

X-ray Binaries

An artistic rendering of an X-ray binary system. A central white neutron star is surrounded by a multi-layered accretion disk. The innermost part of the disk is bright white and yellow, transitioning through orange and red to purple and blue at the outer edges. Two powerful jets of high-energy radiation, one yellow and one purple, are shown being emitted from the poles of the neutron star. The background is a dark space filled with distant stars.

Neutron Stars, Winds and Puzzles

Nathalie Degenaar

Study X-ray Binaries:

Why, How and What

Study X-ray Binaries: The Why

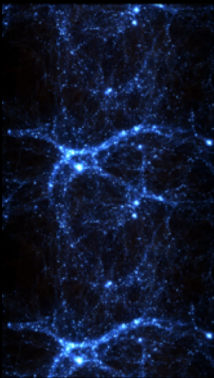
1. Black holes and neutron stars are fascinating!



Probe **extreme** physics

Involved in many **explosive** phenomena

2. Accretion is a very important process

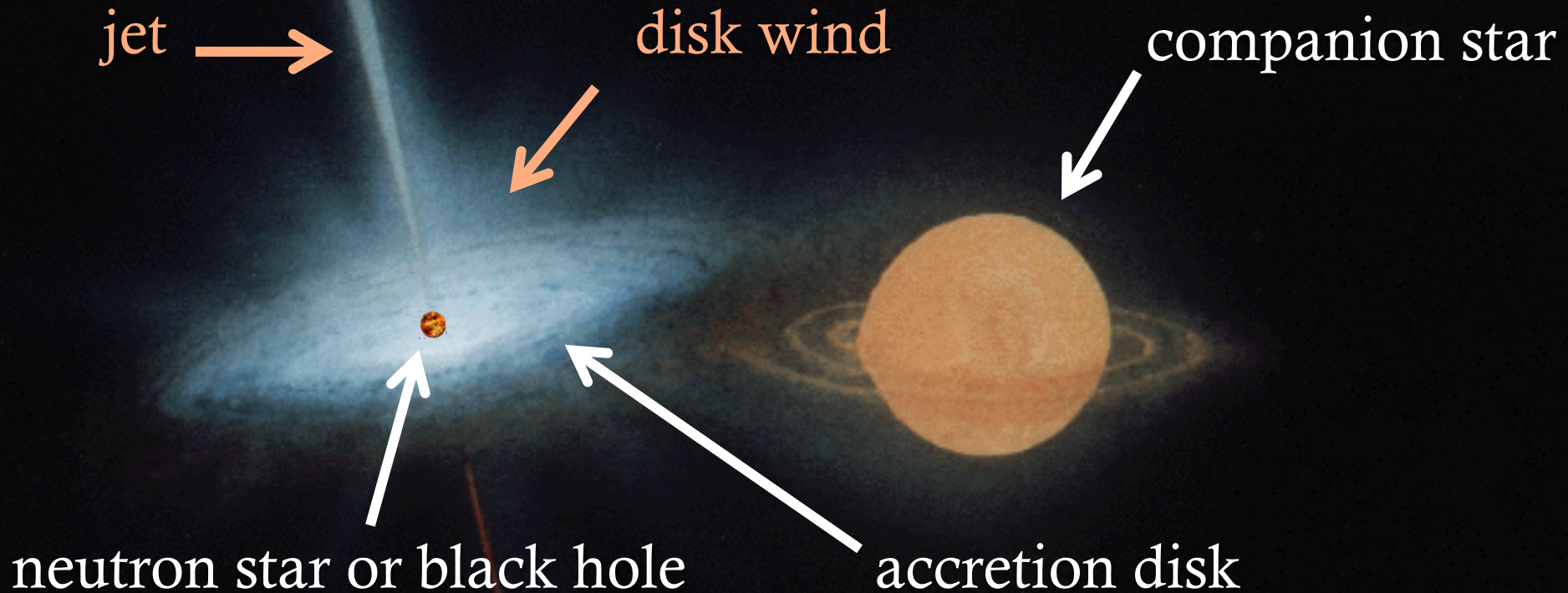


Occurs **everywhere** in the universe

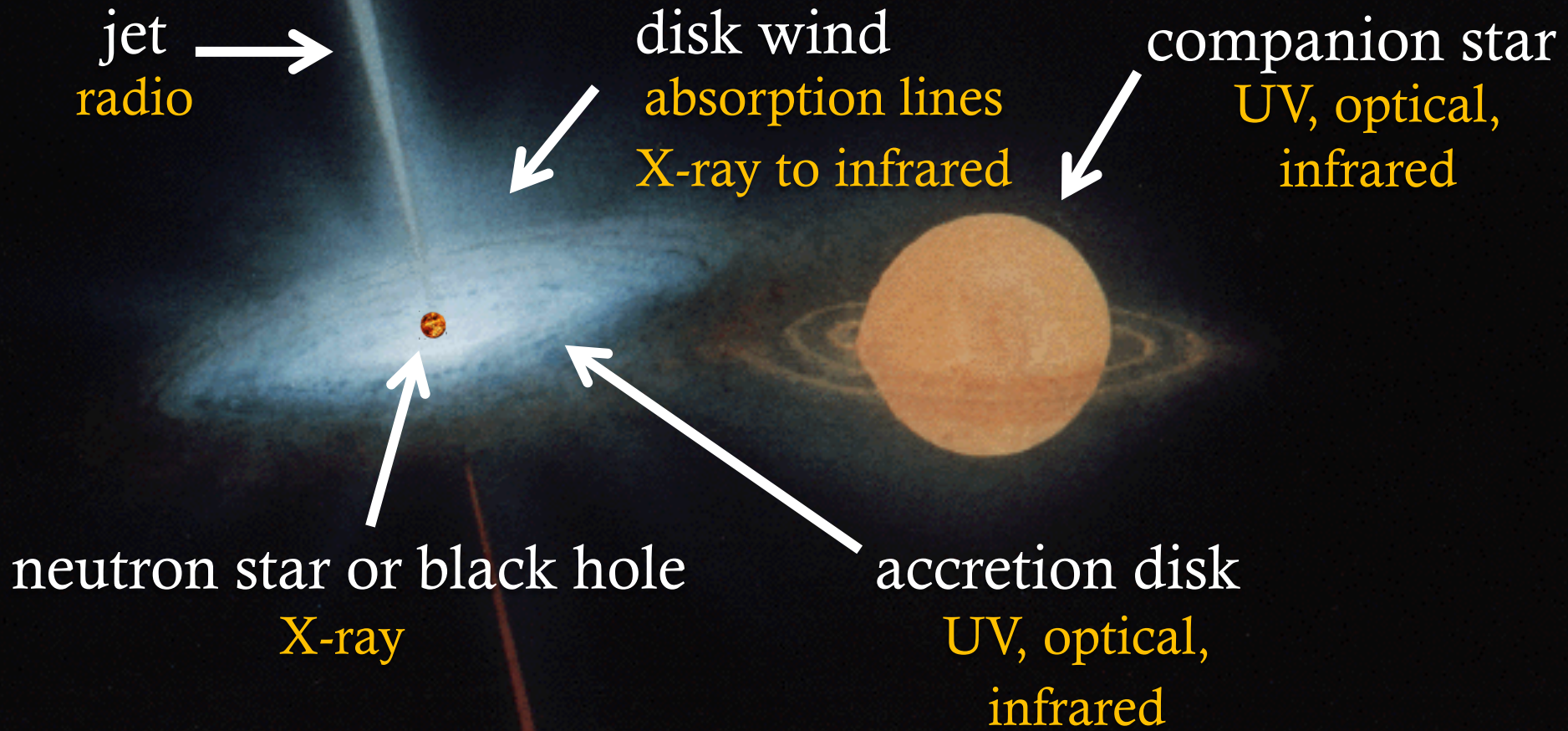
Huge **impact** on binary evolution + environment

➔ Study physics of NSs/BHs + many physical processes

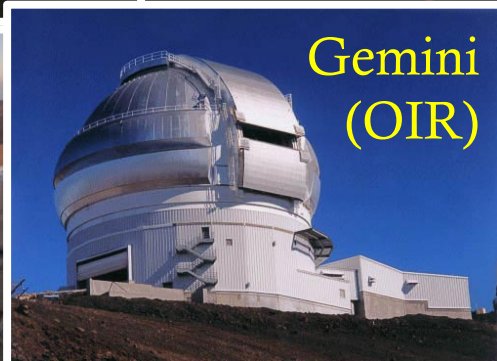
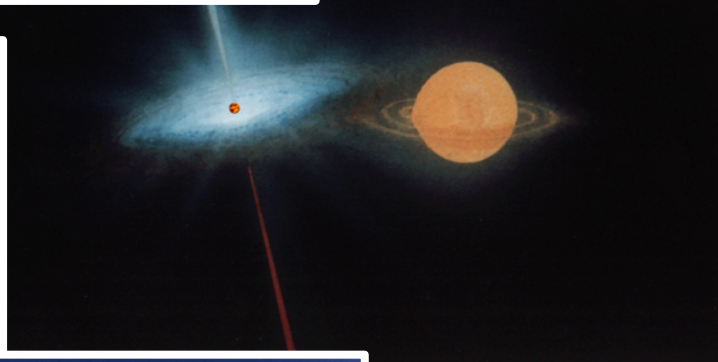
Study X-ray Binaries: The How



Study X-ray Binaries: The How



Study X-ray Binaries: The How



Study X-ray Binaries: The What



Stefanie Fijma
PhD student yr-3



Eleonora Caruso
PhD student yr-1



Noud Hover
MSc project



Karla Rojas Martinez
MSc project



Research areas:

Neutron stars &
dense matter

Accretion, jets and
winds

Thermonuclear
explosions

Binary evolution

MSc projects 2024-2025
On key open questions

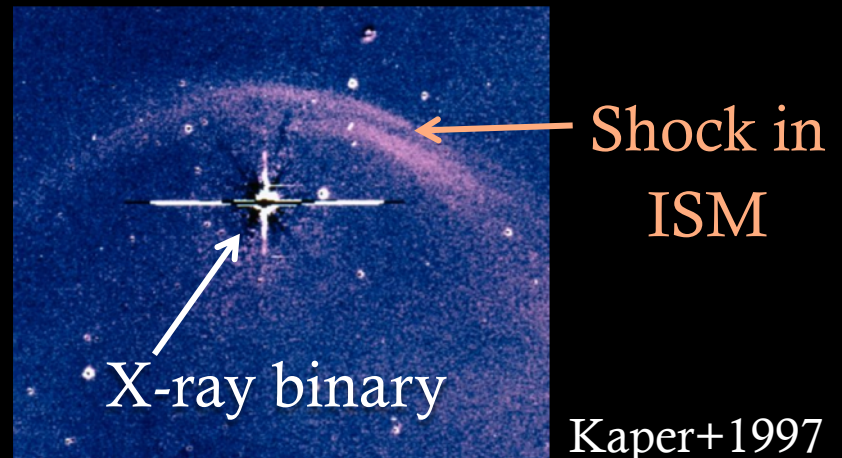
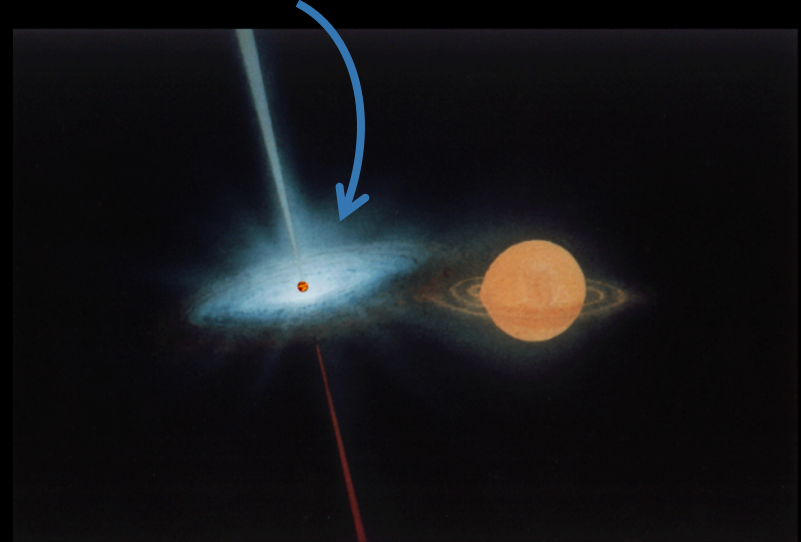
Project I: Winds of Change

Neutron stars and black holes drive winds into space →
broad astrophysical impact

Limit growth (mass gain) of black
holes and neutron stars

Accelerate shrinking binary orbit
→ gravitational wave **merger rates**

Slam into interstellar medium
(ISM) → stimulate **star formation**



Kaper+1997

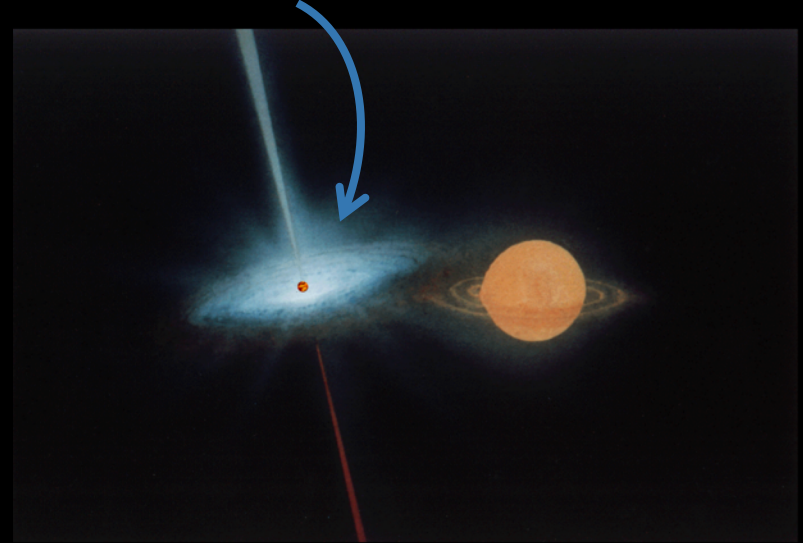
Project I: Winds of Change 🗨️

Neutron stars and black holes drive winds into space →
broad astrophysical impact

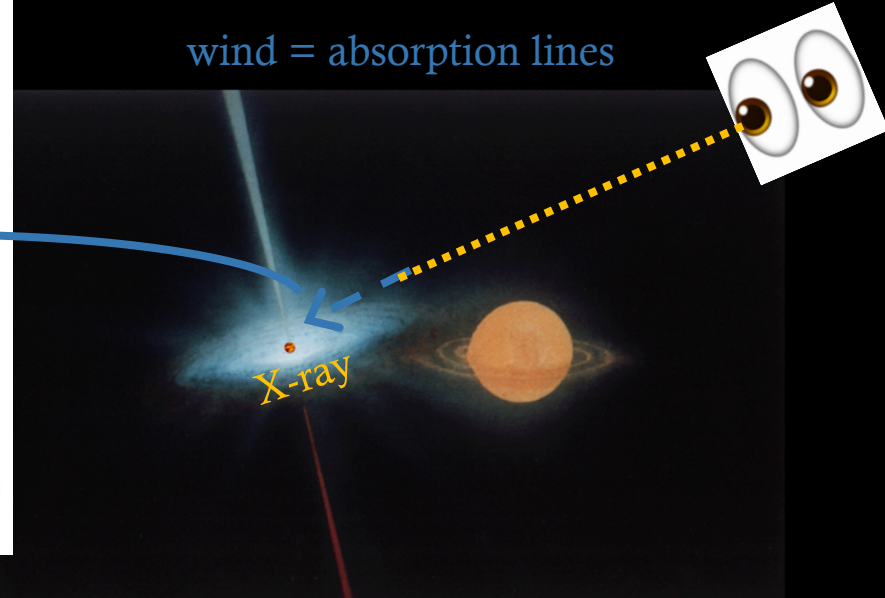
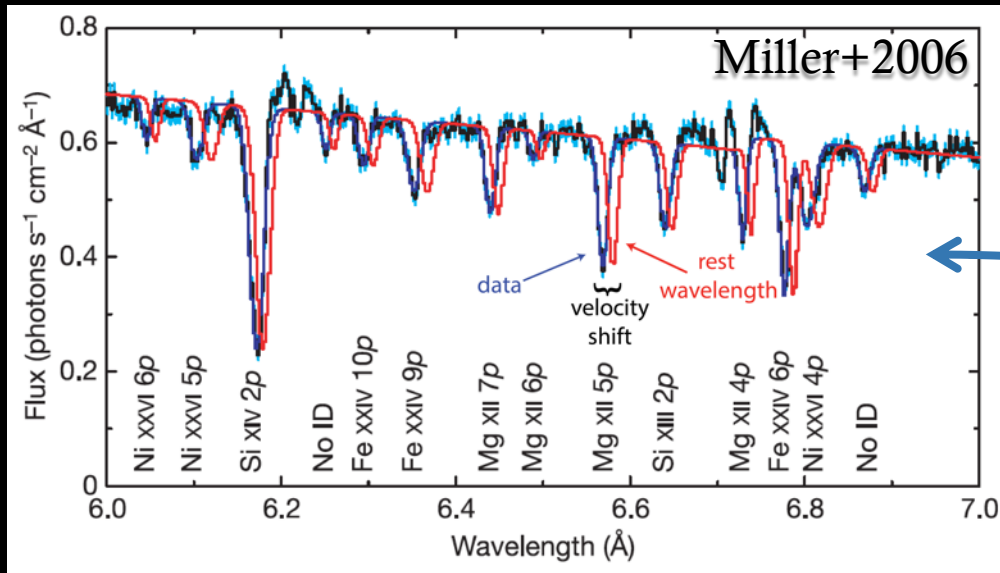
Key question:

How much mass do winds
carry away?

(or: how common are
winds, when do they occur)



Project I: Winds of Change



Recent result: Winds switch on/off in hours (Fijma+2023)

→ Is this common? What is the astrophysical impact?

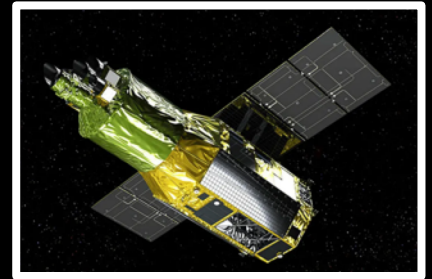
Project I = Very first X-ray variability study of winds

→ Pathfinder for XRISM satellite launched Sep 2023!

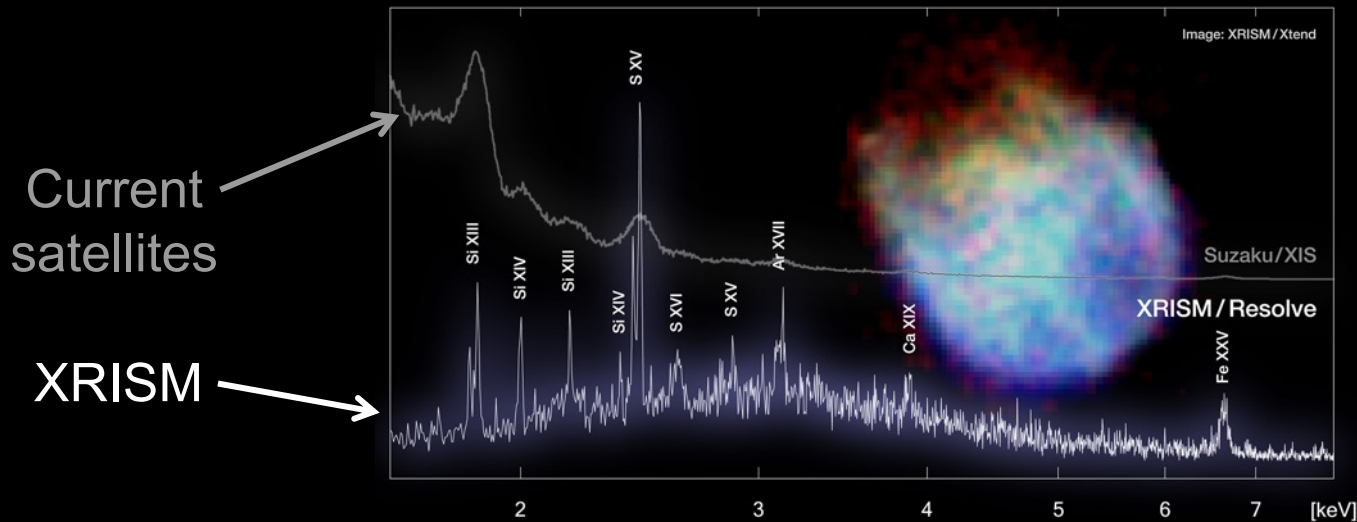
Project I: Winds of Change

XRISM = brand-new X-ray satellite (Japan/Europe)

High energy resolution at X-ray energies
NEVER explored before!



Your project will be a **pathfinder** for XRISM



Project I: Winds of Change

Data: XMM-Newton, prep for XRISM!

Analysis: X-ray spectra, NASA software

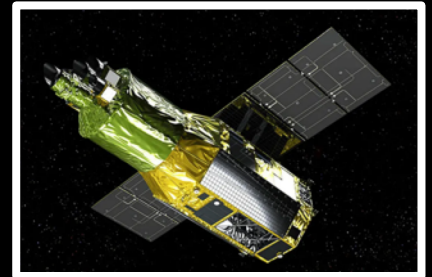
Target(s): Two famous bright neutron stars
(Hercules X-1, Cygnus X-2)

Joint project with:

Elisa Costantini (SRON, Leiden)

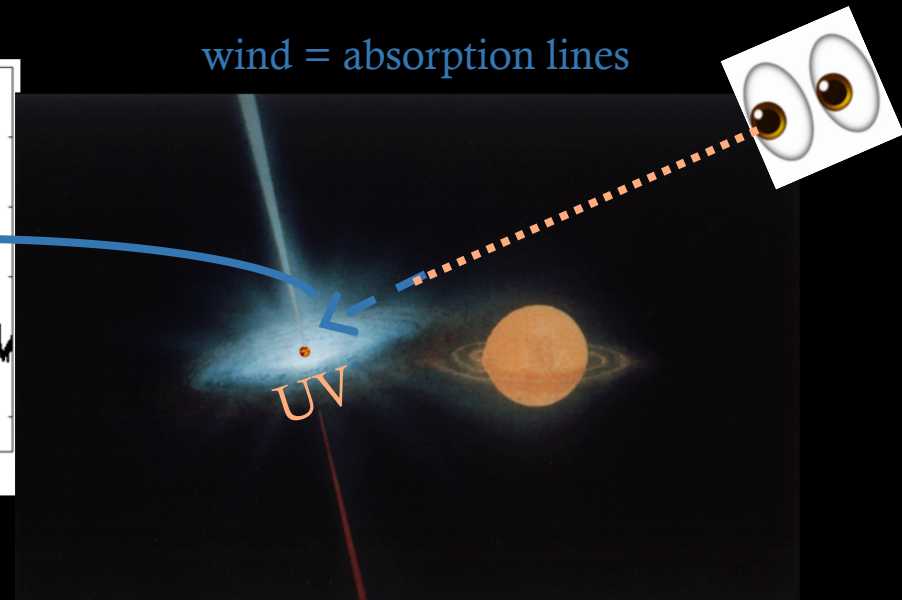
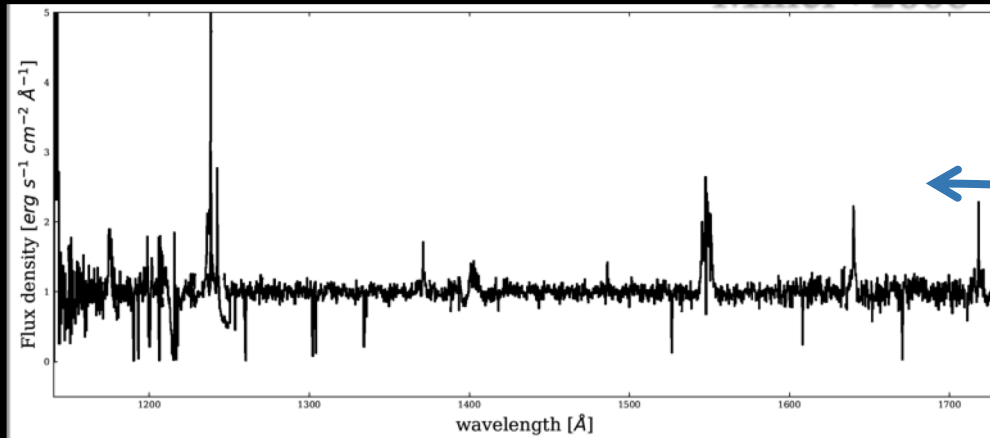


Maria Diaz Trigo (ESO, Germany)



Project can include a 1-month work visit to ESO

Project II: Winds of Change - UV 🤪



Recent result: Winds switch on/off in hours (Fijma+2023)

→ Is this common? What is the astrophysical impact?

Project II = The uncharted territory of UV winds

→ Very few wind studies in UV, new results are awaiting!

Project II: Winds of Change - UV 🧐

Data: Hubble Space Telescope

Analysis: UV spectra, (own) python coding

Target(s): Two famous bright neutron stars
(Hercules X-1, Cygnus X-2)

Project I + II are very complementary

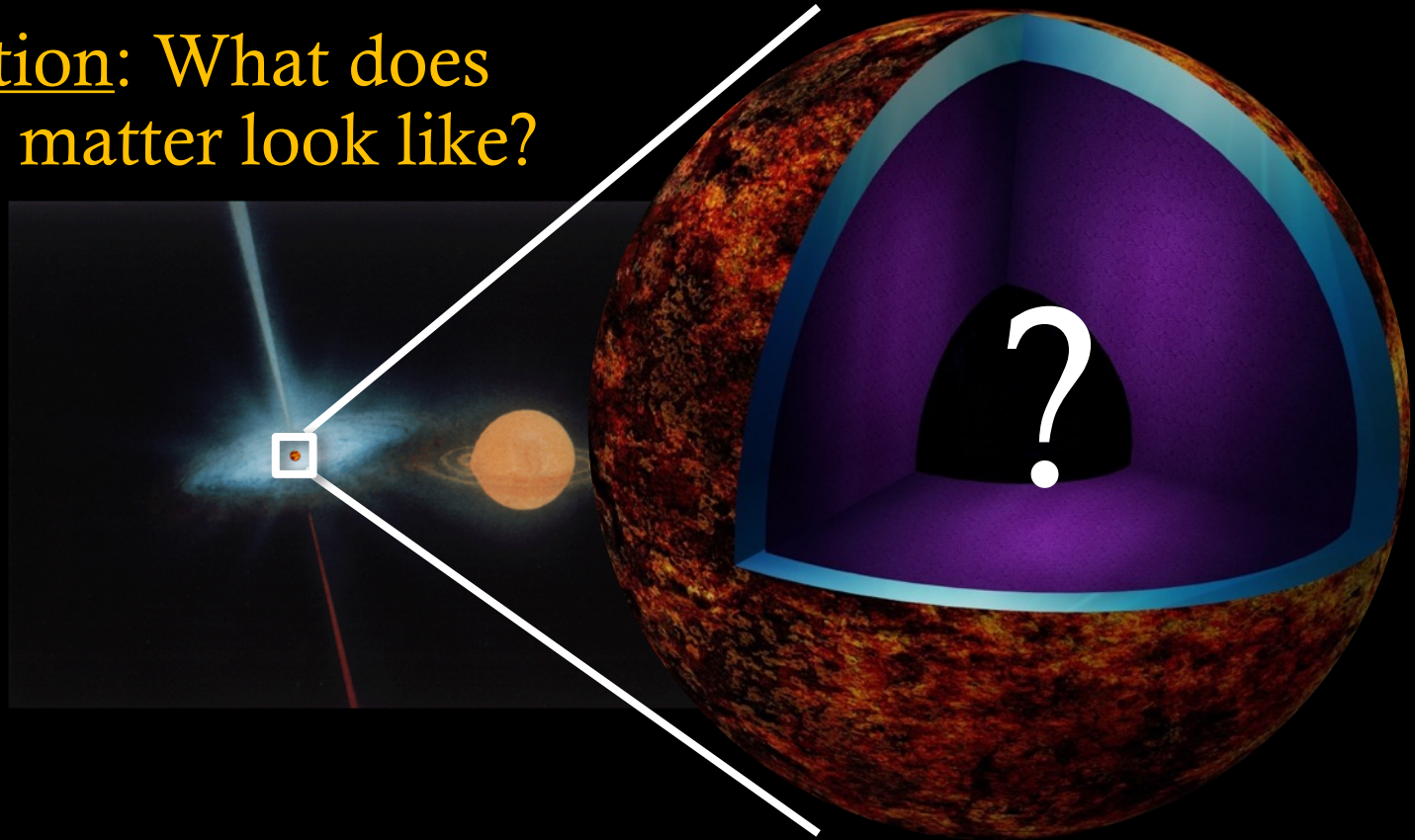
Can each be stand alone projects

but also great to work with team of 2 students



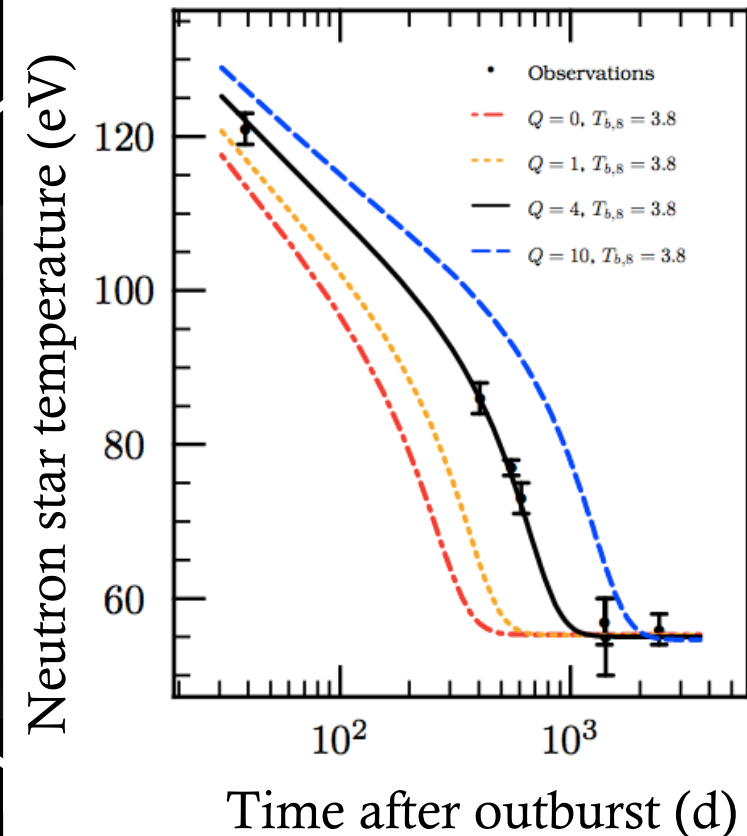
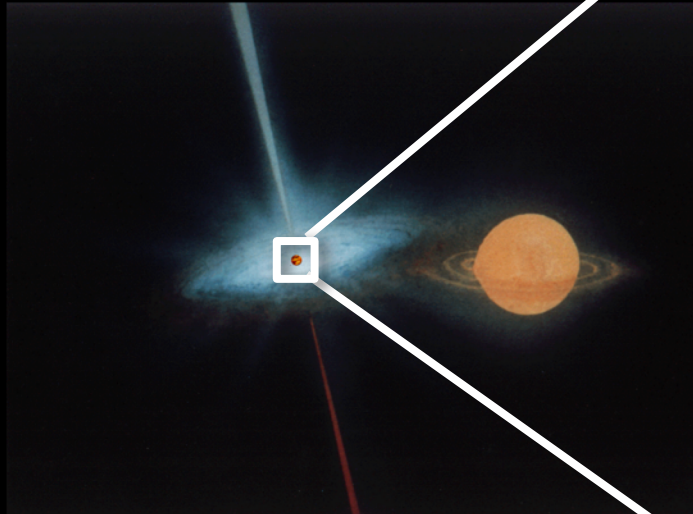
Project III: Neutron Star Anatomy

Key question: What does ultra-dense matter look like?



Project III: Neutron Star Anatomy

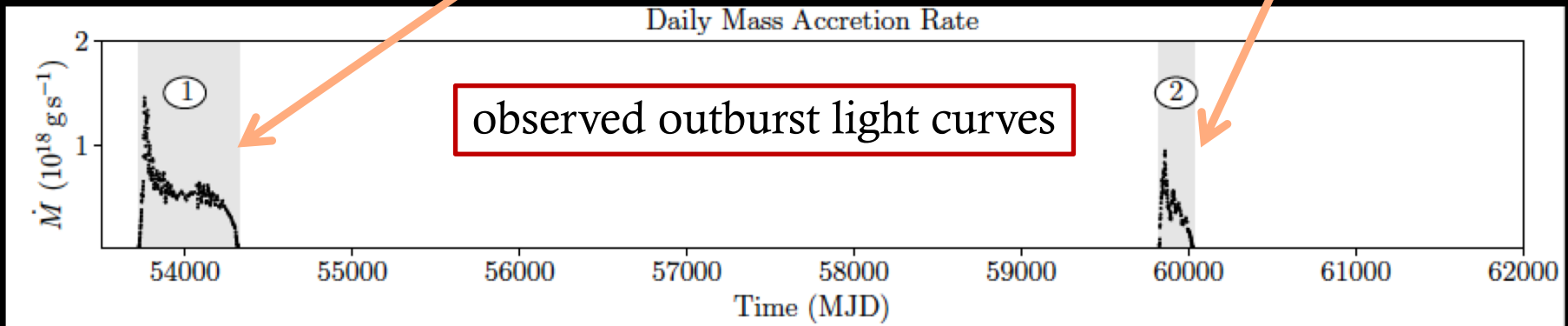
Key question: What does ultra-dense matter look like?



Neutron stars heated during accretion, cool afterwards
→ Compare to theoretical models to understand interior

Project III: Neutron Star Anatomy

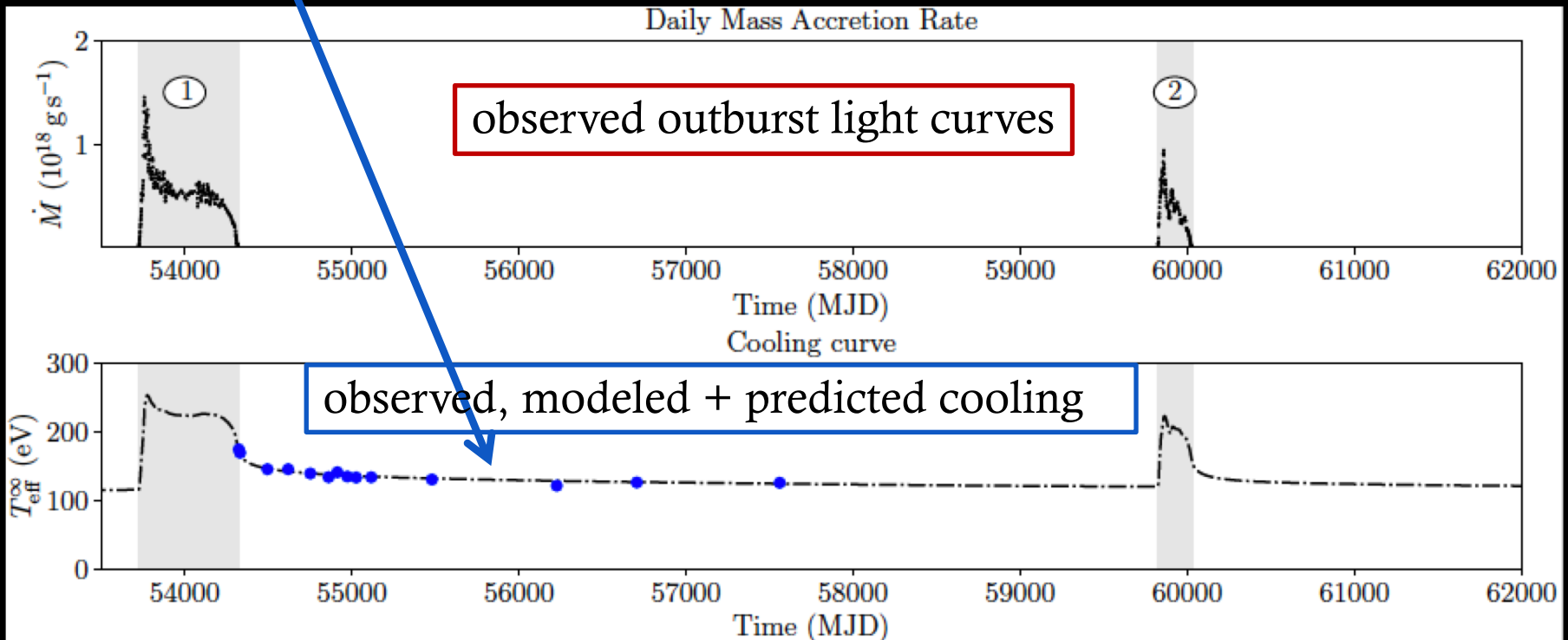
XTE J1701: outburst in 2006-2007, new one in 2022



Project III: Neutron Star Anatomy

XTE J1701: outburst in 2006-2007, new one in 2022

Cooling after 2006-2007 outburst

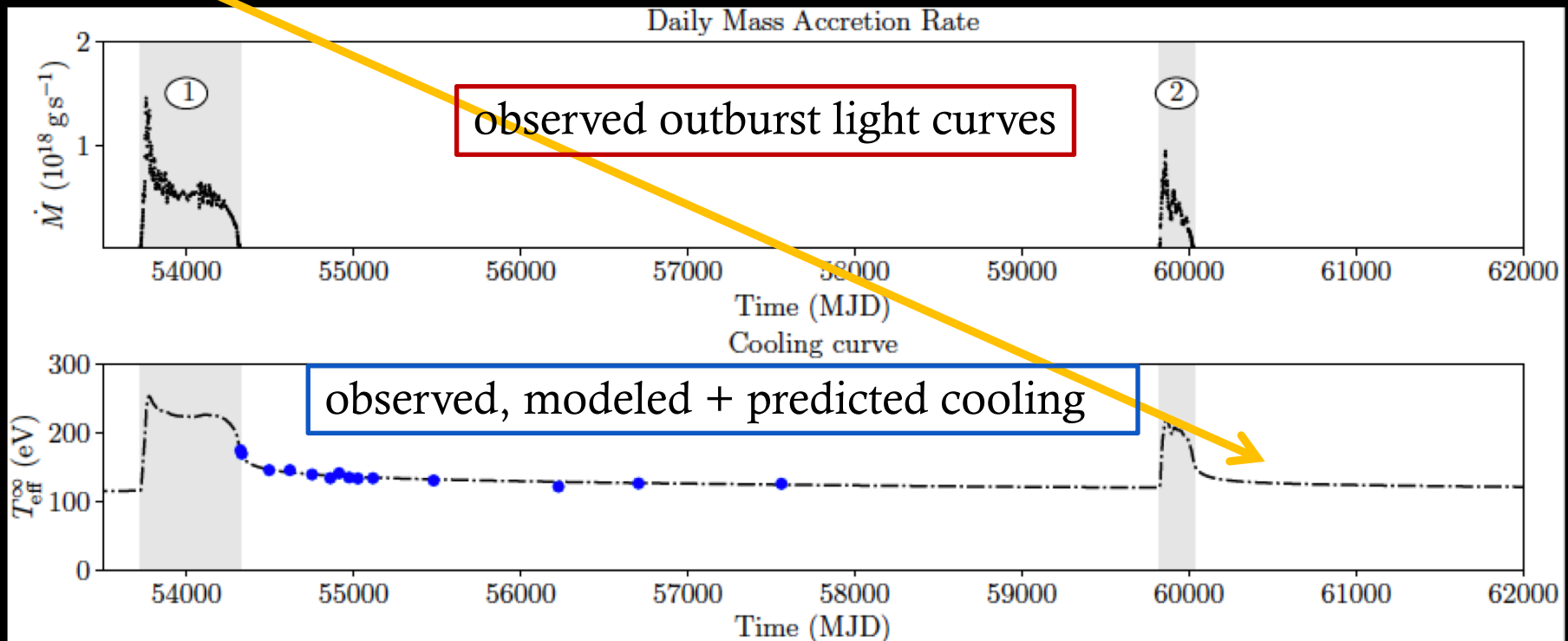


Project III: Neutron Star Anatomy

XTE J1701: outburst in 2006-2007, new one in 2022-23

Cooling after 2006-2007 outburst

New data after 2022-23! Does it follow the predictions?



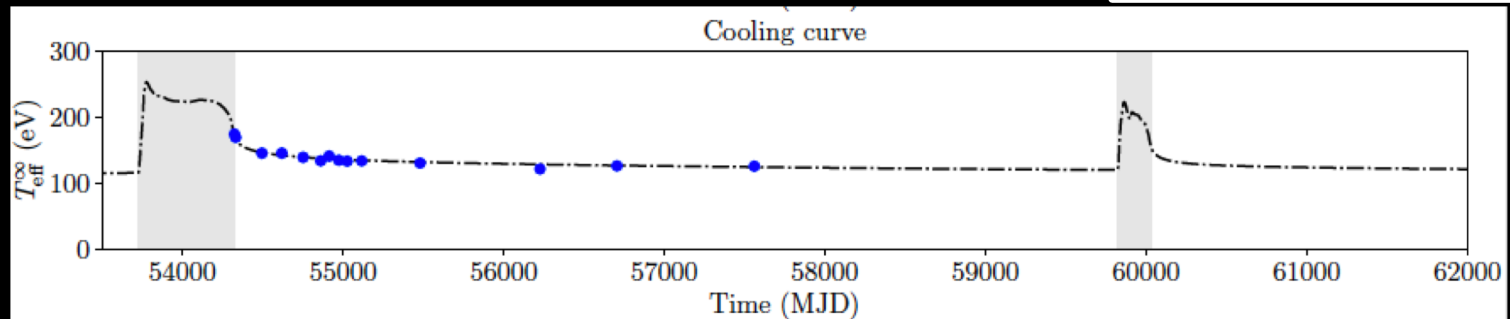
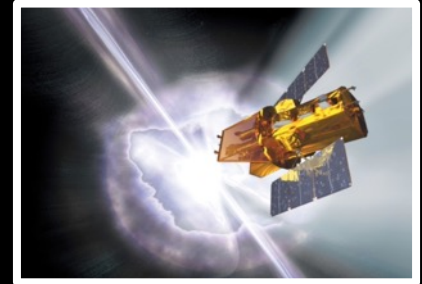
Project III: Neutron Star Anatomy

Data: Chandra + XMM-Newton + Swift

Analysis: X-ray spectra, NASA software

Target(s): One or more neutron stars

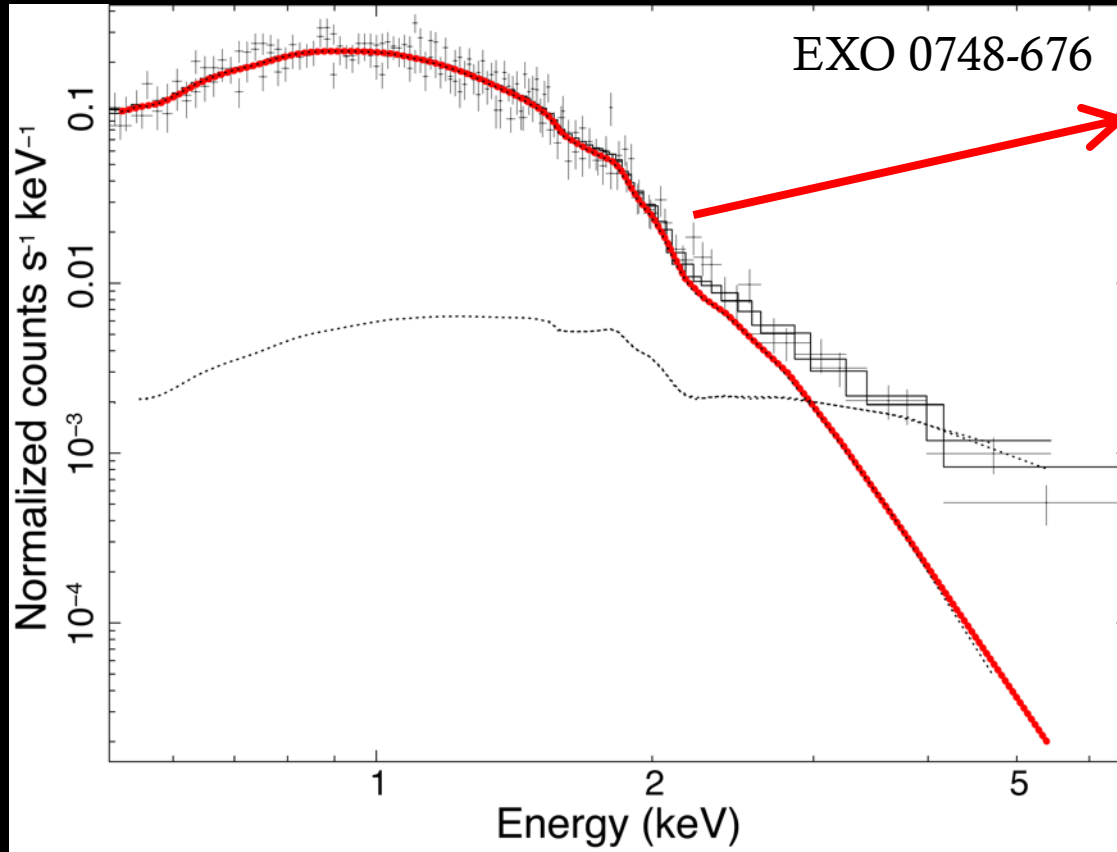
Joint project with:
Rudy Wijnands



Project IV: X-ray Puzzle

What causes X-rays of quiescent neutron stars?

Thermal glow neutron star

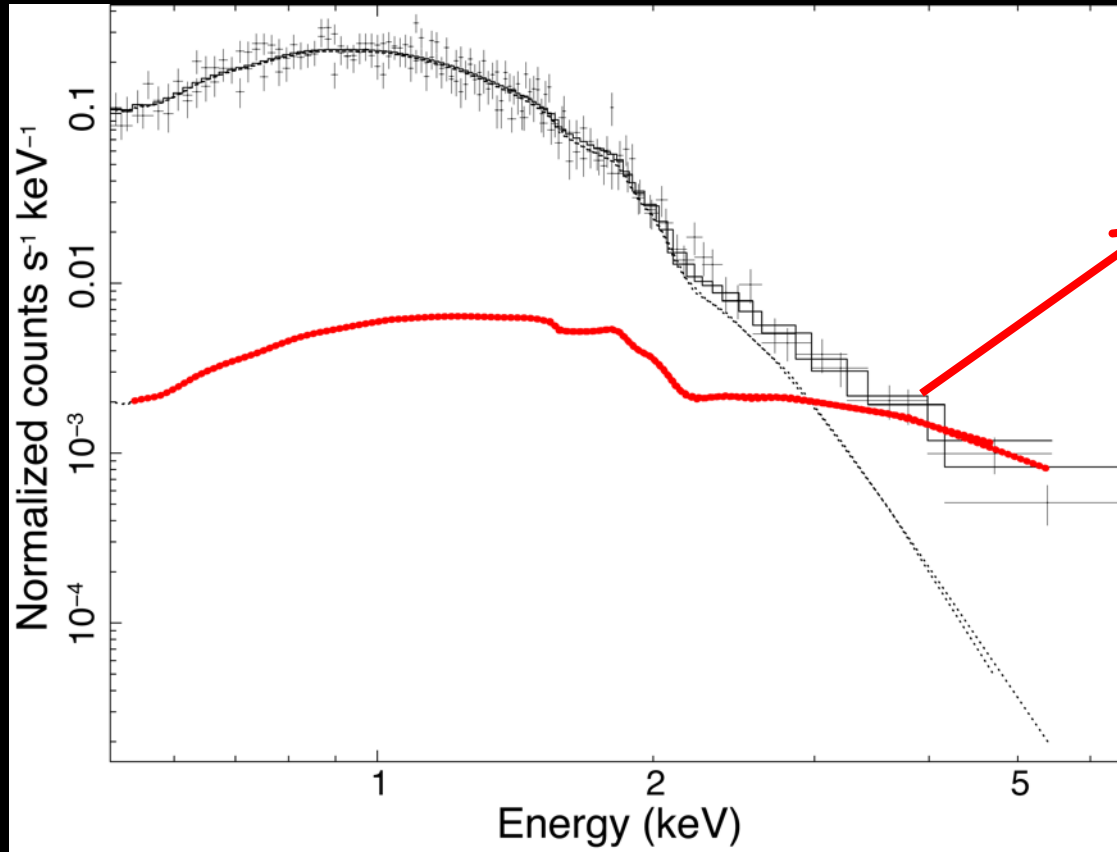


Thermal emission of
the hot neutron star:
Probe interior of star
= project III

Project IV: X-ray Puzzle

What causes X-rays of quiescent neutron stars?

Thermal glow neutron star + *some other process*



Additional emission component:
unknown origin!
Weak accretion?
Magnetosphere?

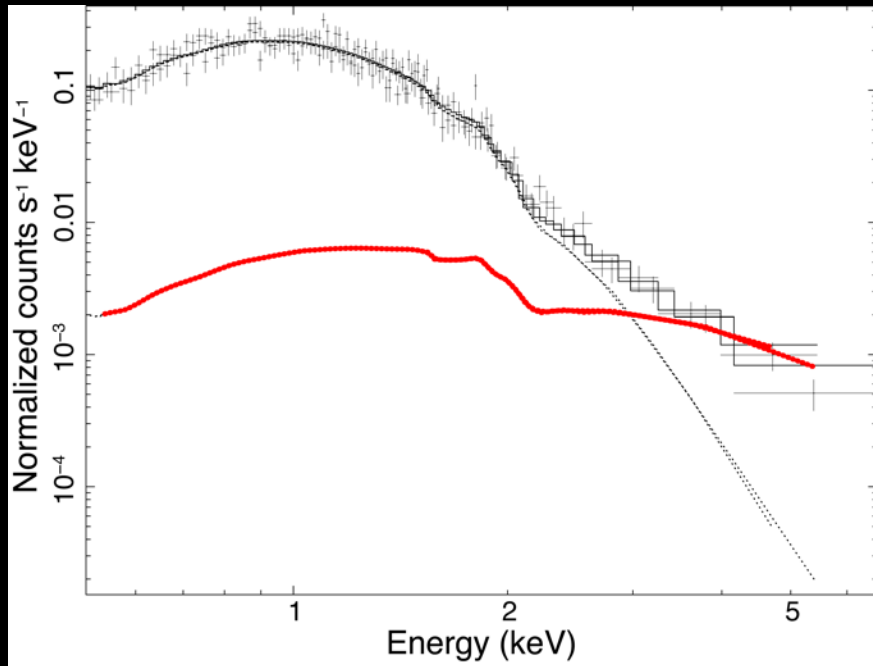
Is it the same in
all neutron stars?

Project IV: X-ray Puzzle

Data: Chandra and/or XMM-Newton

Analysis: X-ray spectra, NASA software

Target(s): ~15 neutron stars



Project X: Build Your Own



A **tailored project** is also possible

X-ray binaries

Neutron stars

Thermonuclear bursts

Jets

Disk winds

Multi-wavelength data

Check out my website for ideas of research done in my group

Summary

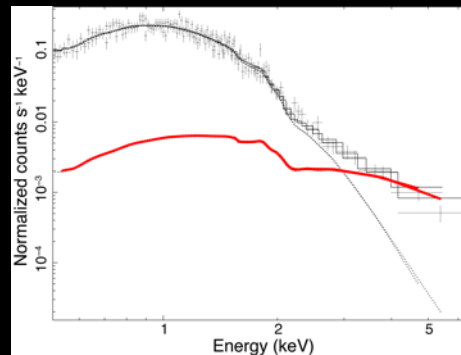
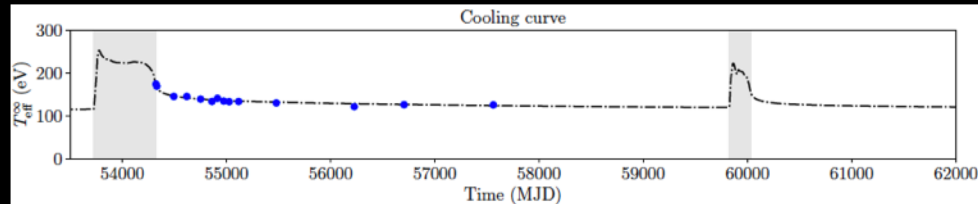
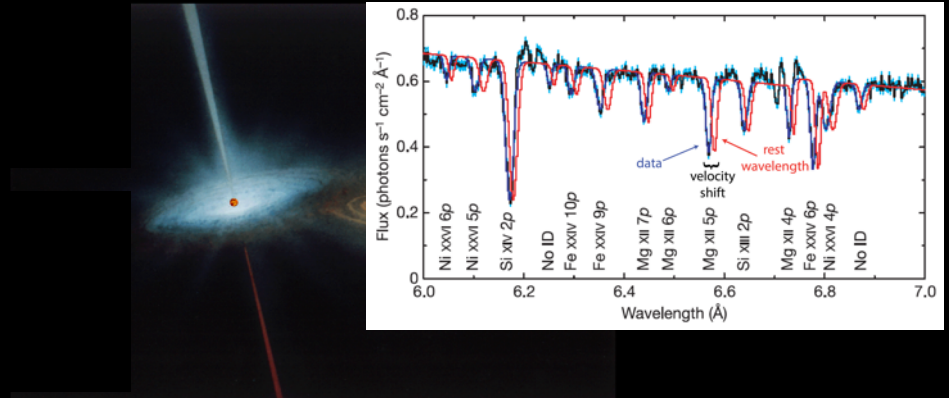
I. **Winds** of change
(X-ray data)

II. **Winds** of change
(UV data)

III. **Cooling** neutron stars
(X-ray data)

IV. **Puzzle** of energetic
X-rays in quiescence
(X-ray data)

X. Build **your own**





Get in Touch!

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