Predicting the X-ray emission from the magnetar remnant of binary neutron stars mergers

application to the SVOM mission

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ACME conference

Can we constrain the nature of a binary neutron star merger remnant ?

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Gravitational waves

Electromagnetic waves

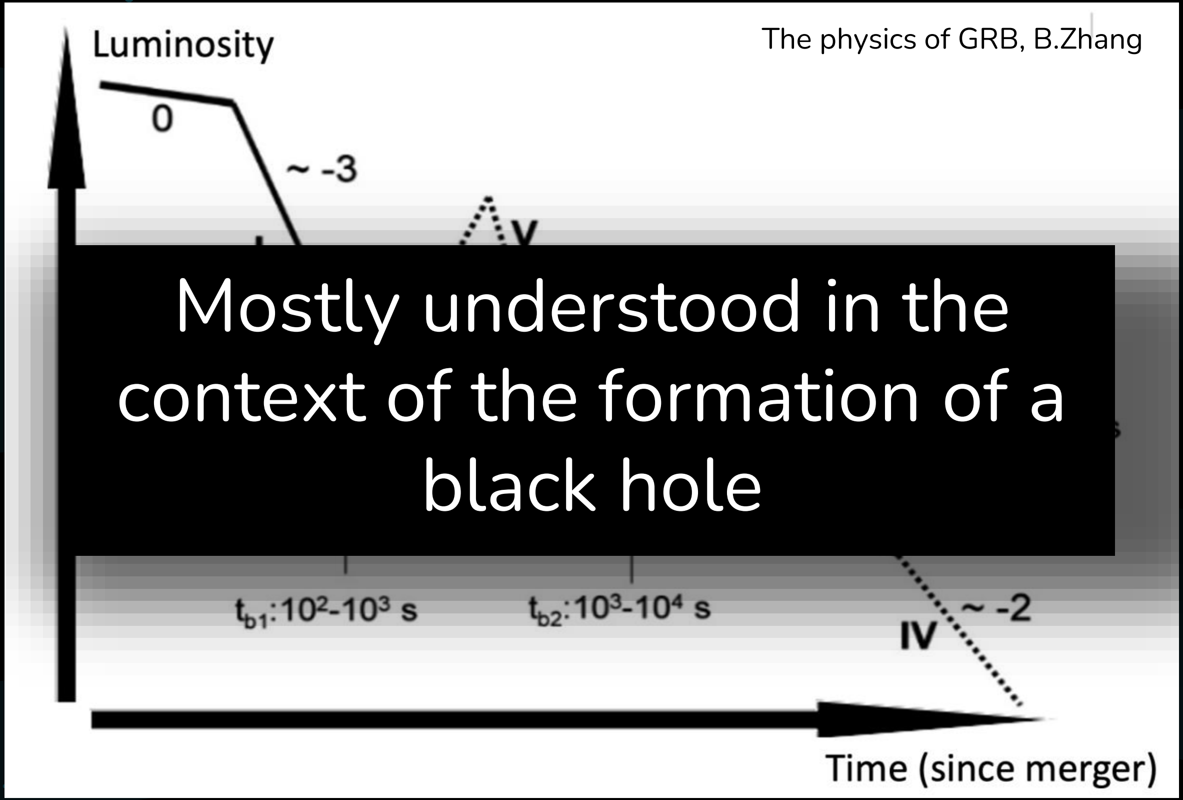
Can we constrain the nature of a binary neutron star merger remnant ?

Gravitational waves

X-rays

Gamma-ray bursts X-ray afterglow

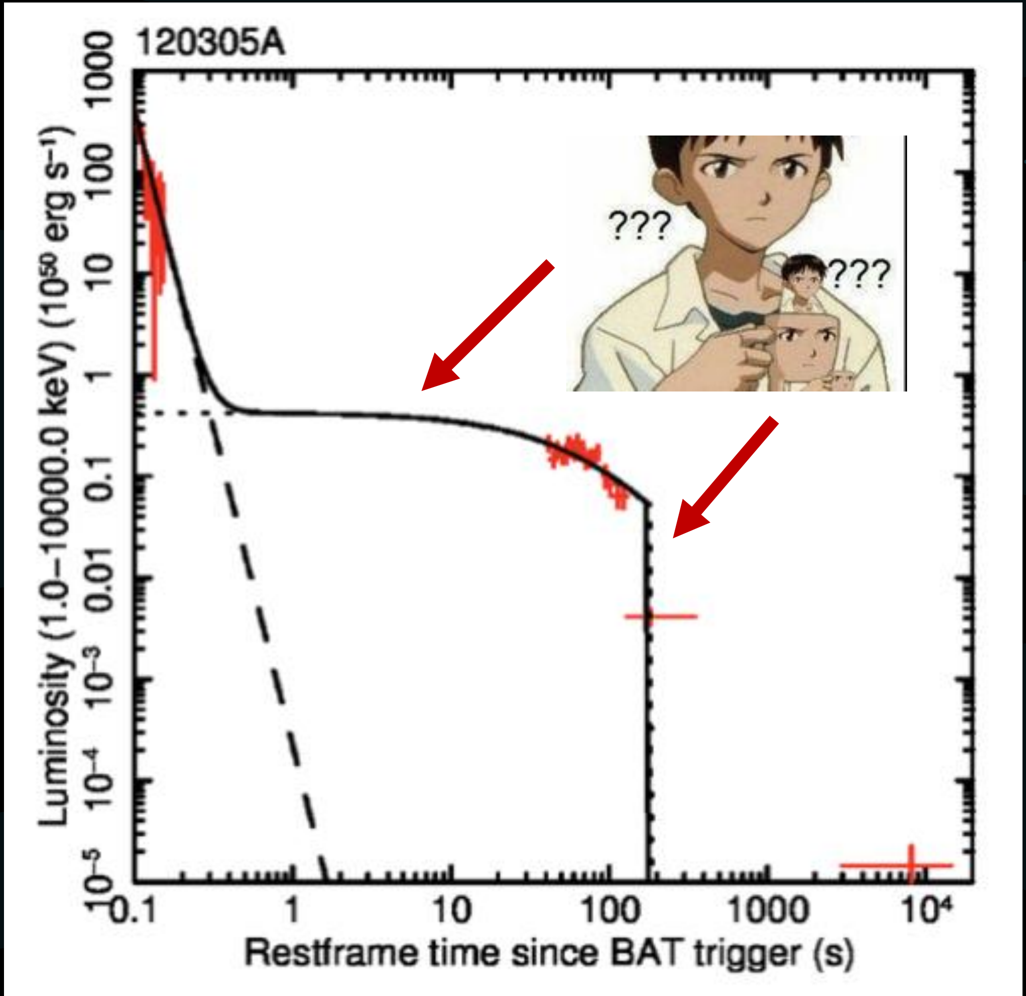
X-ray lightcurve (see M. Bernardini's talk)



The physics of GRB, B.Zhang

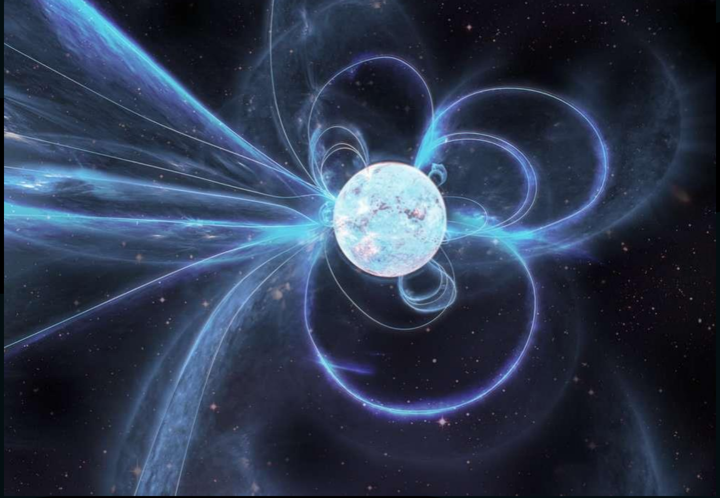
Mostly understood in the context of the formation of a black hole

X-ray lightcurve from a short gamma-ray burst



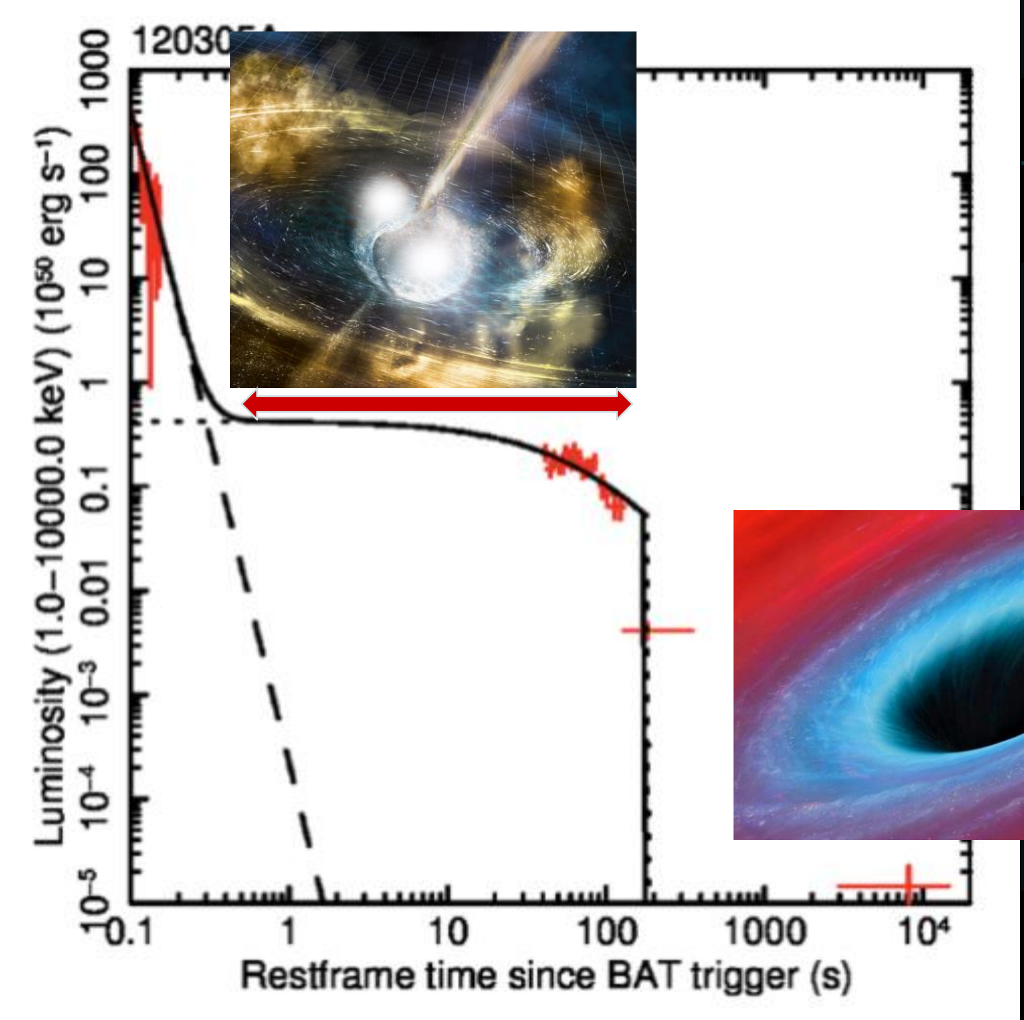
Observations of Rowlinson et al. (2012)

About magnetars



- Associated with Anomalous X-ray Pulsars (AXP) and Soft Gamma Repeaters (SGR)
- Over 30 magnetars identified in the galaxy

-> Slow rotating (2s-10s) magnetars exist

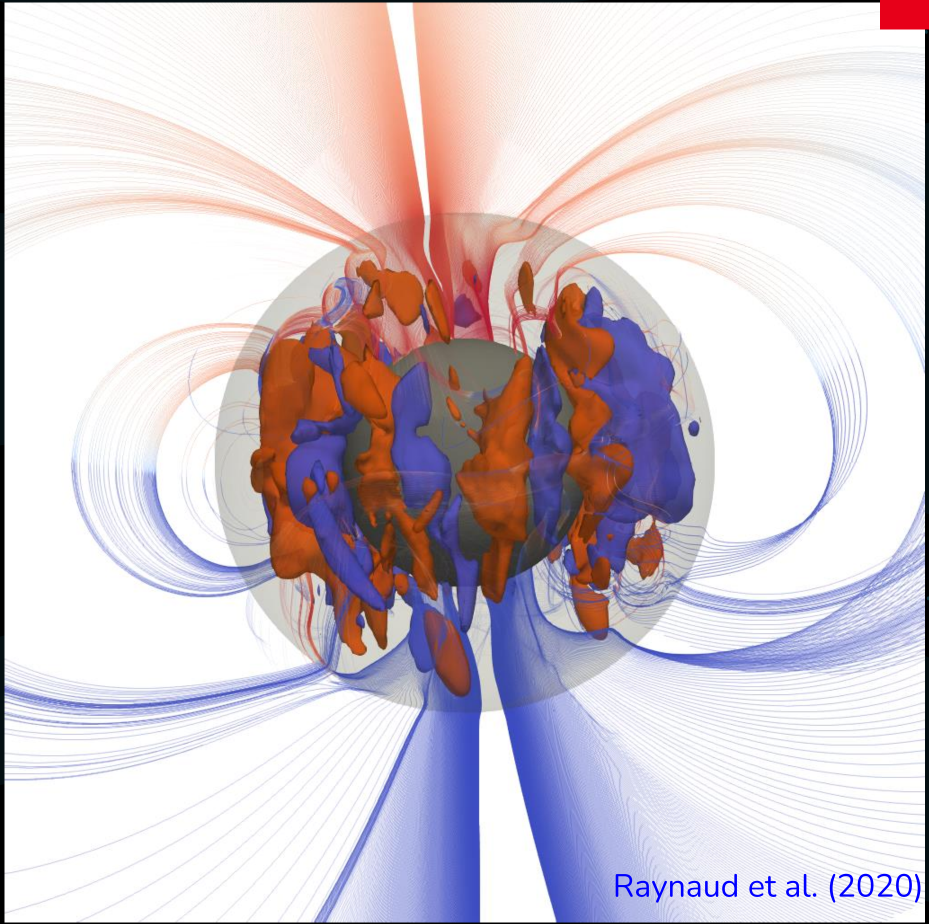


12030
Luminosity (1.0–10000.0 keV) (10^{50} erg s^{-1})
1000
100
10
1
0.1
0.01
10^{-3}
10^{-4}
10^{-5}
0.1
1
10
100
1000
10^4
Restframe time since BAT trigger (s)

1

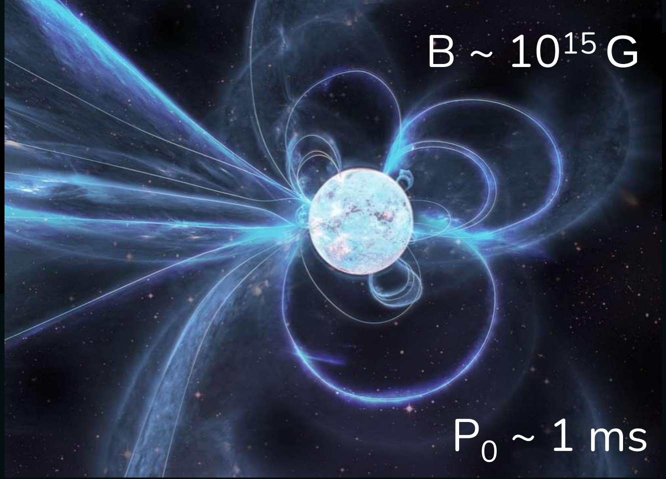
Simulation

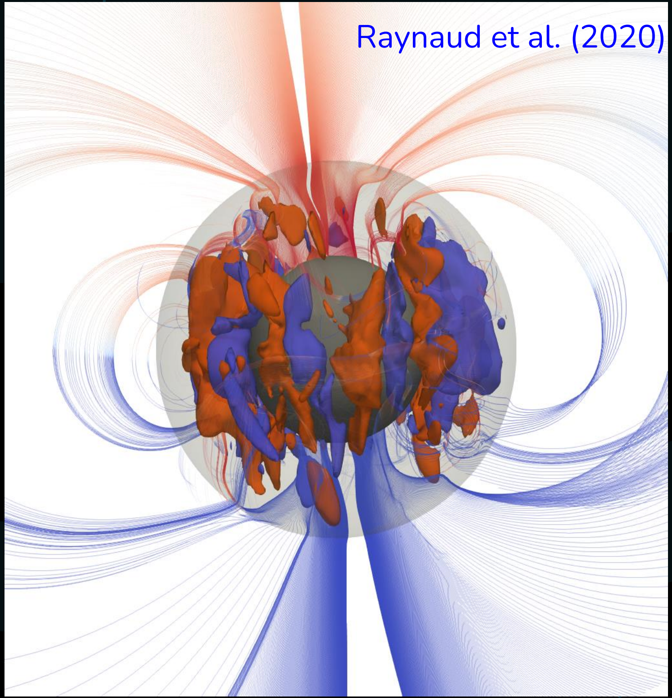
Can we detect this kind of neutron stars?



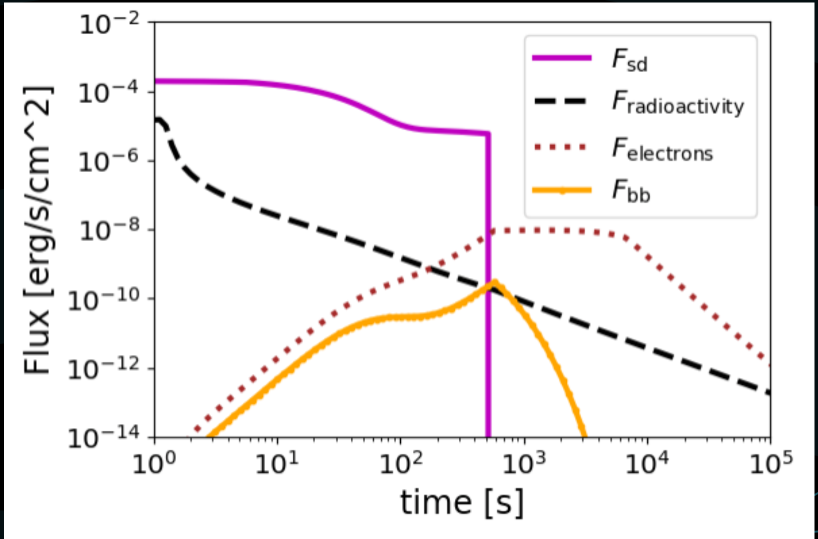
Raynaud et al. (2020)

The millisecond magnetar



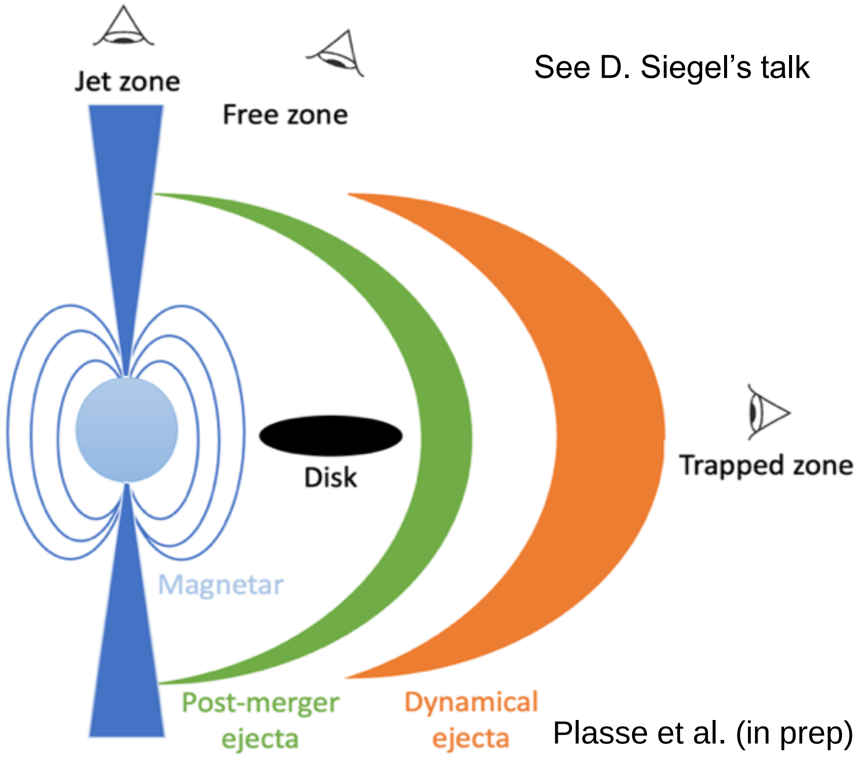


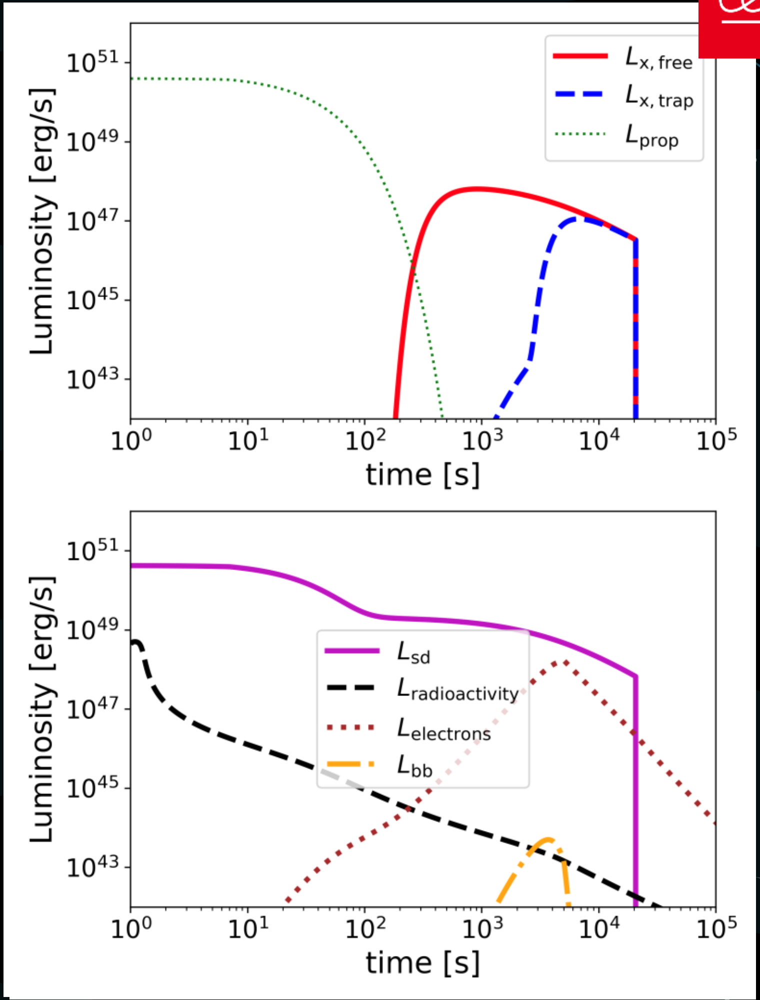
Assuming the equation of state



Lightcurve simulation

GRB: Guilet, Raynaud, Bugli

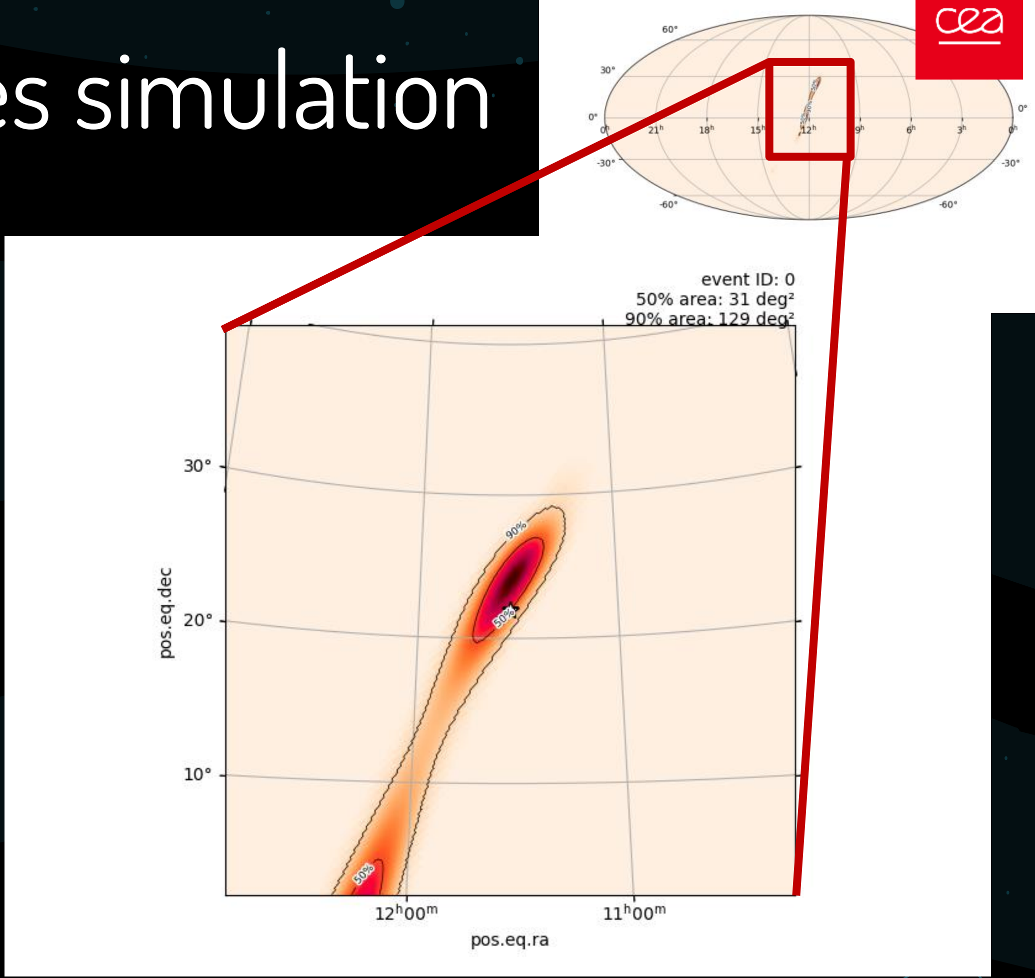




Gravitational waves simulation

With pycbc

- In a given LVK observing run (O4, O5)
- Input << NS progenitors masses and distances
- Output >> SNRs, skymaps (localisation on the sky)



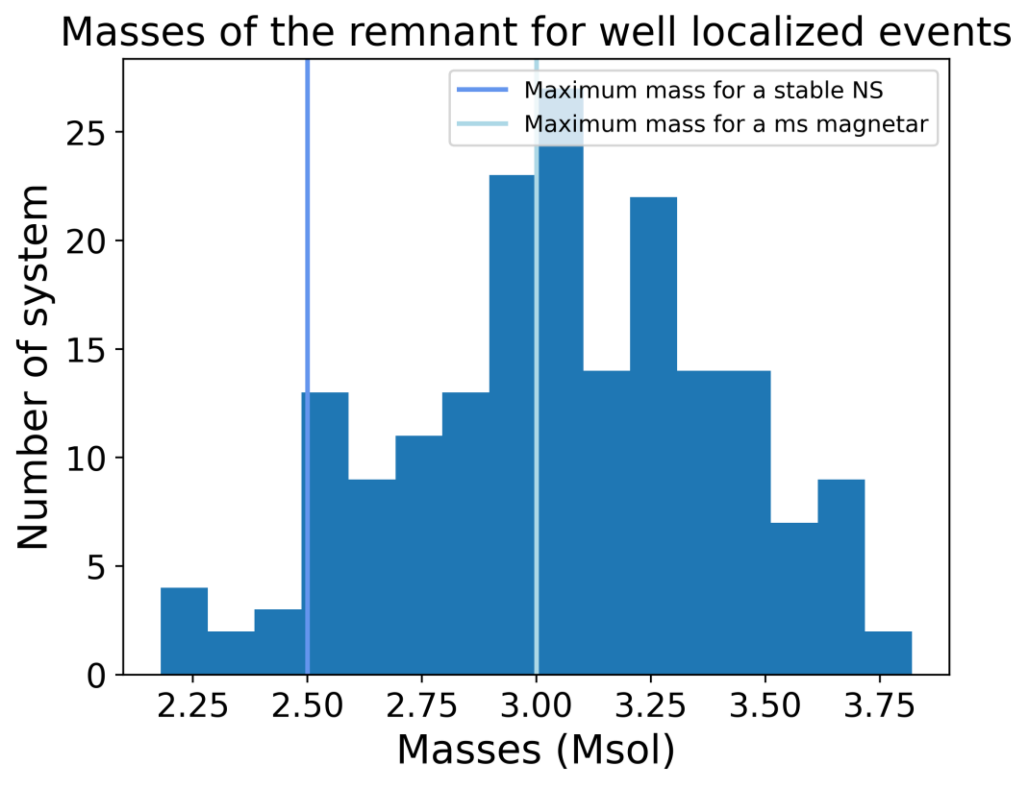
Simulation of a population of binary neutron stars

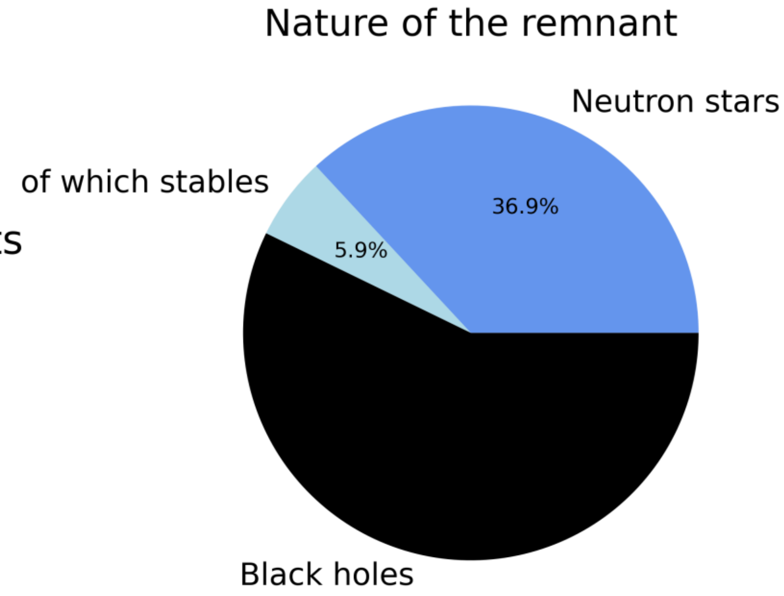
The recipe for O4 and O5:

1. Chose masses according to our current gravitational waves observations (LVK O3)
2. Simulate the gravitational wave signal of the BNS merger through the PyCBC detection pipeline for sky localization
3. Select well localized systems
4. GRB analysis on remaining systems to infer predictions on future X-ray observations

Do we magnetar ?

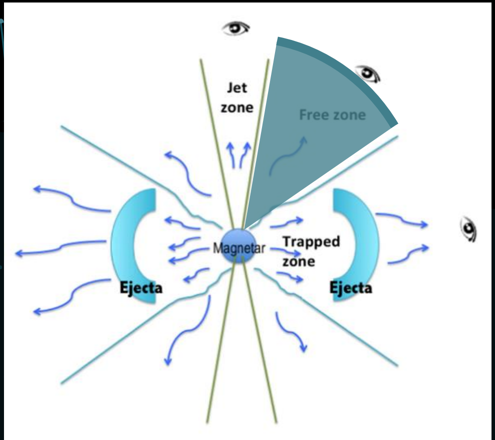
Consideration of remnant mass only





On 1000 simulated binary neutron stars

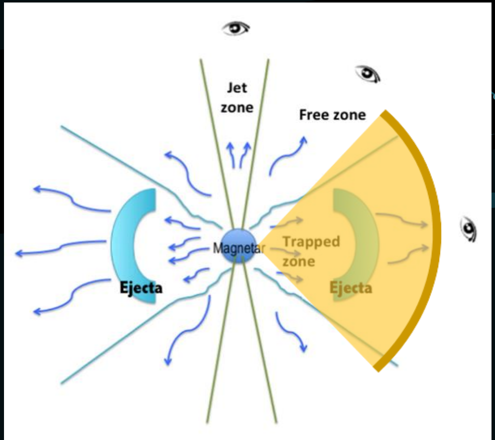
2 detection scenarios



In the free zone

- Small solid angle coverage,
- Higher luminosity : mean flux ~ 3 10^{-9} $erg.s^{-1}cm^{-2}$,
- Shorter duration emission.

-> Detection with wide FoV instruments (EP/FXT)

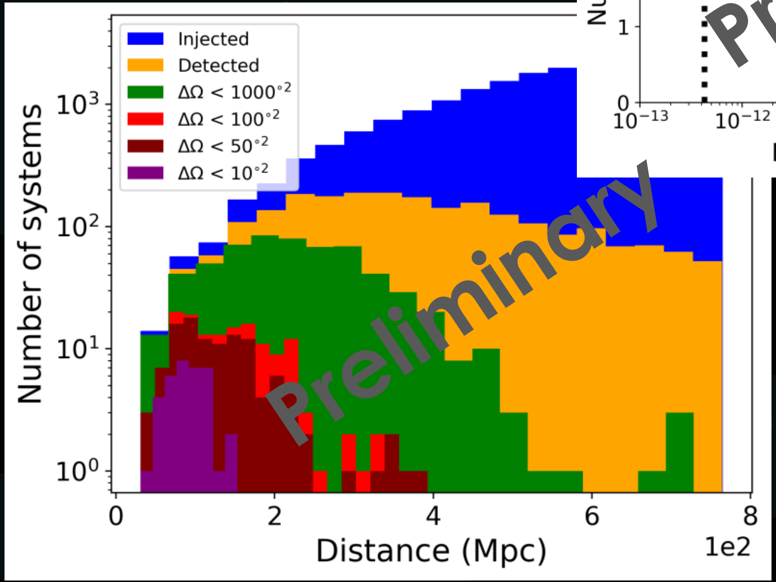


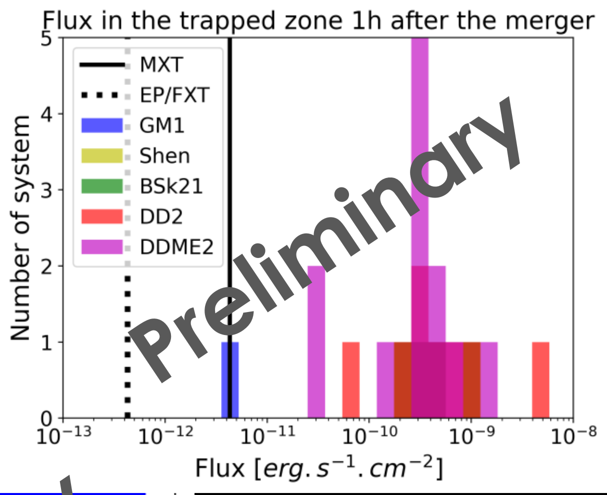
In the trapped zone

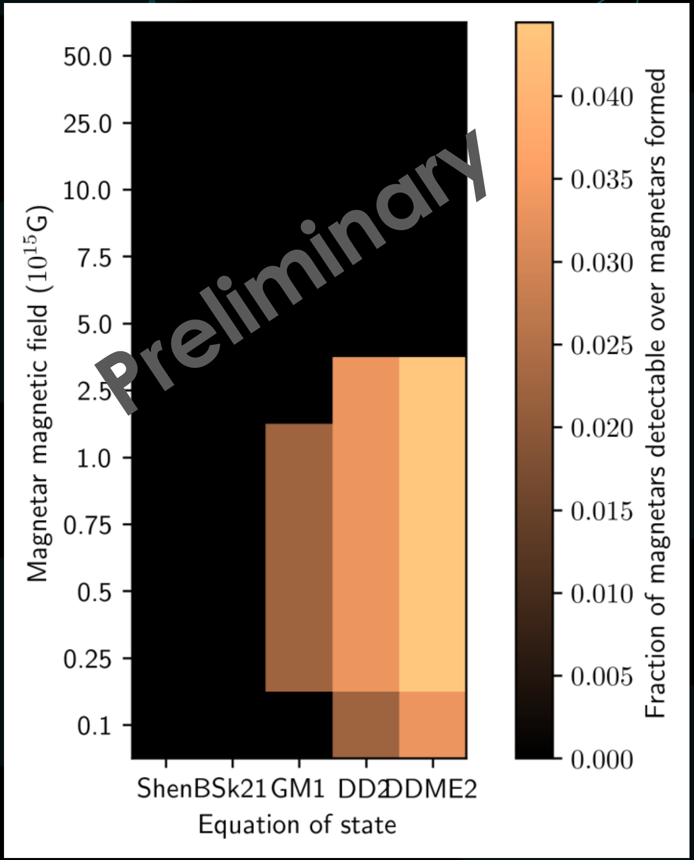
- More solid angle coverage,
- Lower luminosity,
- Radiation reprocessed -> longer emission (even after a collapse into a BH !).

-> Detection with smaller FoV, "tiling" instruments (SVOM/MXT)

Other fun stuff







Averaging over the equations of state (O4):

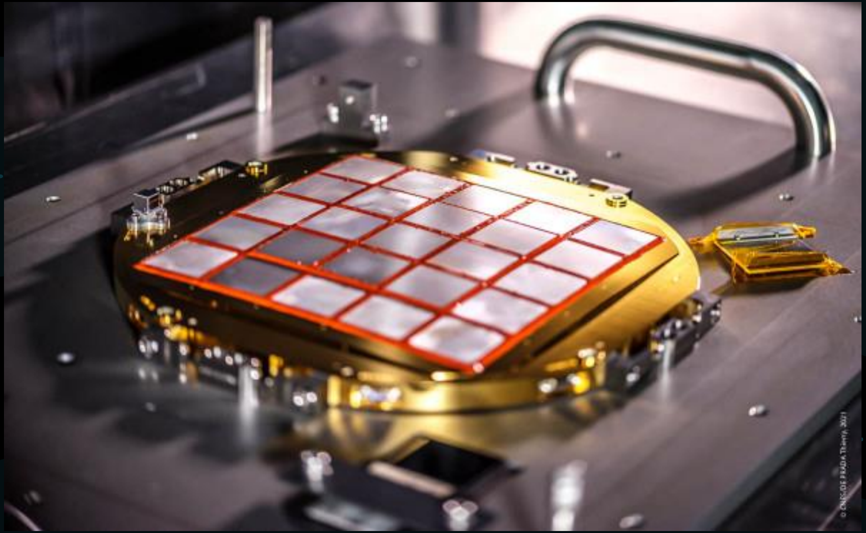
< 1%

detectable ms magnetar

2

Instrumentation

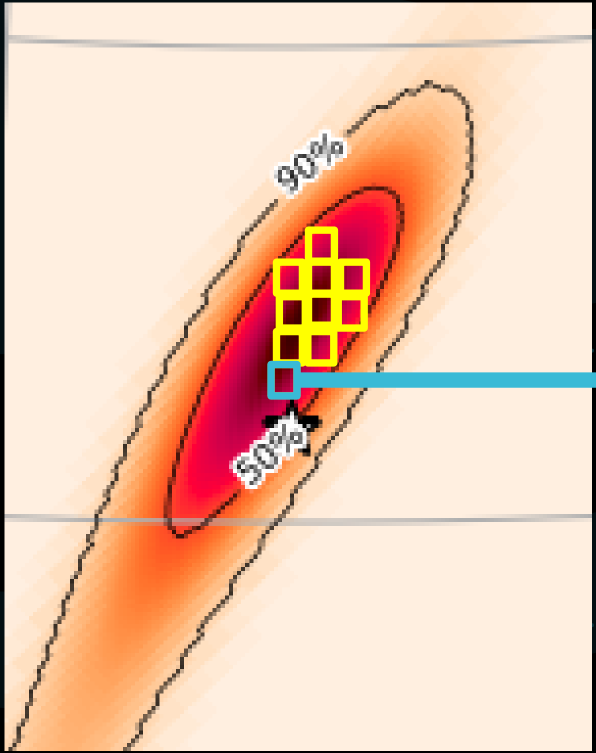
How can we observe these neutron stars ?



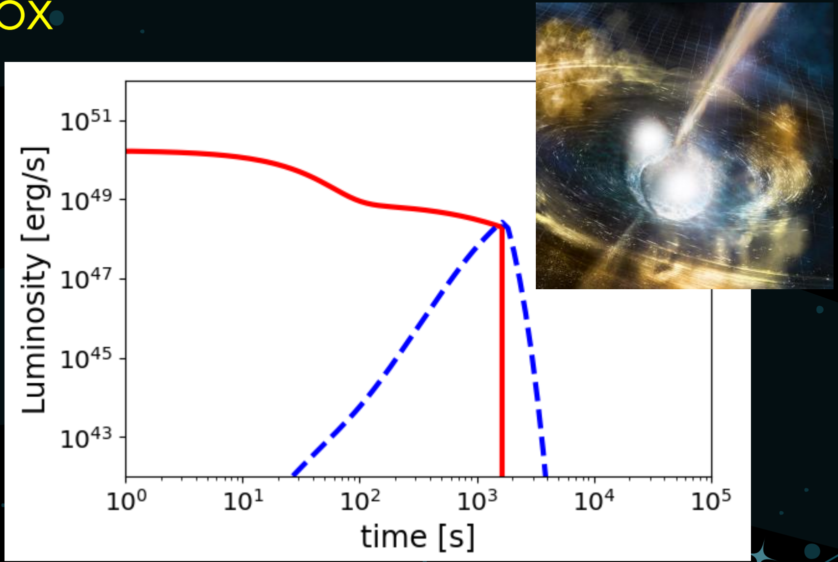
Space Variable Object Monitor (SVOM)

Successfully launched on 22nd June

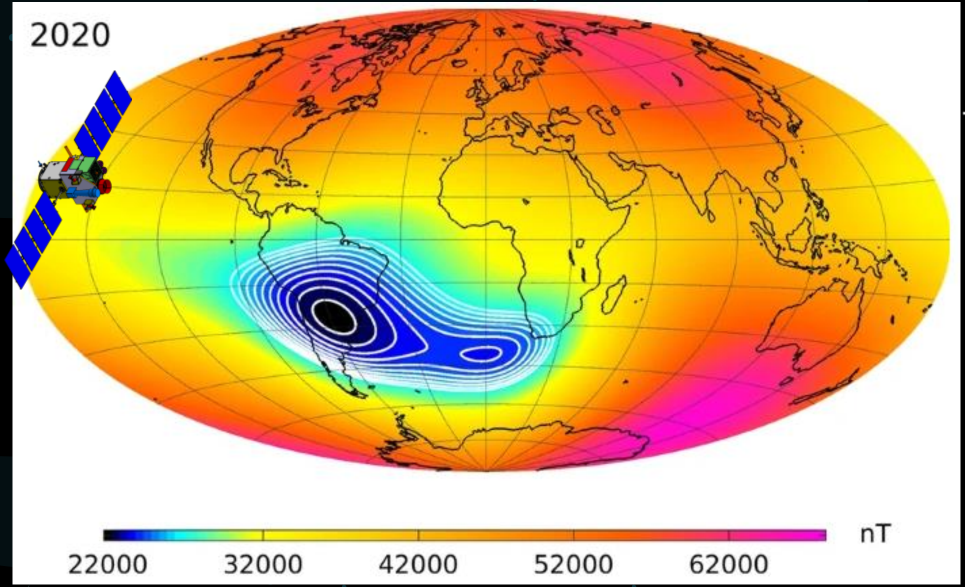
In case of a gravitational wave alert from a binary neutron stars merger:



MXT, with its relatively wide FoV (1°x1°), will pave the gravitational wave errobox



A 6 s observation with MXT



Conclusions

- The nature of GRBs central engine is still an open question: black hole or neutron star ?
- We simulate a magnetar central engine to predict their X-ray emission. Very rare event. But detection possible: organize follow ups now + later (O5 + ET)
- SVOM is designed to unveil the nature of GRBs central engines.
- A single detection would be an important step for GRB physics and merger physics