Limits on a compact object in Supernova 1987A

Dennis Alp[★,1], Josefin Larsson[1], Claes Fransson[2]

Introduction

• Supernova (SN) 1987A, shown in Fig. 1, was the brightest and nearest SN for more than three centuries.
• A compact object is expected to reside in the SN remnant but has not been detected despite more than 30 years of searches spanning the entire electromagnetic spectrum. The initial neutrino burst remains the only evidence of its existence.
• If a neutron star is detected, it would allow for study of the early evolution of neutron stars and provide insight into the connection between the progenitors, SN explosions, and their compact remnants.

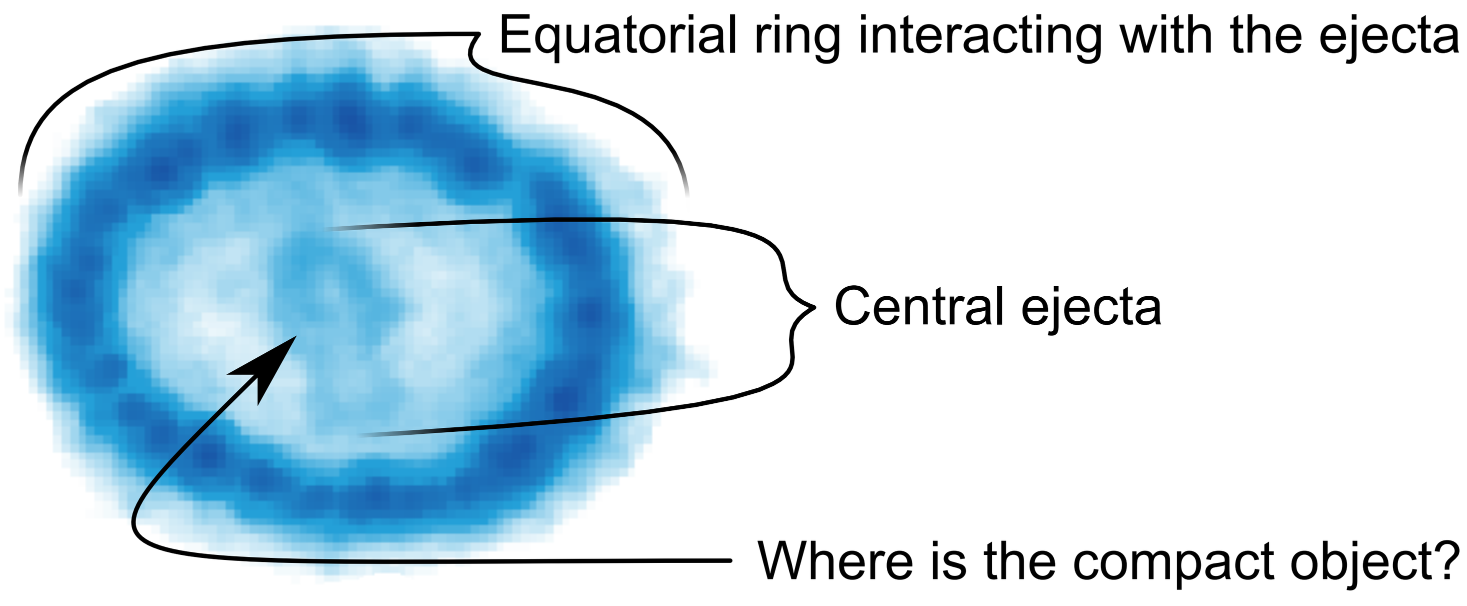


Fig. 1 *Hubble* image of SN 1987A

Methods

Spatial information is used to limit the contribution from a point source and spectra are used to constrain any continuum component. These limits can then be compared to the spectra of known compact remnants. The Crab Nebula and the central compact object in Cas A are chosen as illustrative extreme cases. The limits have been corrected for interstellar reddening but ignores any absorption by the SN ejecta.

Limits

The limits, shown in Fig. 2, clearly exclude a pulsar wind nebula similar to the Crab in the remnants of SN 1987A but an analogue of the central compact object in Cas A is currently undetectable. However, a much younger neutron star created by SN 1987A is expected to have a significantly higher temperature. The thermal emission peaks at soft X-ray energies for temperatures in the range ~2-4 MK and is therefore significantly absorbed by the expanding SN ejecta.

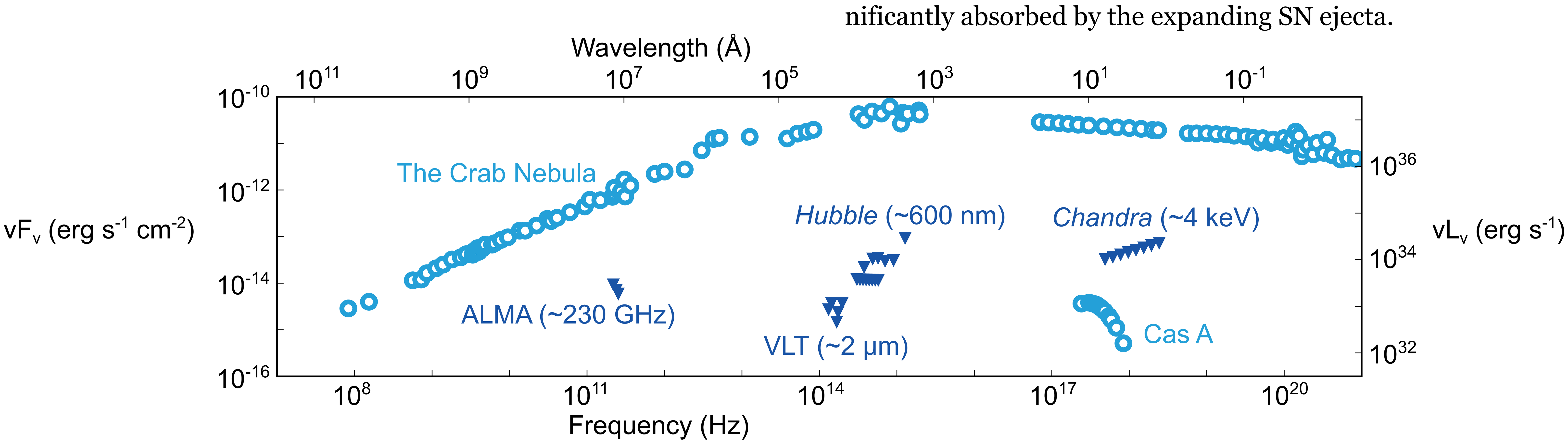


Fig. 2 Limits on a compact object (dark triangles ▾), the observed spectra (light circles ○) of the Crab Nebula (Bühler & Blandford 2014, and references therein), and the central compact object in Cas A (Posselt et al. 2013).

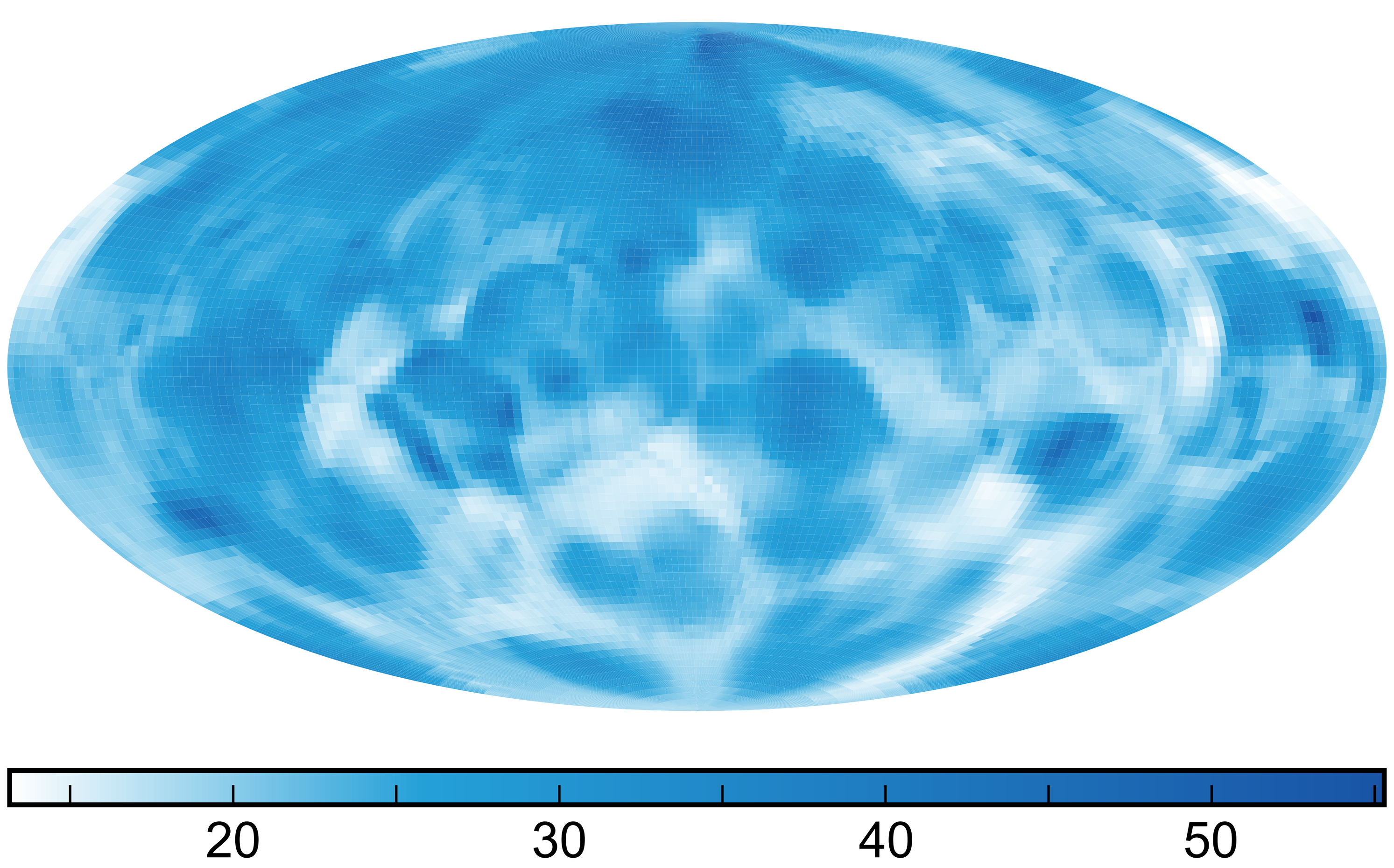


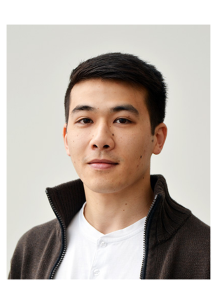
Fig. 3 Distribution of the optical depth at 2 keV 10 000 days (~27 years) after explosion.

Absorption

The amount of absorption in X-ray by the SN ejecta is estimated using 3D SN explosion models (Wongwathanarat et al. 2015). Absorption of soft X-ray emission is very high during early times, which can be seen in Fig. 3. This is because of the relatively high densities of the expanding ejecta and, importantly, the significantly higher metallicity of SN ejecta compared to more typical ISM abundances. The opacity at 10 000 days corresponds to an ISM hydrogen column number density of ~6×10^{23} cm^{-2}.

Conclusions

• Extreme cases, such as the Crab Nebula, are excluded. However, fainter objects, such as the Cas A neutron star, are currently undetectable.
• Soft X-ray absorption by the SN ejecta is high at 10 000 days (~27 years) after explosion.
• A neutron star created by SN 1987A could remain undetected for a long time if the only emission is thermal.



★dalp@kth.se
https://www.kth.se/profile/dalp?l=en

[1]Department of Physics, KTH Royal Institute of Technology
[2]Department of Astronomy, Stockholm University
[1,2]The Oskar Klein Centre, AlbaNova, SE-106 91 Stockholm, Sweden

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