Decomposing X-ray Pulsar Pulse Profiles using Blind Source Separation

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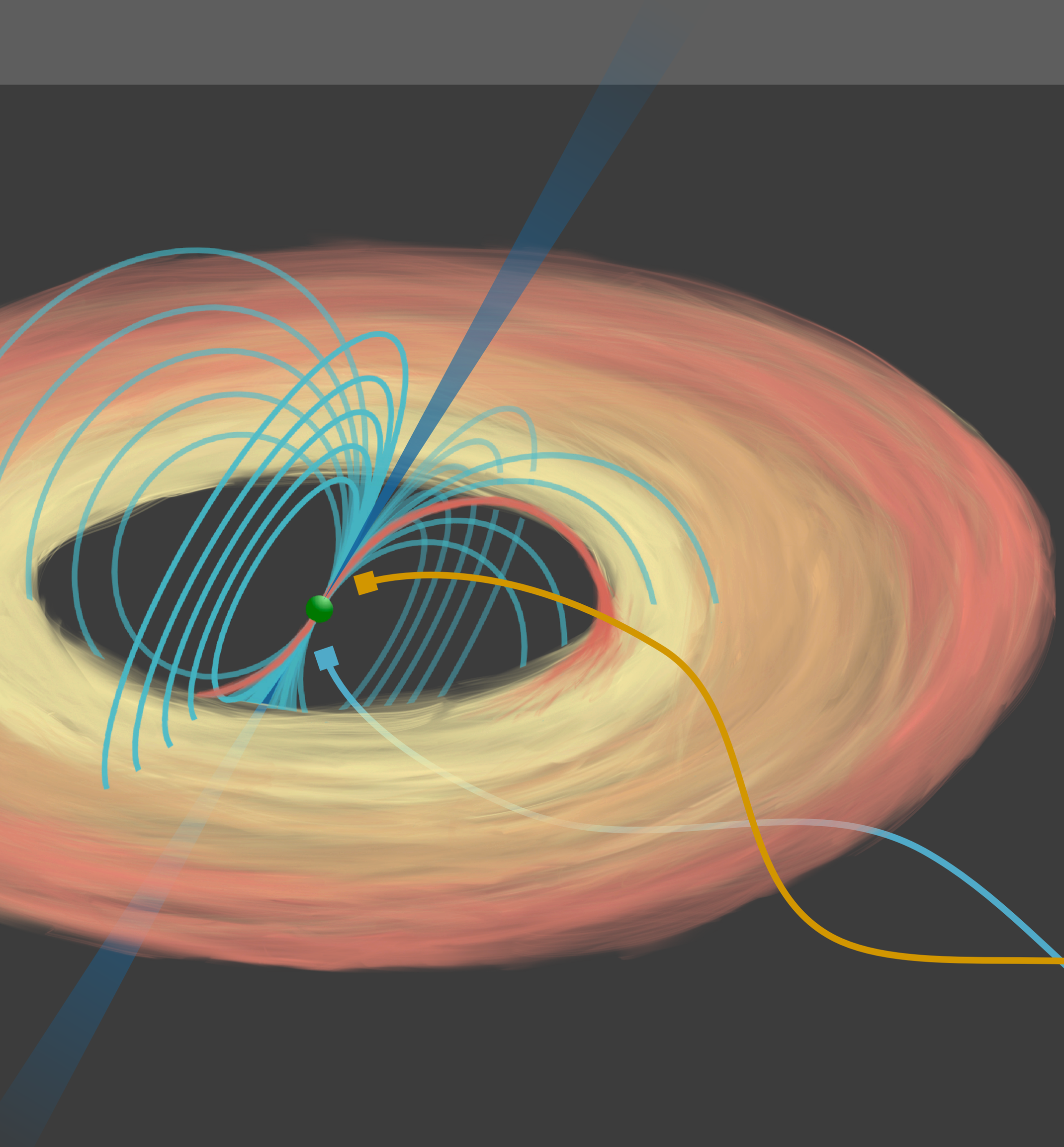


1. Pulse Profiles & Their Decomposition

In accreting X-ray pulsars, the geometry of the system, the emission region close to the neutron star, and the deflection of matter by the magnetic field in the inner accretion disk affect the **pulse profile** (the intensity of the emission averaged over a rotation). **However, the contributions from each pole and their intrinsic emission properties remain unknown.** To disentangle these contributions, we use a **blind source separation (BSS)** technique. This method, known as non-negative matrix factorization (NMF), allows us to exploit the uniquely variable emission of the two poles, caused by a fluctuating accretion rate, to separate the contributions of each pole.

2. The Framework

2.1 Signals

The **signals (s_m)** are traced by the accretion rates at the **two** poles. These accretion rates are subject to **independent fluctuations** and approximately translate to observed variations in the X-ray intensity.

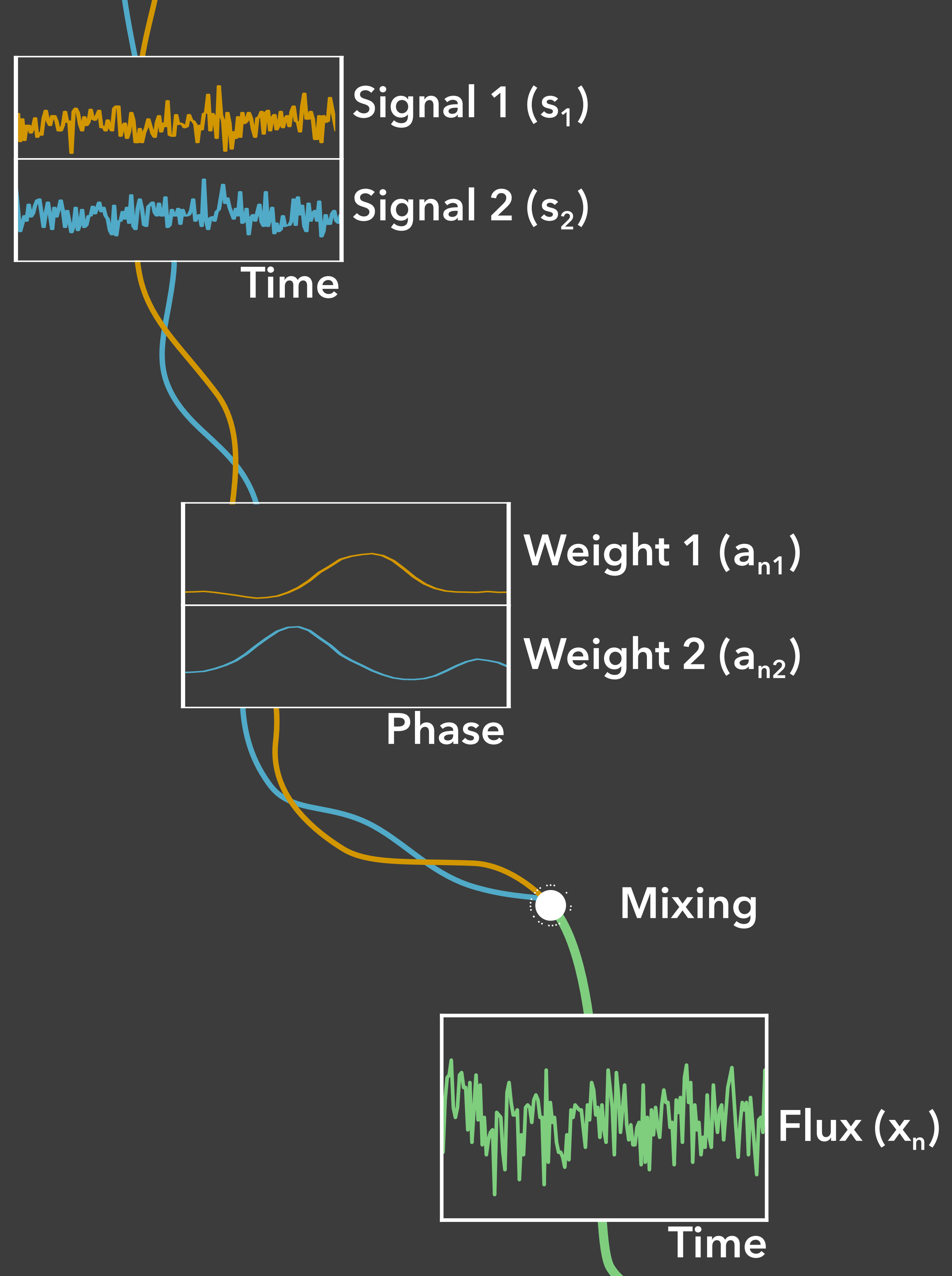
2.2 Weights

The **mixing parameters (a_{nm})** are the **weights** to the observed flux and determine how the signals are mixed in a given phase. These are the **single-pole pulse profiles** that we are interested in.

2.3 Observations

We assume that the **observed flux (x_n)**, in any given pulse phase is a **mixture** of the two signals, each weighted by the intensity of the emission from each pole. Our analysis is based on the n-phase resolved light curves.

$$x_1(t) = a_{11}s_1 + a_{12}s_2$$
$$x_2(t) = a_{21}s_1 + a_{22}s_2$$
...



3. Blind Source Separation

The classic **"cocktail party"** scenario is a good analogy for this problem. Imagine a guest at a party, surrounded by multiple conversations and various background noises. In the midst of this chaos, the guest tries to focus on a particular conversation and filter out the surrounding noise.

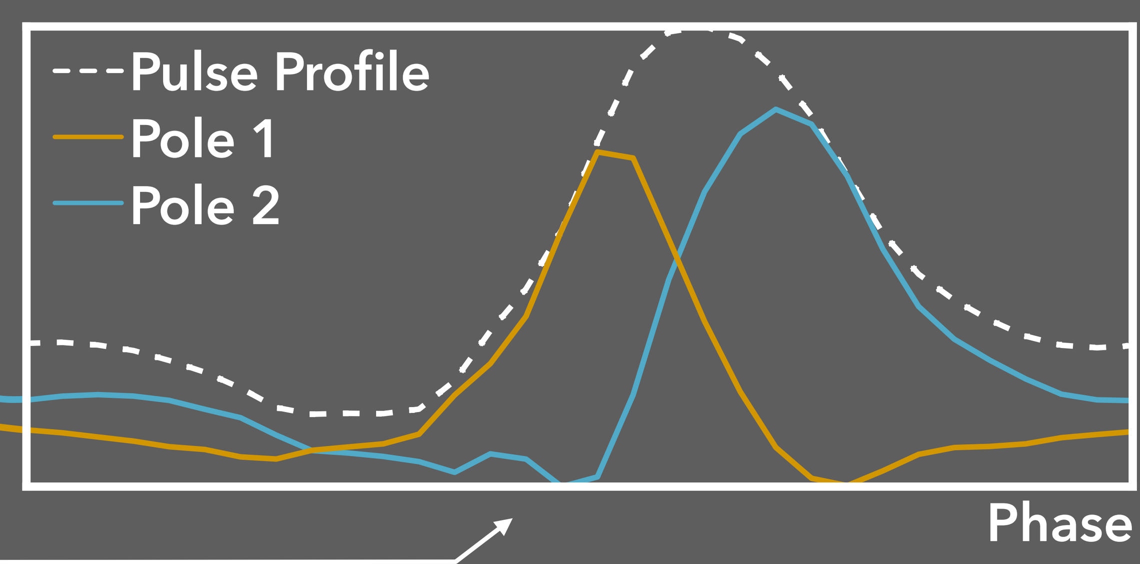
While the human brain is very good at this kind of **selective listening**, it is very challenging for machines. It's not an impossible task, however, and there are several algorithms that can tackle it. One such algorithm is **non-negative matrix factorization (NMF)**, which we apply in this context to **"listen to the accretion voices" of the X-ray pulsar**.

In this application, we call this new method the **Phase Correlated Variability Analysis (PCVA).**

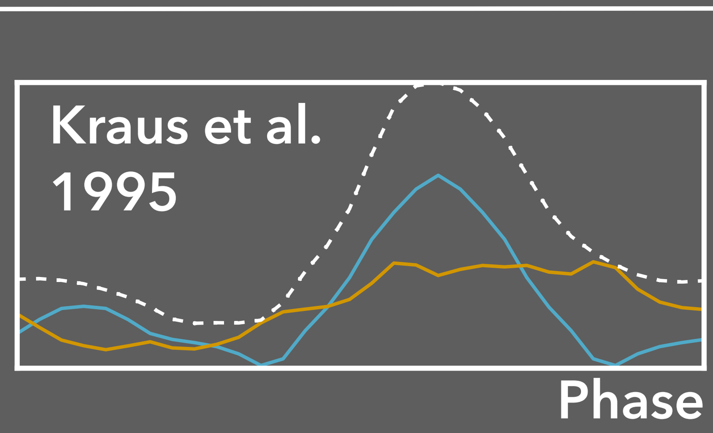
4. Results: PCVA of Cen X-3

The PCVA decomposition for Cen X-3 shows that the primary peak consists of two distinct peaks of similar amplitude. The two profiles are remarkably **asymmetric** in phase.

Asymmetries can arise when the magnetic field is **not perpendicular** to the surface of the neutron star, which can be caused by more complex magnetic field structures.



For comparison, analysis of the data using the method by **Kraus et al. 1995** gives very different results. Our results are incompatible with their **assumption** that the two single-pole pulse profiles are symmetrical.



Kraus, U., et al., 1995, ApJ, 450, 763

More information

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