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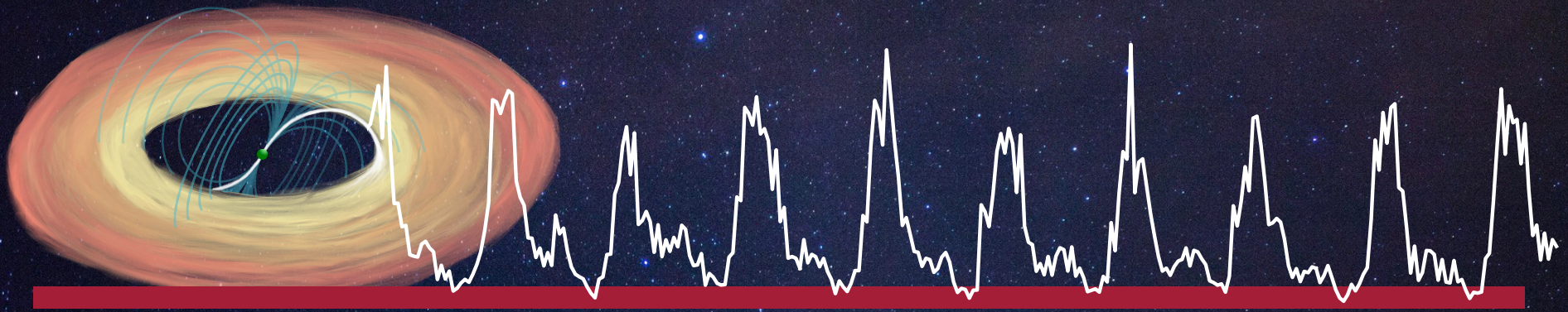
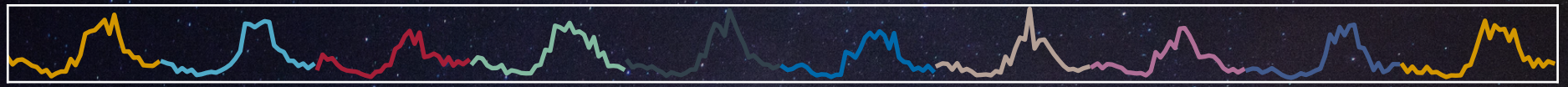


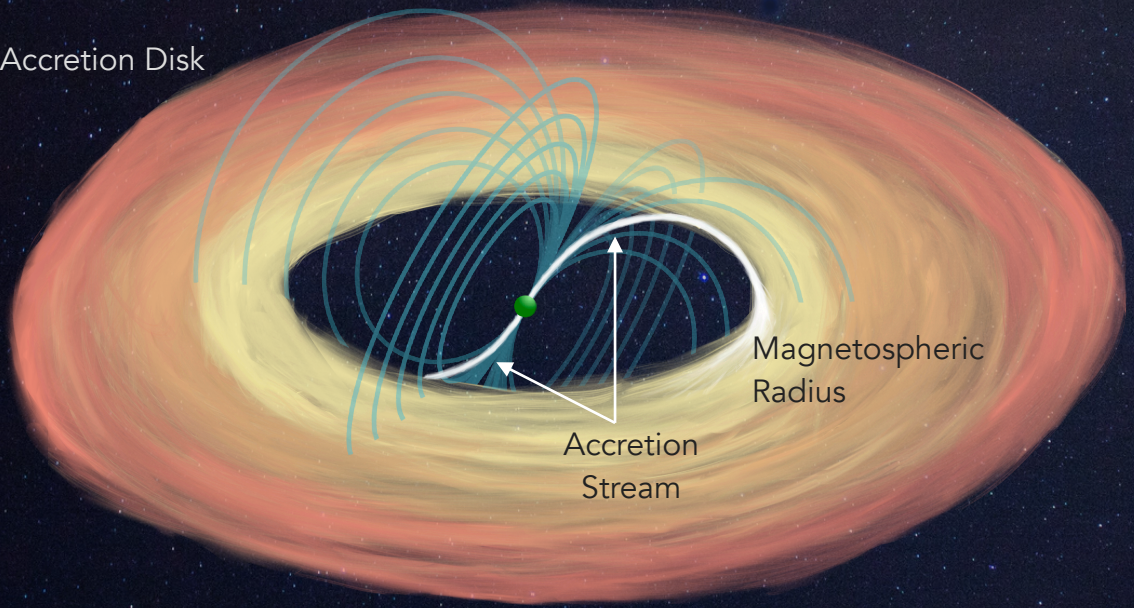
Pulse Profile Decompositions — A Blind Source Separation Approach

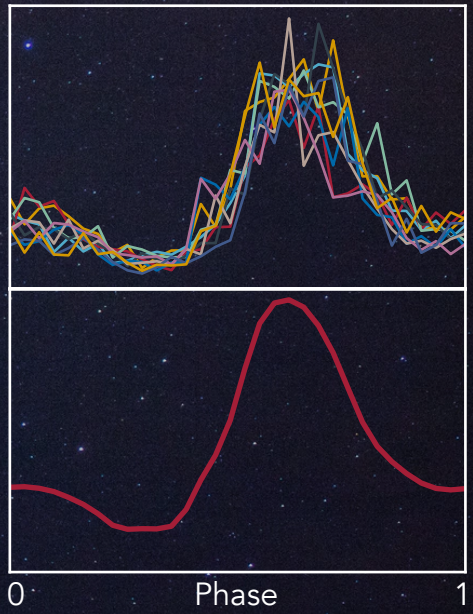
Inga Saathoff, Victor Doroshenko, Andrea Santangelo

31st Texas Symposium on Relativistic Astrophysics, Prague, Czech Republic, September 2022

X-ray Pulsars

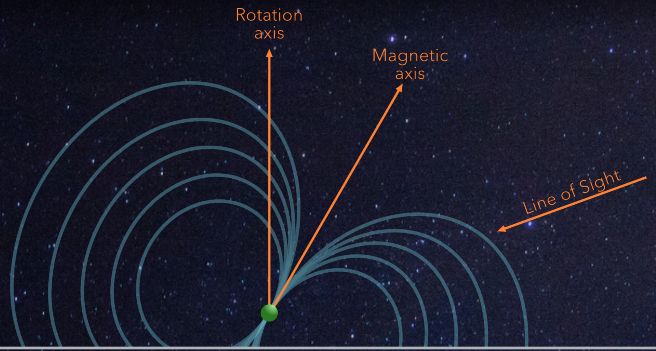




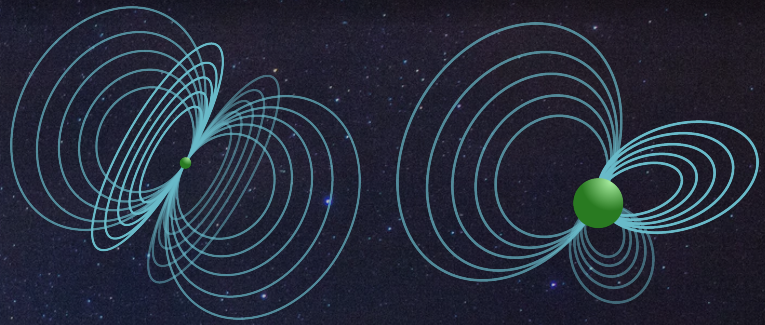


X-ray Pulsars

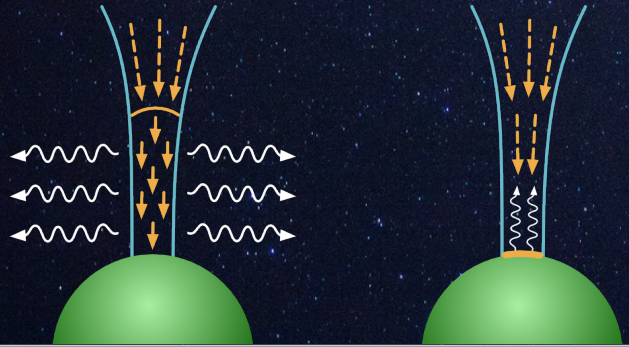
Geometric configuration



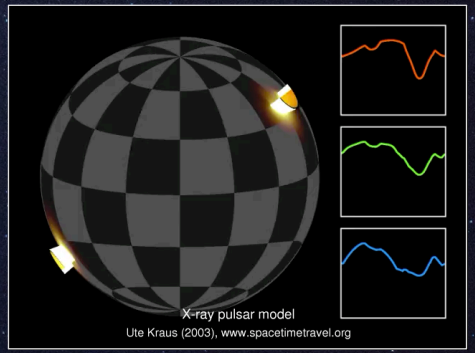
Magnetic Field Configuration



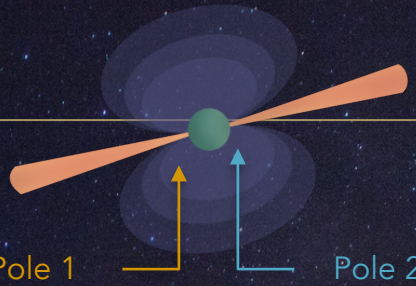
Anatomy of the Emitting Region

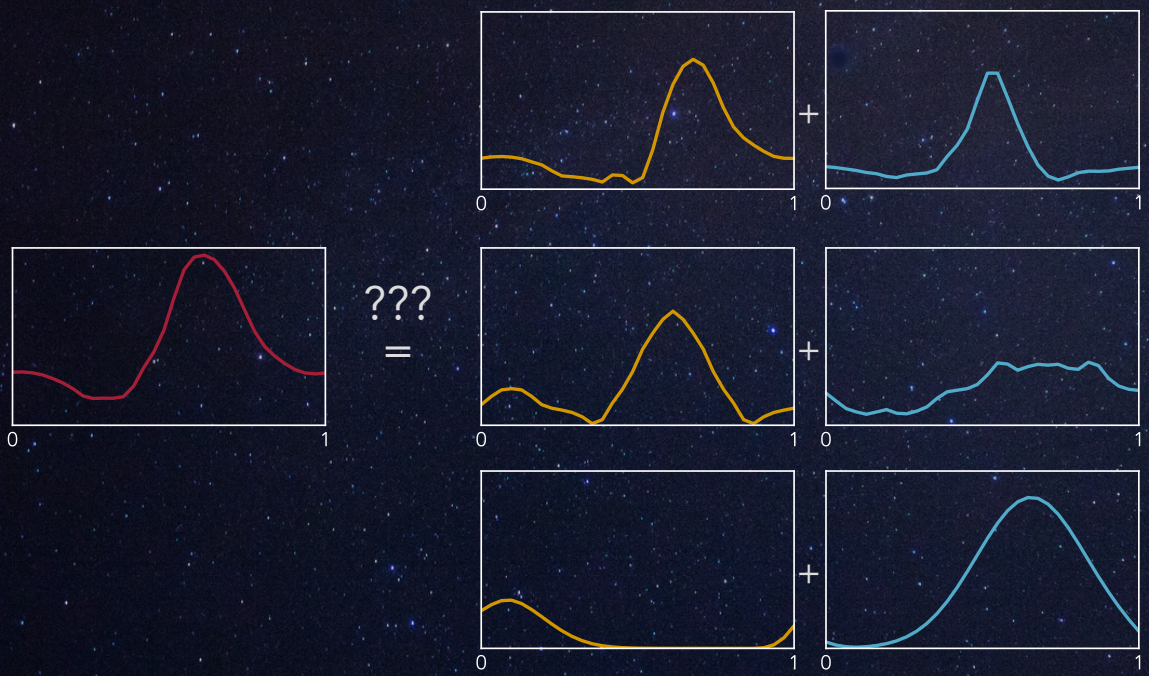


Gravitational Light Bending; Reflection



Problem Statement





We still don't know the contributions of the individual poles and their intrinsic emission properties!

Observed Variability

Inner accretion disk: magnetic dipole moment dominates.

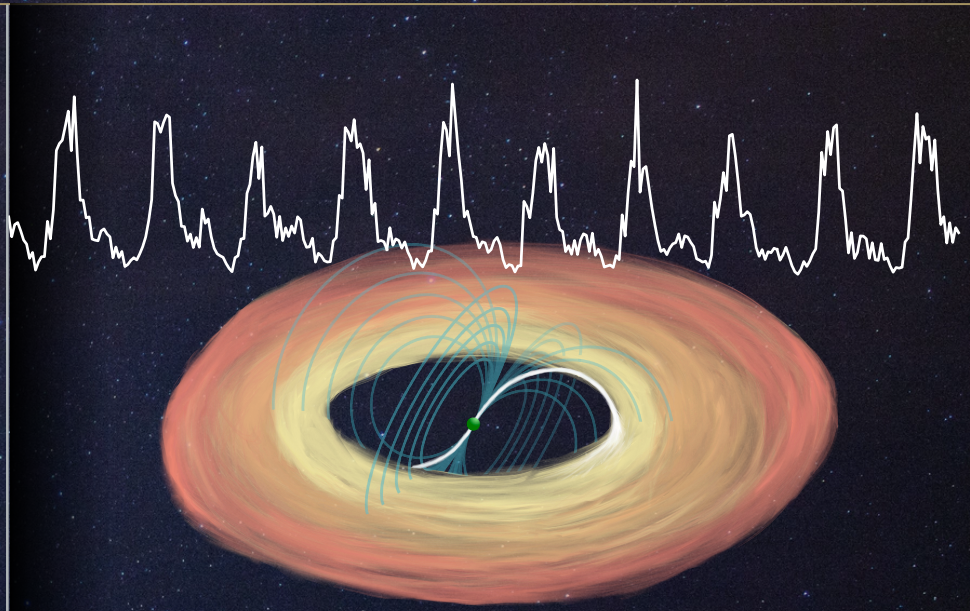
⇒ We assume the matter comes from ~opposite edges.

The accretion rate is subject to stochastic fluctuations.

These are observable in the variability of the X-ray emission.

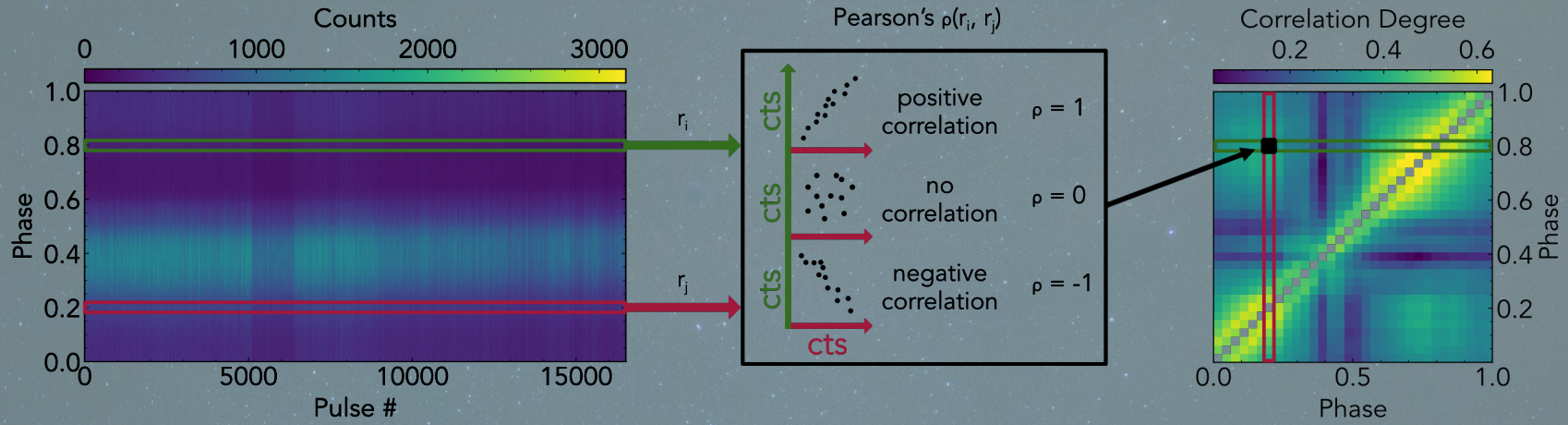
Fluctuations are observed at frequencies ≥ spin frequency.

⇒ Fluctuations in the accretion rate on the two poles of the NS are at least partially independent.



The only requirement is that the fluctuations in the accretion rate on each of the poles are not fully correlated.

Correlations



When correlating light curves at different phases, we expect to see a

- higher degree of correlation, if the radiation emerged at a single pole and
- lower correlation, if it is a mix of two separate poles.

We can use this to disentangle the contributions of the individual poles.

There should be two signals that could in principle be separated!

⇒ This is called …

Blind Source Separation (BSS)

What is BSS?

Separation of source signals from mixed signals without knowing about the source signals or the mixing.

Ex.: cocktail party problem — A guest tries to listen to only one conversation in noisy surroundings.

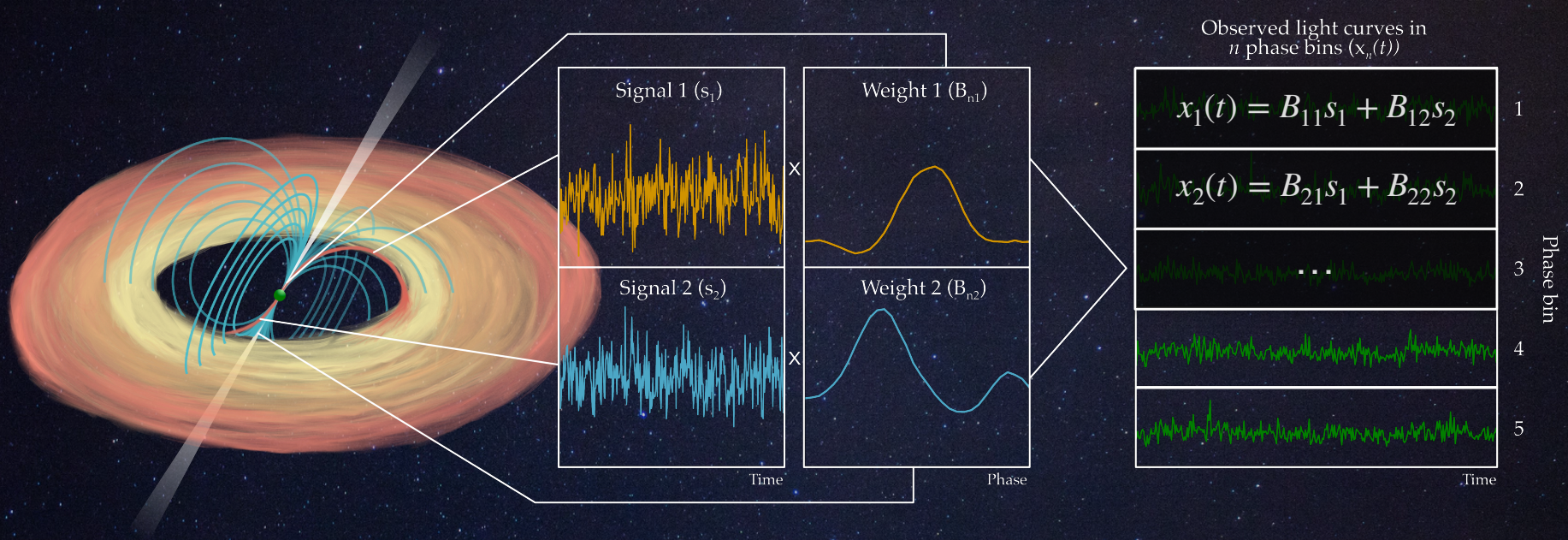
Applications

Medicine: monitoring a foetus' health by taking an electrocardiogram (ECG)

Astronomy: Analysing exoplanets, improving calibration, studying temperature maps,…

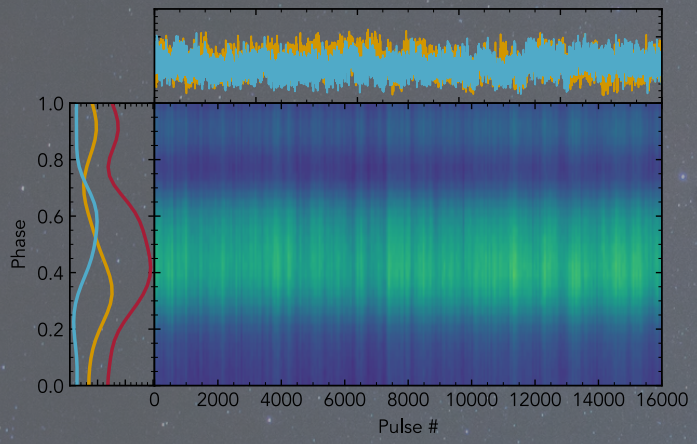
Does it work for accreting X-ray pulsars?

Blind Source Separation (BSS)



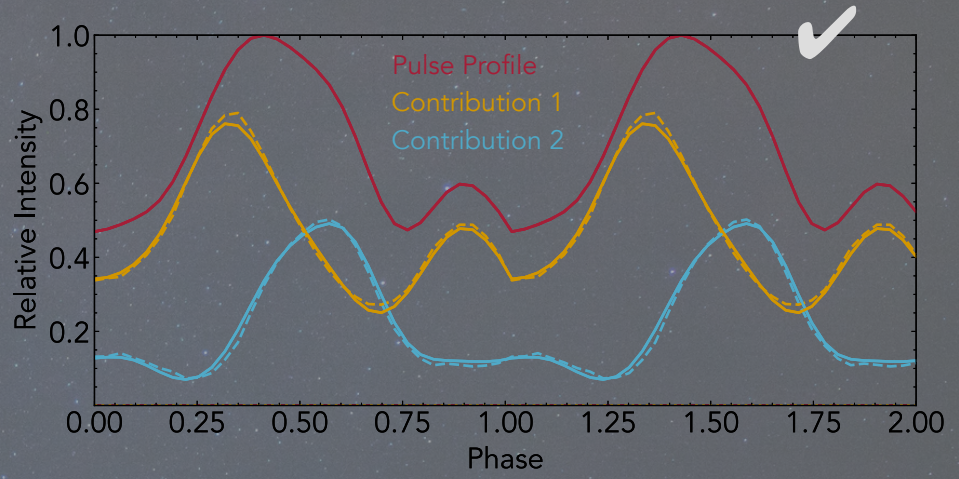
We want to estimate the mixing contributions / weights using only the observed light curves.

Simulation



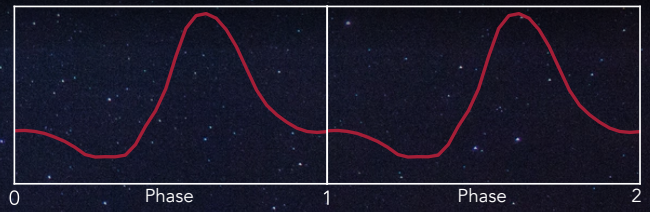
BSS

Two pulses back-to-back for clarity

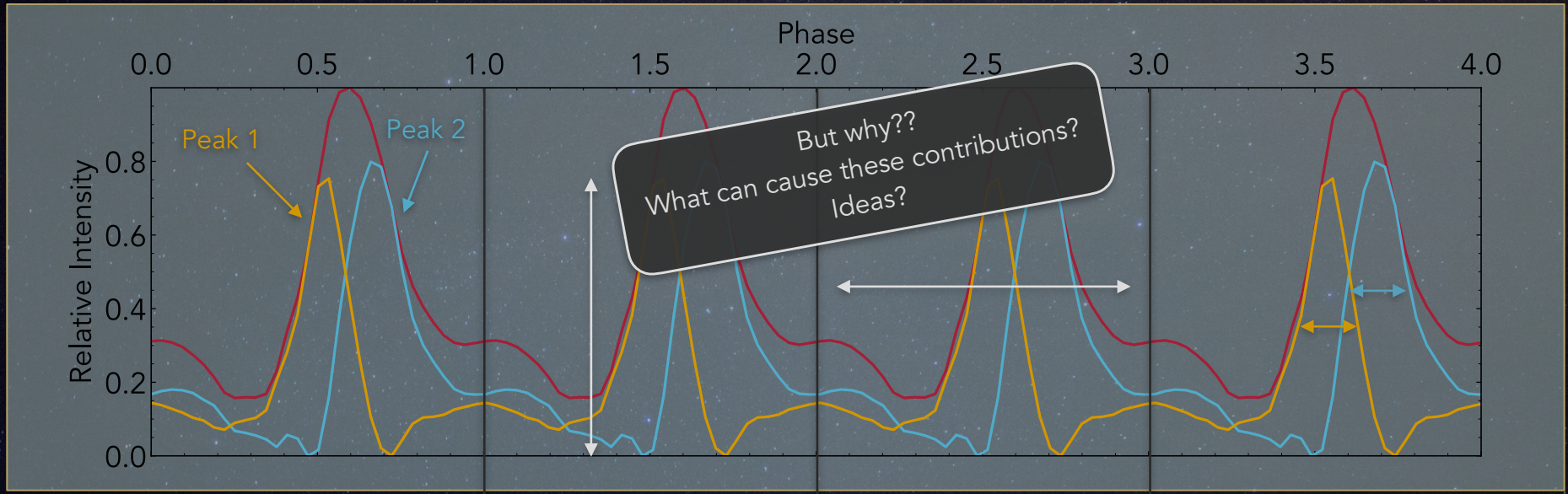


Simulations show that the method works as expected.

Application to real RXTE data of Cen X-3?



Decomposition Results of Cen X-3

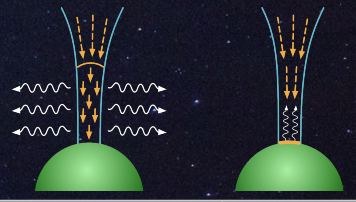


Primary peak: composed of two distinct peaks

Both peaks ~ equal amplitude

Both asymmetric in phase

Narrow peaks



Summary

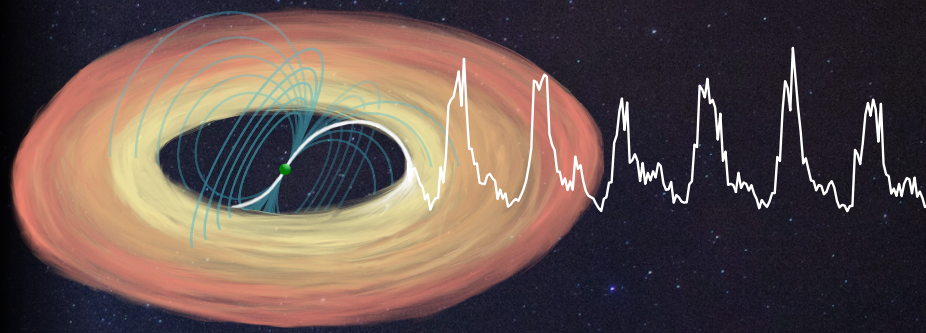
Fluctuations in the accretion rate on each of the two poles are not fully correlated.

The observed correlation properties support the idea that we have two separate signals.

We can disentangle them using blind source separation.

Simulations show that the approach works to recover given single-pole pulse profiles.

First results of Cen X-3 show surprising results, especially the recovery of asymmetric profiles.



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