Gamma-rays from young SNRs in dense circumstellar environments

R. Brose[1,2], J. Mackey[1,3]

1 Dublin Institute for Advanced Studies, D02 XF86 Dublin, Ireland
2 University of Potsdam, 14476 Potsdam, Germany
3 DIAS Dunsink Observatory, D15 XR2R Dublin, Ireland

Introduction

Supernova remnants are considered as possible sources of the Galactic cosmic-rays (CRs). So far, no indications of PeV-particles – the highest energetic particles observed in Galactic CR-spectrum - from SNRs have been found. A proposed explanation is the acceleration of CRs to PeV-energies only during the initial decades of the SNRs life. The lack of firmly detected gamma-rays from very young SNRs makes it yet impossible to test this hypothesis.

Supernova explosions of massive stars in dense circumstellar medium – Type-IIP and Type-IIn explosions - have the best chances of being detected by current-generation instruments. Here, we theoretically examine the detection prospects of these events.

Model

Radiation **A**cceleration **T**ransport **Pa**rallel **C**ode (RATPaC) – a numerical toolset to study particle acceleration in SNRs [1]

Hydrodynamics:

- Gasdynamical equations solved in 1D for core-collapse SNRs in a free-expanding wind
- Luminous blue variable (LBV) and Red Supergiant (RSG) progenitors

$\dot{M}_{LBV} = 10^{-2} M_{Sol}/\mathrm{yr}$ $\quad$ $\dot{M}_{RSG} = 8 \cdot 10^{-5} M_{Sol}/yr$
$v_{LBV} = 100 km/s$ $\quad$ $v_{RSG} = 15 km/s$

Cosmic rays:

- Kinetic test-particle approach, solved in 1D spherical symmetry
- Synchrotron and IC-cooling for electrons

Magnetic turbulence:

- Passively transported large-scale field
- Large-scale ambient field constant or $B(r) \propto 1/r$
- Self-consistent amplification of Alfvenic turbulence

Gamma-ray emission

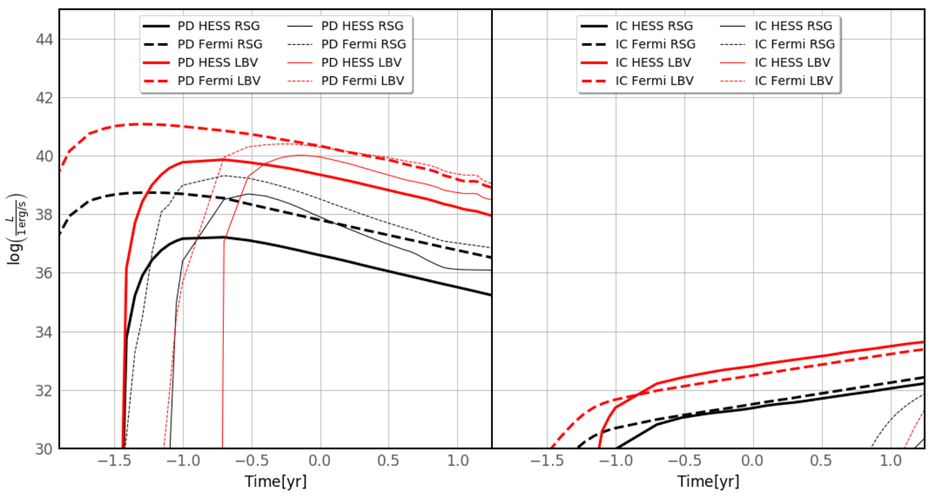

Figure 2: The PD-luminosities are shown on the left-hand side, the IC-luminosities on the right. Thick lines correspond to a constant ambient field, thin lines to stronger, radially dependent fields. RSG-models in black, LBV-models in red.

- Inverse-Compton (IC) emission is strongly suppressed compared to Pion-decay (PD) emission due to the lack of target photons

- Peak-luminosities for H.E.S.S. might not be reached before one month (constant field) seven months (strong field) after explosion
- **Reason:** overall enhanced damping in strong fields
  - Both, turbulent growth- and damping rate scale with the Alfven velocity → the effect of the high field cancels
  - High field shifts resonance to small-scales → scale-dependent damping (Kolmogorov-cascade) stronger at small scales

- SNe from LBVs reach generally higher luminosities in both energy-bands → higher ambient density
- Opposite effect of strong field:
  SN luminosity for LBV-progenitors reduced ←→ SN luminosity from RSG-progenitors enhanced

- Only few observed, close-by SNRs → No detection expected yet

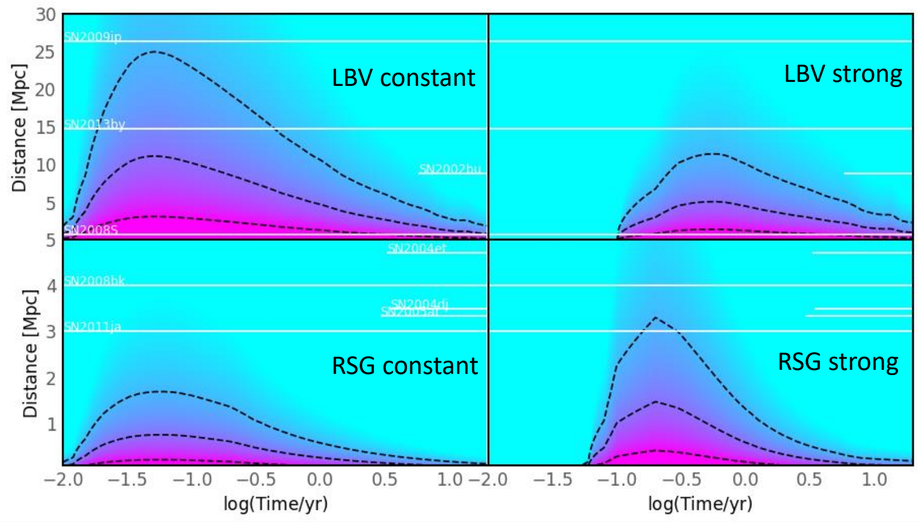

Figure 3: Flux from SNRs over time in the Fermi-LAT energy-band. The black lines correspond to fluxes detectable within a day, a month and a year respectively. Known, close-by SNRs are marked in white. The bars indicate their coverage by Fermi-LAT.

Thermal X-ray emission

- Predicted X-ray luminosities match reasonably well the experimental data
- Absorption in and close to the SNR significantly reduces the observed X-ray luminosities
- Crucial ambient structure:
  - signs of X-ray rebrightening in various observed objects
  - potential additional absorption due to yet unshocked dense material

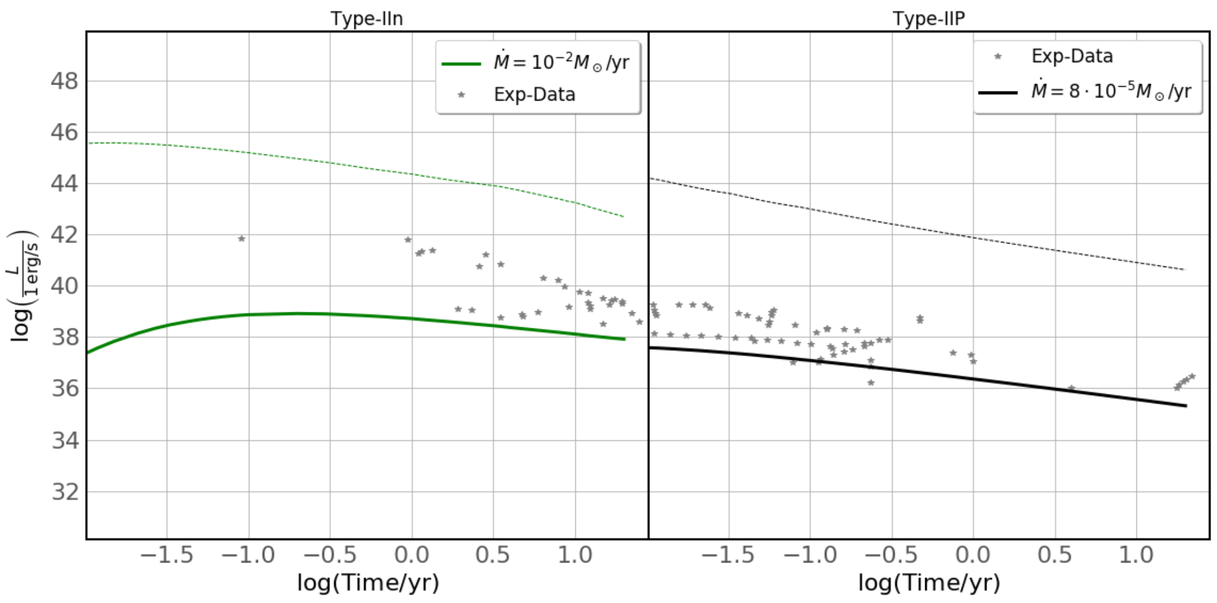

Figure 1: Thermal X-rays from two very young SNRs. The thick lines represent the predicted thermal X-ray continuum luminosity including local absorption while the thin lines represent the intrinsic/unabsorbed X-ray luminosity. The experimental data is taken from [2].

Conclusions and Outlook

- Peak gamma-ray luminosity might be reached only months after the explosion
- Strong ambient magnetic fields do not necessarily guaranty acceleration to higher energies
- Future: Account for the structure around RSGs and LBVs → dense photoionization shells and shells from previous high mass-loss can enhance the luminosities years after the explosions

Selected Publications

1. Brose, R., Telezhinsky, I., & Pohl, M. 2016, A&A, 593, A20
2. Dwarkadas, V. V. 2014, MNRAS, 440, 1917

Learn more about me at:

https://homepages.dias.ie/broserob
broserob@cp.dias.ie

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn
Powered by RATPAC