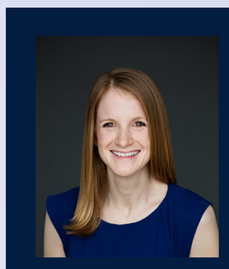

Probing Neutron Star Astrophysics With Laboratory Experiments

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1. The Background: Neutron Stars

- Neutron stars form in **supernova** explosions of massive stars. As their names suggest, they are mainly composed of neutrons.
- Because of their extreme nature, neutron stars are excellent **cosmic laboratories** to study the behaviour of dense matter.
- These remnants are very cold in terms of their densities, giving the neutrons the special ability to flow **without friction**. The **superfluids** rotate by forming arrays of quantised vortices.

~1.4 solar masses

densities exceed those of atomic nuclei

rotate up to 700 times per second

~10 km radii

strongest known magnetic fields

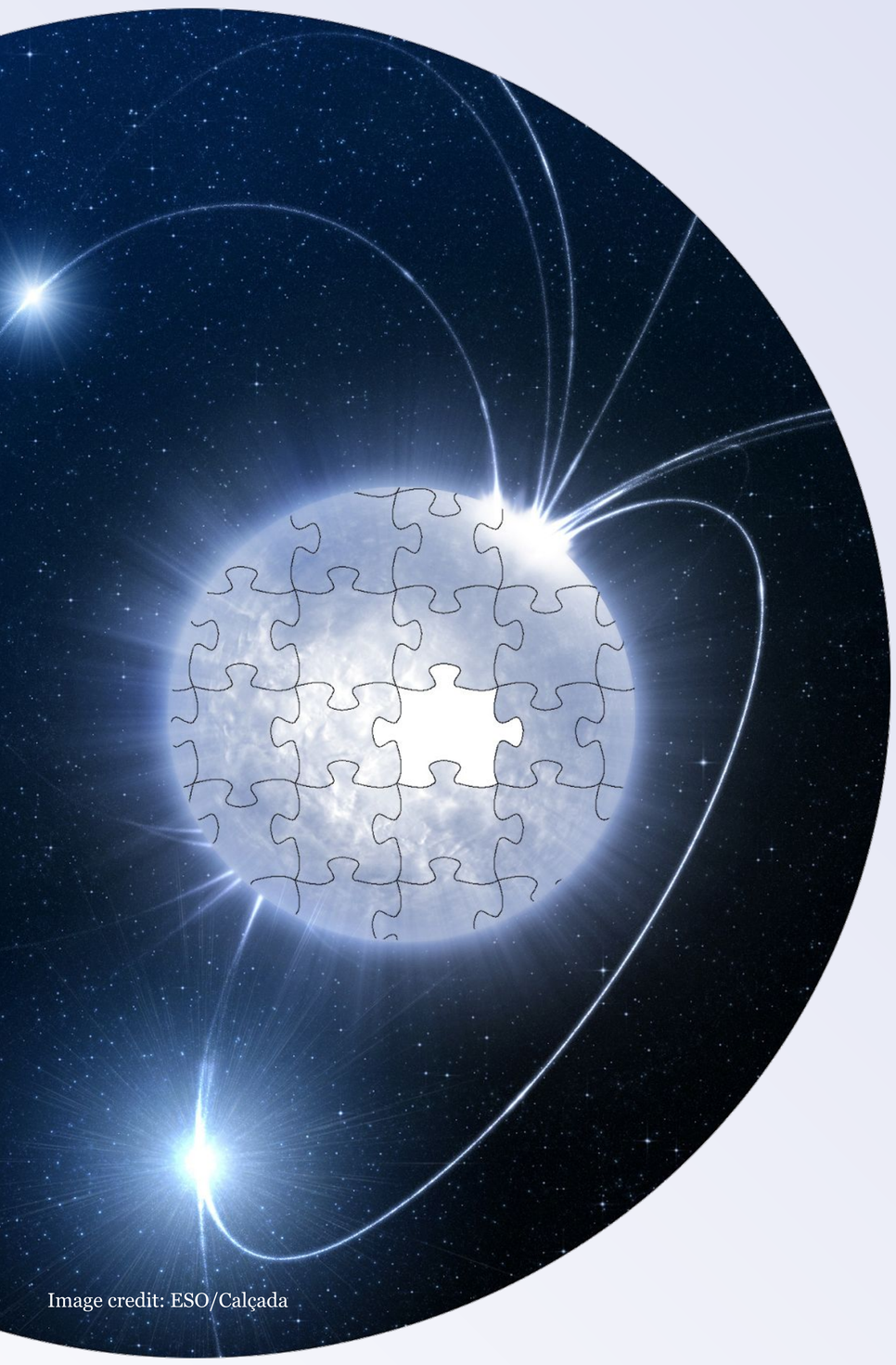

Image credit: ESO/Calçada

2. The Problem: Modelling Glitches

- As their rotation and magnetic axes are misaligned, neutron stars emit radiation like a lighthouse. These **radio pulses** are observable on Earth.
- The regular neutron star spin down is sometimes interrupted by **glitches**, sudden **spin ups** that are attributed to the internal superfluids.
- To compare glitch **models** with **observations**, we need to understand how superfluid vortices (tiny, rapidly rotating tornados) interact with their surroundings. Extreme conditions make the modelling **challenging.**

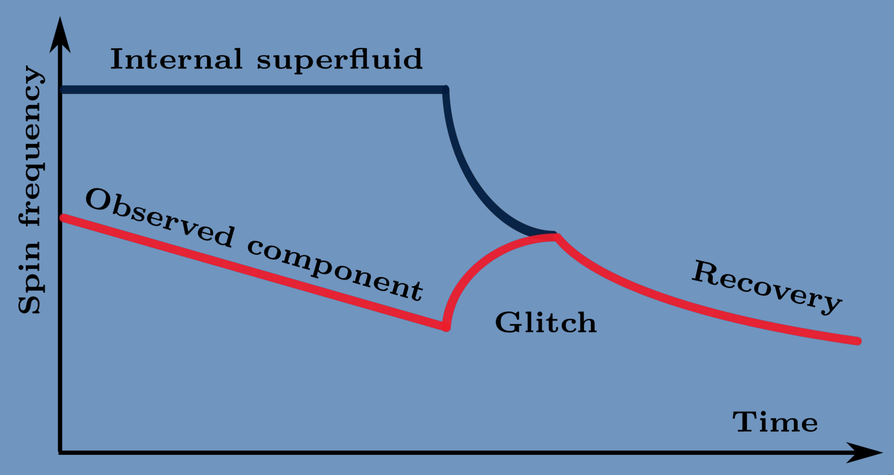

Figure 1: Sketch of an idealised glitch. Once the glitch is triggered the two components recouple and the observed component spins up.

3. The Solution: Laboratory Analogues

- Neutron star superfluids are **exotic versions** of quantum condensates observed in laboratory experiments. They have several similarities with terrestrial superfluids, e.g., **helium** cooled to cryogenic temperatures.
- While not capturing all neutron star extremes, laboratory condensates are very **versatile** and allow us to probe specific neutron star features.
- In particular, laboratory helium experiments can help to better understand the role of superfluid **vortex dynamics** in neutron star glitches.

design experiment to monitor rotation of superfluid helium

use simulations to model vortices

analyse instabilities and pinning

advance ideas of Tsakadze & Tsakadze (1980)

Selected references: Espinoza et al., Monthly Notices of the Royal Astronomical Society, 414, 1679 (2011)
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