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Towards multi-messenger detections of core-collapse supernovae harbouring choked jets

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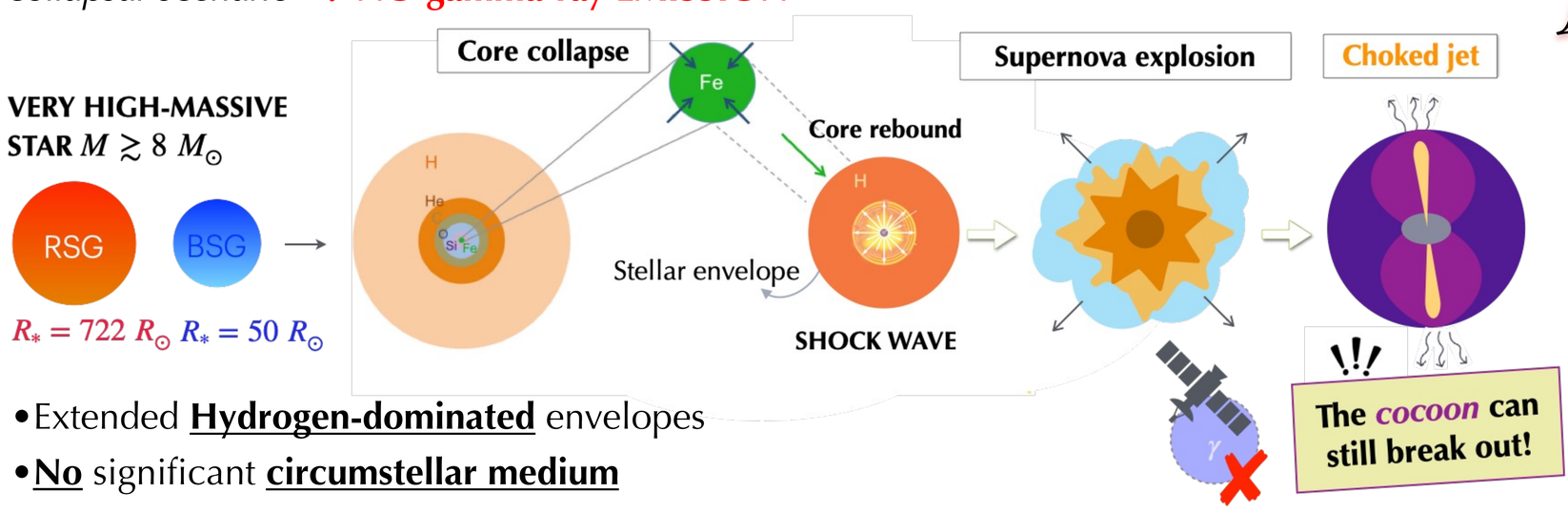
Choked jets in the multi-messenger field

Type II core-collapse supernovae (**CCSNe**) accompanied by a **Gamma-Ray Burst (GRB)-like outflow** that **do not manage to break out from the star** in the *collapsar scenario* → **NO gamma-ray EMISSION**

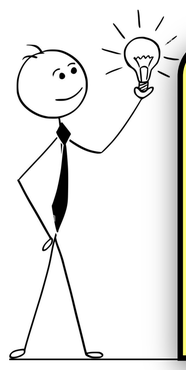


- Extended **Hydrogen-dominated** envelopes
- **No** significant **circumstellar medium**

Zegarelli A. *et al.*, A&A, 690, A187 (2024) A&A, 698, C1 (2025)

Look at our paper!

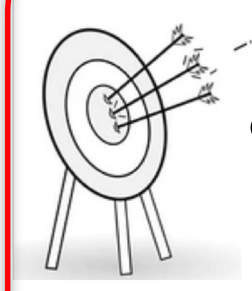
Theoretical challenge



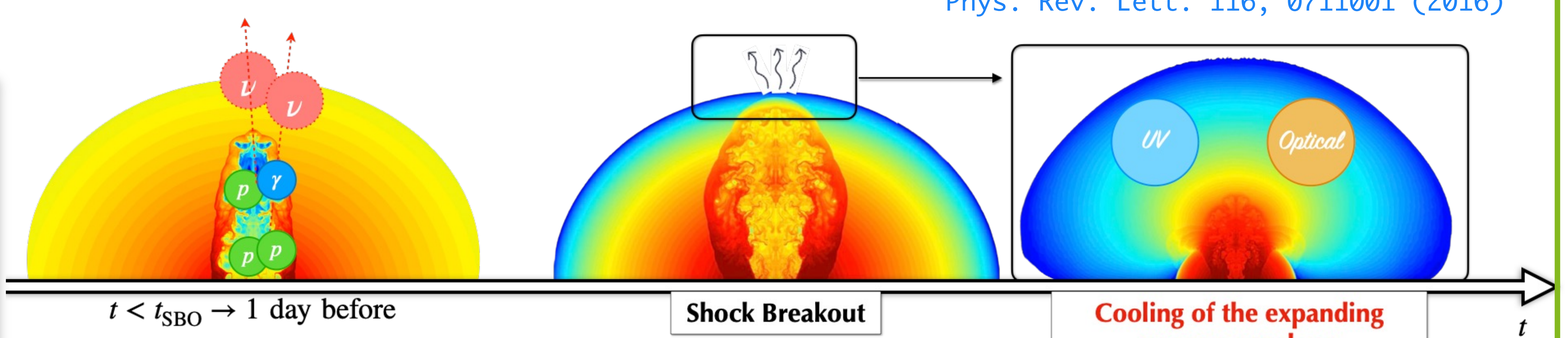
Gamma-ray hidden sources as **possible explanation for** the **tension between Fermi-LAT (gamma)** and **IceCube (neutrino)** data

e.g., Murase et al., Phys. Rev. Lett. 116, 0711001 (2016)

Aims of the work



- Quantify the possibility to **detect other electromagnetic (EM) signals**
- Define a **proper follow-up strategy** with current and future facilities



Neutrino producted during **the shock propagation inside the stellar envelope**

Kistler et al., ApJ 778, 81 (2013)

UV/optical emission depends on progenitor parameters (radius, ejecta density, released energy, ejected mass)

Waxman et al., ApJ 667, 351 (2007)

Future combined EM detections

Evolution of UV/optical emission for typical RSG and BSG progenitor parameters
+
Instrument capabilities

- **UV** with **ULTRASAT**
  Launch expected in 2028
  Unprecedented field of view (FoV)
- **Optical** with **ZTF**-like instruments

Rate of detectable events

$$\forall\ t \rightarrow \dot{N} = \int d\Omega \int_0^{z_{\rm lim}} \frac{dN(z)}{dz} dz =$$

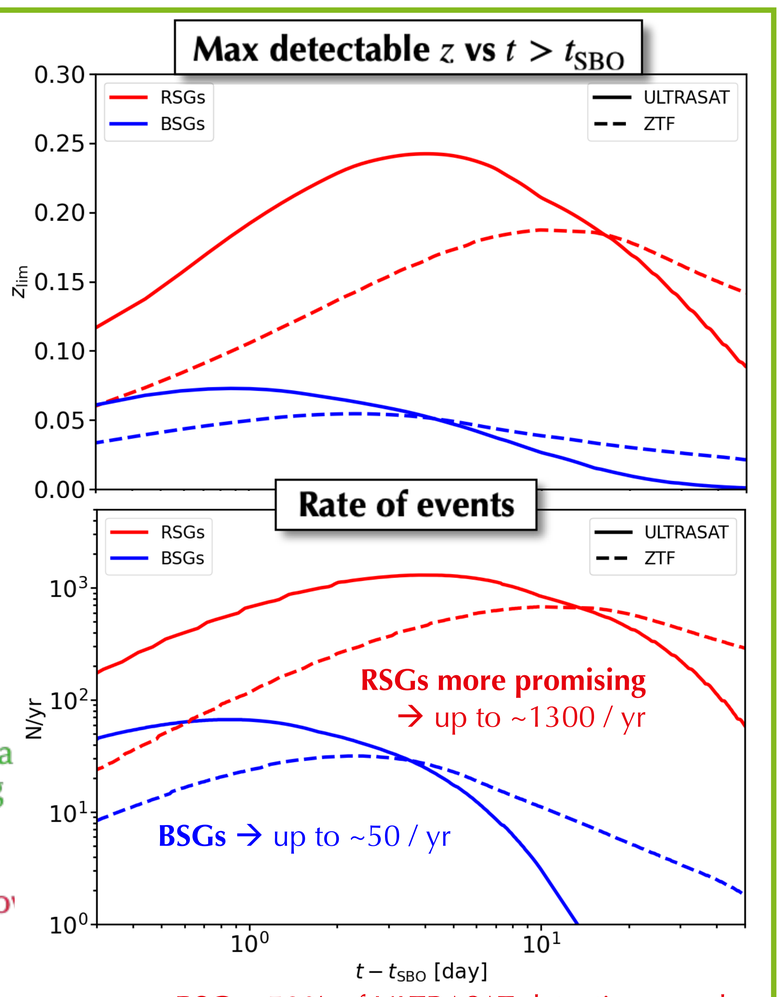
$$= \int d\Omega \int_0^{z_{\rm lim}} \frac{R(z)}{1+z} \frac{dV(z)}{dz} dz$$

Differential comoving volume

Telescope FoV

Comoving rate of sources follow the star formation rate trend

Cosmological time dilation of the observed rate



RSG: ~50% of ULTRASAT detections can be accompanied by an **optical** one **(1 week delay)**

Could choked jets explain the diffuse astrophysical neutrino flux?

- IceCube data for the astrophysical diffuse flux are reproduced for a **local rate of choked GRBs from RSG progenitors of ~80 $\rm Gpc^{-3}yr^{-1}$**

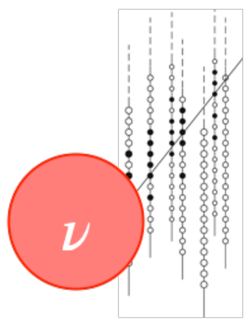
  Fasano et al., JCAP09, 044 (2021)
- Type IIP SNe (associated to RSGs) might contribute to the production of high-energy neutrinos for **~60% of astrophysical diffuse flux between 10^3 and 10^5 GeV**

  IceCube Collaboration, ApJL 949, L12 (2023)

!!!

Up to 20% of CCSNe from RSGs detectable in UV with ULTRASAT could host a choked jet and release TeV neutrinos

High-energy neutrino/UV/optical follow-ups



1. **Neutrino alert** from Cherenkov-based high-energy neutrino telescopes (e.g., IceCube, KM3NeT)

5 days

10 days

2. ULTRASAT(ZTF-like telescopes) could point at the suggested direction in the sky within **~5(10) days maximising the number of detectable sources**

Shock propagation inside the stellar envelope

t_{SBO}

t

Need to run these MM analyses for several years
+
additional **photometric and spectroscopic follow-ups** with compelling **evidence for a relativistic jet launched by the central engine**

Magnetohydrodinamical Relativistic Simulation of choked jets and predictions of related neutrino fluxes ongoing
See *Pais, Celli, Peretti and Zegarelli, PoS**ICRC2025**(2025)1138*

Stay tuned!