A mysterious feature in the NICER spectrum of 4U 1820–30

A gravitationally redshifted absorption line?

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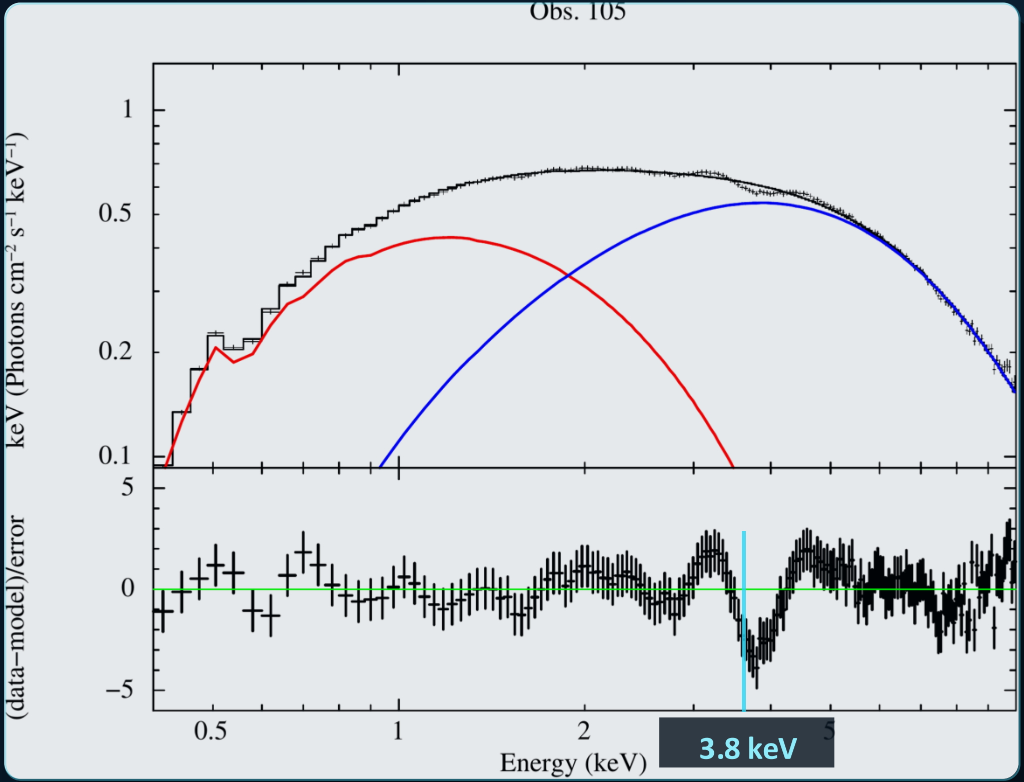
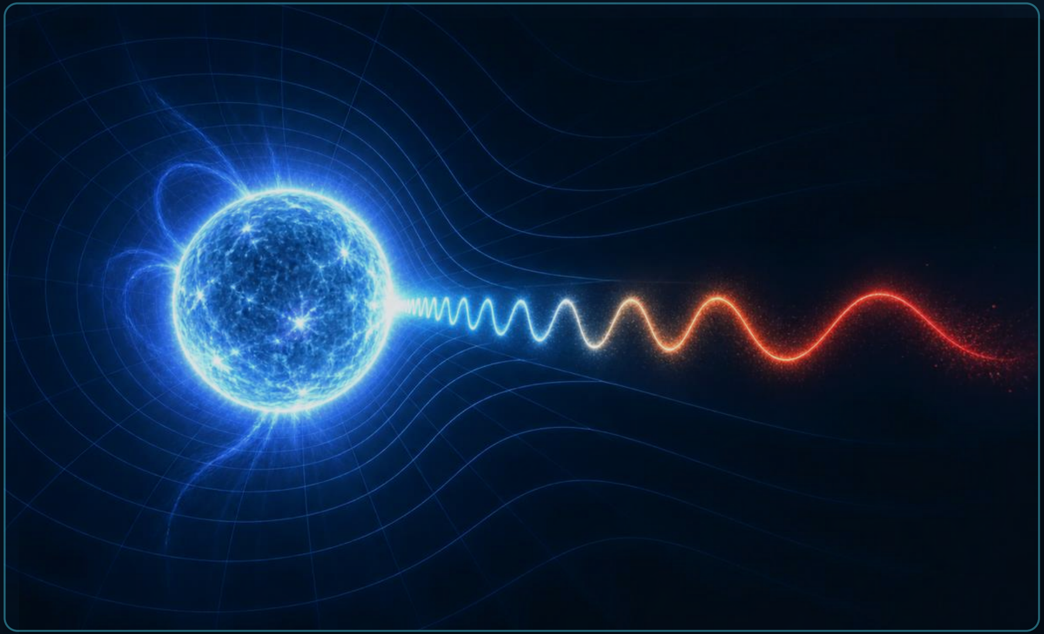


A surface line would directly measure neutron-star compactness

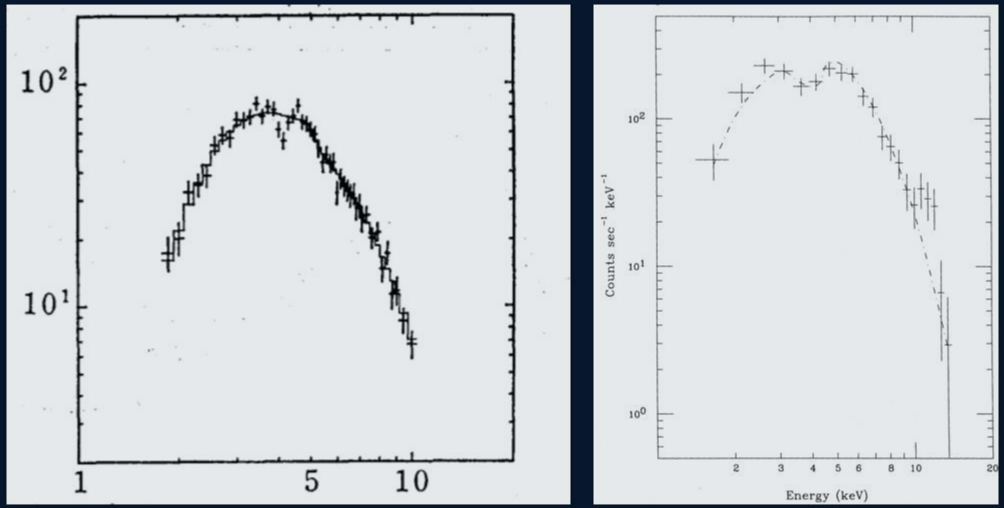


$$1 + z = \left(1 - \frac{2GM}{Rc^2}\right)^{-1/2}$$

$$z = \frac{E_0 - E_{obs}}{E_{obs}}$$

A **secure line identification** and a surface origin provide a direct measurement of M/R.

Broad 4-keV absorption features were already seen in type-I bursts



Two early burst detections

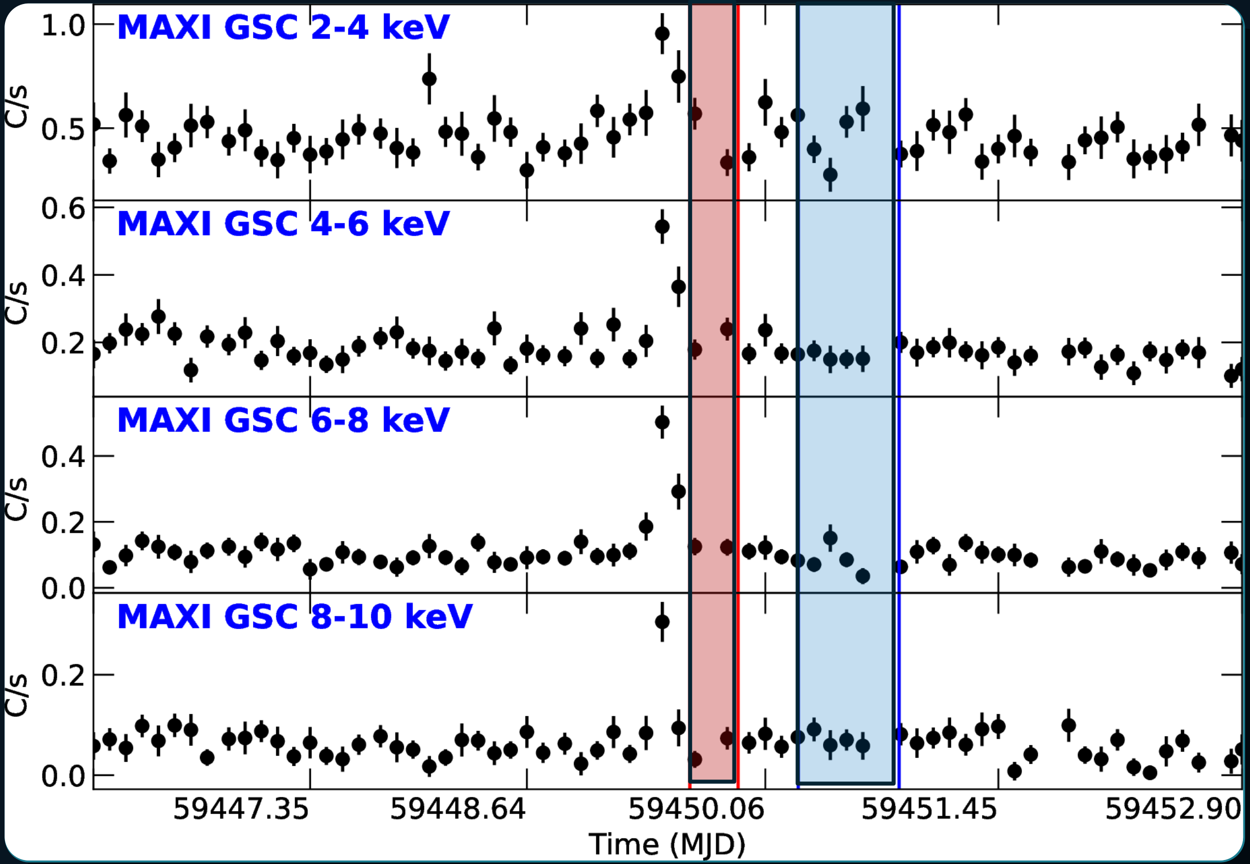
X 1636–536 · Tenma
≈4.1 keV in the burst decay

EXO 1747–214 · EXOSAT
4.05 ± 0.12 keV in the burst rise

Possible redshifted Fe — never conclusively identified

Waki et al. 1984 → Magnier et al. 1989

NICER observed 4U 1820–30 only ~6 h after a superburst



POST-SUPERBURST TIMELINE

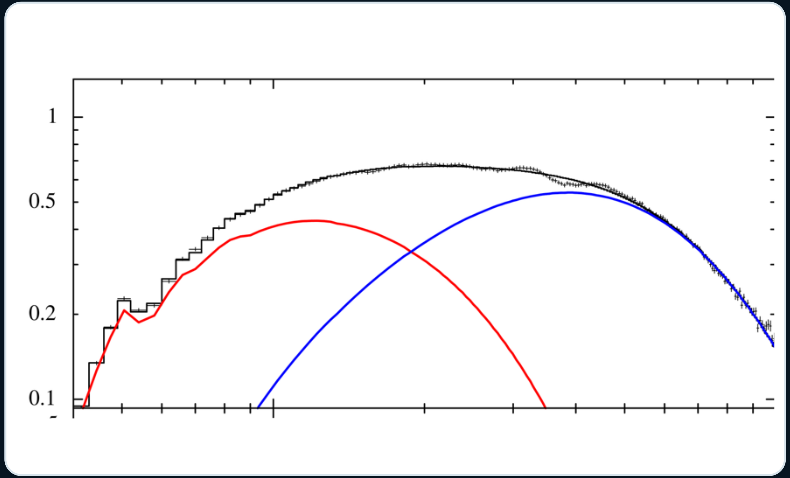
Superburst detected by MAXI → NICER follow-up begins ~6 h later

Serino et al. (2021, ATel 14871)

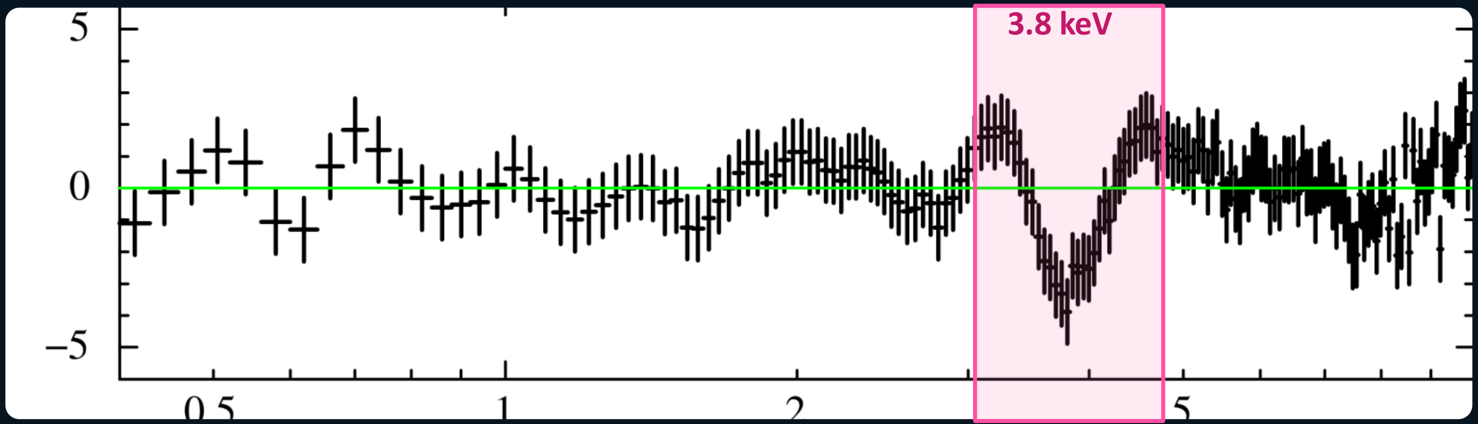
NICER Obs. 105 and Obs. 106

A broad absorption feature appears at 3.8 keV

UNFOLDED SPECTRUM



CONTINUUM RESIDUALS



Energy (keV)

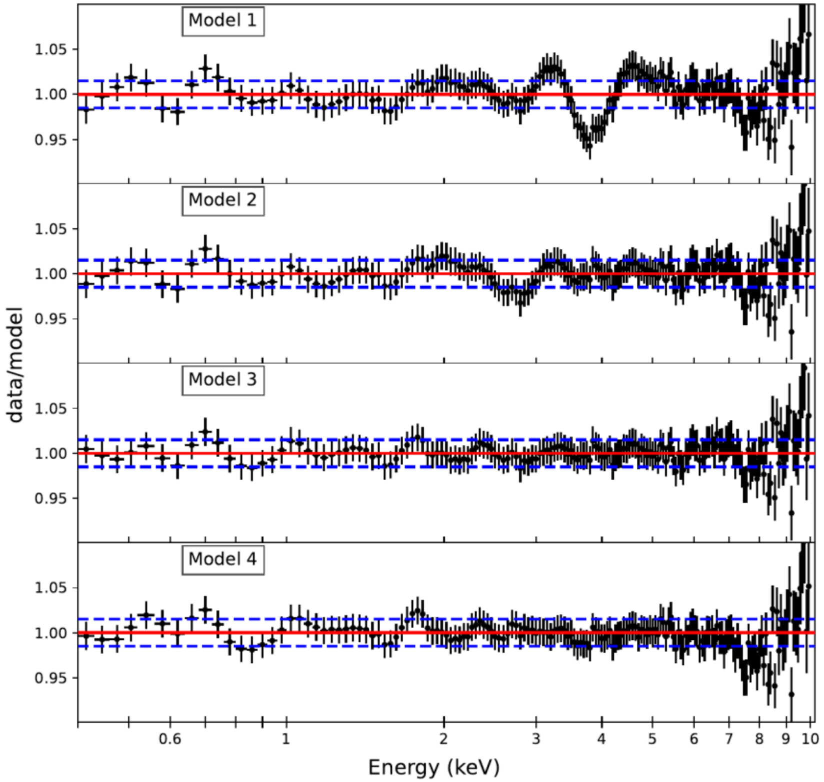
A GENUINELY BROAD FEATURE
FWHM ≃ 0.59 keV

$E_{o\beta s}$ = 3.80 ± 0.05 keV
σ = 0.25 ± 0.05 keV

EW = 44 ± 7 eV
SIGNIFICANCE = 6.1σ

SPECTRAL ROBUSTNESS

A photoionized absorber explains the 3.8-keV feature



PROGRESSIVE MODELLING

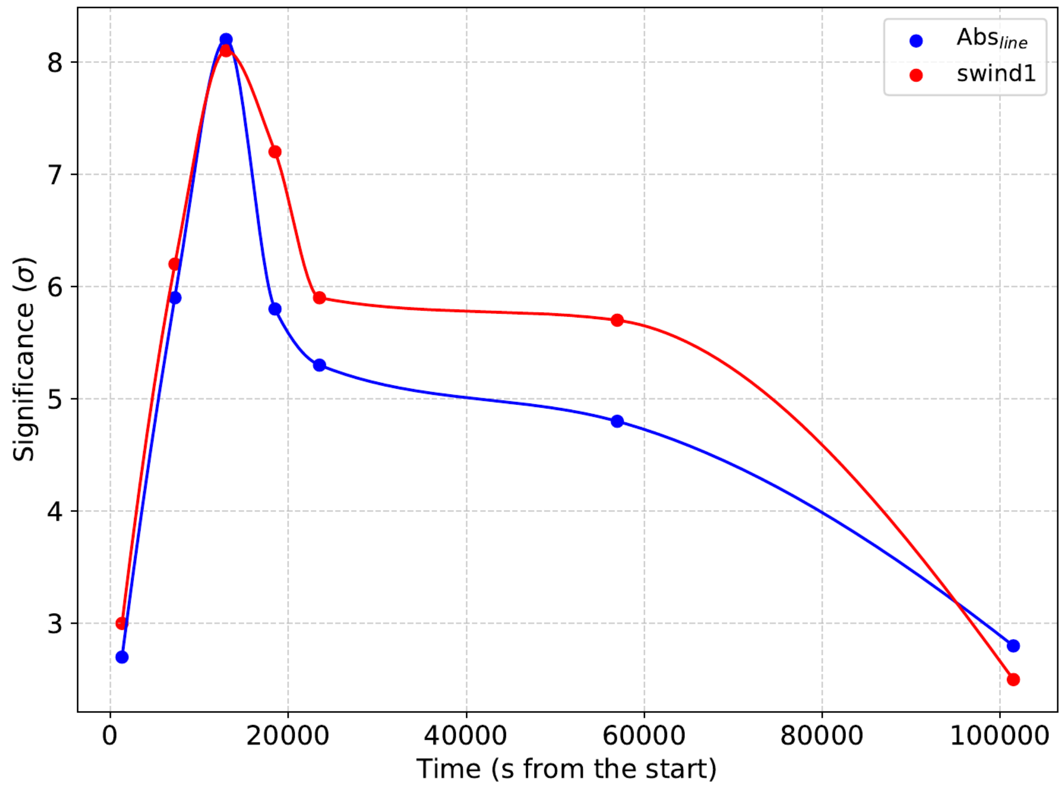
1. **Baseline continuum**
   Broad deficit remains at 3.8 keV
2. **+ absorption Gaussian**
   Feature modelled phenomenologically
3. **+ low-energy emission lines**
   Remaining soft residuals accounted for
4. **Photoionized absorber**
   Physical, self-consistent description

χ^2/dof 233.1/163 → 97.6/155

The feature is not a continuum artifact: phenomenological and physical models recover consistent parameters.

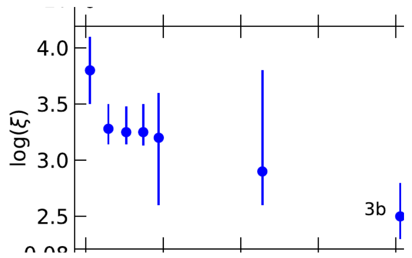
TIME-RESOLVED EVOLUTION

The line weakens as the post-superburst spectrum evolves

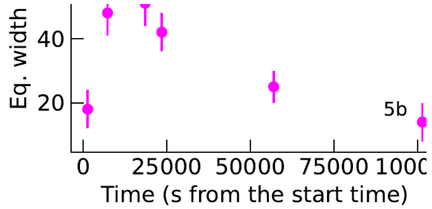


Peak significance >8σ; the feature becomes marginal in the final interval

PHYSICAL EVOLUTION



Ionization decreases



Equivalent width fades

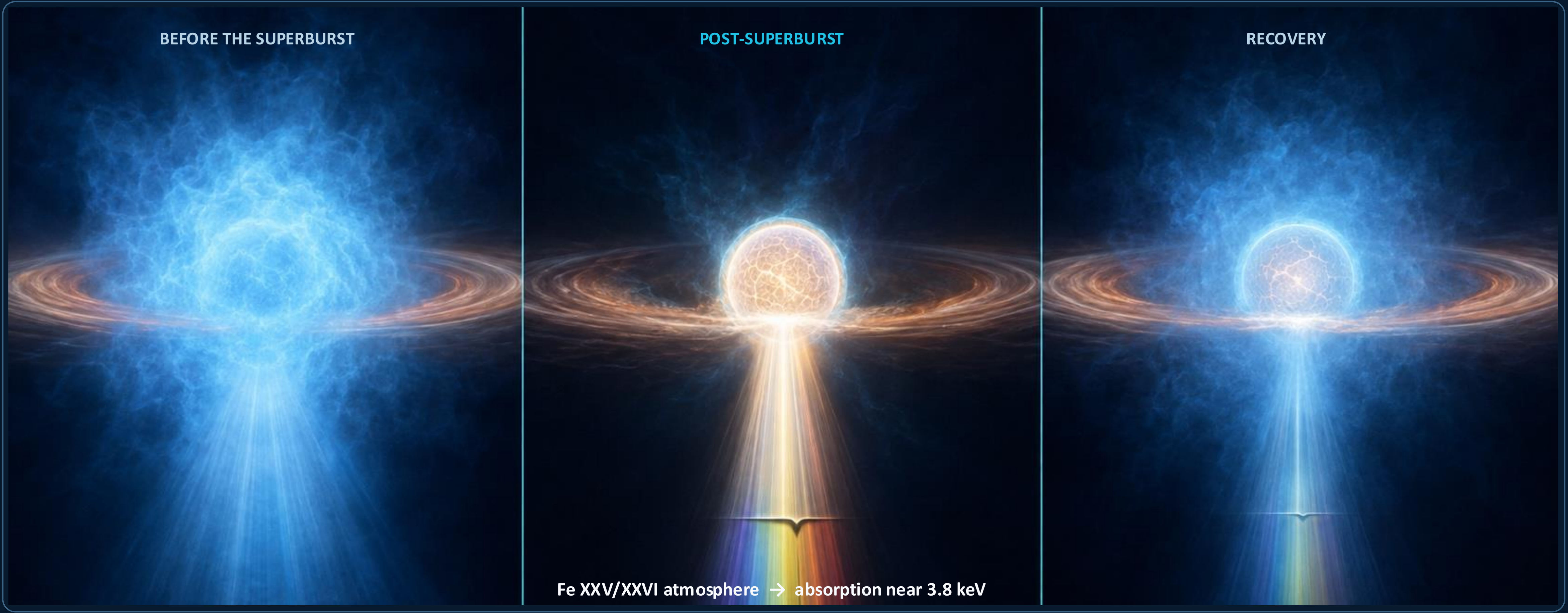
Redshift remains approximately consistent

The transient behavior links the feature to the post-superburst spectral evolution.

6.1σ average fit
>8σ time-resolved fits

A PROPOSED PHYSICAL SCENARIO

The superburst may briefly expose the photosphere



The burst changes the viewing geometry — it need not produce the observed iron.

EW consistent with ~solar Fe abundance
(within a factor of two)

A SELF-CONSISTENT IDENTIFICATION

A redshifted Fe absorber explains both energy and width

ENERGY SHIFT

Fe XXV / Fe XXVI

REST-FRAME K TRANSITIONS

6.7–7.0 keV

→ gravitational redshift

MEASURED REDSHIFT

$1 + z$

1.72 ± 0.05

$E_{obs} = E_{rest} / (1 + z)$

→

OBSERVED TROUGH

≈ 3.8 keV

in the NICER spectrum

ROTATIONAL WIDTH CHECK

$v_{spin} = 716$ Hz • $i = 31°$ • $R = 10$ km → $v_{eq} / c = 2\pi R v_{spin} / c \approx 0.15$ → $v_{eq} \sin i / c \approx 0.08$

Jaisawal et al. 2024 • Anitra et al. 2025

MEASURED

$\sigma / E = 0.06 \pm 0.02$

≈

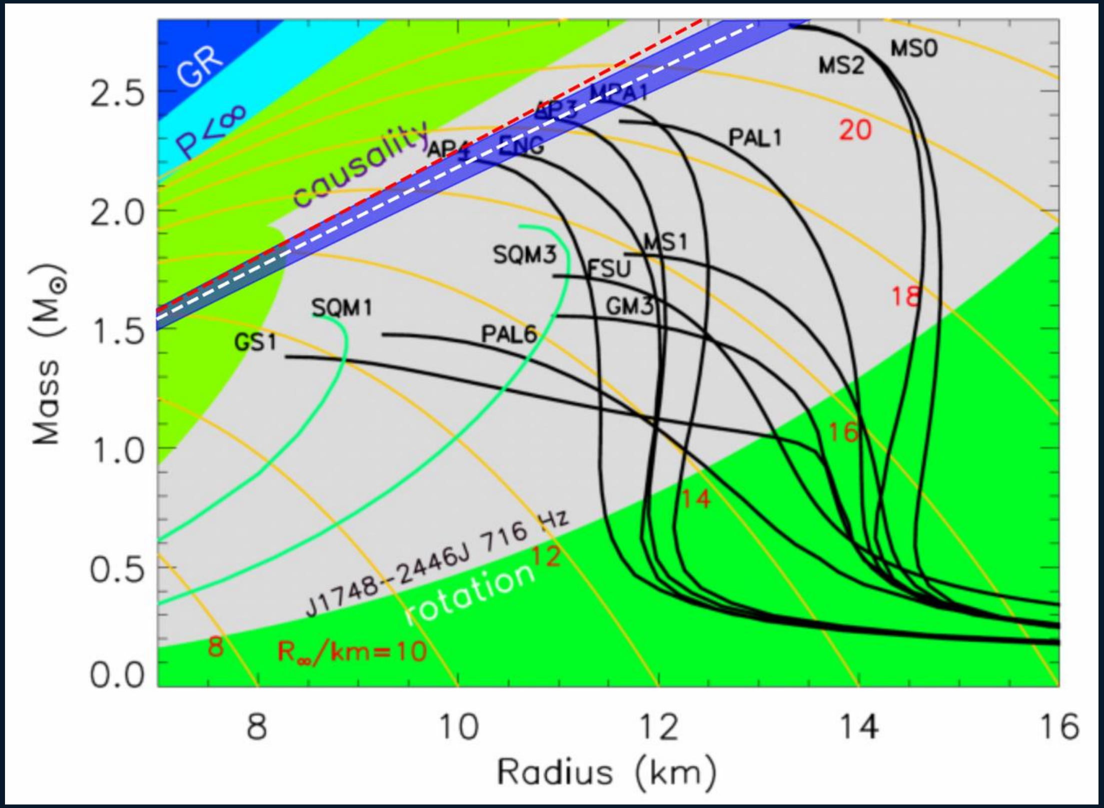
PROJECTED DOPPLER SCALE

$v_{eq} \sin i / c \approx 0.08$

same order of magnitude; the two quantities are not strictly identical

The width agrees in scale with rotation — it is not a rotational-profile fit.

The Fe interpretation implies an unusually compact neutron star



RED DASHED — static NS: best-fit value only

WHITE DASHED + BLUE STRIP — rotating NS at 716 Hz: best fit + redshift uncertainty

STATIC COMPACTNESS FROM THE REDSHIFT

R / M

4.46 ± 0.13

km $M_\odot^{-1}$

= 3.02 ± 0.09 (G = c = 1)

THE SAME CONSTRAINT, TWO READINGS

$M = 1.4\,M_\odot \rightarrow R \simeq 6.4$ km

$R = 10$ km $\rightarrow M \simeq 2.18\,M_\odot$

Plausible EOS region
$M \simeq 1.8$–$2.3\,M_\odot$ • $R \simeq 8.3$–11 km

The measured quantity is compactness — not mass or radius separately.

Recent work has sharpened — not resolved — the interpretation

COMPOSITION & FORMATION SITE

PERO & WEINBERG 2026

Burst winds can carry intermediate-mass and iron-group elements.

Surface, wind, or accretion-flow origin?
The alternatives are compared, not discriminated.

IF NOT PHOTOSPHERIC

The feature becomes a probe of post-superburst ejecta.

MASS–RADIUS CONSEQUENCES

DE AVELLAR ET AL. 2026

Take the measured redshift as input

$M_{max} = 2.3\,M_\odot$: difficult to reconcile EOS radii, NICER constraints, and previous burst estimates.

Allowing $M_{max} \approx 2.6\,M_\odot$ improves EOS overlap, but increases the tension with burst-based estimates. They do not reanalyse the spectral feature.

The key observational question remains the line identification and formation site.

A transient line may provide a direct view of the neutron-star surface

01 NICER detected a transient broad absorption feature at 3.8 keV after a superburst.

02 A photoionized Fe absorber provides a self-consistent description.

03 The inferred redshift, $1 + z = 1.72 \pm 0.05$, implies $R/M = 4.46 \pm 0.13$ km $M_{\odot}^{-1}$.

04 Future high-throughput spectroscopy must confirm the atomic identification and formation site.

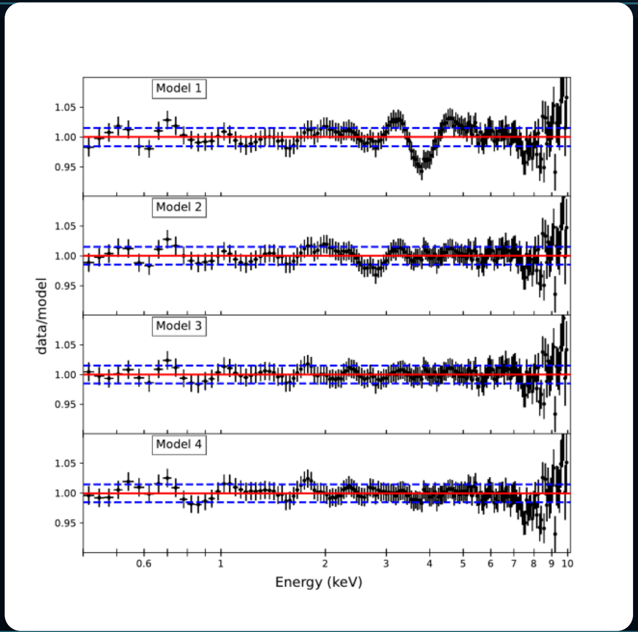
Thank you · rosario.iaria@unipa.it

> The feature is transient; its implications for neutron-star structure could be far-reaching..

Thank you for your attention

Rosario Iaria · rosario.iaria@unipa.it

The 3.8-keV deficit is robust against the continuum choice



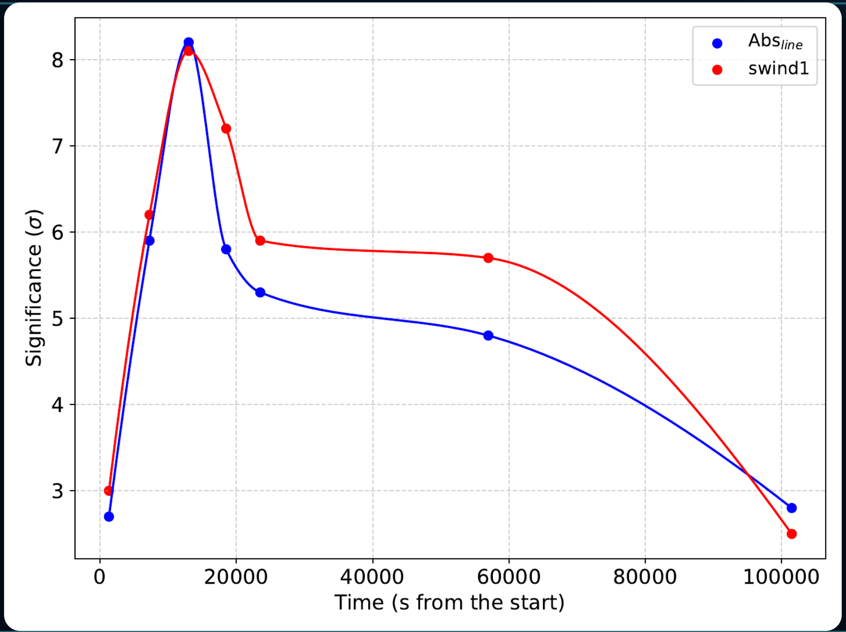
Four continua, the same trough

- Model 1 · continuum only
- Model 2 · + Gaussian absorption
- Model 3 · + low-energy emission lines
- Model 4 · photoionized absorber

The feature is not produced by continuum curvature

Model 1 → Model 2: $\Delta\chi^2 = 123.2$ for 3 parameters

The feature reaches more than 8σ in the central intervals



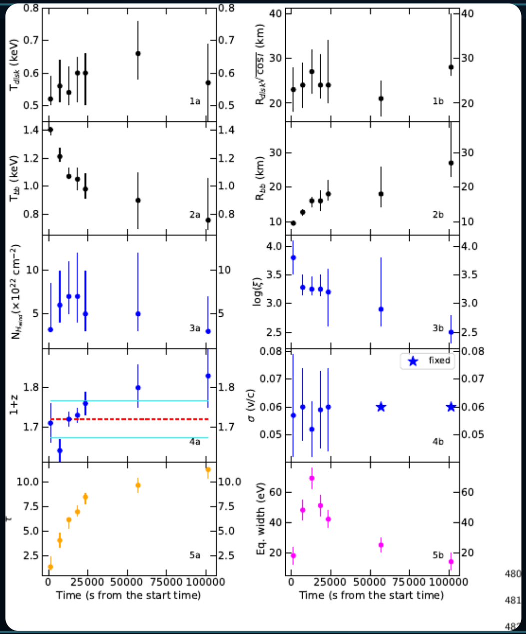
Two descriptions give the same evolution

Averaged spectrum · 6.1σ
Time-resolved peak · >8σ
Intermediate intervals · ≈5–7σ
Final interval · ≈2.5–2.8σ

The detection weakens as the post-superburst spectrum evolves

Blue: Gaussian line · Red: swind1 absorber

The absorber evolves together with the post-superburst spectrum



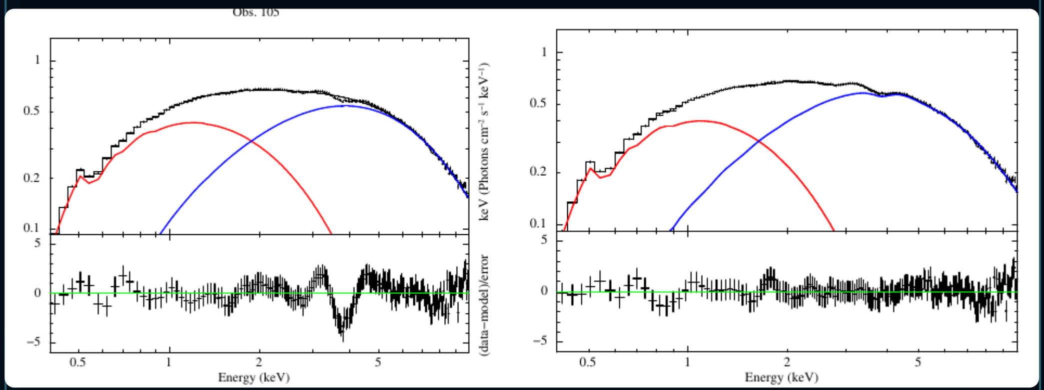
The line is transient, not stationary

Redshift · broadly consistent
Ionization · decreases
Equivalent width · 15–60 eV
Compton optical depth · increases

A rebuilding corona can progressively hide the surface spectrum

Seven intervals across NICER Obs. 105 and 106

Alternative identifications imply very different formation sites



Identification controls the inferred compactness

Fe XXV/XXVI · 6.7–7.0 keV
→ 1+z ≈ 1.72; surface candidate

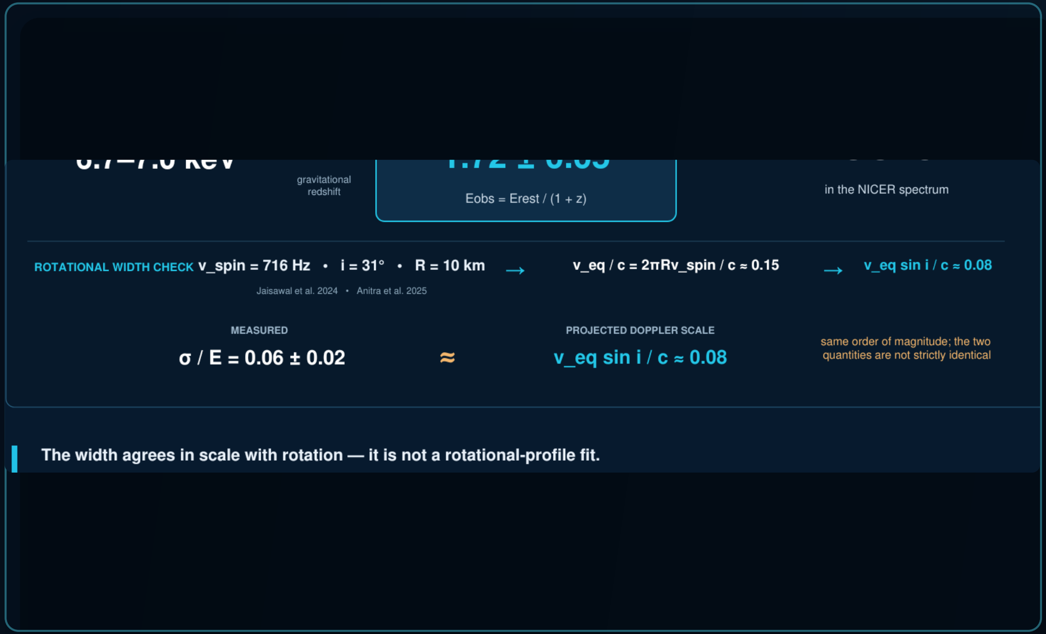
Ca XX or Ti K · ≈4.1–4.5 keV
→ moderate shift; disk/outflow alternatives

Ar XVIII · 3.32 keV
→ would require a blueshift at 3.8 keV

Atomic ID and formation site must both be secure

Observed centroid: ≈3.8 keV

The observed width is compatible in scale with rapid rotation



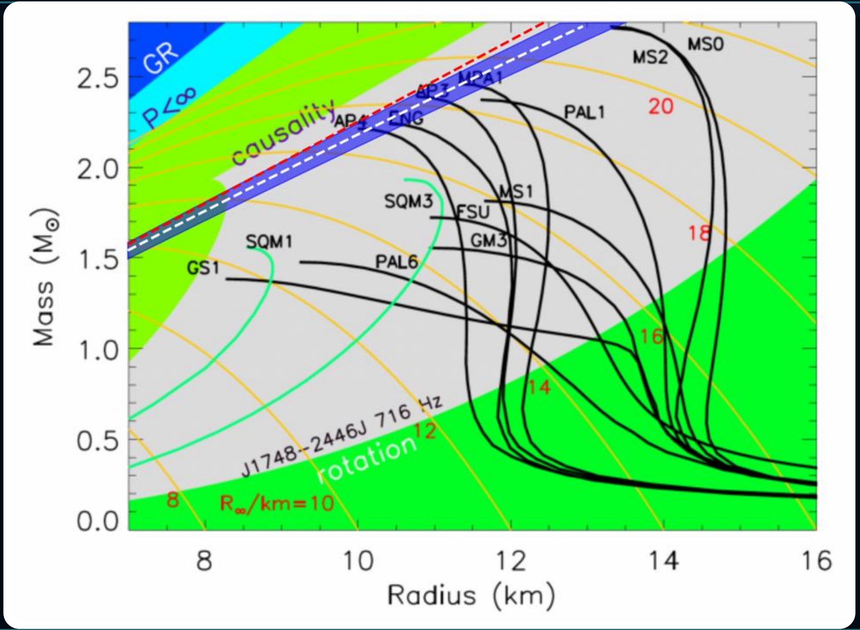
A consistency check — not a line-profile fit

Measured width · $\sigma/E = 0.06 \pm 0.02$
Spin candidate · 716 Hz
Inclination · 31°
Radius range · 8.3–11 km

Projected rotation gives $v \sin i/c \approx 0.06$–0.08

Agreement in scale does not prove a surface origin

The mass–radius strip is conditional on five key assumptions



What enters the compactness constraint?

1 · Fe XXV/XXVI identification
2 · formation at the NS surface
3 · 1+z = 1.72 ± 0.05
4 · spin = 716 Hz and i = 31°
5 · rotation metric approximations

Static result: R/M = 4.46 ± 0.13 km M⊙$^{-1}$

The blue strip includes rotation; the red line is static