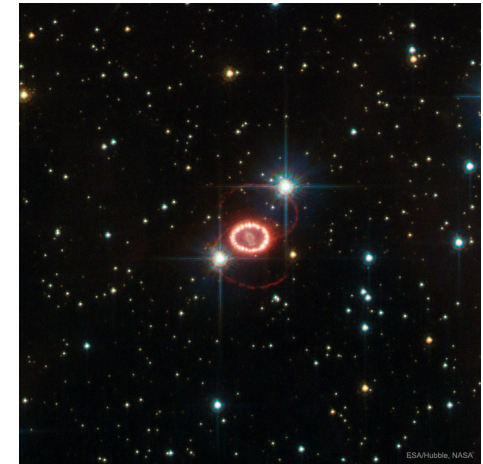


Evidence for recent GeV brightening of the SN 1987A region



Introduction

- Type II SN occurred 23rd Feb. 1987 in LMC (~ 50 kpc)
- peak optical magnitude ~ 3
- progenitor – a blue supergiant Sanduleak -69 202

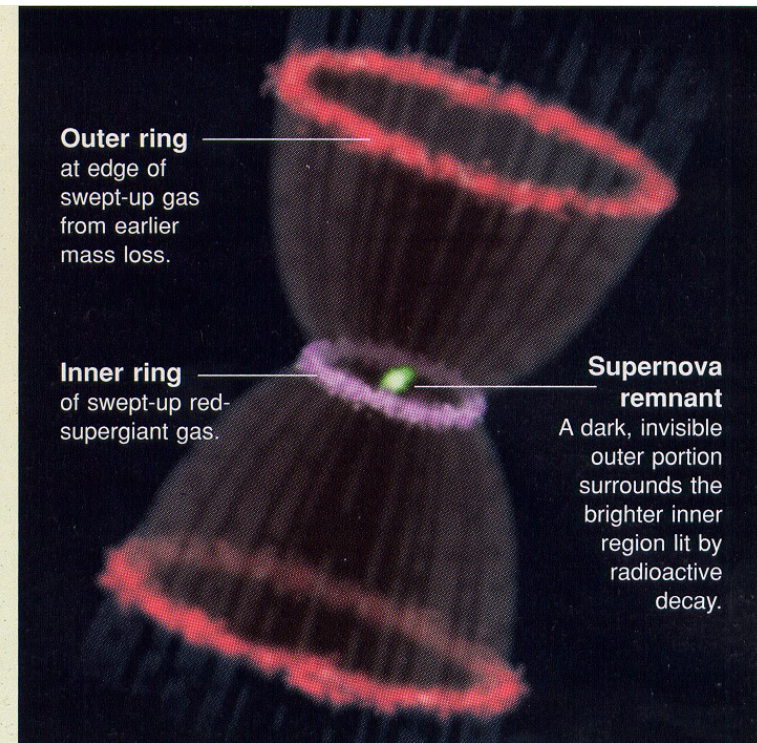
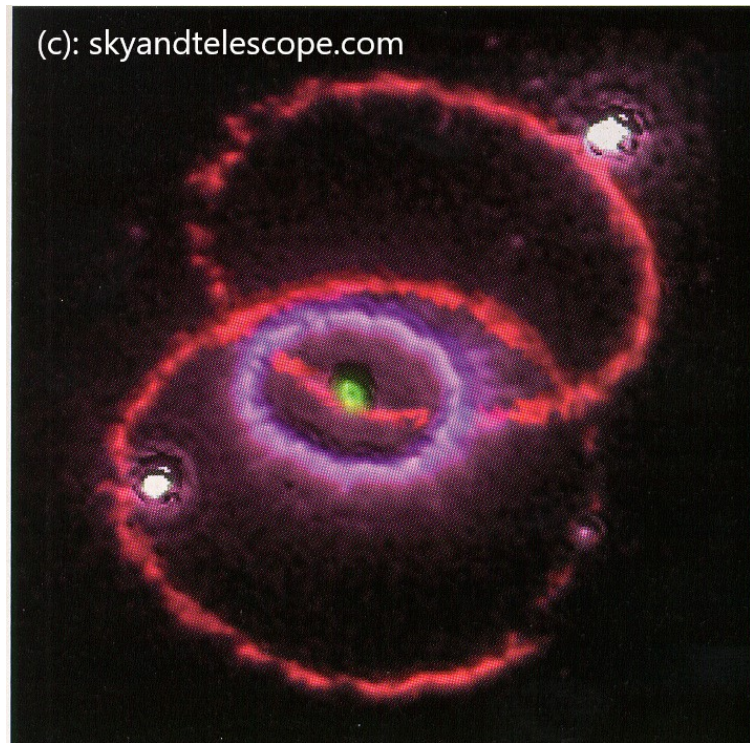


Explosion detected in

- Neutrinos (Kamiokande II: 12 antineutrinos; IMB: 8; Baksan: 5) in ~ 10 s burst (core collapse)
- 2–3 h later in optics (blast wave reached the surface)
- *NO* detection in hard X-rays (0.3–9 MeV, SMM/GRS, effective area ~ 100 cm²)



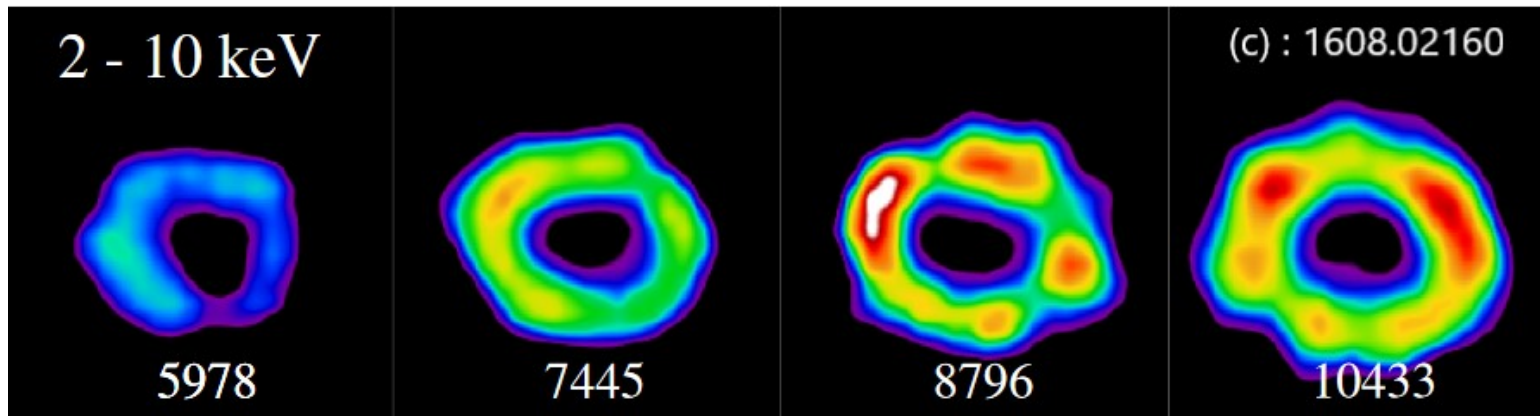
Introduction



Now the remnant develops in a complex hour-glass shape cavity bounded by a dense ring in equatorial plane. The evolution of the central ring is clearly traced in optics(HST) and X-rays(Chandra)



Introduction

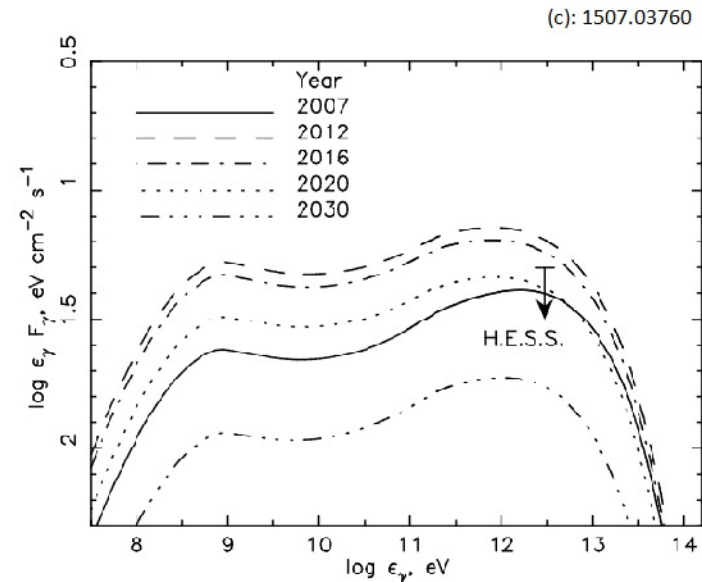
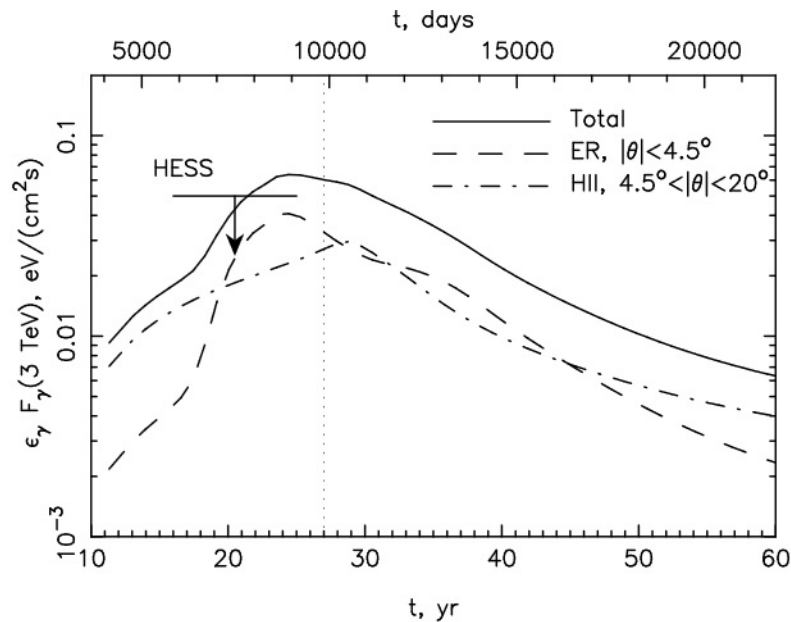


Recent (2016) hints that the blast wave is leaving the dense equatorial ring.

SN explosion event and SNR evolution become a laboratory for

- SN explosion modelling
- SNR expansion modelling
- particle acceleration on the shock (DSA) modelling
- Axion and sterile neutrino studies

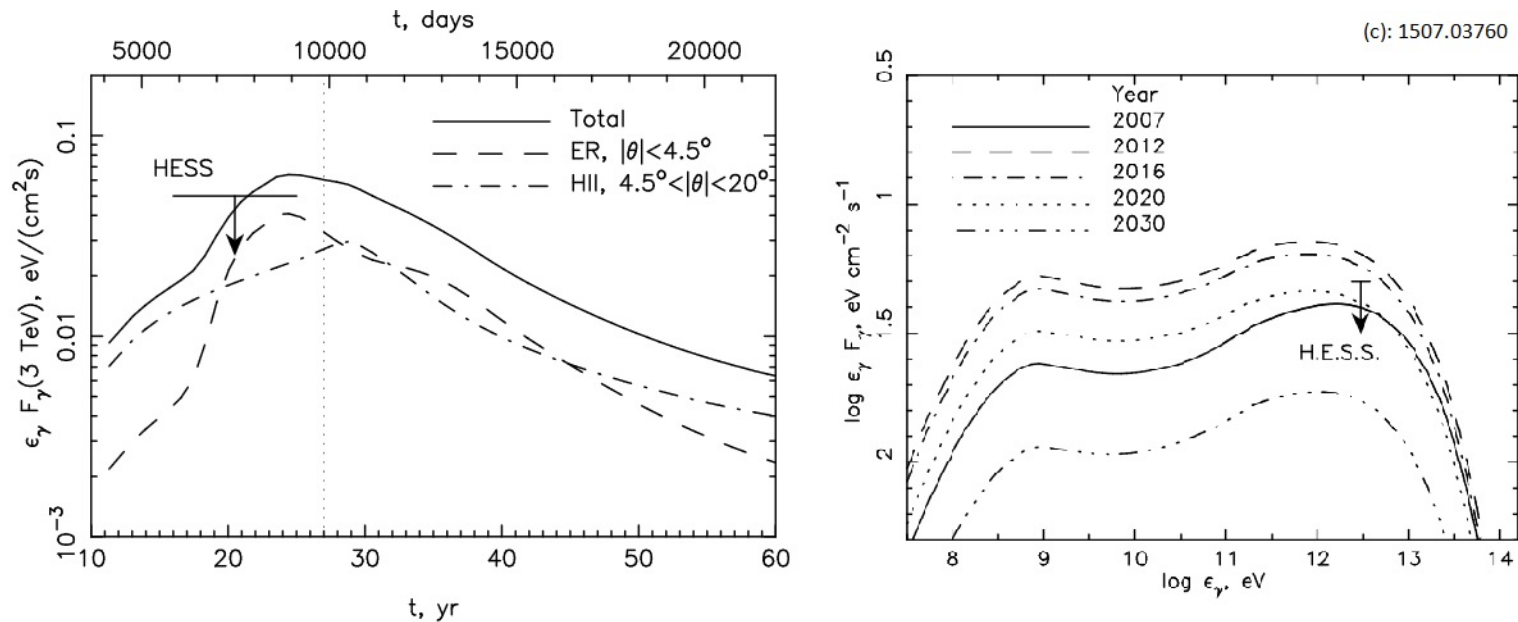
Predictions from DSA models



Within DSA models GeV-TeV emission from SNR 1987A is expected:

- The emission is hadronic (cosmic ray protons are accelerated on the shock)
- Emission is variable (variable density of the medium + acceleration timescale)

Predictions from DSA models

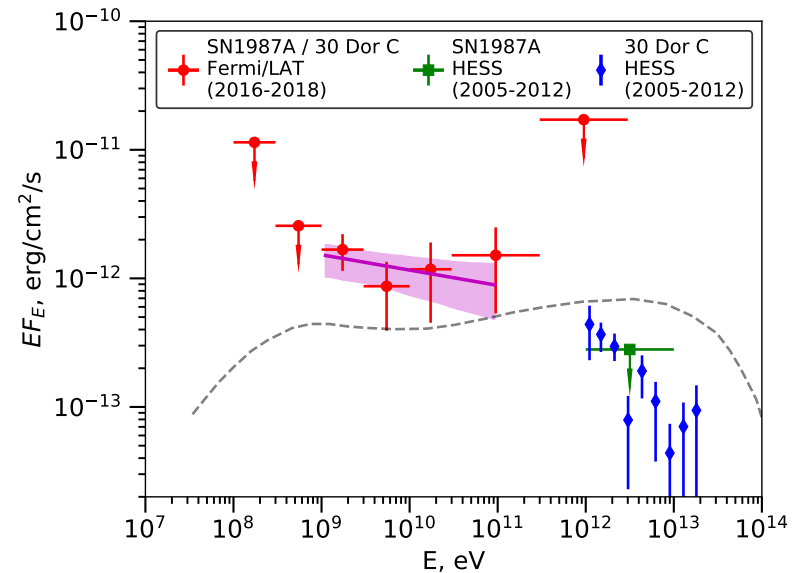
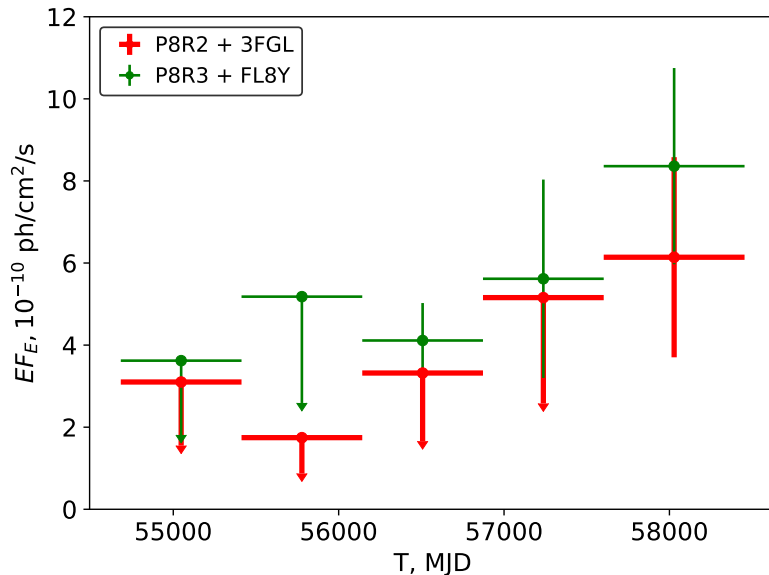


Within DSA models GeV-TeV emission from SNR 1987A is expected:

- Maximum of the emission expected 2007 – 2017

NO GeV-TeV emission detected in GeV (1509.06903) and TeV (1501.06578) till ~ 2015 ...

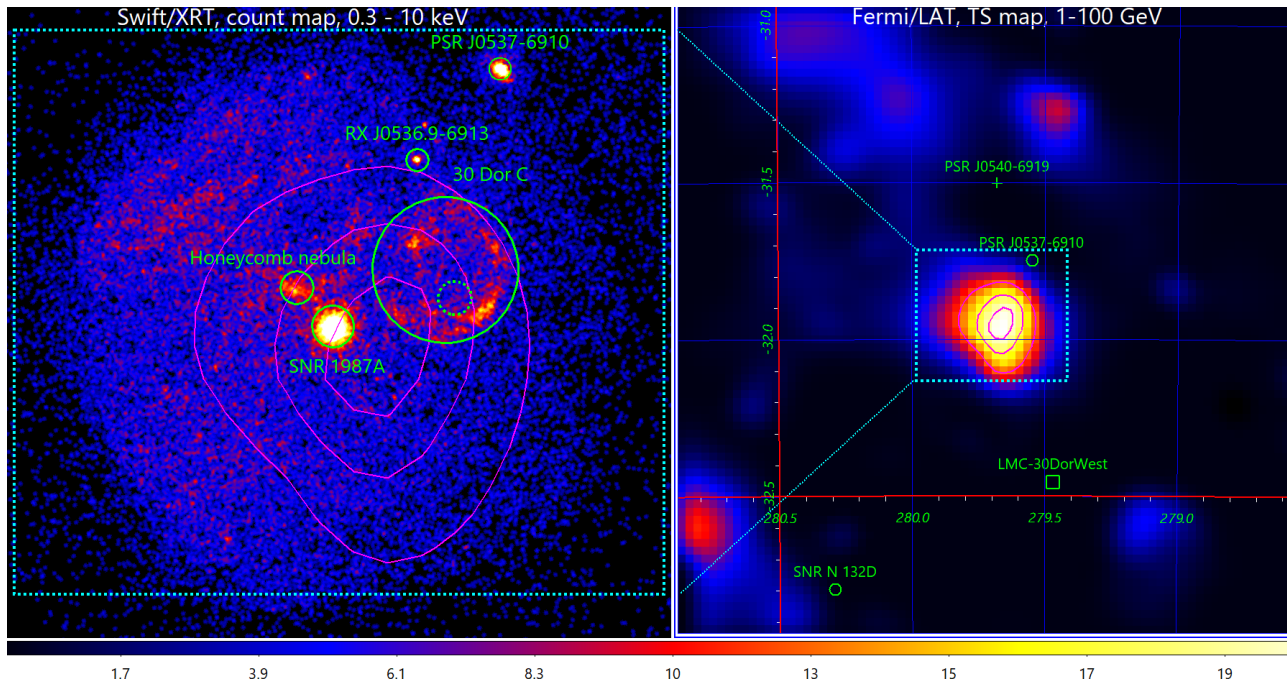
Fermi/LAT observations



- During last 2–4 years Fermi/LAT data indicate gradual brightening of SN 1987A region
- Brightening is more significant if analysis is performed with P8R3 data calibration released few months ago
- The signal is seen only at $\gtrsim 1$ GeV energies and is comparable to predicted by DSA models



Possible counterparts

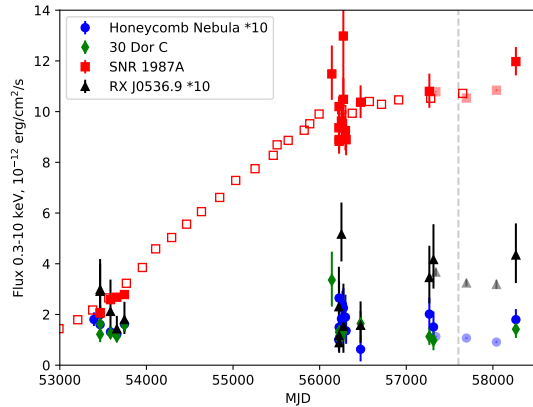


The region is crowded and includes several potential counterparts:

- SN 1987 A
- 30 Dor C
- Honeycomb nebula
- RX J0536.9-6913/Transient



Possible counterparts

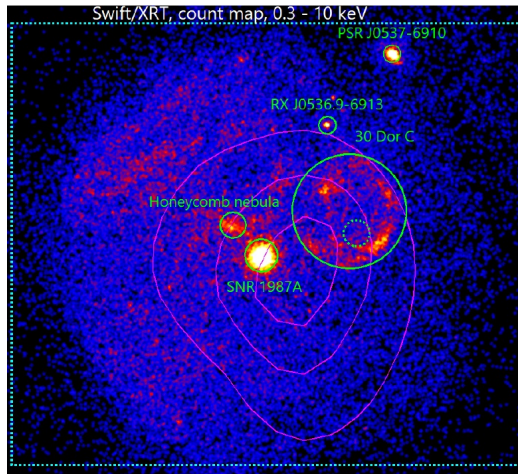


None of these sources demonstrate a clear increase of X-ray flux.

Potential origin of GeV emission:



Possible counterparts



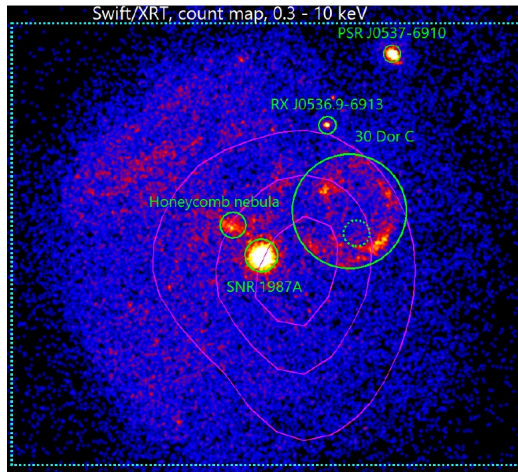
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Potential origin of GeV emission:

- **SN 1987A:** GeV-TeV brightening is expected; hints of X-ray flux increase



Possible counterparts



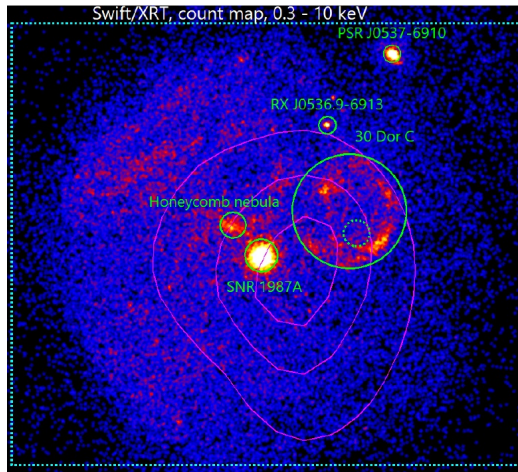
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- **30 Dor C**: superbubble; GeVs from individual SNR? Filament detected by HESS in TeVs (1501.06578)?



Possible counterparts



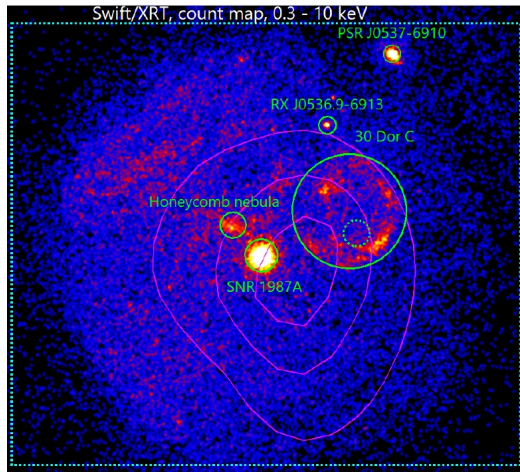
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Potential origin of GeV emission:

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- **30 Dor C**: superbubble; GeVs from individual SNR? Filament detected by HESS in TeVs (1501.06578)?
- **Honeycomb nebula**: origin not clear; SNR developing in a shell of material of an older explosion? Microquasar?



Possible counterparts



None of these sources demonstrate a clear increase of X-ray flux.

Potential origin of GeV emission:

- **SN 1987A**: GeV-TeV brightening is expected; hints of X-ray flux increase
- **30 Dor C**: superbubble; GeVs from individual SNR? Filament detected by HESS in TeVs (1501.06578)?
- **Honeycomb nebula**: origin not clear; SNR developing in a shell of material of an older explosion? Microquasar?
- *RX J0536.9-6913/Extragalactic transient...*



Conclusions

- $\sim 4\sigma$ excess seen by Fermi/LAT from SN 1987A position during last 2–4 years
- flux increase is long-expected by DSA models but not seen previously in GeV/TeV
- Poor localization allows several other counterparts (30 Dor C; Honeycomb nebula; transient)
- No clear variability in X-rays – a hint for hadronic emission from SN 1987A?
- Joint HESS/XMM proposal accepted. More results by the end of 2019.
- MeerKAT (radio) observations may take place (under discussion)

- Stay tuned!



Danke.

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