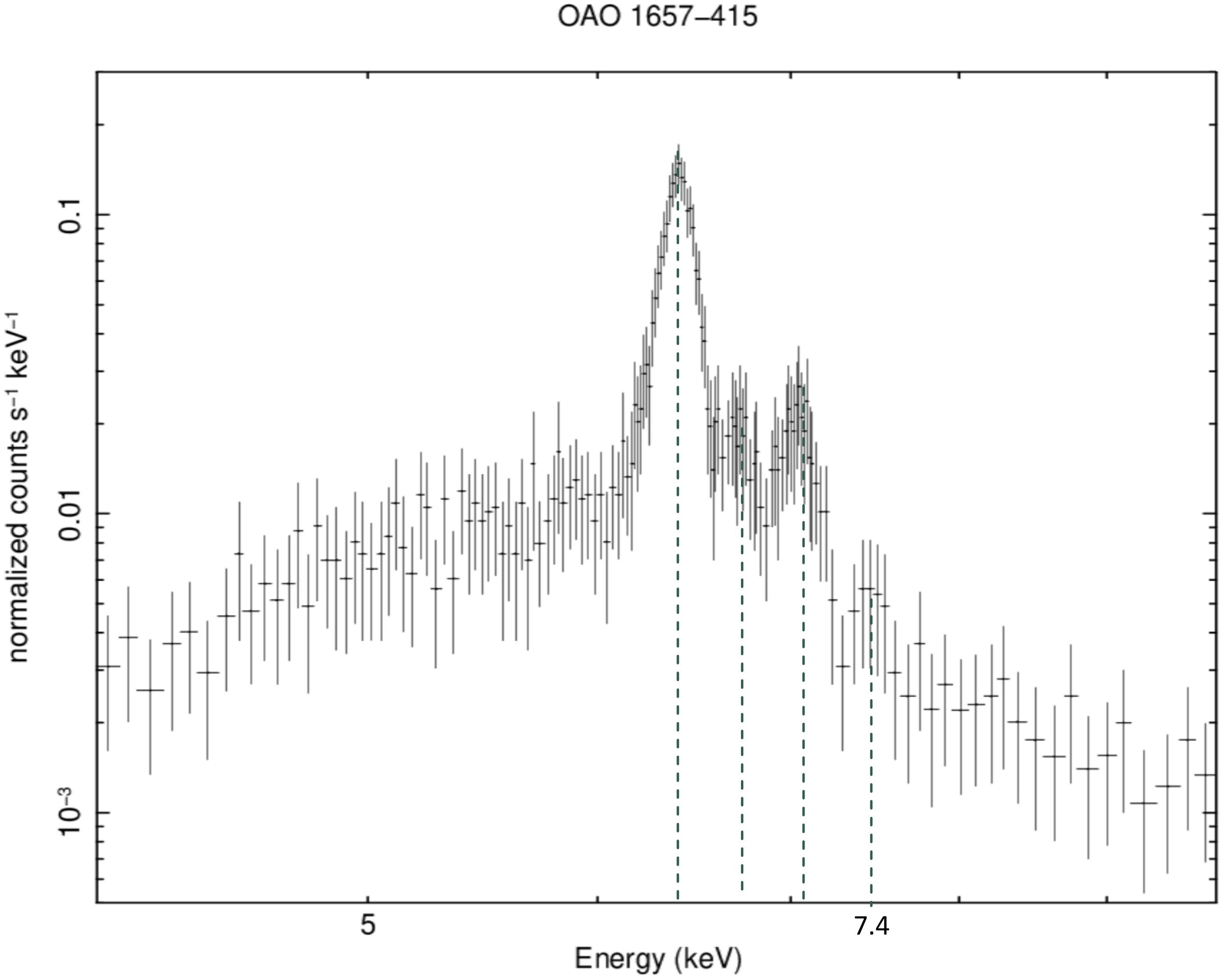
OAO 1657−415
normalized counts s⁻¹ keV⁻¹
0.1
0.01
10⁻³
5
6.4
Energy (keV)

OAO 1657–415

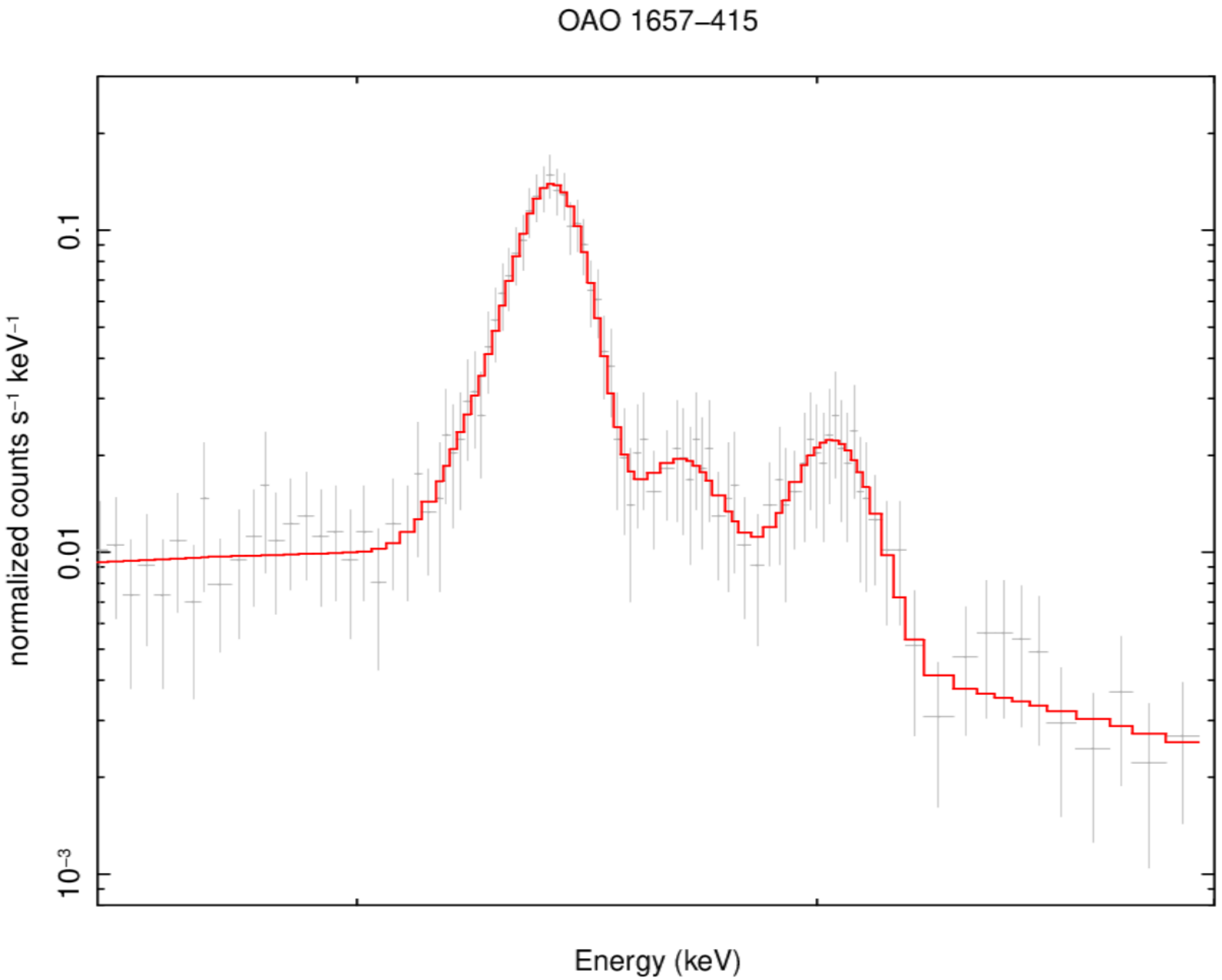


OAO 1657–415





OAO 1657–415
normalized counts s⁻¹ keV⁻¹
0.1
0.01
10⁻³
5
7.4
Energy (keV)



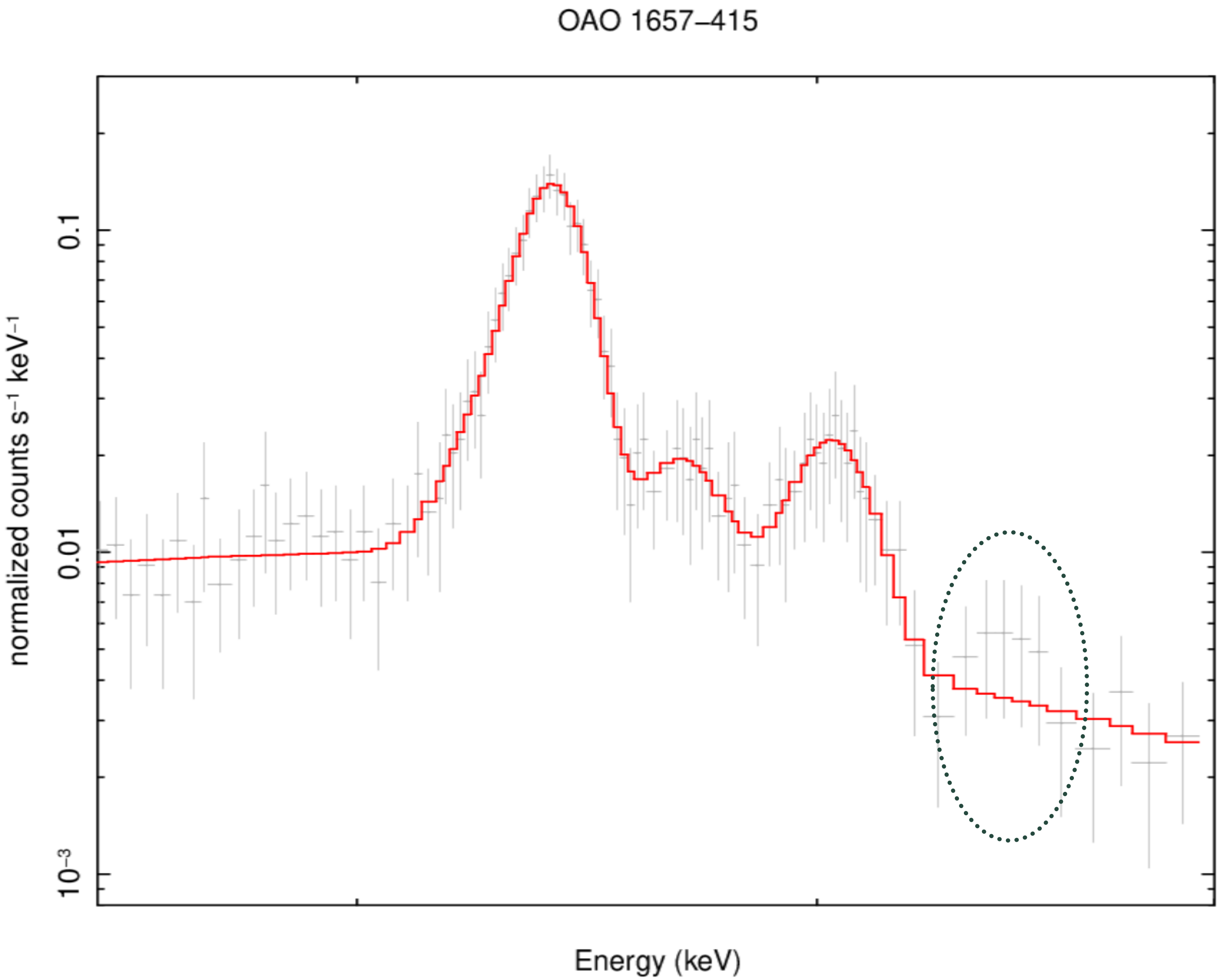
Is this the best fit?

Let's focus on the gaussian we have. The model we've used include five gaussians, approximately at:

- 6.301 KeV
- 6.409 KeV
- 6.411 KeV
- 6.690 KeV
- 7.047 KeV

This model has $\chi^2_{red} = 0.2179$

The values of the model are setted by default

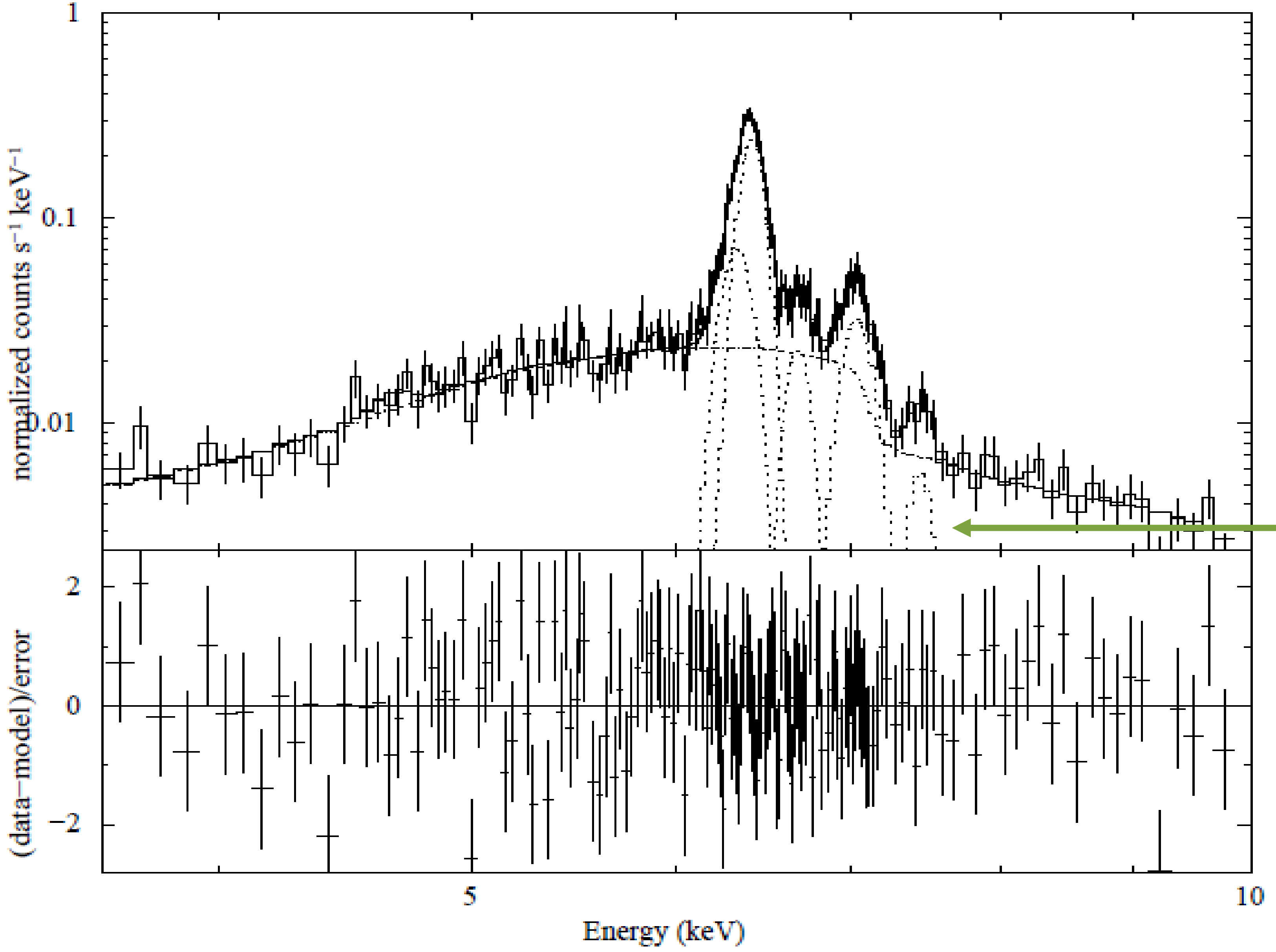


Is this the best fit?

The line at 7.4 KeV is not included in our model

We could think that we have confused a line with something else, like a fluctuation or some kind of error in the elaboration

Comparing our hypothesis with a paper of Pragati Pradhan, Gayathri Raman and Biswajit Paul, we conclude that there should be a line



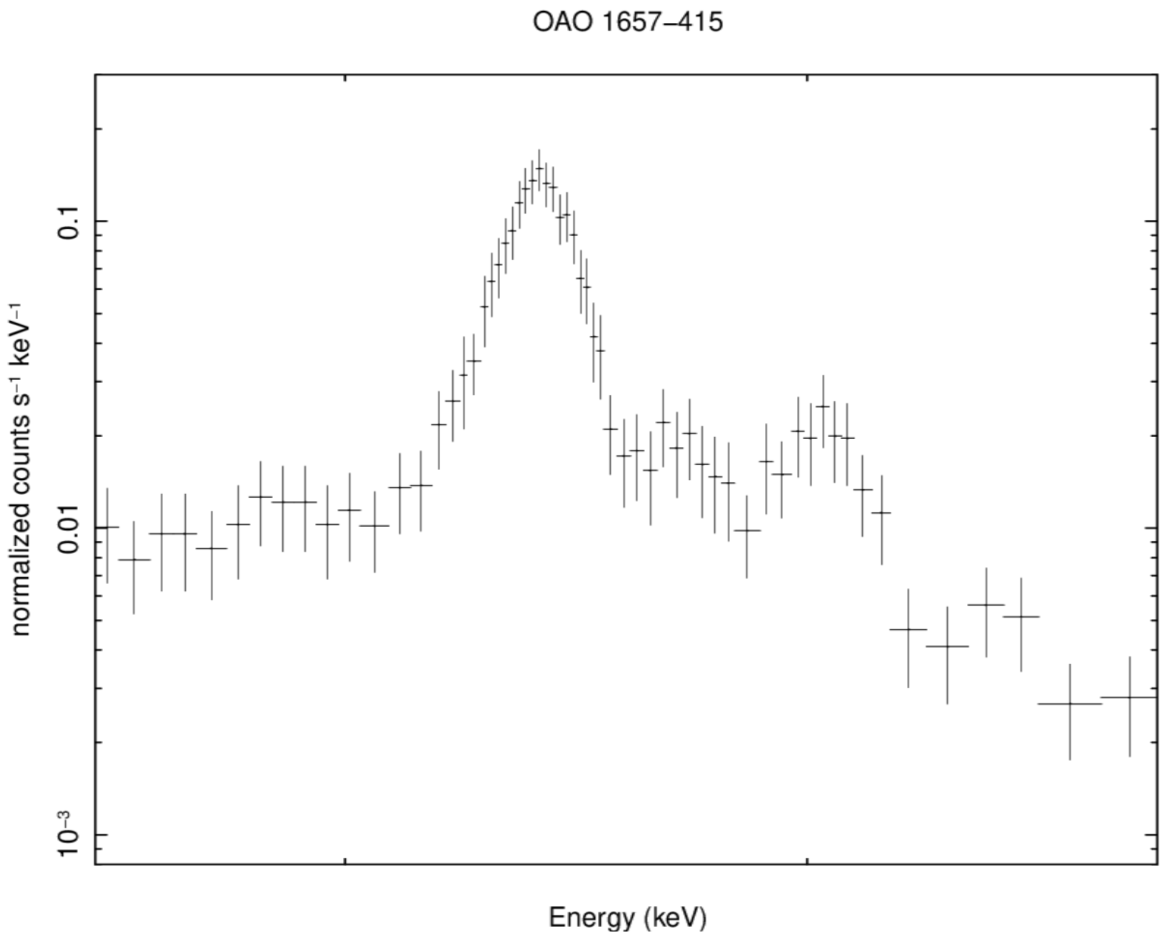
from

“Multitude of iron lines including a Compton scattered component in OAO 1657–415 detected with Chandra”

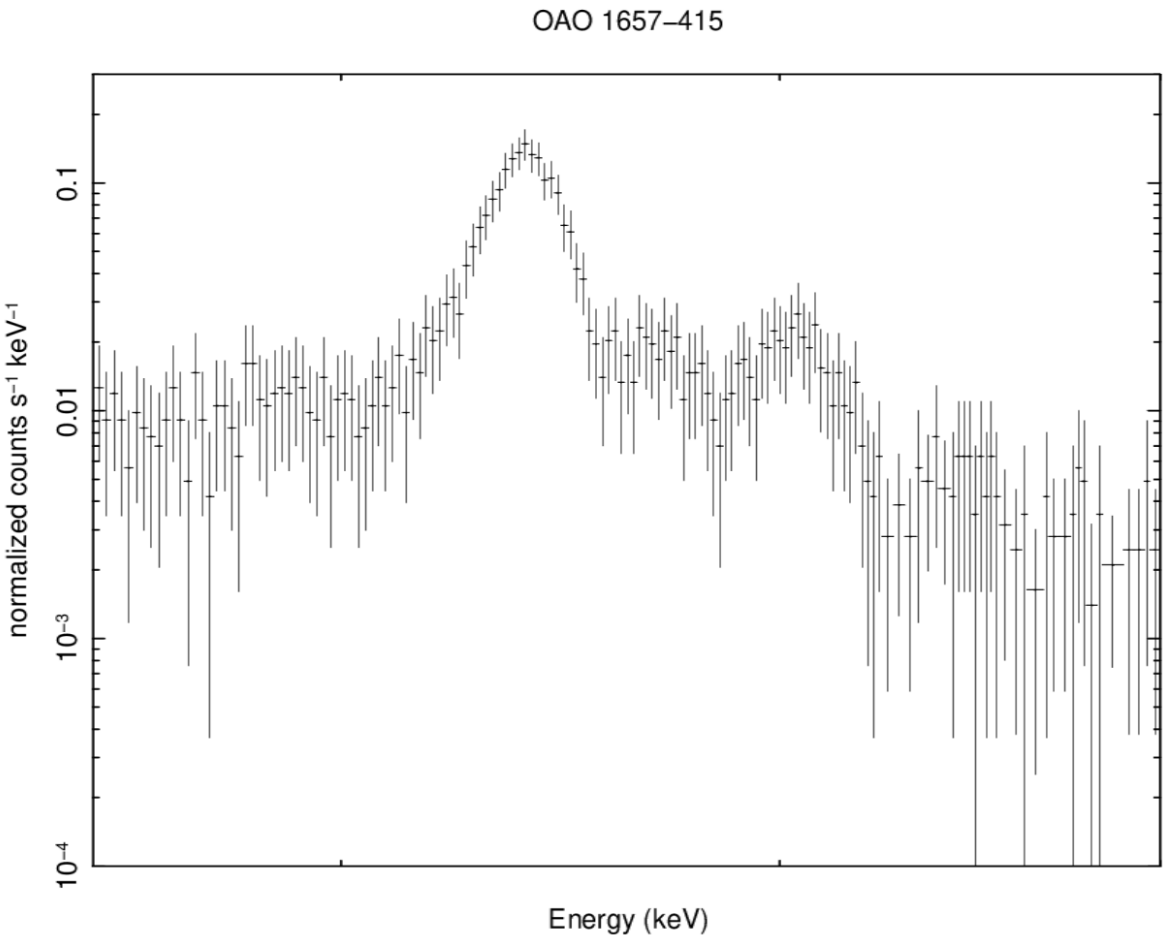
P. Pradhan, G. Raman, B. Paul

Gaussian

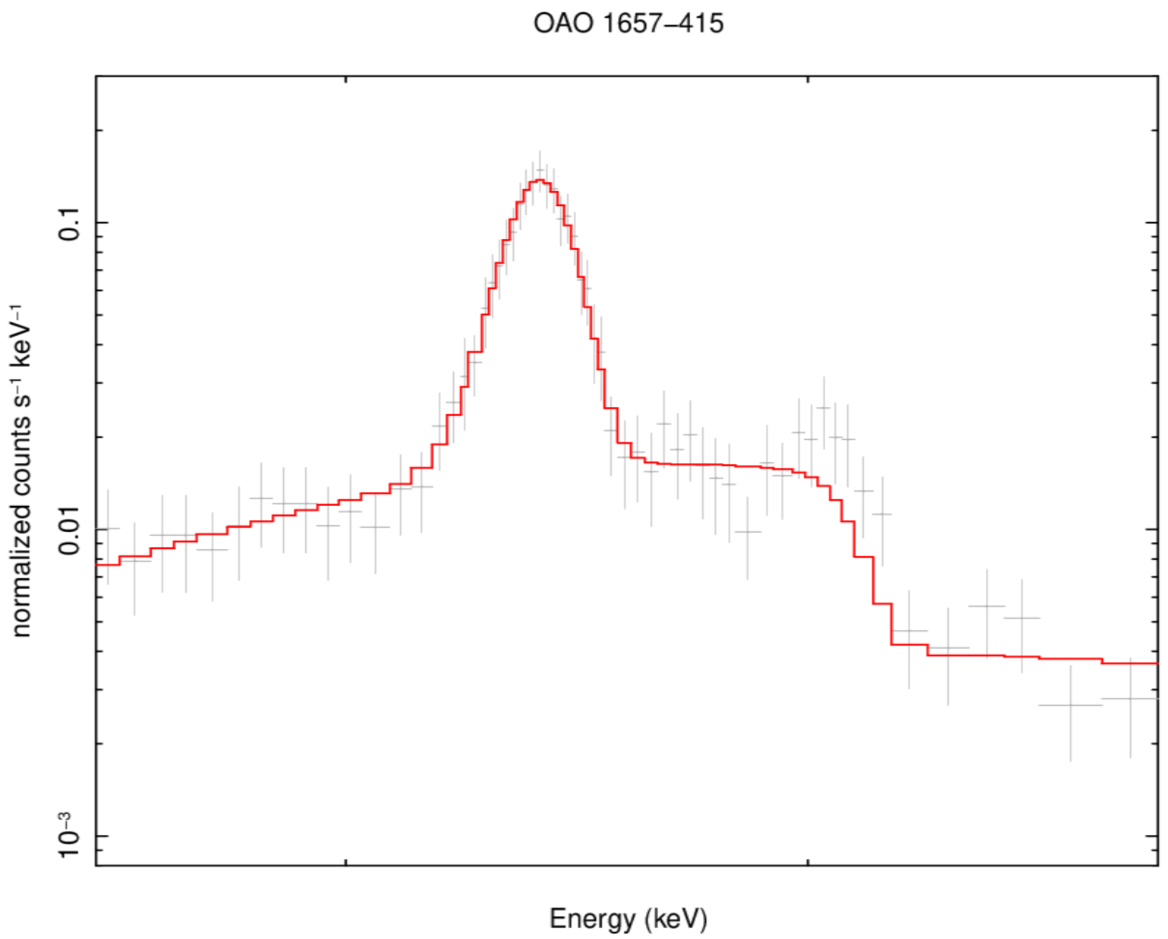
They detected the line at 7.4 KeV and added it in their model, with a $\chi^2_{red} = 0.92$

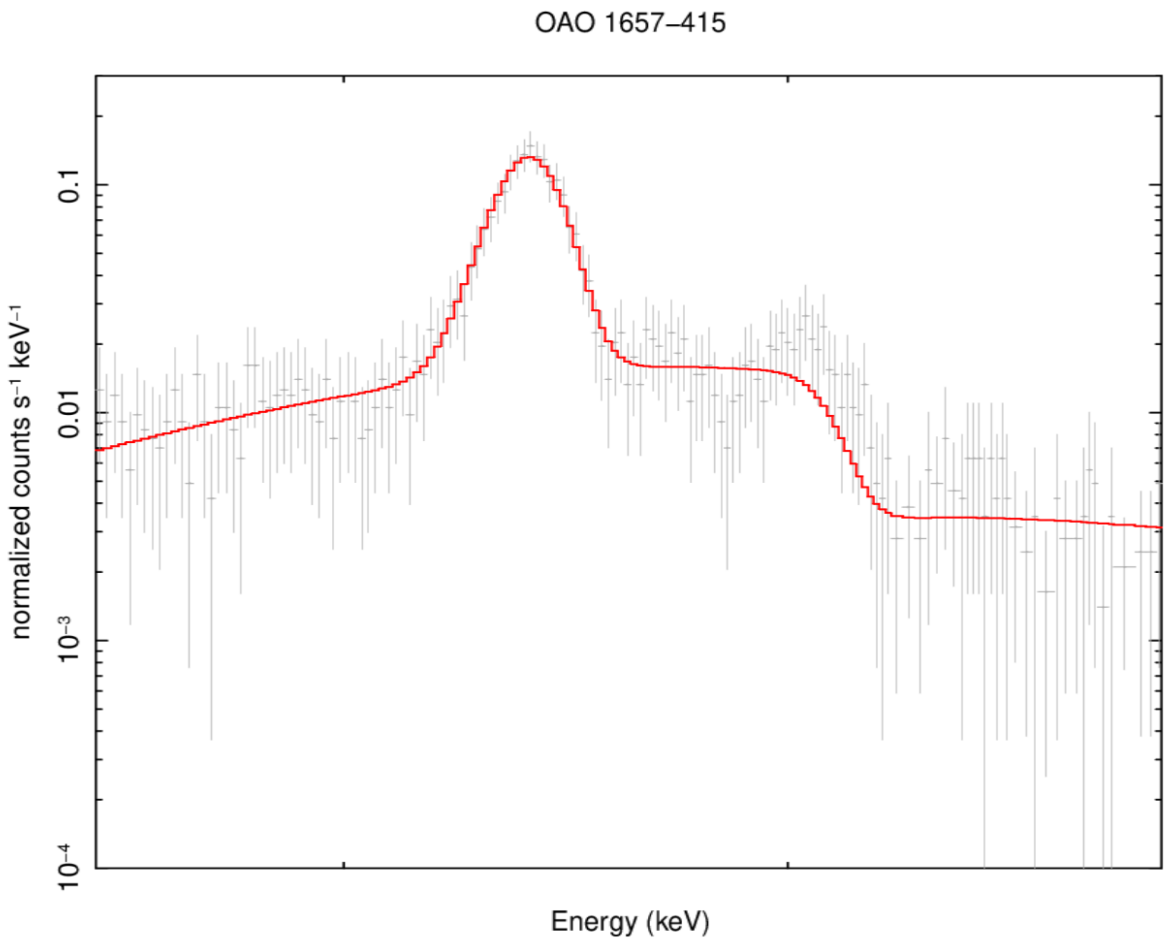


Rebinned 40



Rebinned 5



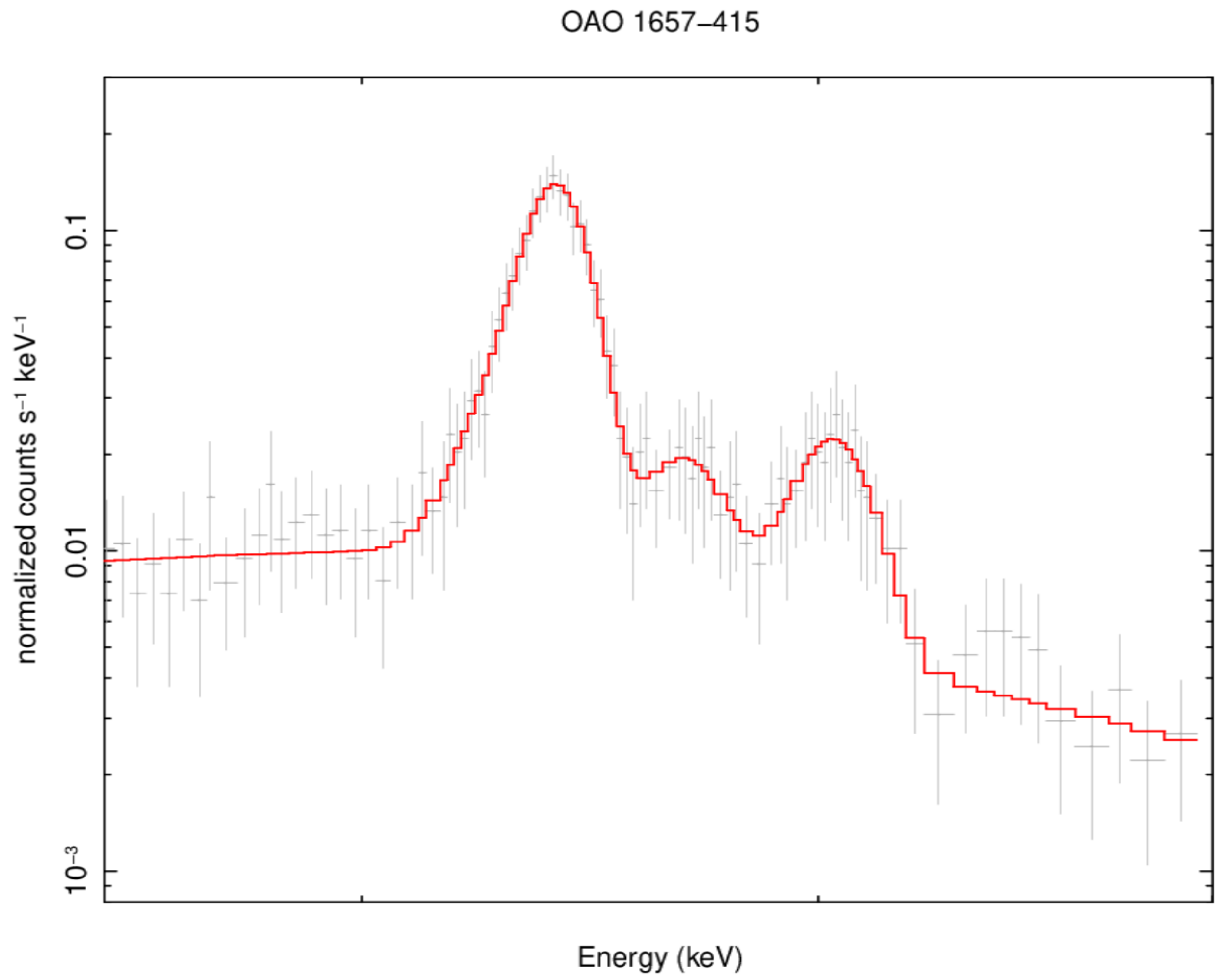


Rebinned 40

$\chi^2_{red} = 0.6305$

Rebinned 5

$\chi^2_{red} = 0.3713$



THE MODEL

Wabs

Black Body

5 Gaussian

WABS

- Multiplicative component of the model
- It take into account the effect of the photo-electric absorption using the following law:

$$M(E) = \exp\left(-\eta_H \sigma(E)\right)$$

- η_H is the equivalent hydrogen column density. The unit is $10^{22}\ atoms \cdot cm^{-2}$
- $\sigma(E)$ is the photo-electric cross section in cm^2

Our model:

$$\eta_H = 41.3882 \pm 8.60547$$

BLACK BODY

- Additive component of the model

- Model formulation

$$A(E) = \frac{norm \cdot 8.0525\, E^2 \mathrm{dE}}{(kT)^4(\exp(\mathrm{E/kT}) - 1)}$$

- kT is the first parameter of this model, and is setted in KeV

- $norm$ is the second parameter, and it's the ratio between luminosity (units of 10^{39} erg/s) and the distance (units of 10 Kpc)

$$norm = L_{39}/D_{10}^2$$

Our model:

$$kT = 3.51311 \pm 1.01822$$

$$norm = (4.78109 \pm 1.80270) \cdot 10^{-4}$$

GAUSSIAN

- Additive component of the model
- Model formulation

$$A(E) = \frac{norm}{\sigma\sqrt{2\pi}} \cdot exp\left(\frac{-(E - E_l)^2}{2\sigma^2}\right)$$

- E_l is the parameter that identifies the energy of the line. Measured in KeV
- σ determines the width of the line. Measured in KeV
- $norm$ is the third parameter equal to the number of photons per cm^2 per s in the line

GAUSSIAN 7.4 KeV

- Line $Ni\ K_\alpha$ $2p \mapsto 1s$
- Line found in few other cases (ex: GX 301-2)

Our model:

$Not\ Found$

GAUSSIAN 7.1 KeV

- Line $Fe\ K_{\beta}$ $3p \mapsto 1s$
- Fluorescent emission

Our model:

$$E_l = 7.04664 \pm 2.43441 \cdot 10^{-2}$$

$$\sigma = 5.86659 \cdot 10^{-2} \pm 3.18798 \cdot 10^{-2}$$

$$norm = 100202 \cdot 10^{-4} \pm 2.38985 \cdot 10^{-5}$$

GAUSSIAN 6.7 KeV

- Line of $He\ like\ Fe$
- Indicative of an highly ionized medium near the source (rare situation for an X-binary)
- Generated near the source

Our model:

$$E_l = 6.68981 \pm 4.90060 \cdot 10^{-2}$$

$$\sigma = 5.41415 \cdot 10^{-2} \pm 7.30785 \cdot 10^{-2}$$

$$norm = 5.39470 \cdot 10^{-5} \pm 2.46803 \cdot 10^{-5}$$

GAUSSIAN 6.4 KeV

- Line $Fe\ K_\alpha$ $2p \mapsto 1s$
- Fluorescent emission
- Typically the strongest line in the X range
- Presence of dense matter in the surrounding of the source that cause the Compton shoulder
- Produced in a region far away from the source

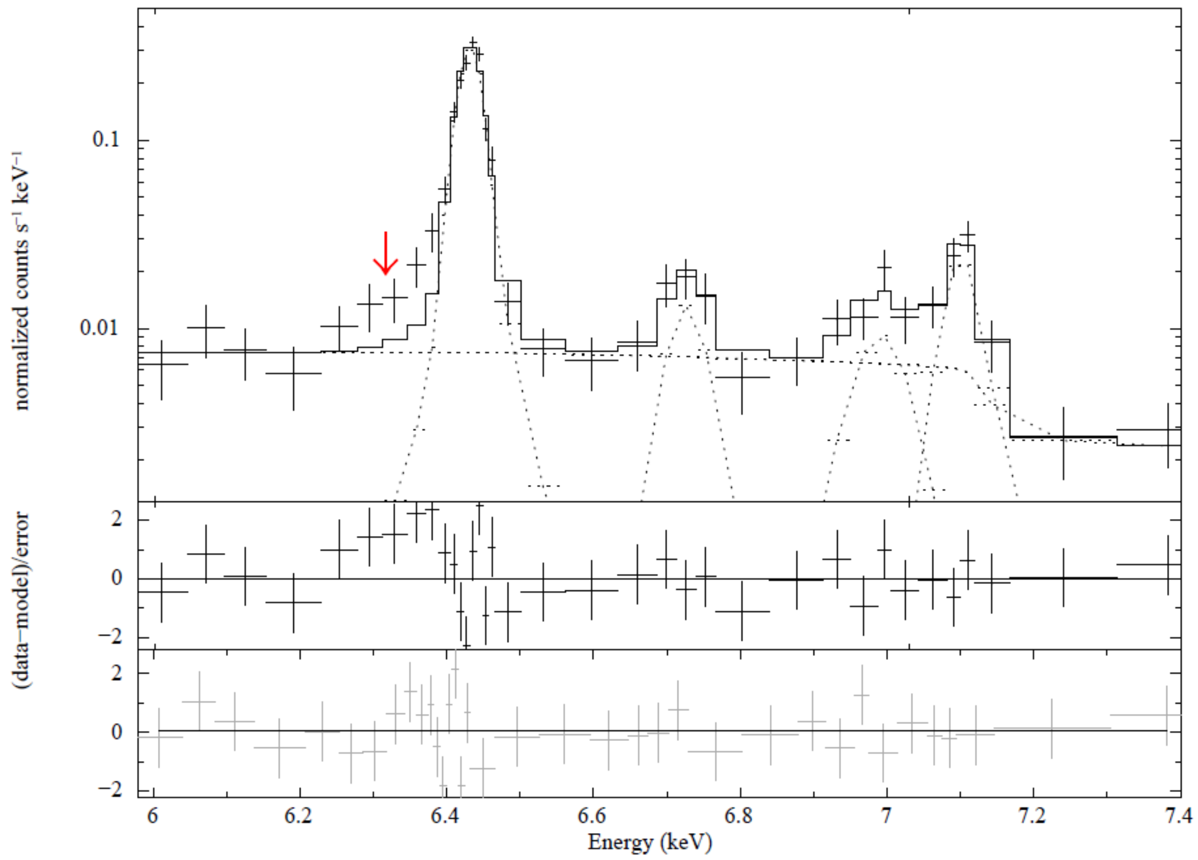
Our model:

$$E_l = 6.30133 \pm 0.348405$$
$$\sigma = 5.91012 \cdot 10^{-2} \pm 0.255700$$
$$norm = 9.57831 \cdot 10^{-5} \pm 2.94260 \cdot 10^{-4}$$

$$E_l = 6.40946 \pm -1.00000$$
$$\sigma = 3.12447 \cdot 10^{-4} \pm 1.92222 \cdot 10^{5}$$
$$norm = 2.36046 \cdot 10^{-4} \pm -1.00000$$

$$E_l = 6.41130 \pm -1.00000$$
$$\sigma = 5.76603 \cdot 10^{-4} \pm 2.47461 \cdot 10^{5}$$
$$norm = 1.76773 \cdot 10^{-4} \pm -1.00000$$

COMPTON SHOULDER



Here we have the model taken by

"Multitude of iron lines including a Compton scattered component in OAO 1657–415 detected with Chandra"

P. Pradhan, G. Raman, B. Paul

We insert ths plot just to show the effect of the compton shoulder formation

OAO 1657-415

IN LITERATURE

OAO 1657-415

Year of discovery	1978 (1993 characterization)
Donor	Neutron Star (pulsar)
Accretor	B0-6Iab (RSG about to become a WR)
Orbital period	10.44 days
Pulsar period	36.9 s (38.22 at the first mensuration)
Distance	6.4 ± 1.5 Kpc
Visible in:	X (disk), radio (pulsar), near-IR (donor)

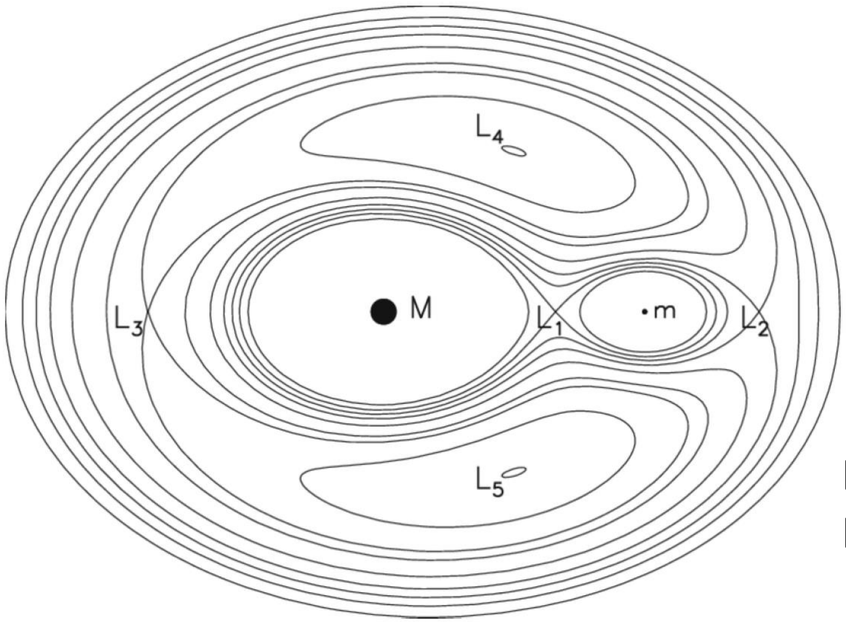
X-RAY BINARY

System composed by:

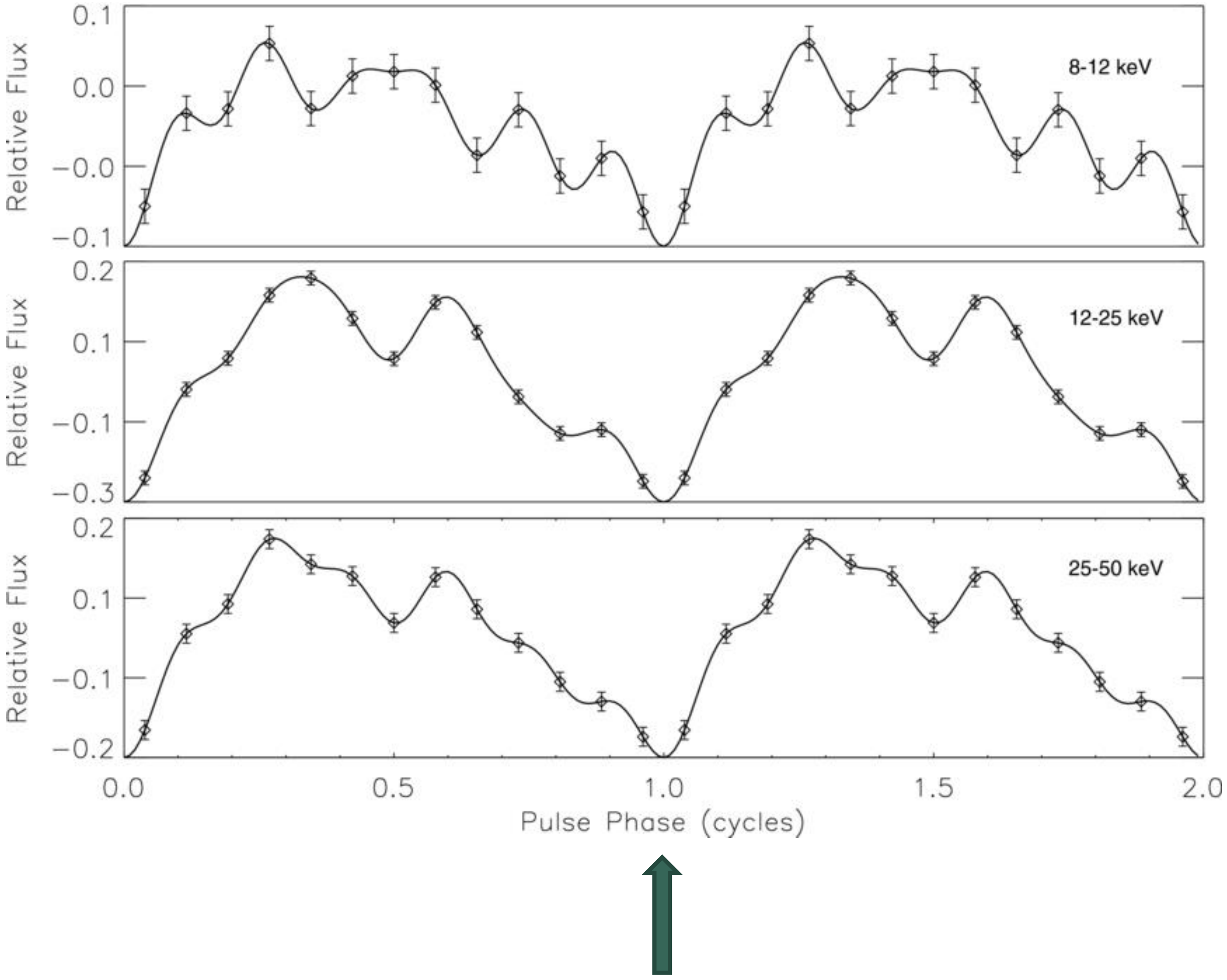
- Donor (late phase star)
- Accretor (compact object)

X-ray sources:

Accreting material, compress and heat up



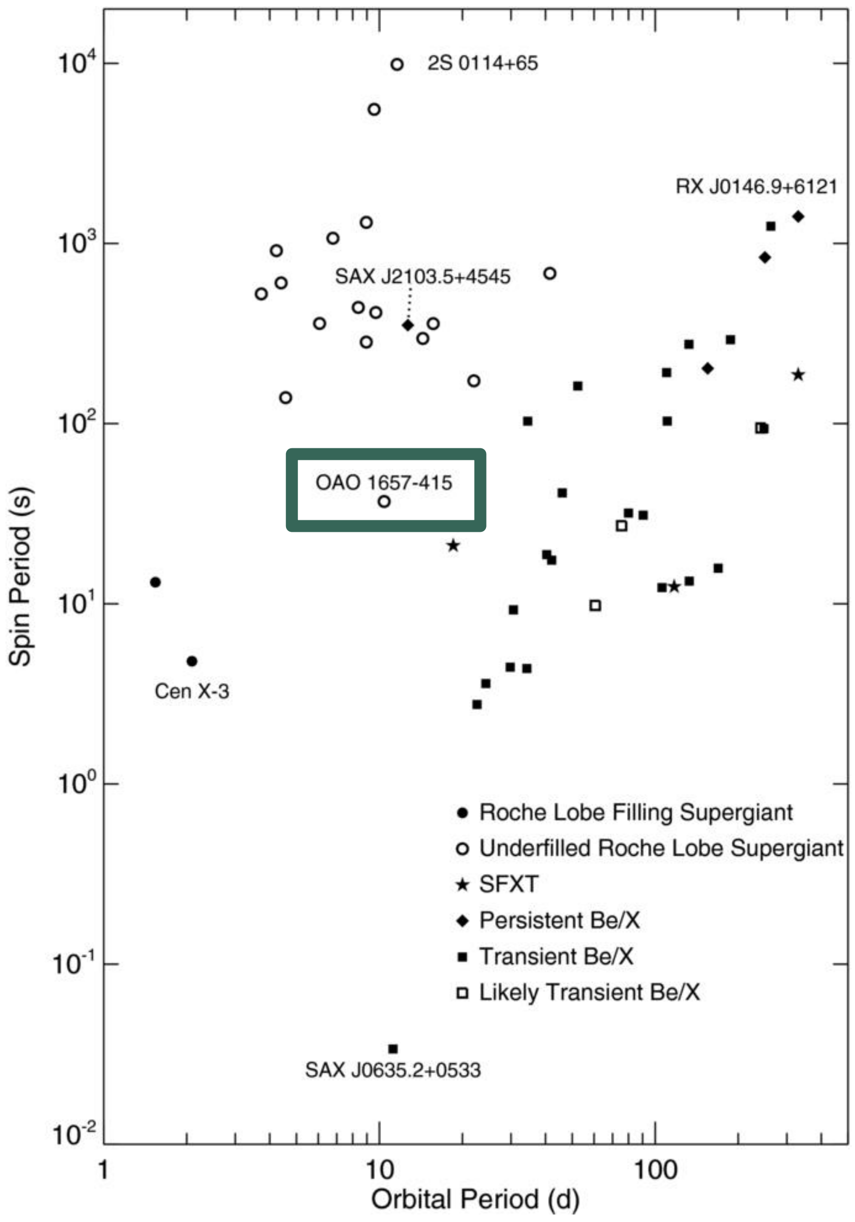
Equipotential sufaces:
Roche Lobe ovefilling



OAO 1657-415 IS AN ECLIPSING BINARY

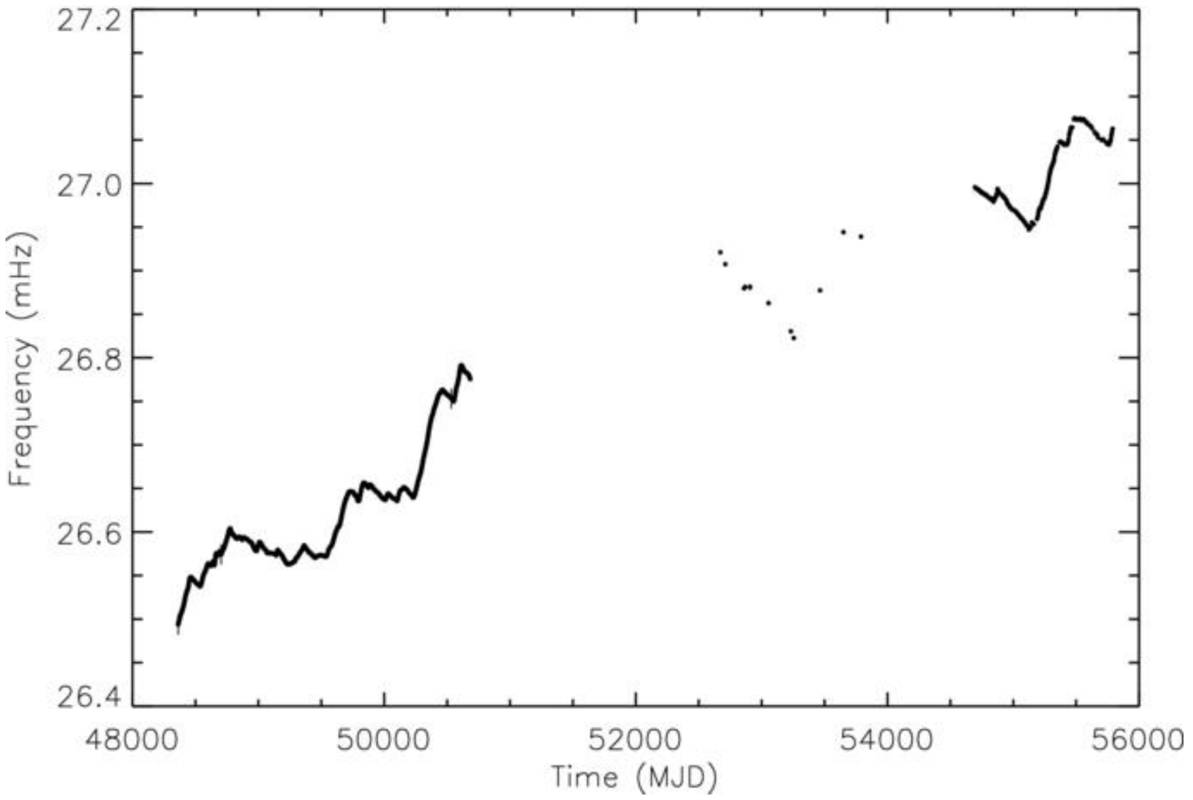
OAO 1657-415

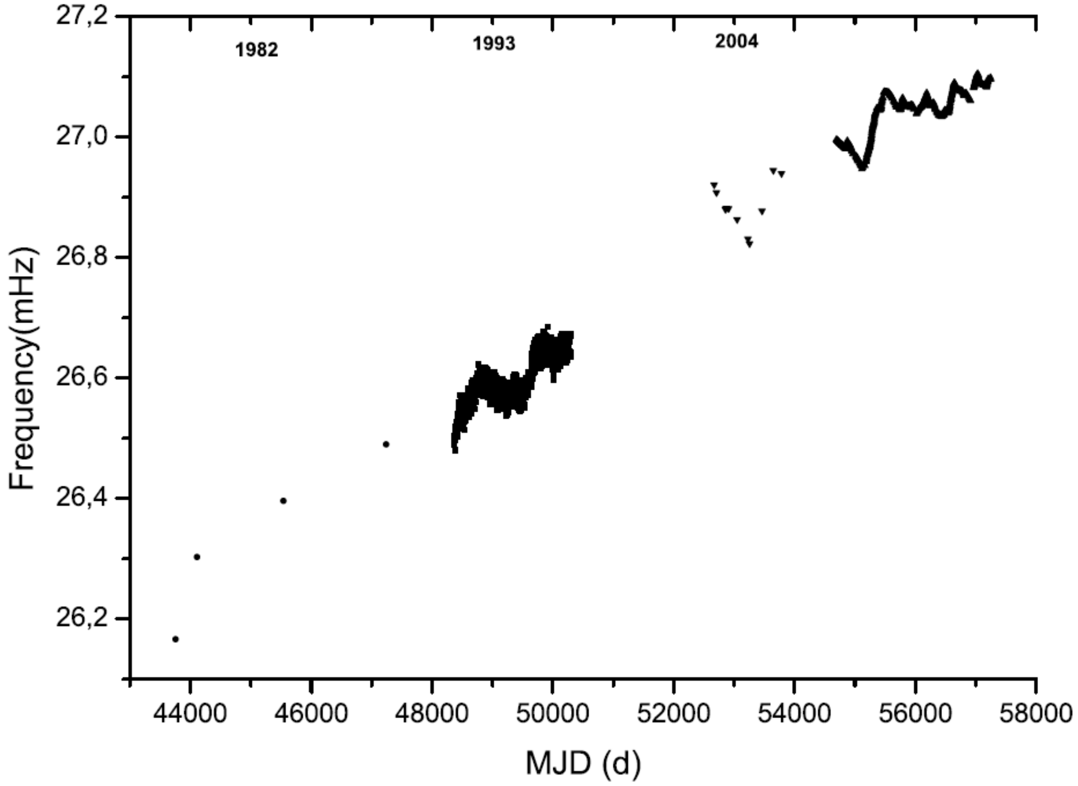
Year of discovery	1978 (1993 characterization)
Donor	Neutron Star (pulsar) $(1{,}42 \pm 0{,}26 M_{\odot})$
Accretor	B0-6Iab (RSG becoming a WR) $(14{,}3 \pm 0{,}8 M_{\odot})$
Orbital period	10.44 days
Pulsar period	36.9 s (38,22 at the first mensuration)
Distance	6.4 ± 1.5 Kpc
Visible in:	X (disk), radio (pulsar), near-IR (donor)



- Fast rotating pulsar to be underfilled Roche Lobe
- Ecliptic and long orbit of the donor

SPIN-ORBIT PECULIARITY OF OAO 1657-415





REGULAR SPIN-UP

$\approx 8 \times 10^{-13}\ Hz/s$

Matter flows towards the neutron star → Moment of inertia increase → Orbital velocity increase

CHAOTIC VARIATION

Many model proposed:

- Wind fed accretion
- Quasi-keplerian disk
- Transition disk
- Magnetically levitating accretion disk
- Unstable transient phase

?

None of them fully fits

SUMMARY

THE MODEL

- Use of an imperfect model with very low χ^2
- Not able to detect the Ni line
- Spectrum dominated by iron lines
- Presence of matter in the surrounding of the NS
- Neutral iron lines formed far from the star
- Ionized iron originated near the star

Combining X-ray data with other regimes we can find new information about our source:

- OAO 1657-415 is a rare eclipsing binary
- Its position in pulsation-period diagram makes the measurement of evolution parameters easy
- Over the years, the source experienced a regular spin up and episodes of rapid spin-up/spin-down

Understanding the mechanism involved in such a kind of object can be a step forward for astrophysics

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