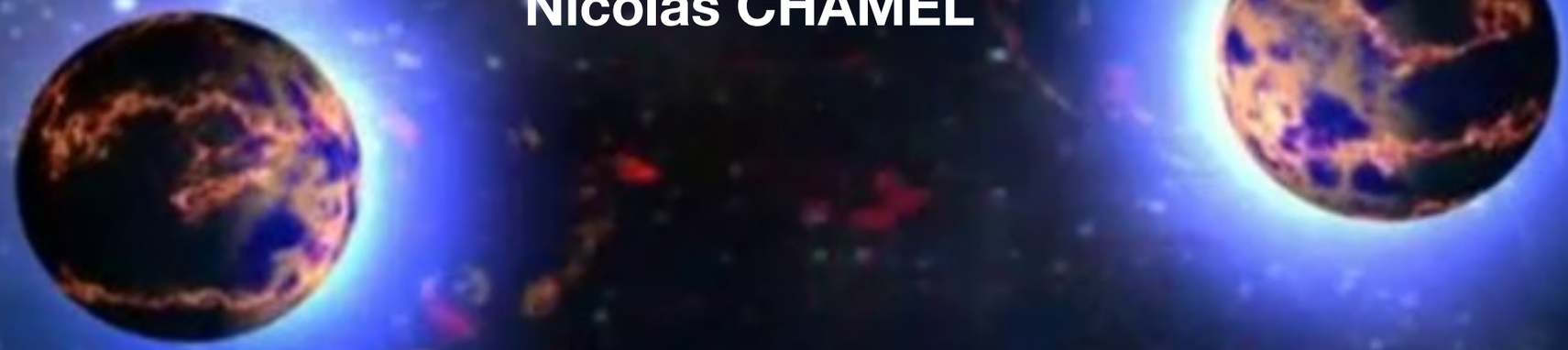
Astrophysics at ULB

Institute of Astronomy and Astrophysics

Nicolas CHAMEL



ULB

Belgian Gravitational Wave Meeting, 27 October 2020

IAA bruxelles

Nuclear astrophysics group

Permanent staff: Nicolas CHAMEL, Stéphane GORIELY

PhD students: Loïc PEROT, Valentin ALLARD, Ina KULLMANN

Postdocs: Erik OLSEN, Guillaume SCAMPS, Wouter RYSSEN

Main research interests:

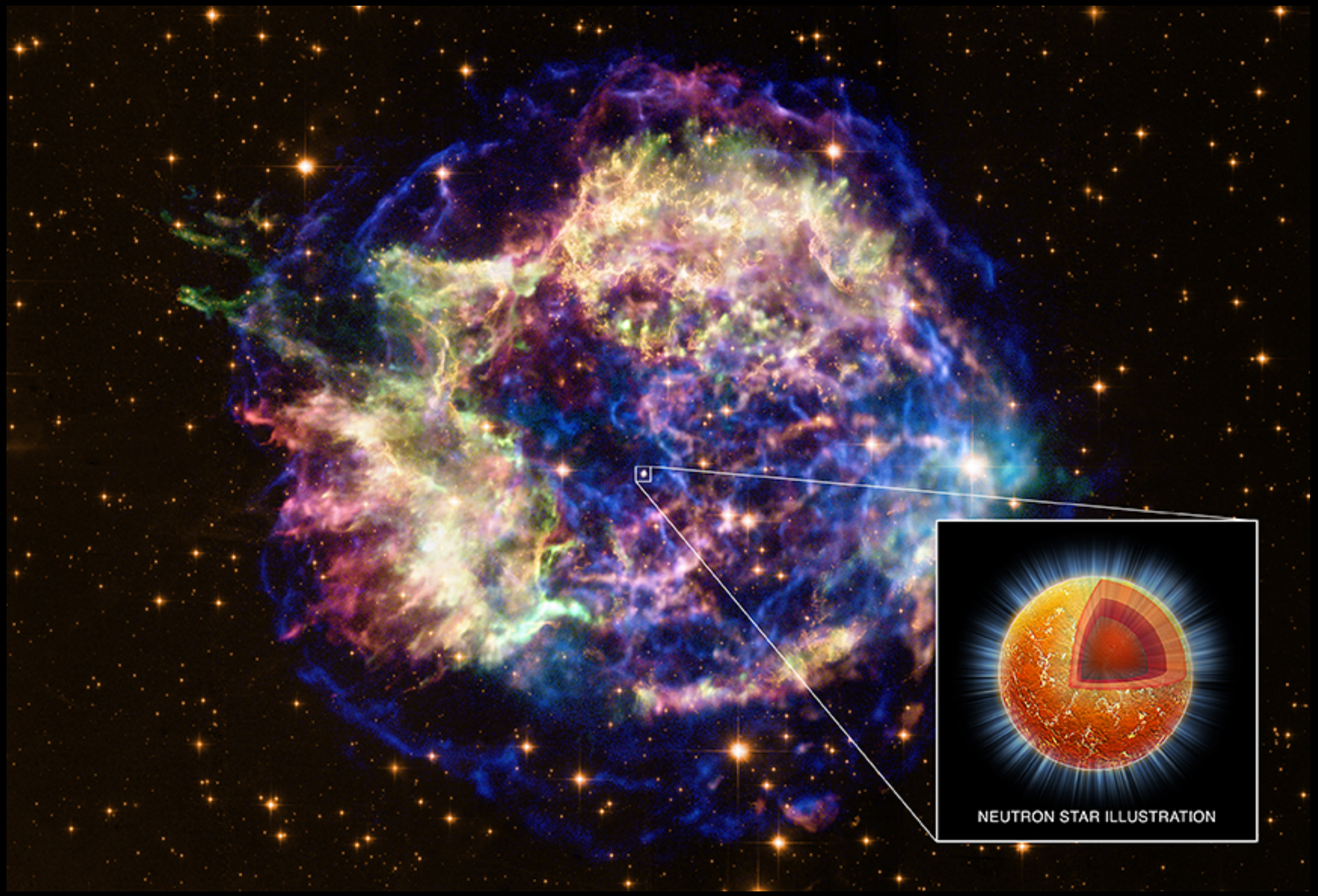
- dense matter in compacts stars
- origin of the heavy elements in the Universe

comp star

PHAROS
THE MULTI-MESSENGER PHYSICS AND ASTROPHYSICS OF NEUTRON STARS

Neutron stars

Formed in gravitational core-collapse supernova explosions, neutron stars are denser than the heaviest atomic nuclei.



R~10 km
M~1-2$M_\odot$

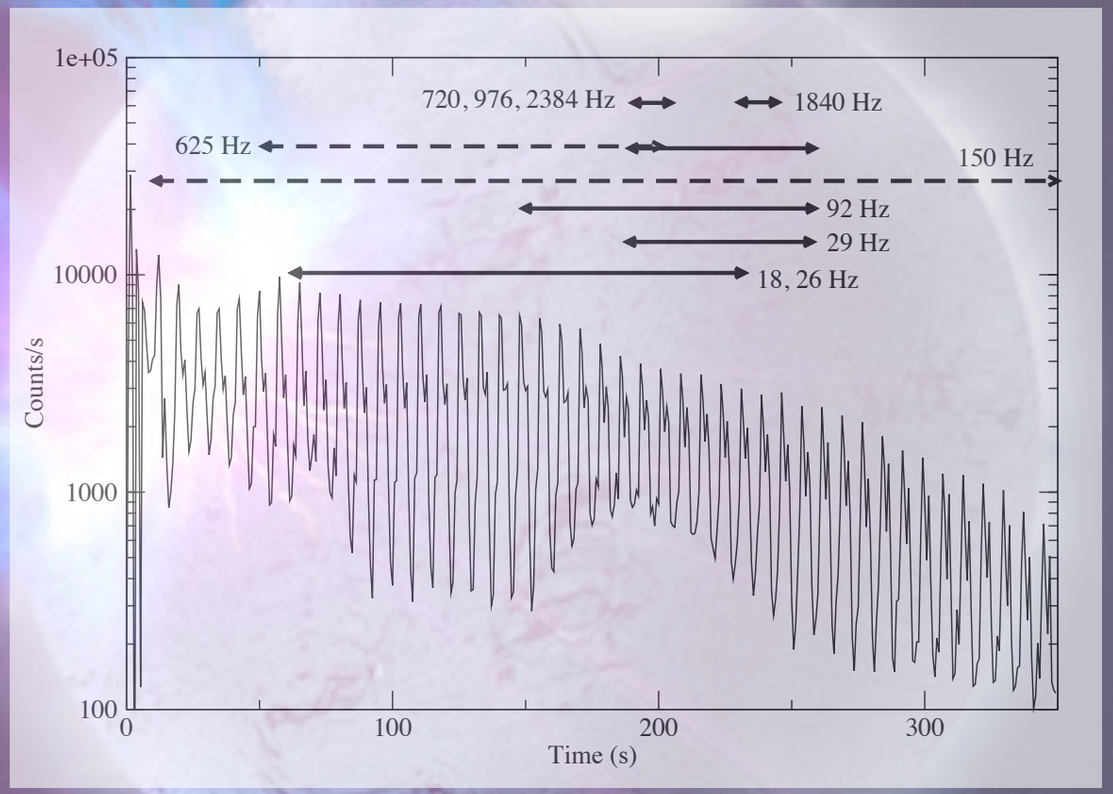
Some neutron stars are endowed with **extremely high surface magnetic fields** ~10^{15} G. Their internal fields may reach ~10^{18} G.

Magnetars are observed as

- soft-gamma ray repeaters,
- anomalous X-pulsars,
- fast radio bursts ?

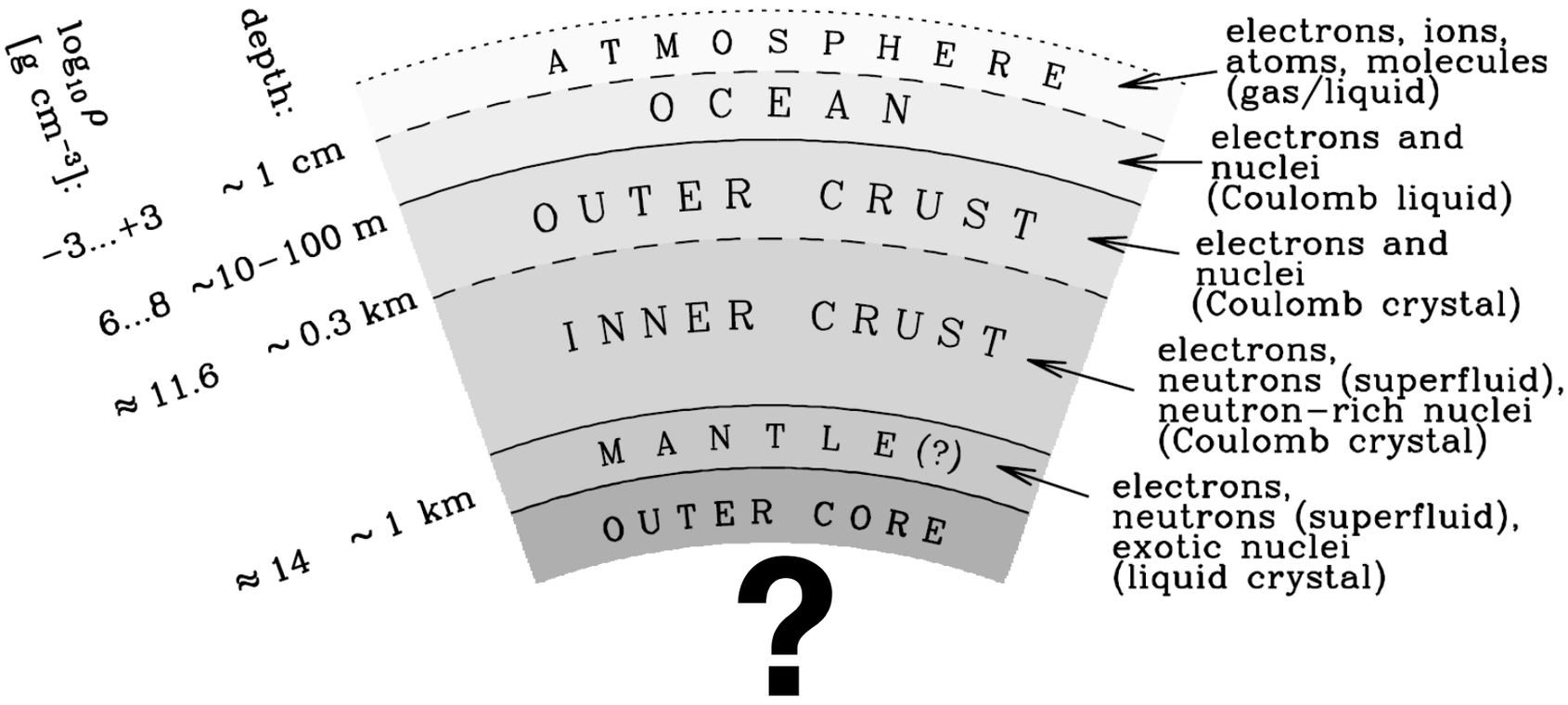
They may be produced by

- supernova explosions
- binary neutron-star mergers.

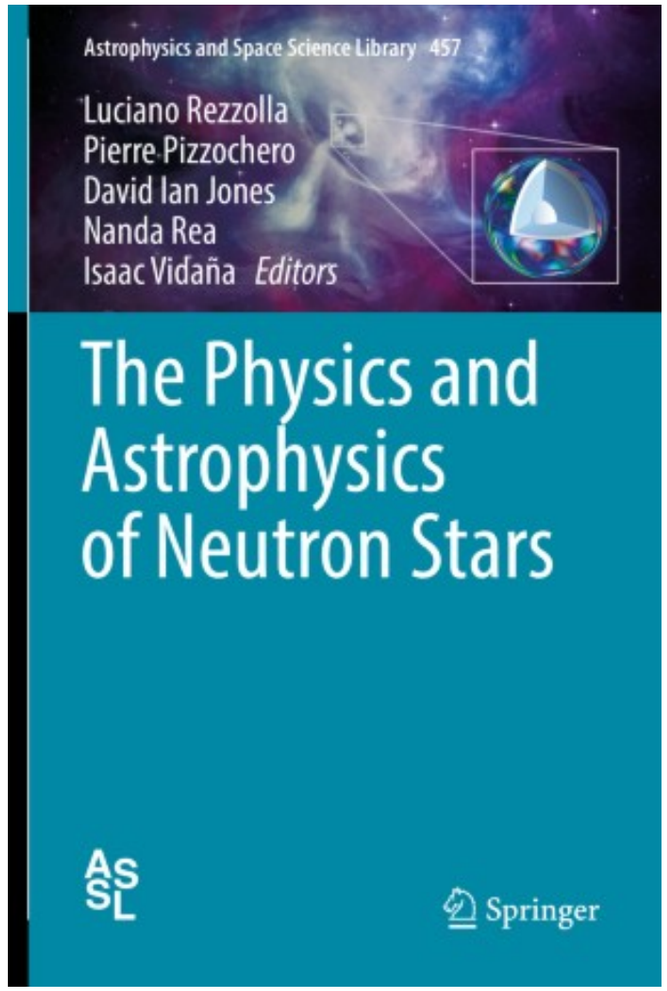


Strohmayer & Watts (2006)

Dense matter in neutron stars



Neutron Stars, Haensel, Potekhin, Yakovlev (Springer, 2007)



The interior of a neutron exhibits **very different phases** (solid, liquid, gas, superfluid, superconducting) over a very wide range of densities and possibly with exotica in their core (e.g. hyperons, deconfined quarks)

Dense matter in neutron stars

Some of our achievements:

- unified equations of state of cold dense matter applicable to all regions of neutron stars
- first calculations of neutron superfluidity in neutron-star crust

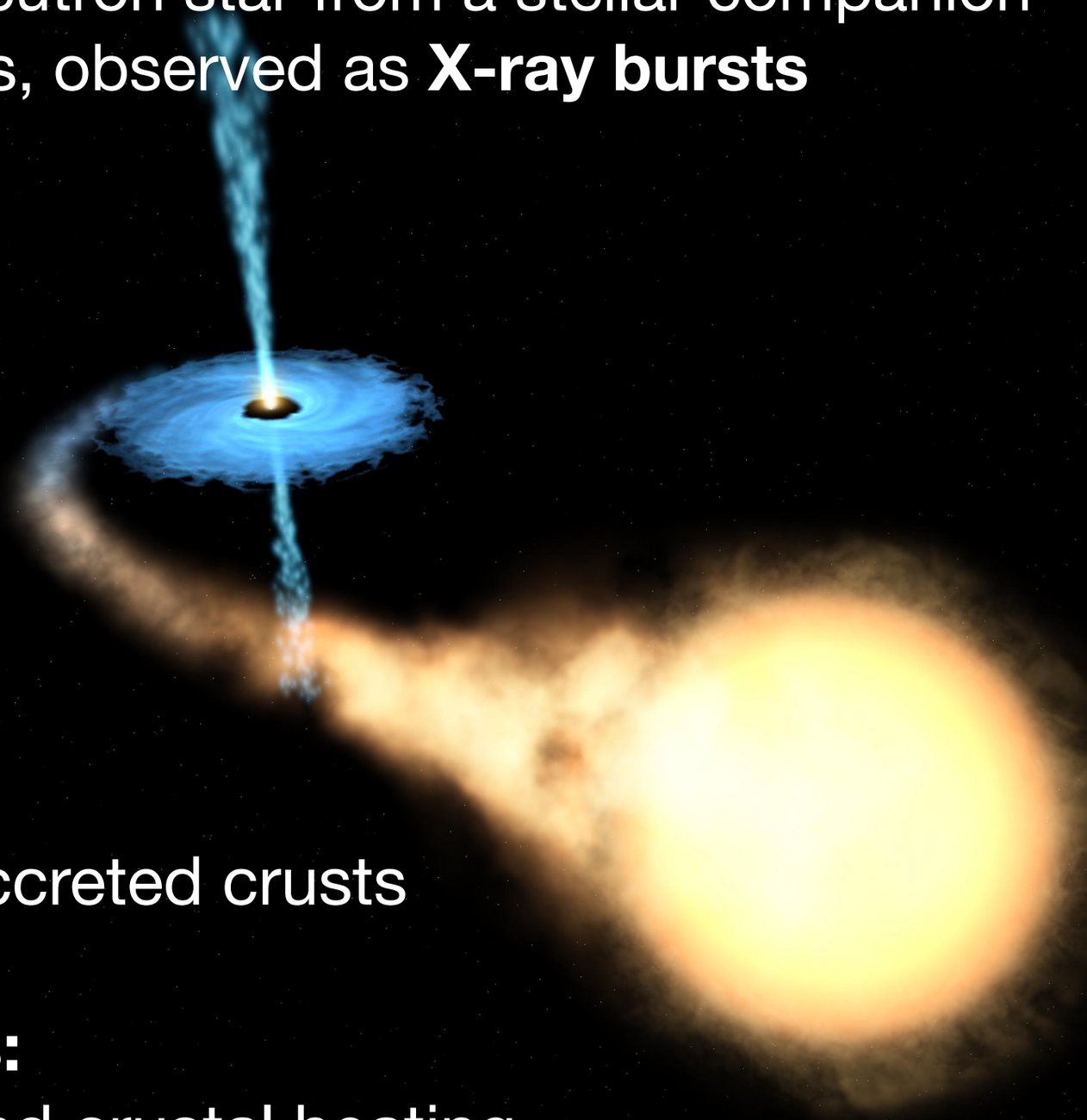
Some of our current activities:

- properties of dense matter under extreme magnetic fields
- cooling and crystallization of neutron-star crust
- formation of « nuclear pastas »
- elasticity of dense stellar matter
- nuclear superfluidity and superconductivity

X-ray binaries

The accretion of matter onto a neutron star from a stellar companion triggers thermonuclear explosions, observed as **X-ray bursts**

Accreted « mountains » drive gravitational-wave emission



Some of our achievements:

- first realistic calculations of accreted crusts

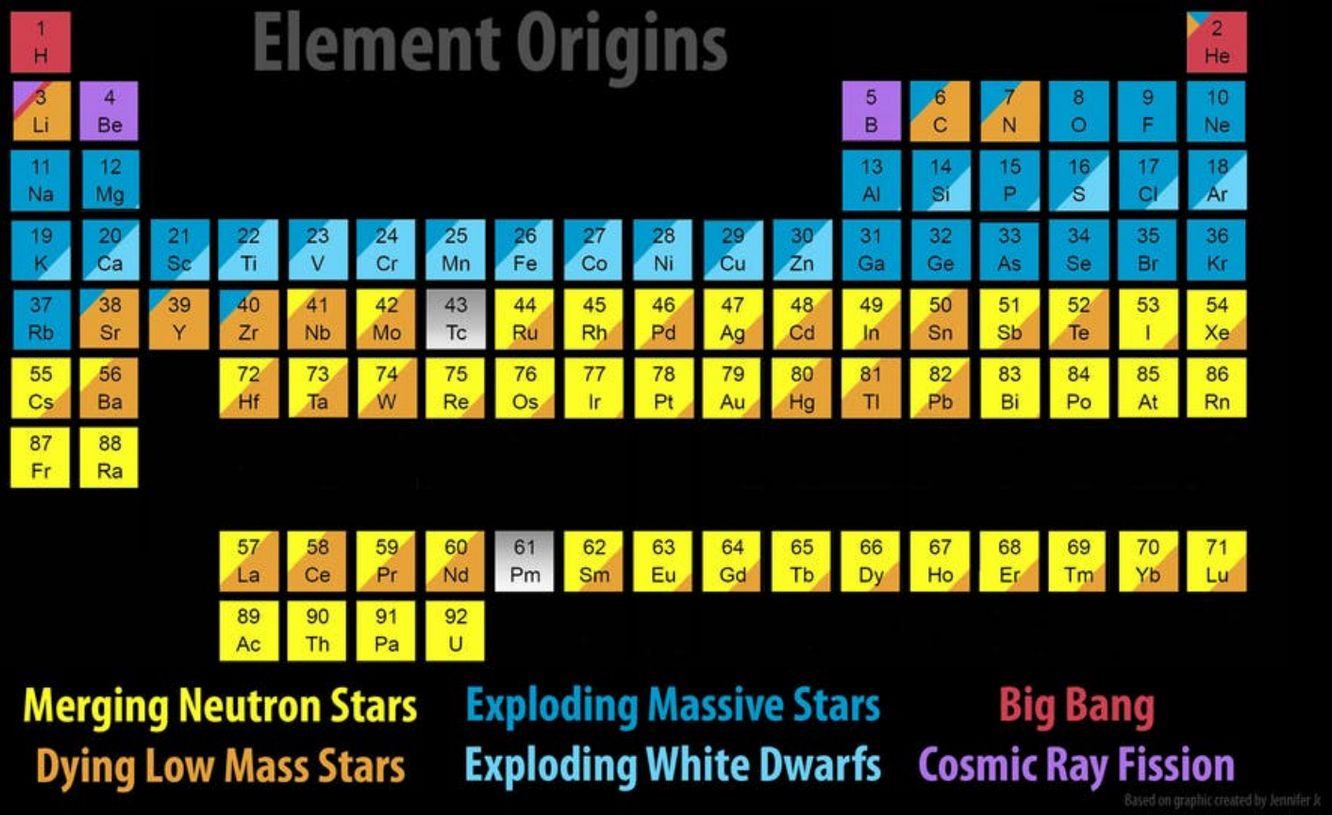
Some of our current activities:

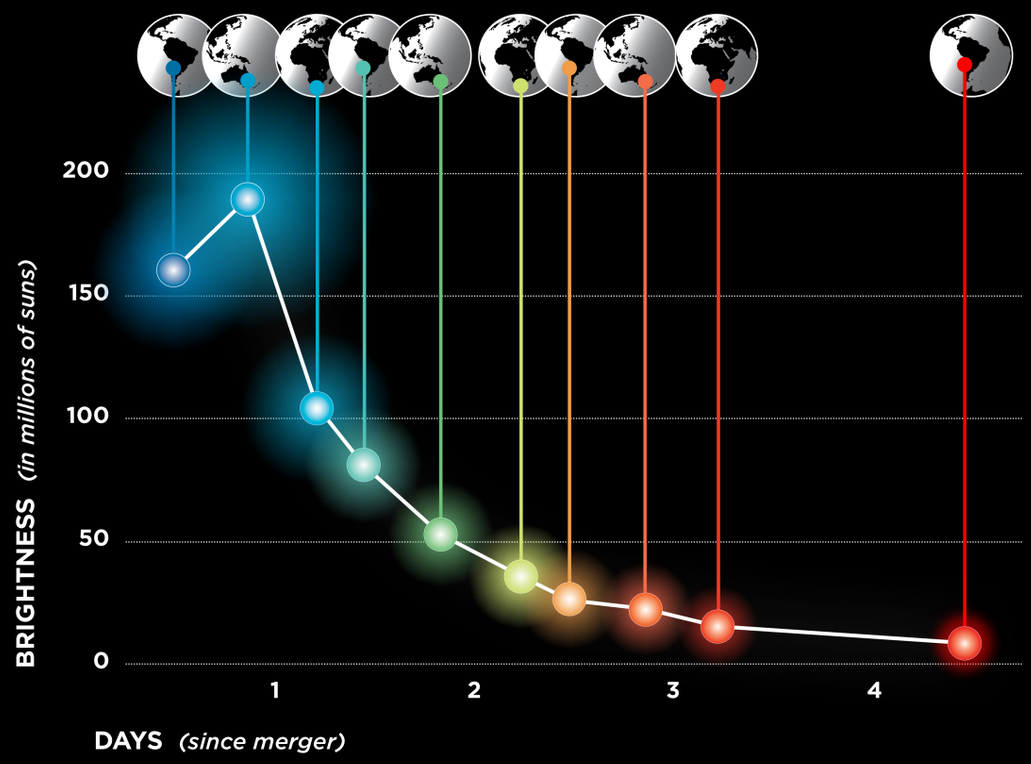
- accretion-driven processes and crustal heating

Binary neutron stars and nucleosynthesis

Some of our achievements:

- database of nuclear inputs for astrophysical applications
- first detailed predictions of the nucleosynthesis from binary neutron-star mergers confirmed by GW170817





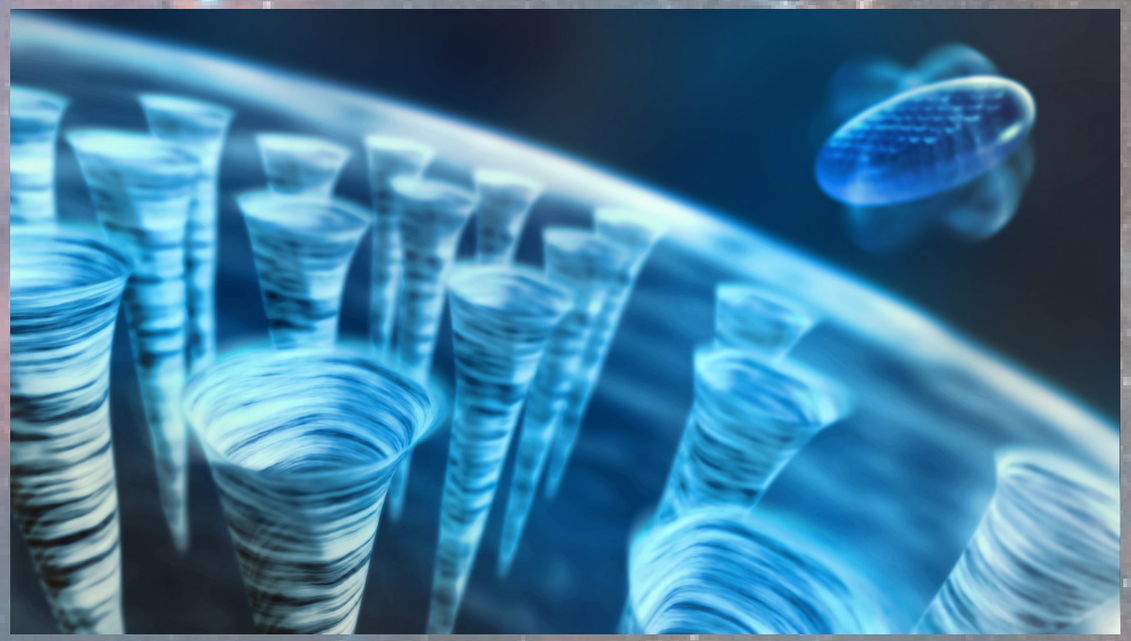
Some of our current activities:

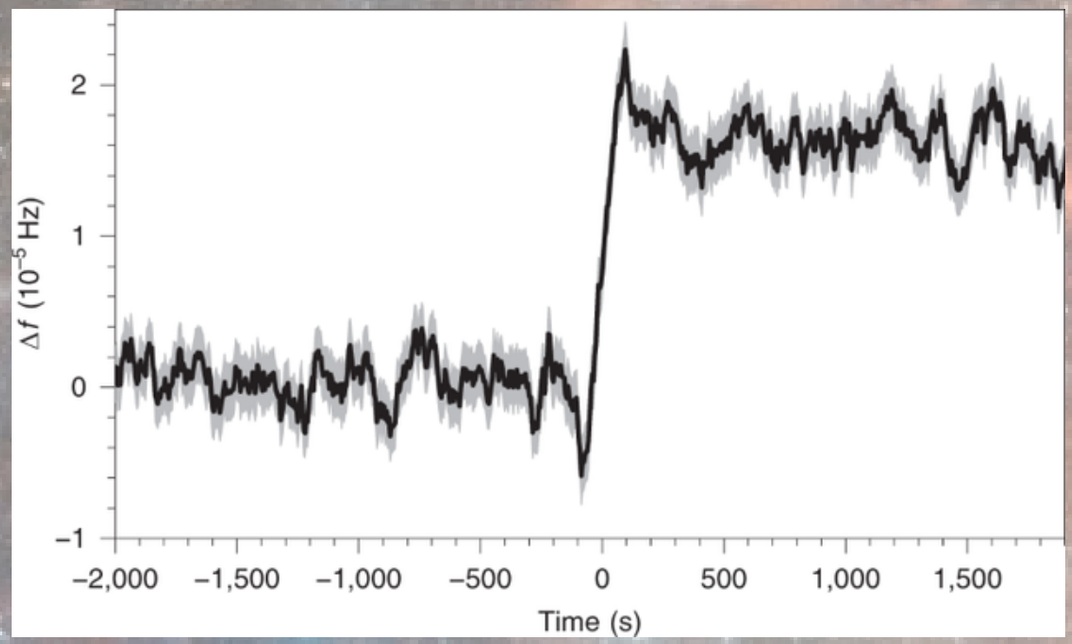
- r-process nucleosynthesis in dense stellar environments

Global models of neutron stars

Some of our achievements:

- general-relativistic simulations of superfluid neutron stars



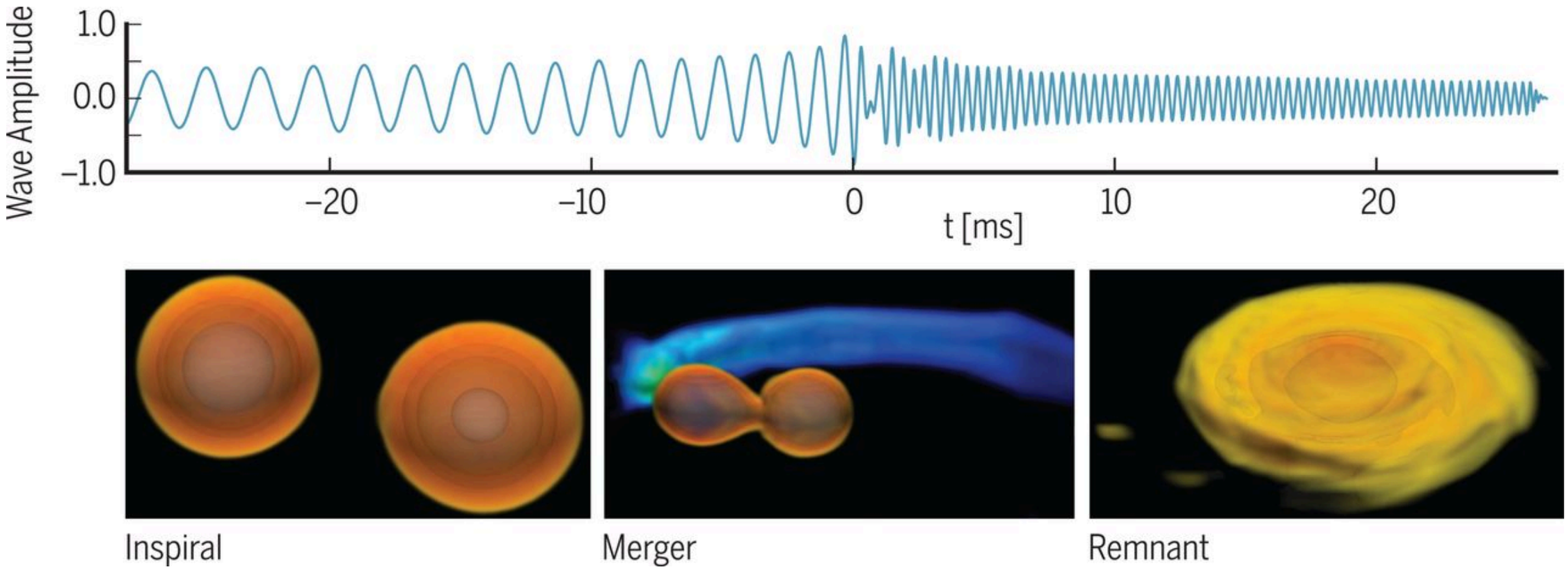


Ashton et al. (2019)

Current activities:

- role of superfluidity and quantized vortices on the dynamics of neutron stars

Gravitational waves from binary neutron stars



Current activities:
Role of dense matter on the tidal deformations of neutron stars and their gravitational-wave emission during their inspiral

What can we learn from gravitational waves ?