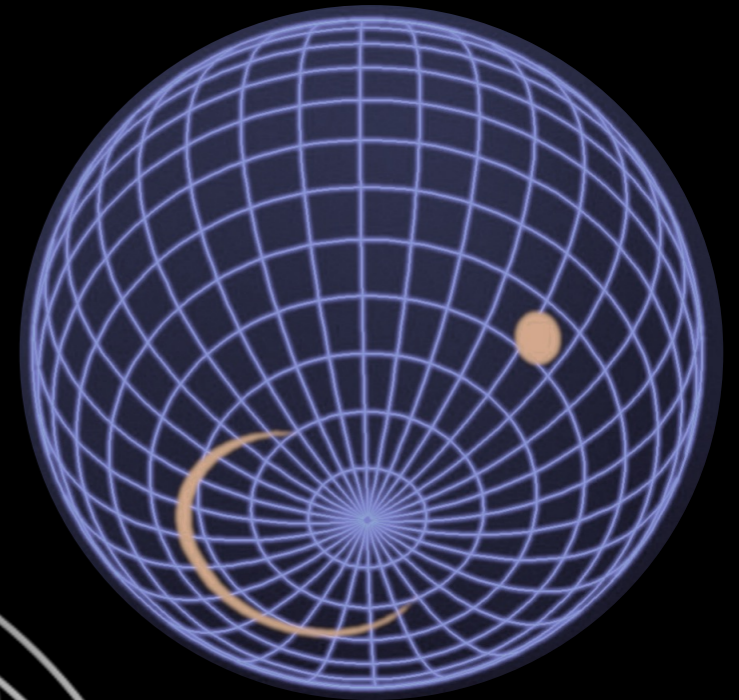
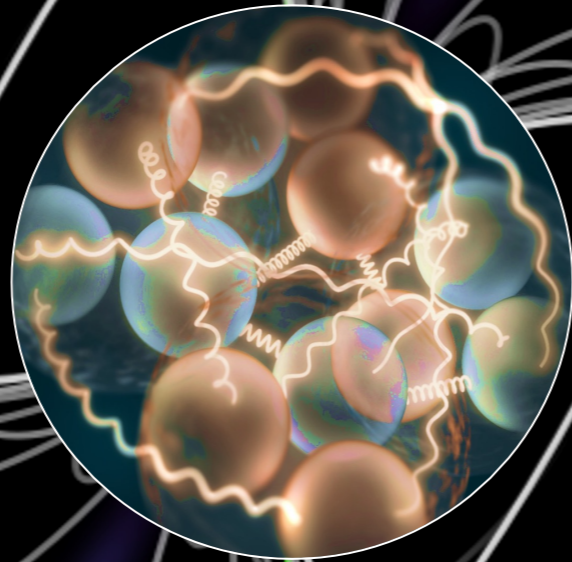


FUTURE X-RAY TELESCOPES

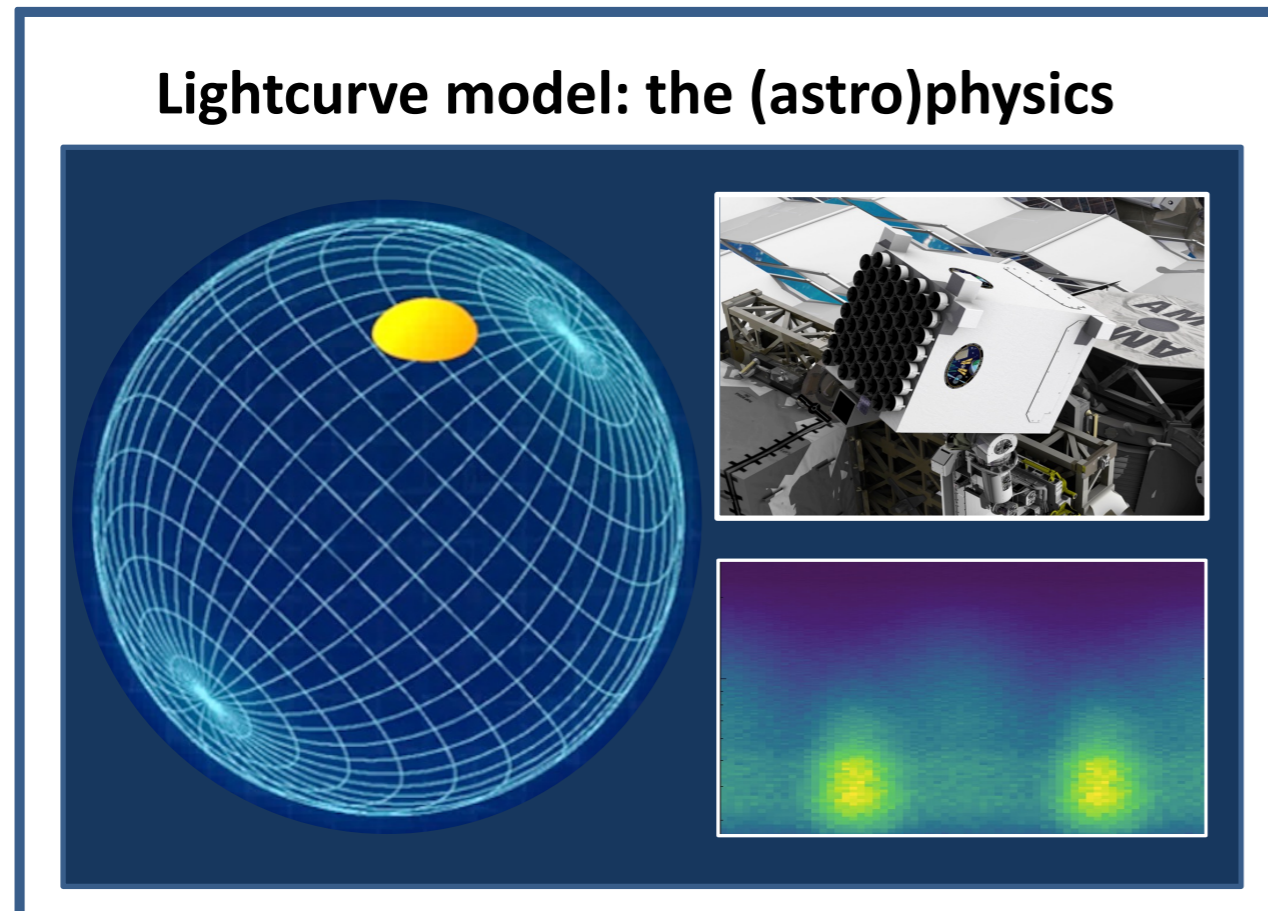
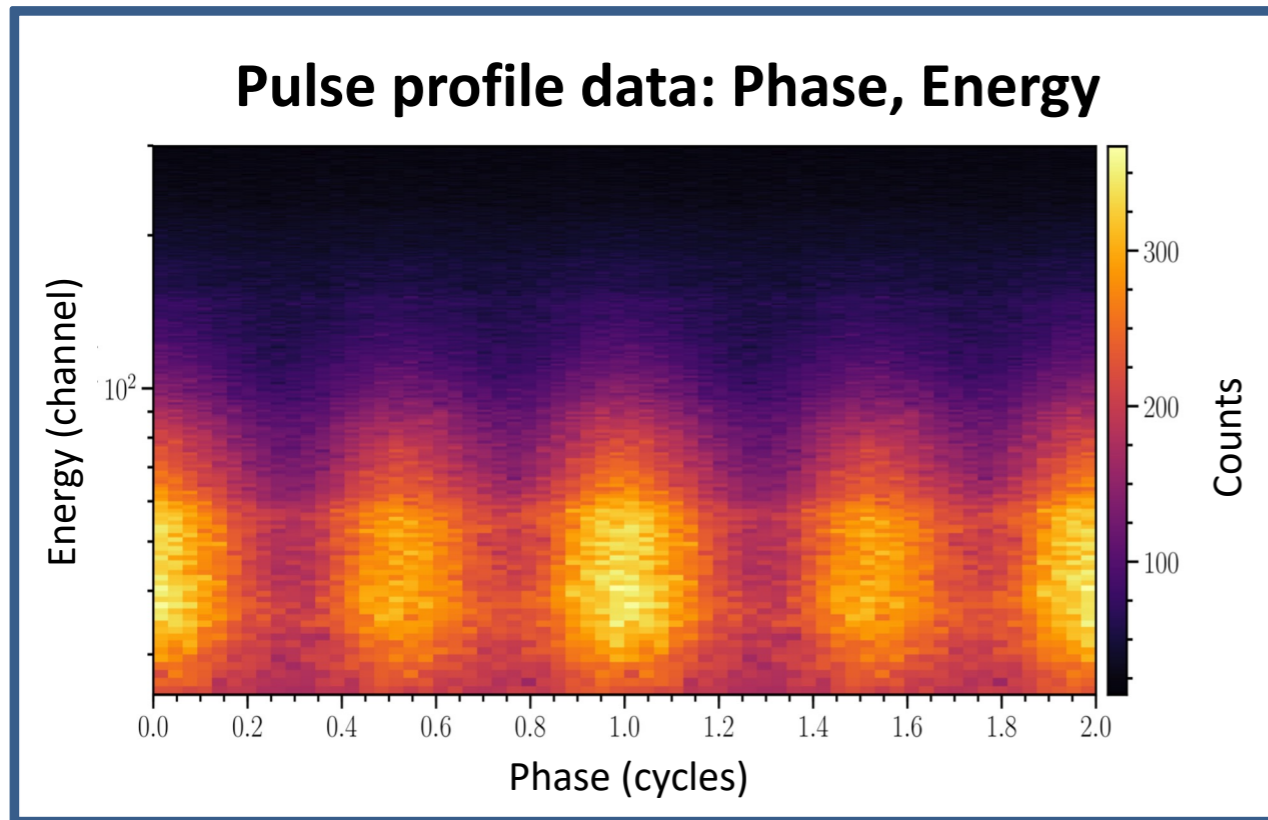


PROF. ANNA WATTS
UNIVERSITY OF AMSTERDAM

X-RAY SPECTRAL TIMING



THE PULSE PROFILE MODELING PROCESS

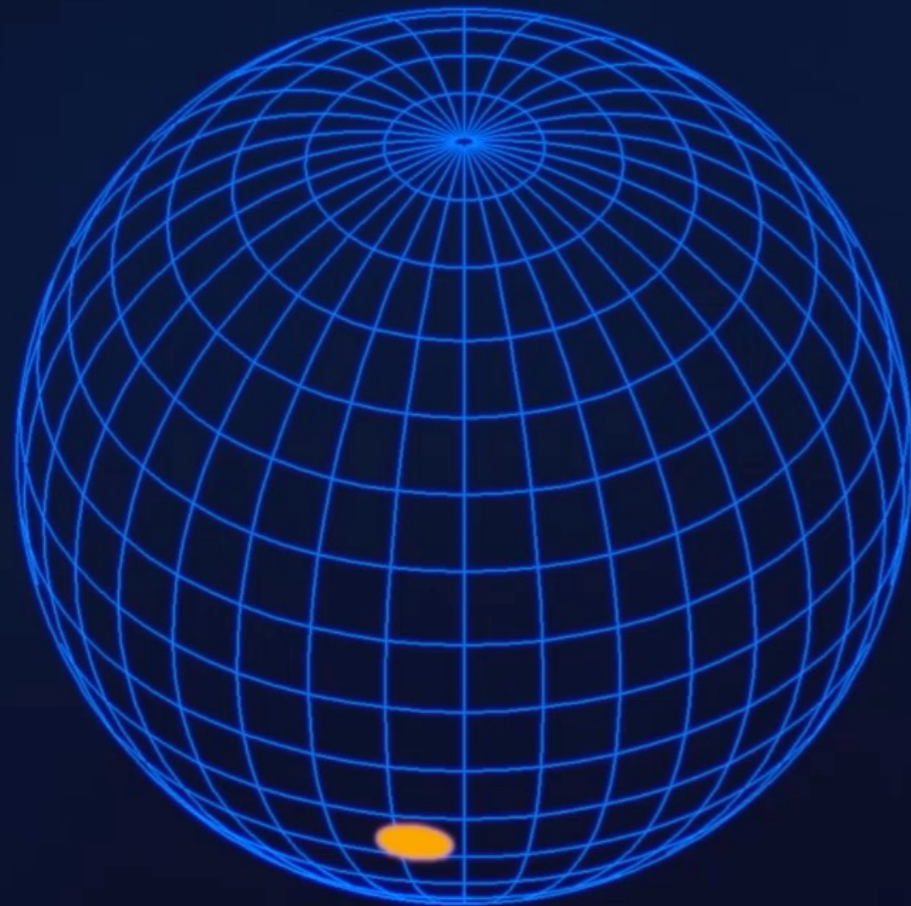


**Bayesian inference of
model parameters
(statistical sampling)**

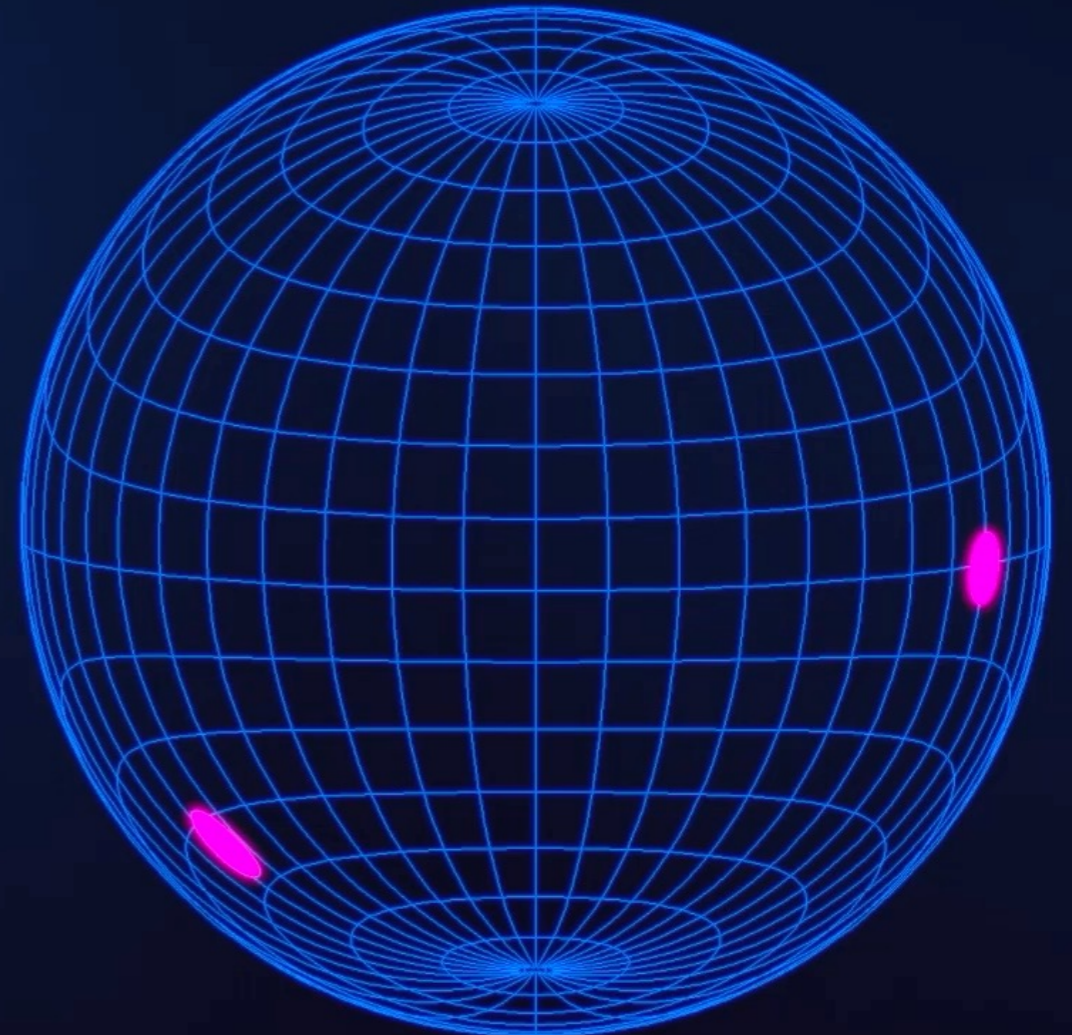
**Model parameters:
Mass and radius
Geometric properties**

MAPPING PULSARS

PSR J0030+0451



PSR J0740+6620



Movie: Sharon Morsink, NASA

Published NICER team papers:

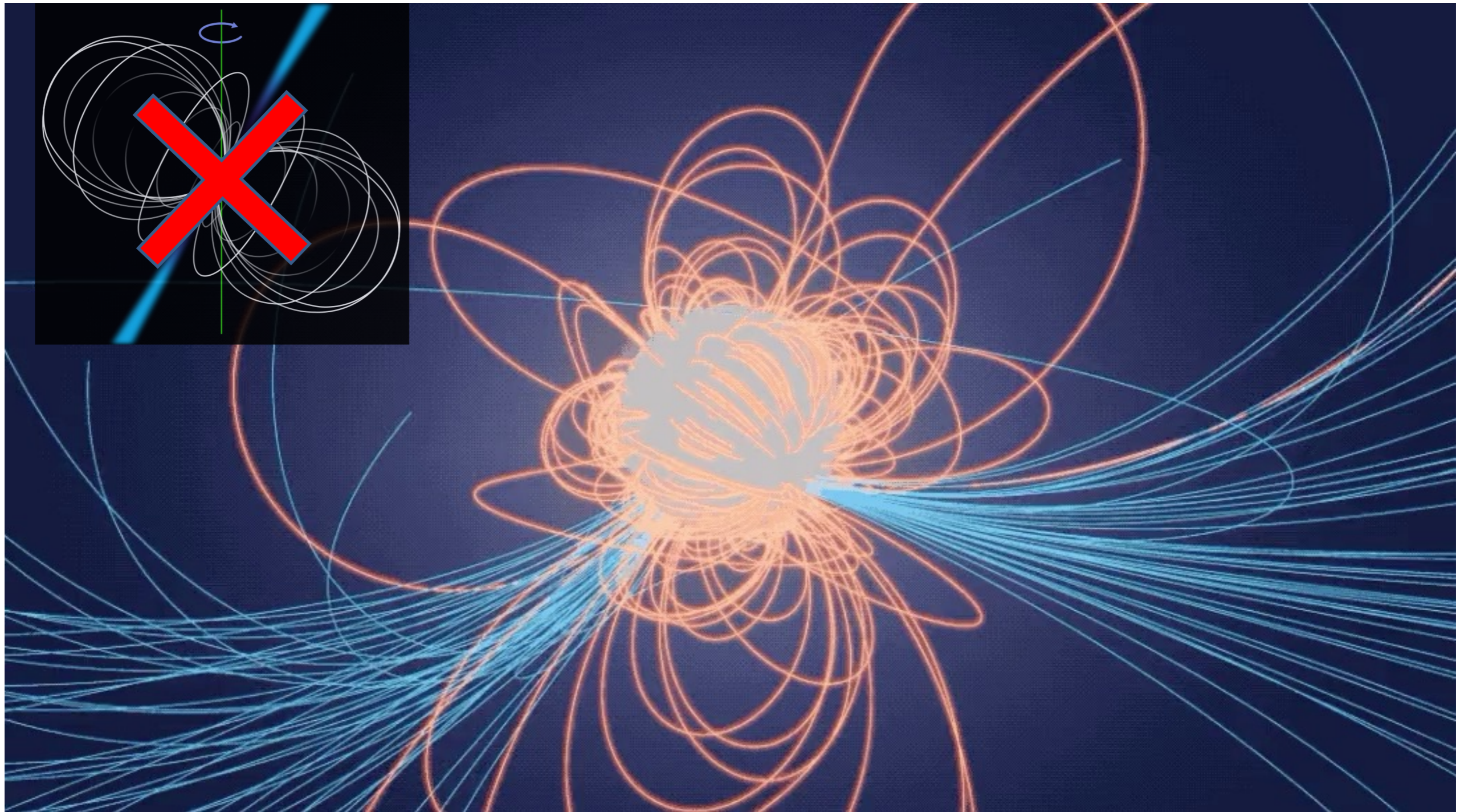
Data + supporting tests/sims: Bogdanov et al. 2019a, 2019b, 2021, Wolff et al. 2021

Mass-radius results: Miller et al. 2019, 2021, Riley et al. 2019, 2021, Salmi et al. 2022

EOS analysis: M19, 21, Raaijmakers et al. 2019, 2020, 2021

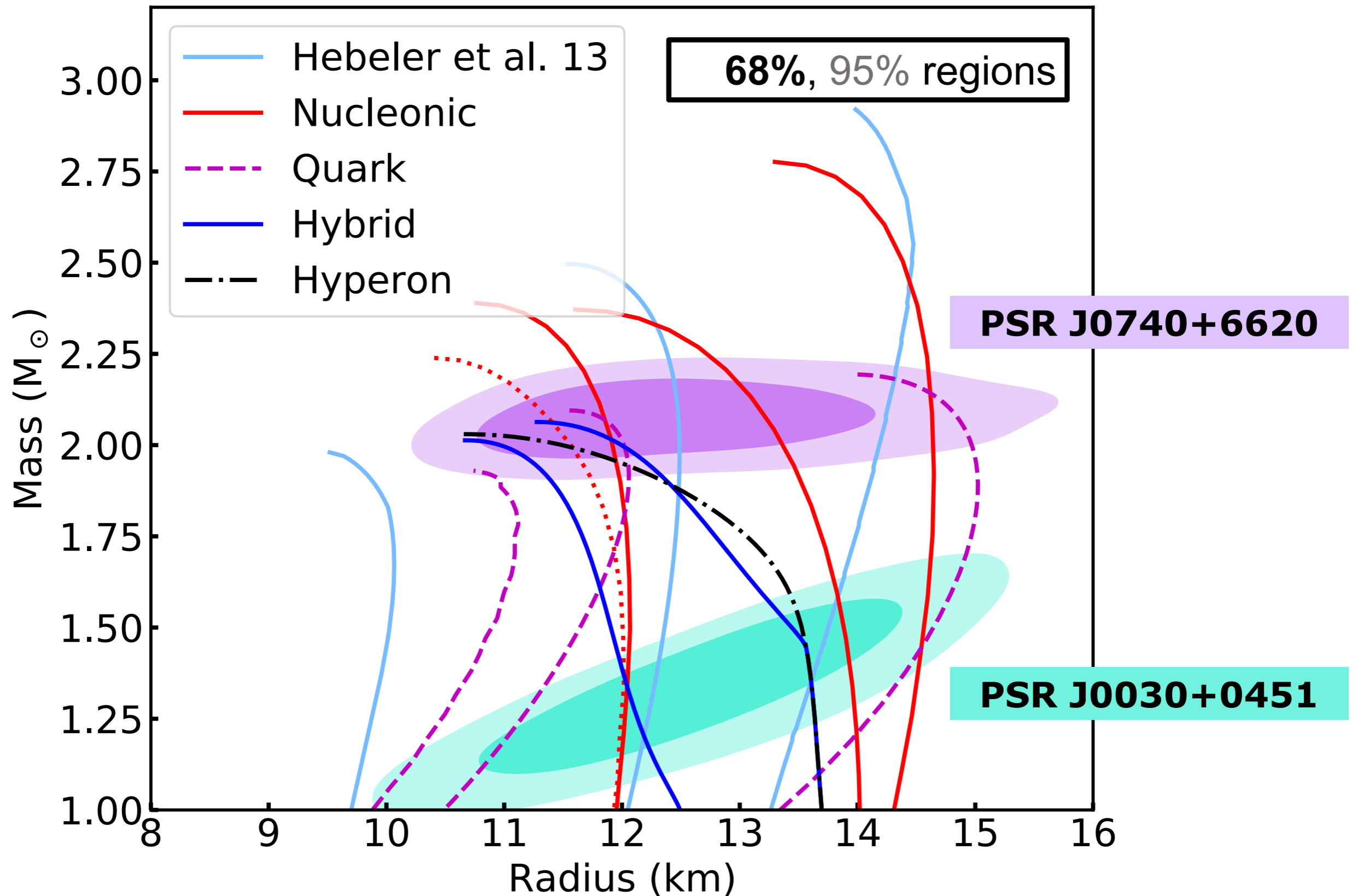
Pulsar geometry: Bilous et al. 2019

COMPLEX MAGNETIC FIELD



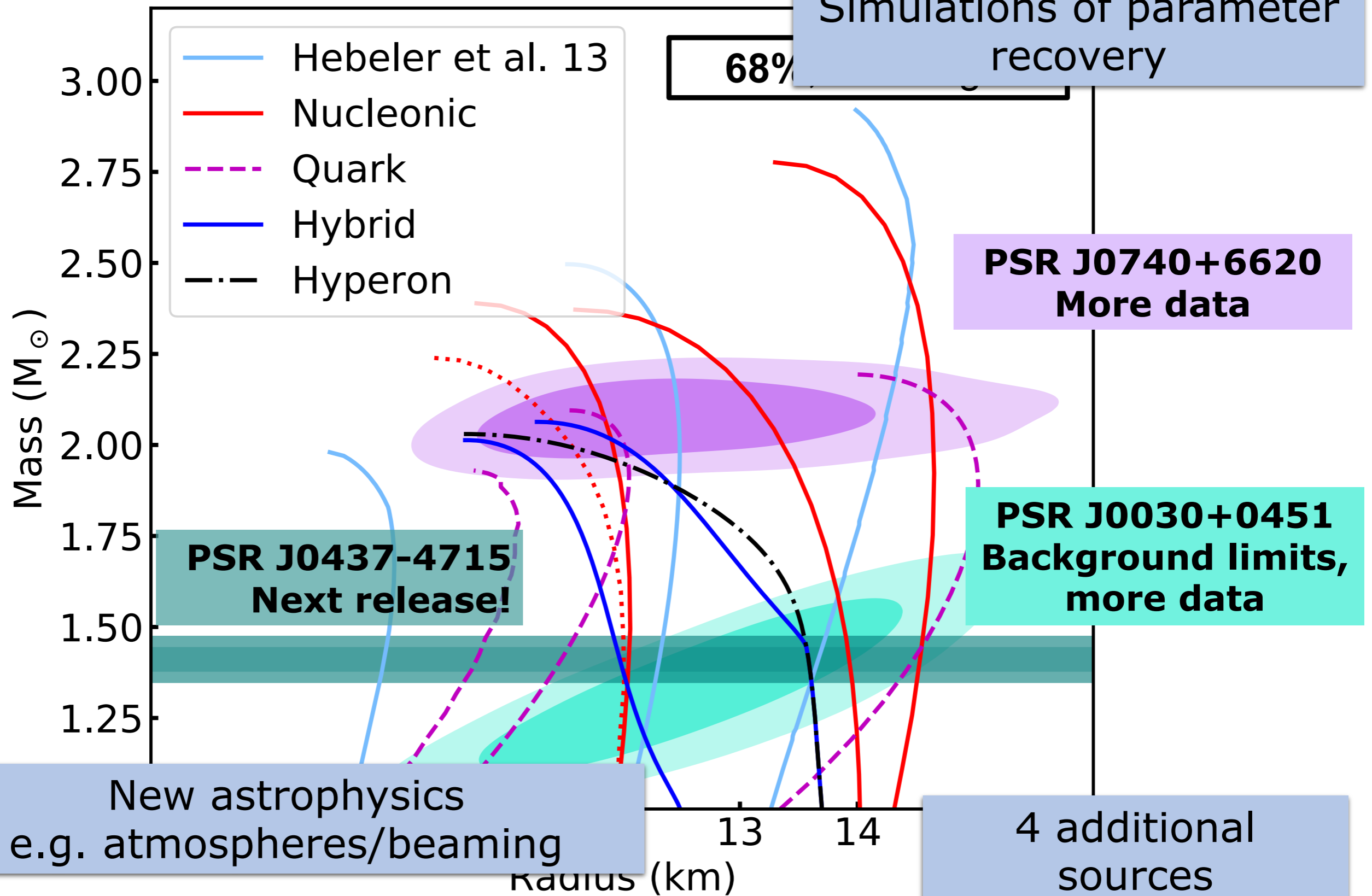
Credit: NASA's Goddard Space Flight Center/Harding, Kalapocharakos, Wadiasingh.

MASS-RADIUS CONSTRAINTS



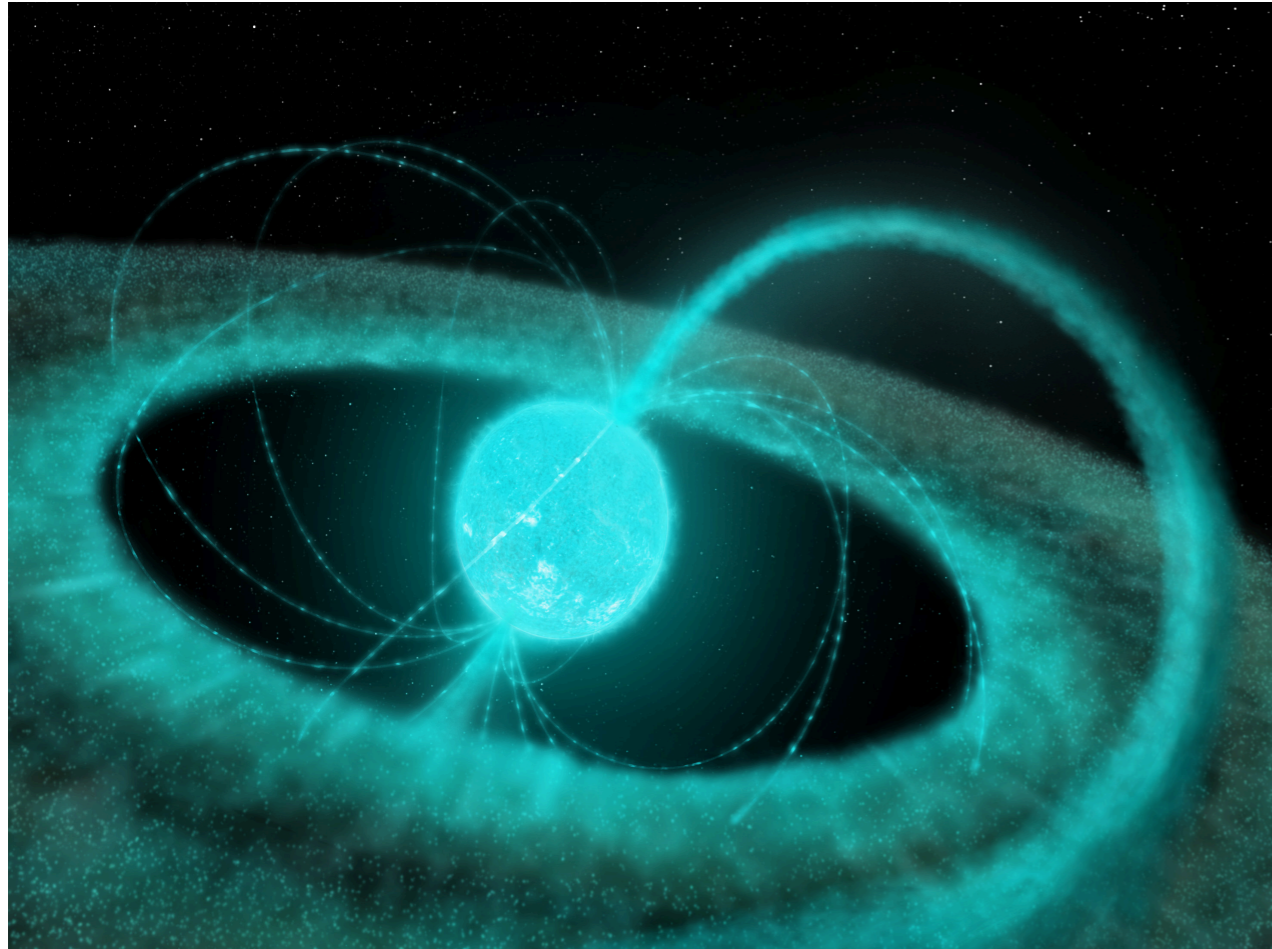
NICER X-PSI M-R Credible regions from Riley et al. 2019, 2021, see also Salmi et al. 2022

WHAT'S NEXT FOR NICER?



PPM FOR ACCRETING/BURSTING NS

The relativistic effects pulse profile modeling exploits are larger for the more rapidly-rotating **accreting** neutron stars.



Accretion-powered millisecond X-ray pulsars



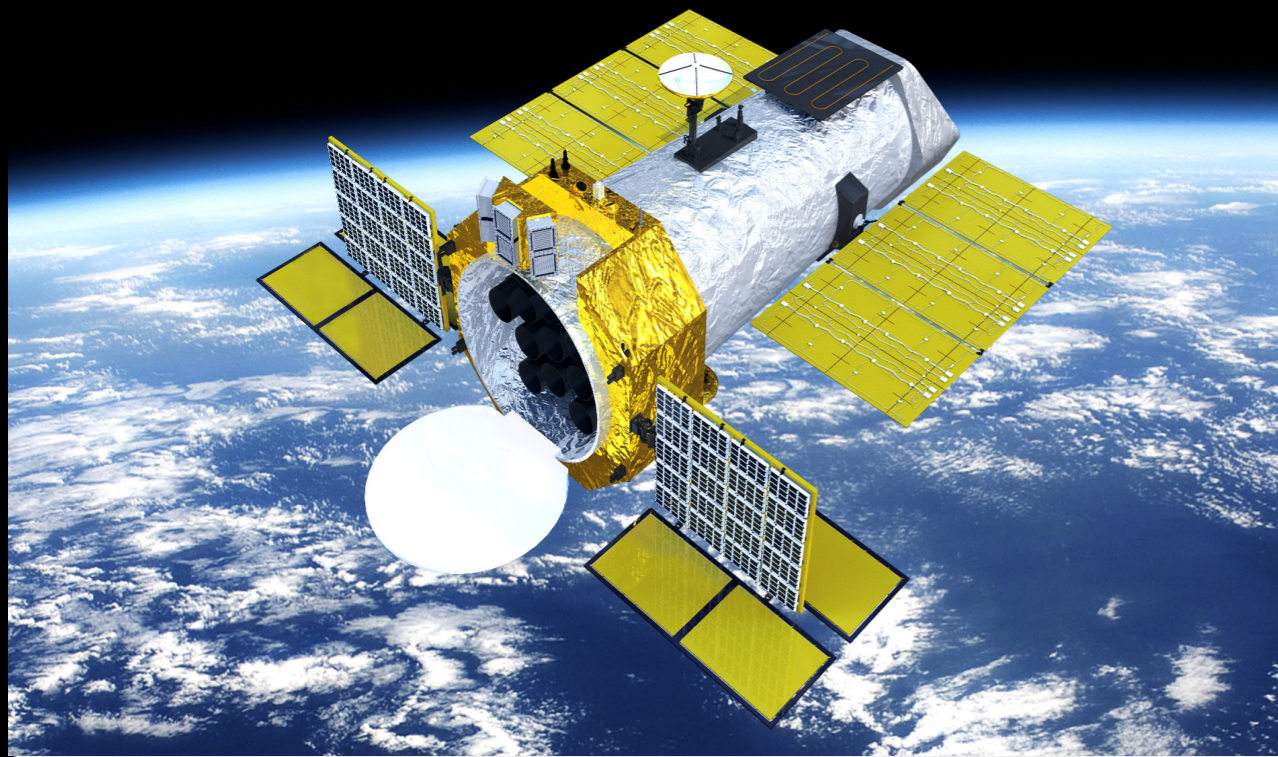
Thermonuclear burst oscillation sources

New modelling and analysis challenges e.g. different atmosphere models, unknown surface pattern, variability

LARGE AREA X-RAY SPECTRAL-TIMING

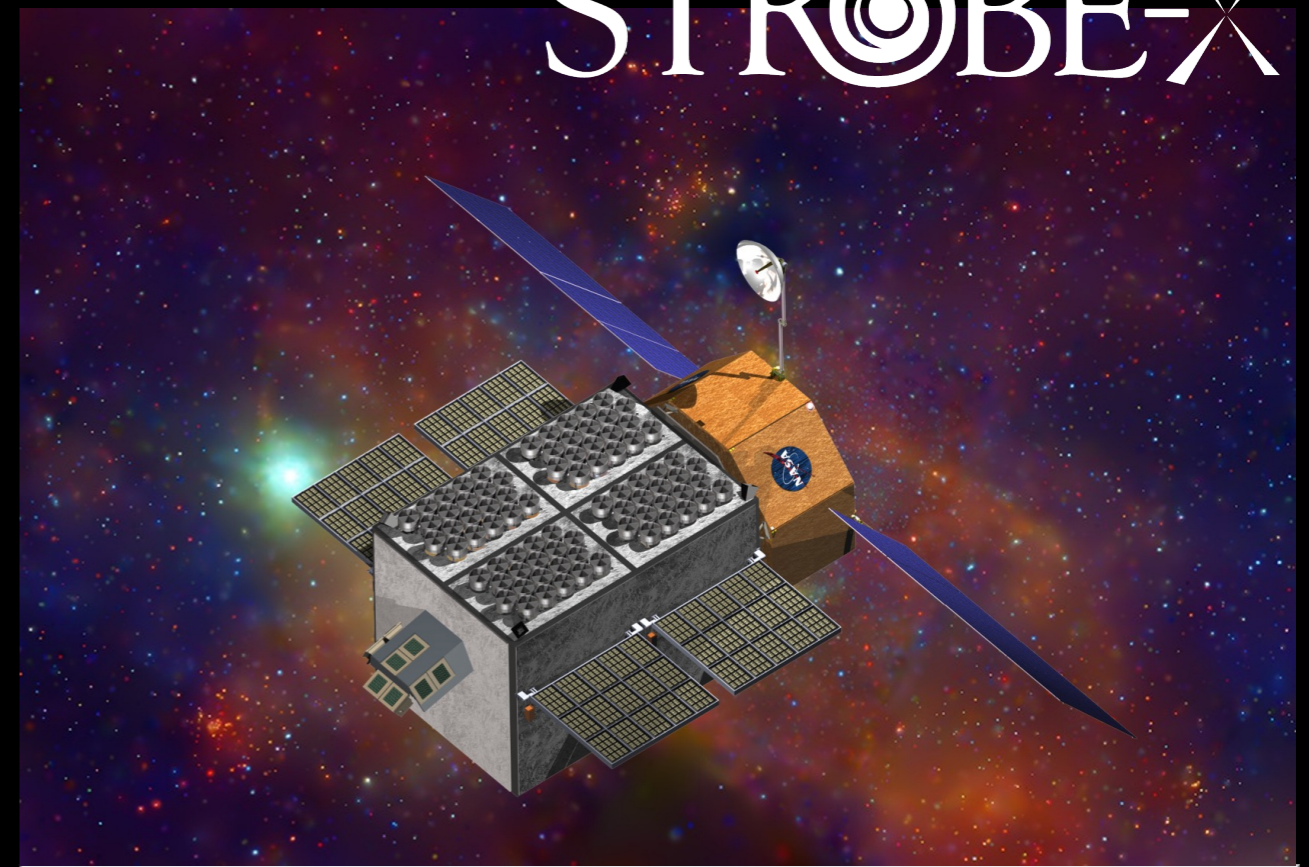
New telescopes will be needed –
larger area, wider X-ray band than NICER

eXTP



Chinese-European project
Zhang et al. 2019

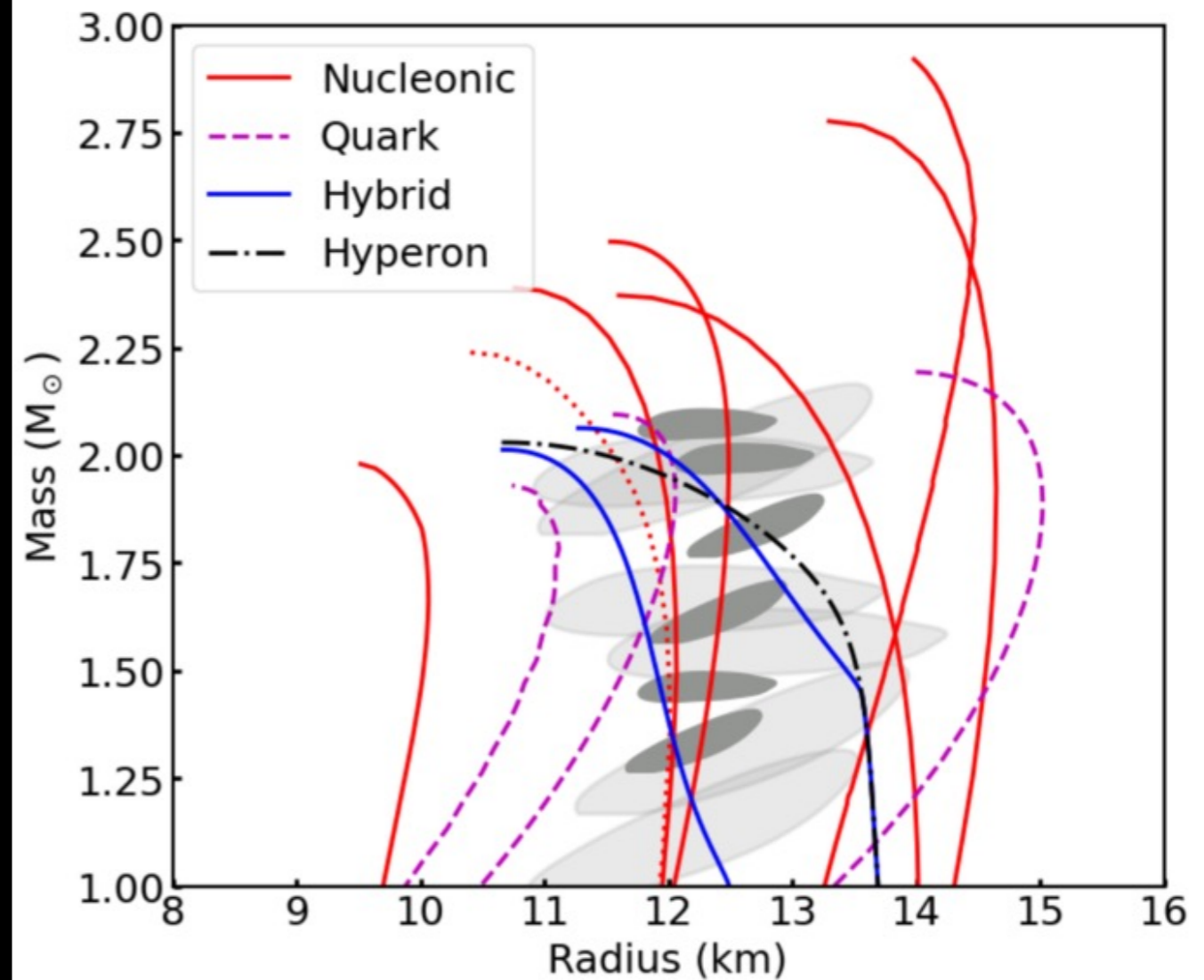
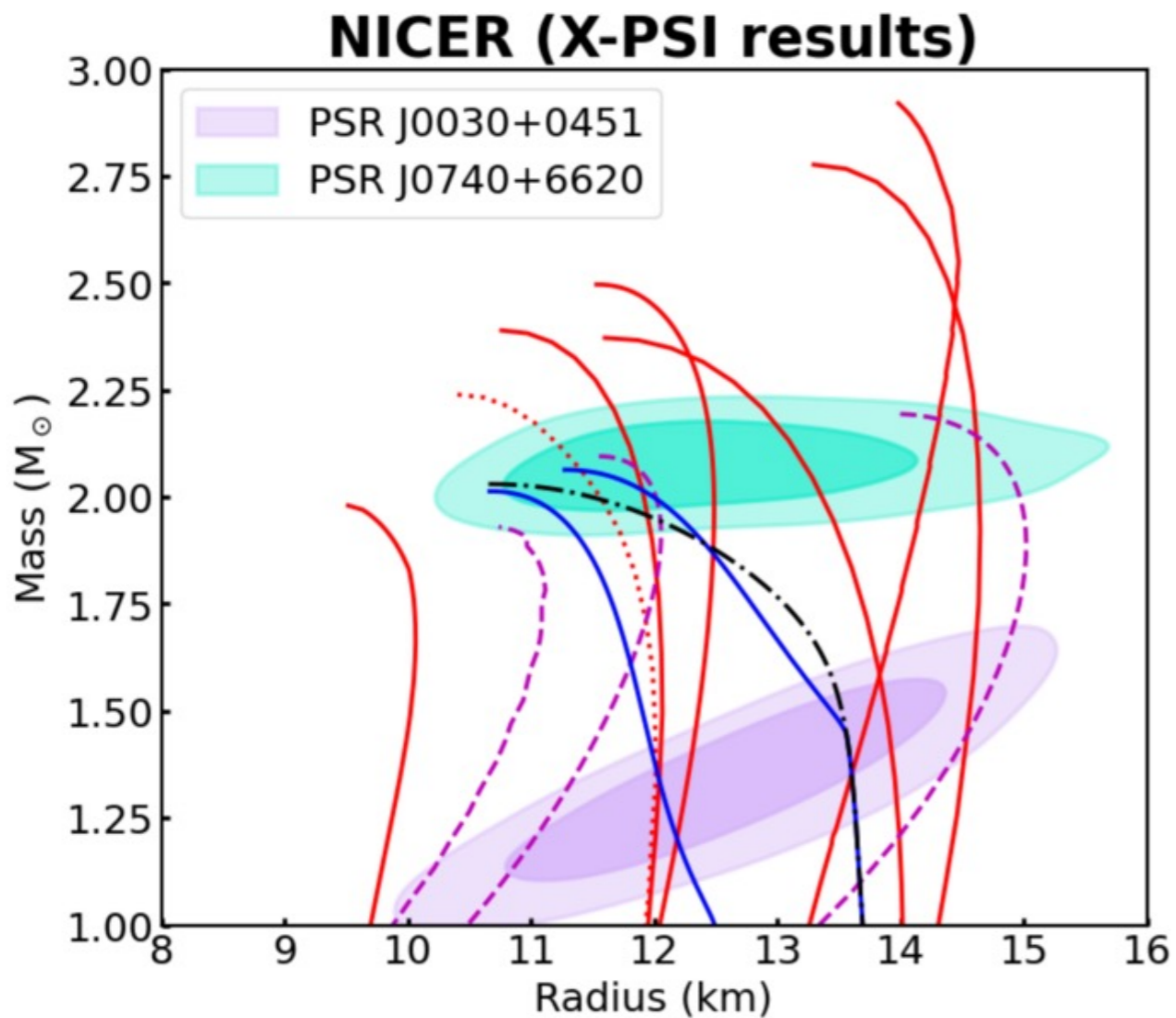
STROBE-X



NASA probe-class proposal
Ray et al. 2019, @strobexastro

Analysis pipelines being developed and tested using
simulated and real (RXTE/NICER) data

STROBE-X/EXTP PROSPECTS



95% credible regions shown

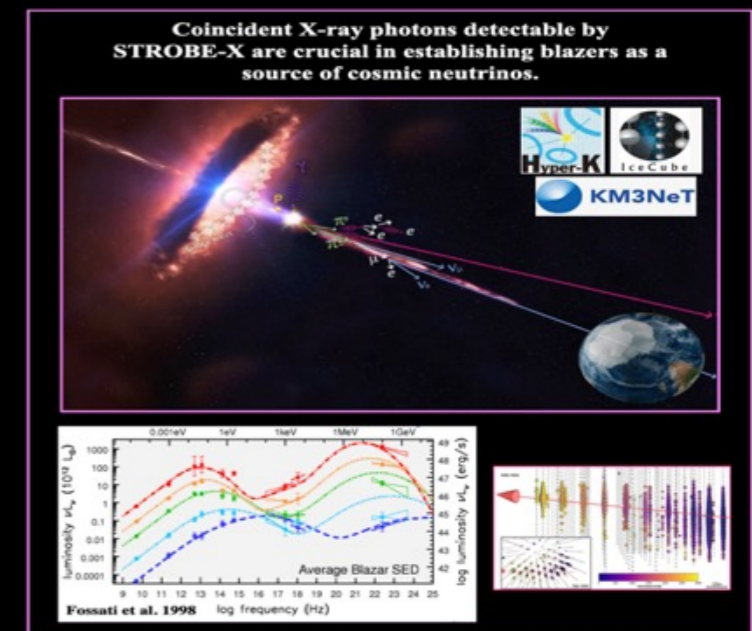
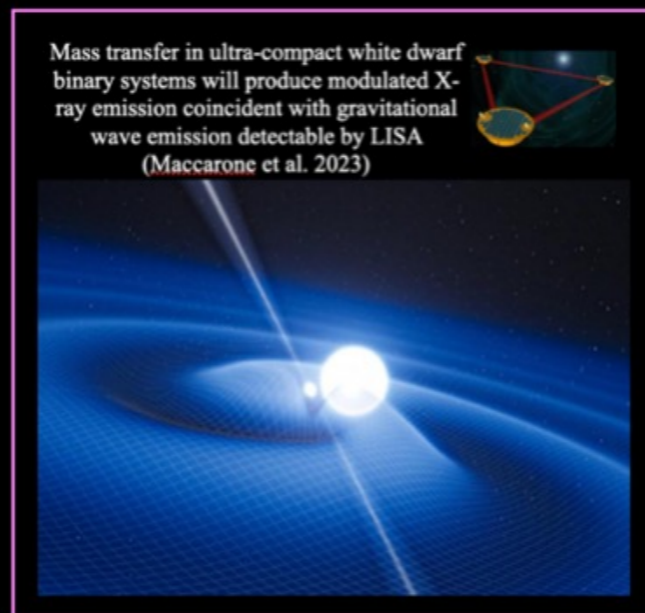
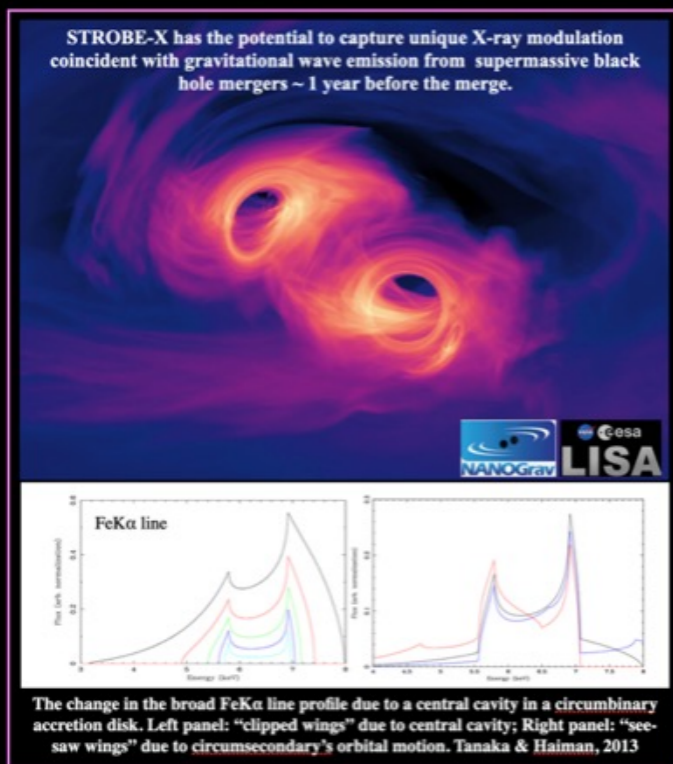
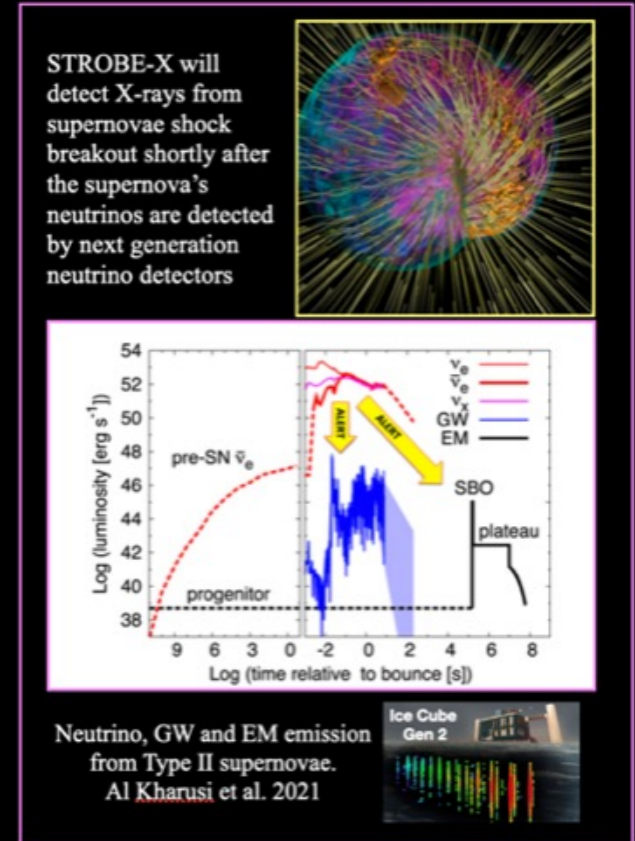
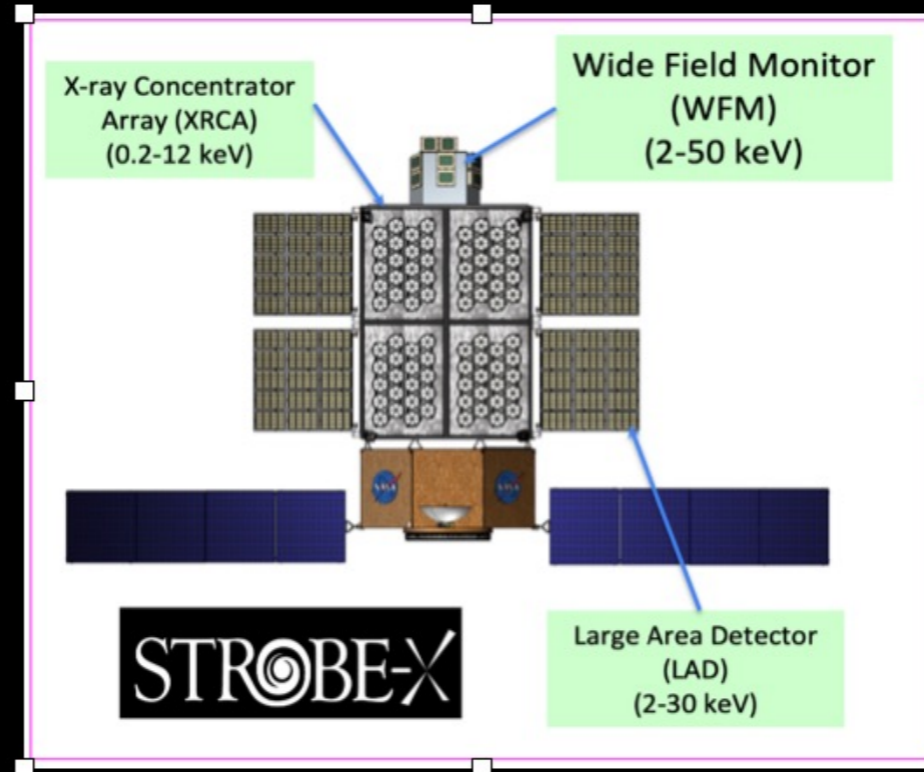
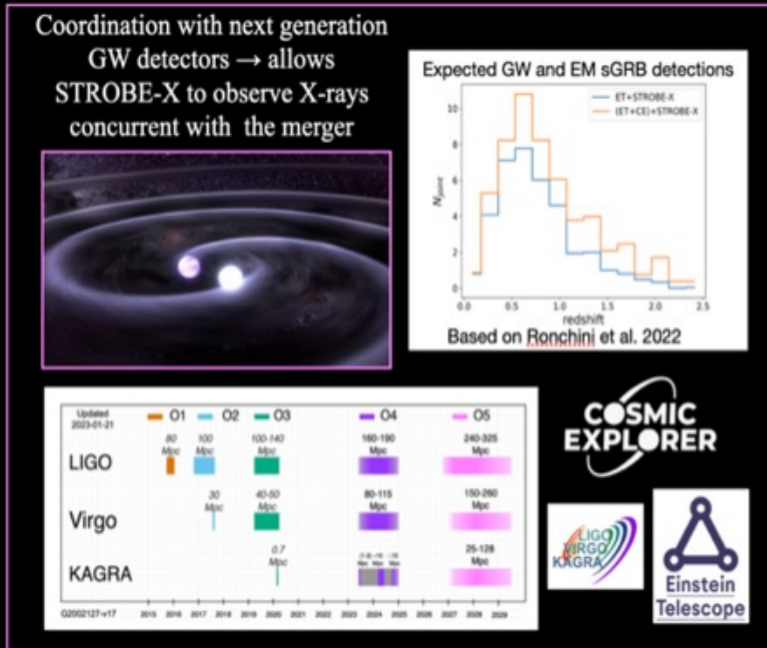
Three different classes of neutron star: rotation-powered millisecond pulsars (more with mass priors), accretion-powered pulsars, thermonuclear burst oscillation sources.

Initial survey at $\pm 5\%$, run cross-checks to address any systematics.
Deep observations to hit $\pm 2\%$ for most promising sources.

Multi-Messenger Astrophysics with the STROBE-X Satellite

Nicole Lloyd-Ronning (Los Alamos National Lab)

on behalf of the STROBE-X team



WE NEED INPUT FROM YOU!

- Pulse profile modelling is a powerful new technique that delivers not only mass and radius but also a surface map. How can you use this?
- Powerful X-ray spectral-timing-(polarimetry?) observatories are being proposed. What could you learn from them (not just PPM)?
- They will also have excellent capability for multi-messenger astrophysics. How can you use this for your work?

