COSMIC RAYS ACCELERATION IN SN 1006

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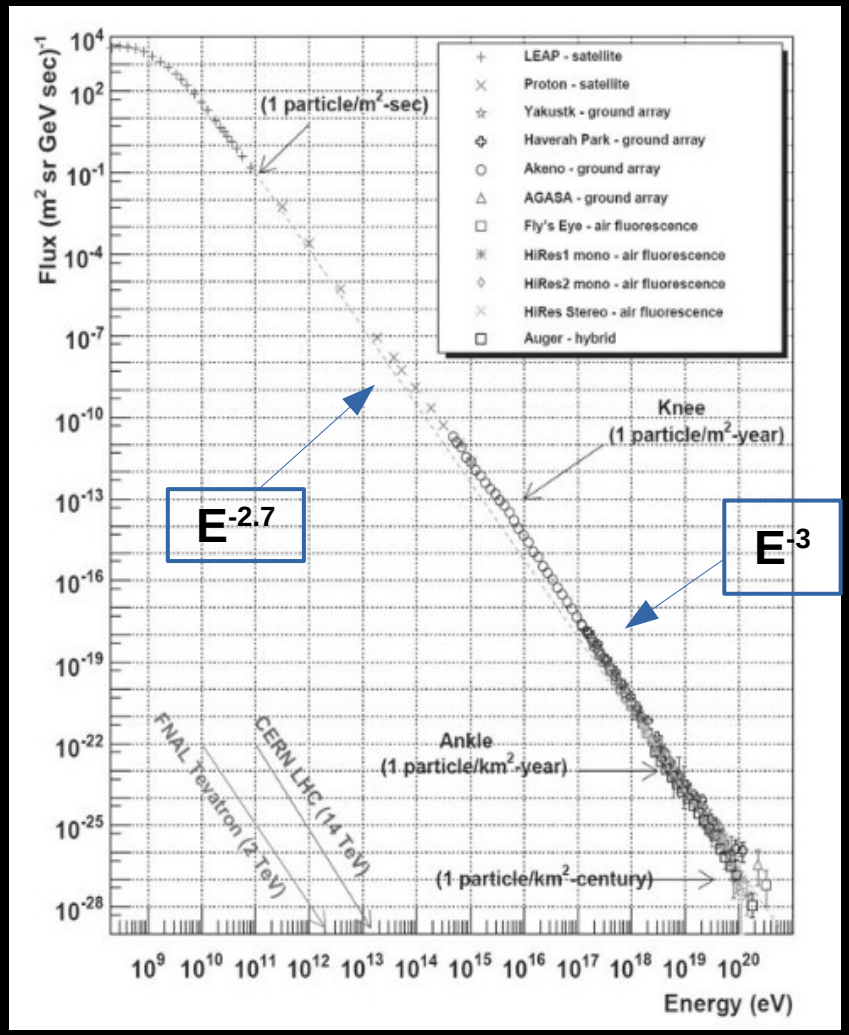
INTRODUCTION

Cosmic rays



$$I_N(E) \approx 1.8 \times 10^4 E^{-2.7}$$

- Low energy ⇒ Solar origin
- High energy (PeV) ⇒ origin from SNR ?
- Very high energy ⇒ Extragalactic origin

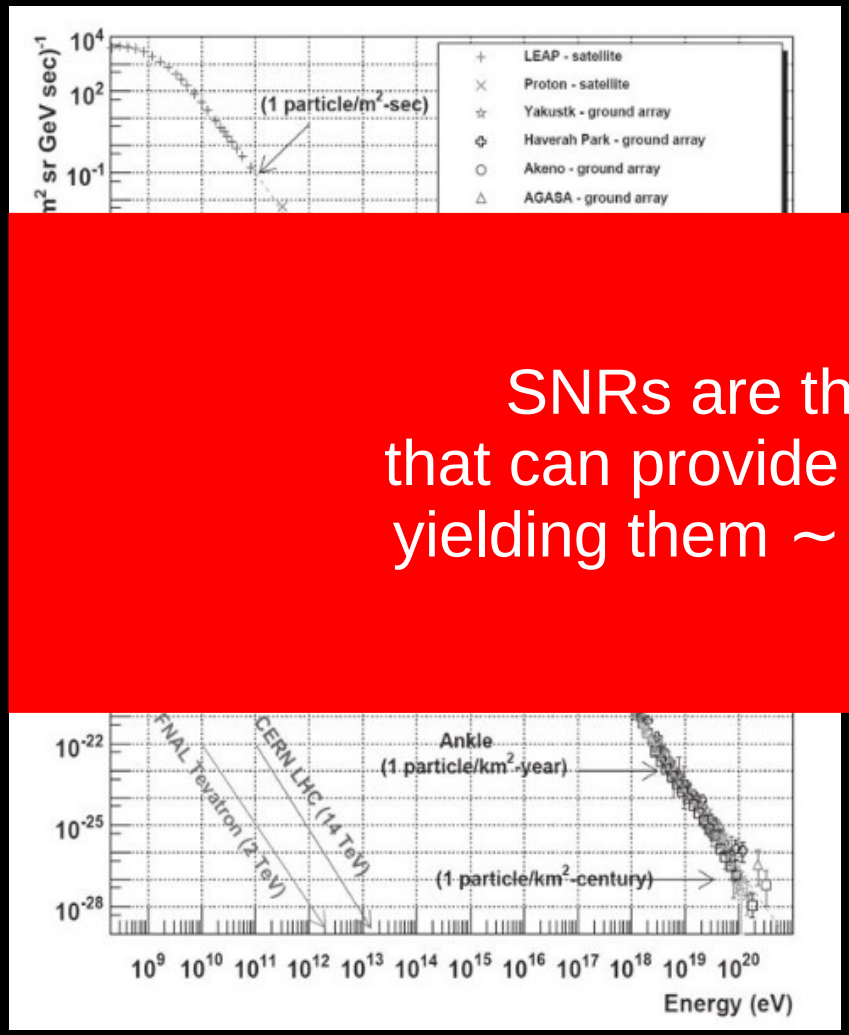
Rate of SNe in the Milky Way ~ 2.5/century

$E_{explosion} = 10^{51}$ erg

Required power to accelerate cosmic-rays = 2×10^{50} erg/century

INTRODUCTION

Cosmic rays



$$I_N(E) \approx 1.8 \times 10^4 E^{-2.7}$$

SNRs are the only galactic sources
that can provide the required power to CRs,
yielding them ~ 10% of their kinetic energy

Rate of SNe in the Milky Way ~ 2.5/century

$E_{explosion} = 10^{51}$ erg

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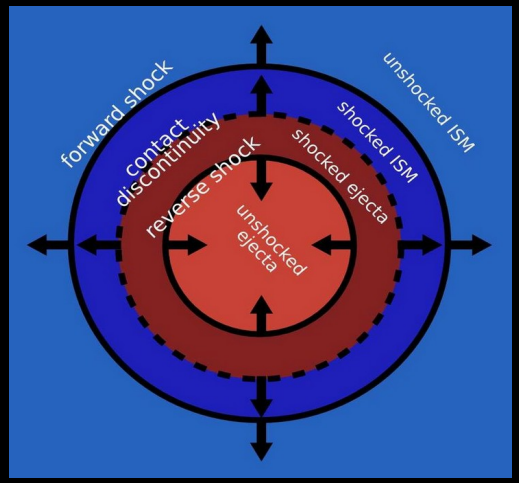
INTRODUCTION

Shock modification



Rankine – Hugoniot equation for adiabatic shock

$$\rho_2 / \rho_1 = 4$$

Drury et al. 1983, Decourchelle et al. 2000, Blasi et al. 2002, Vink et al. 2010

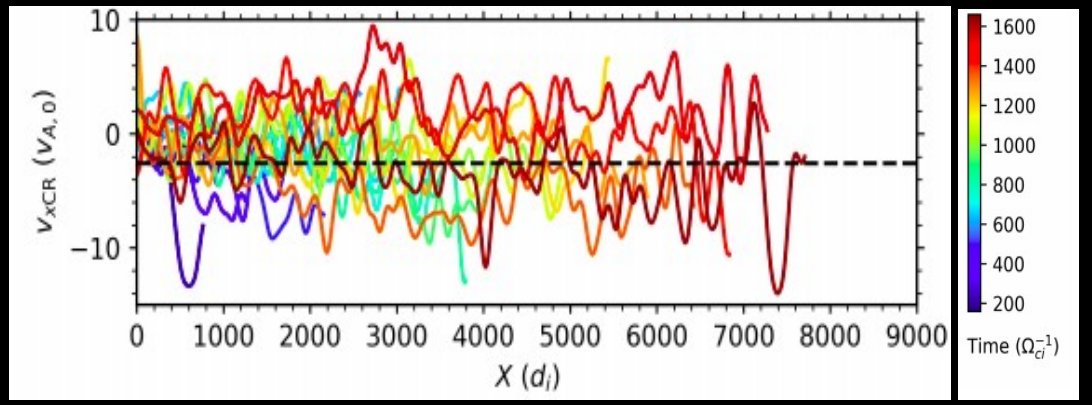
Shocks of SNRs give part of their kinetic energy to accelerate CRs → NON adiabatic shock

$$\rho_2 / \rho_1 > 4$$

→ **Shock modification**

- Upstream CR precursor
- overshoot at the shock
- rise in the downstream

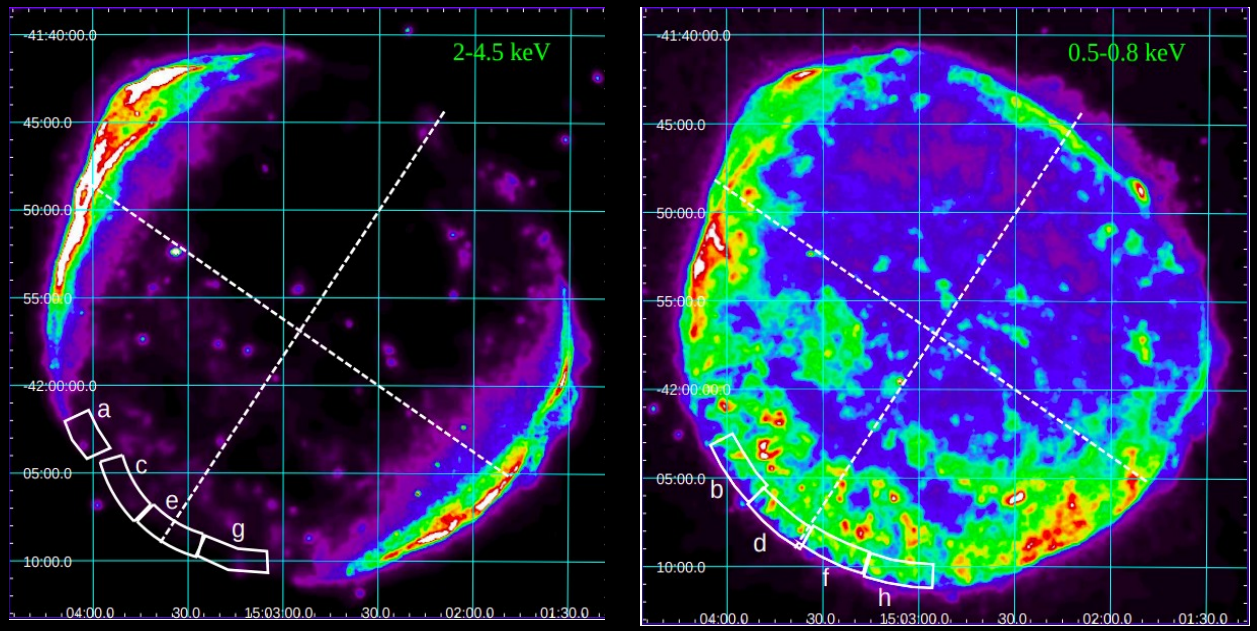
Haggerty et al. 2020, Caprioli et al. 2020



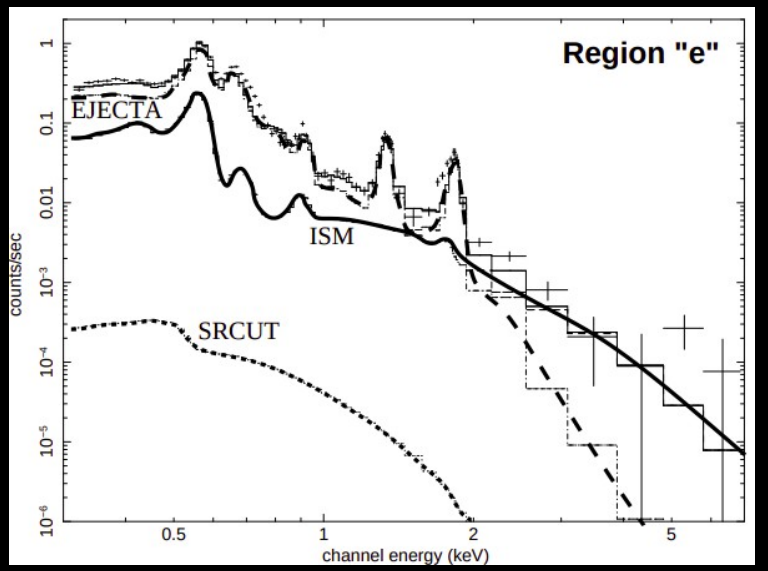
PARTICLE ACCELERATION IN SN 1006

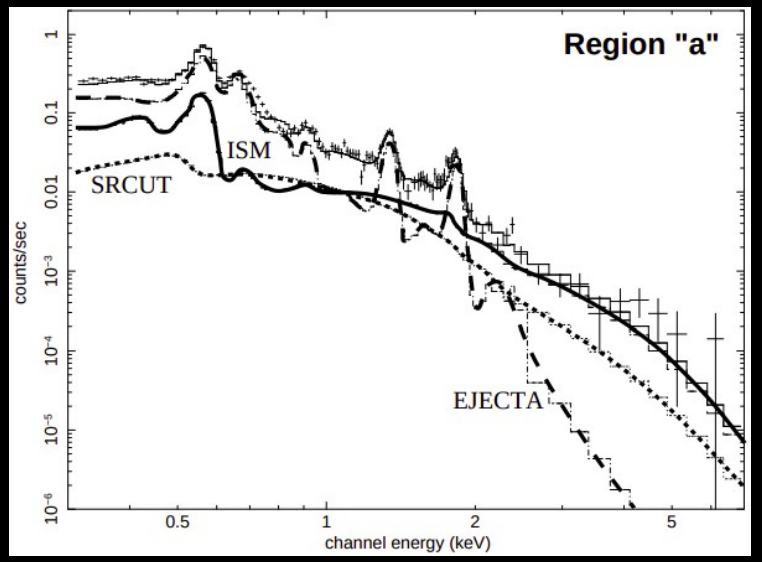
XMM-Newton analysis

Miceli et al. 2012



Rothenflug et al. 2004, Reynoso et al. 2013, Bocchino et al. 2011





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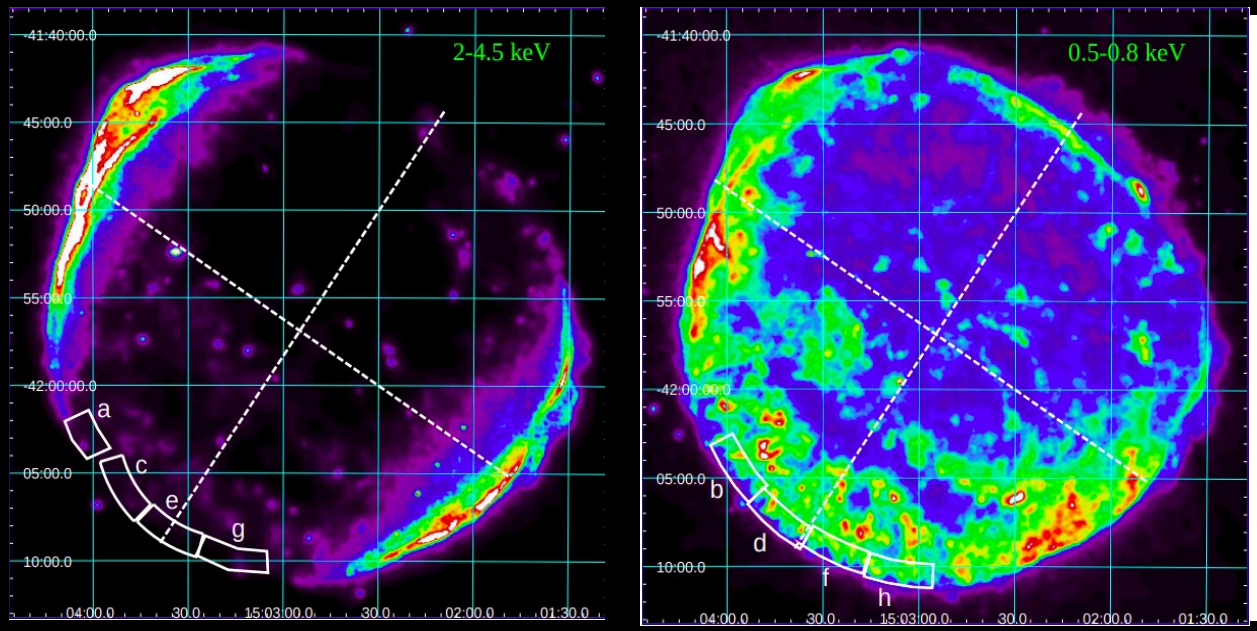

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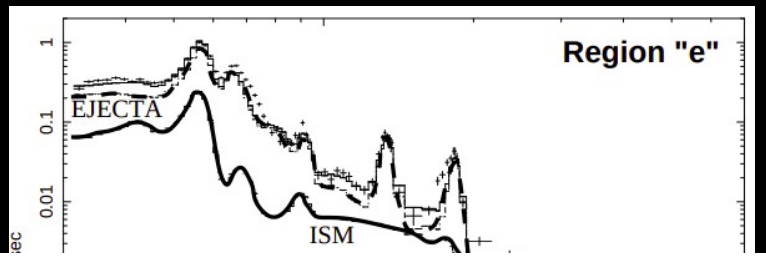

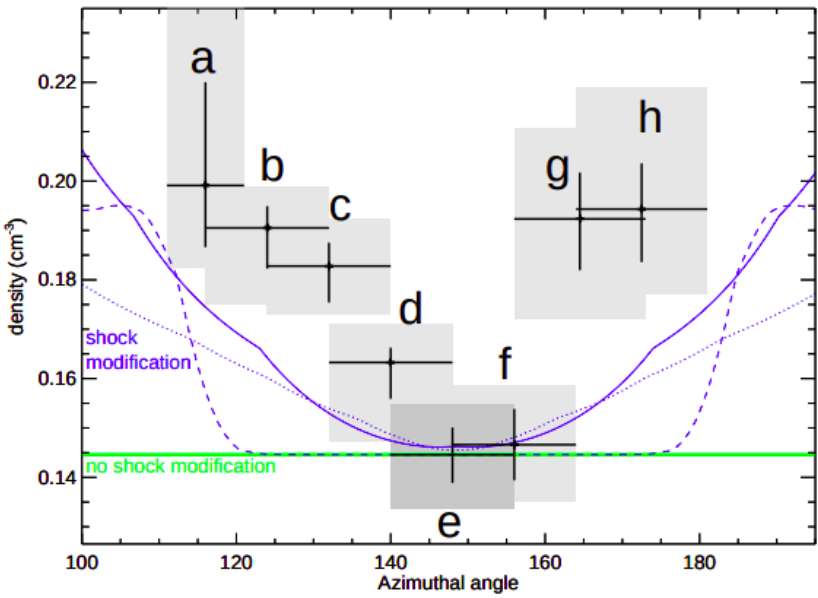

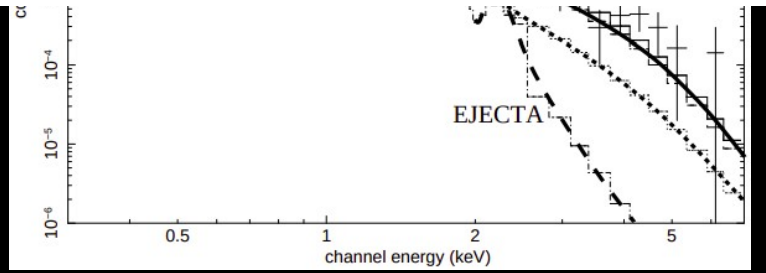

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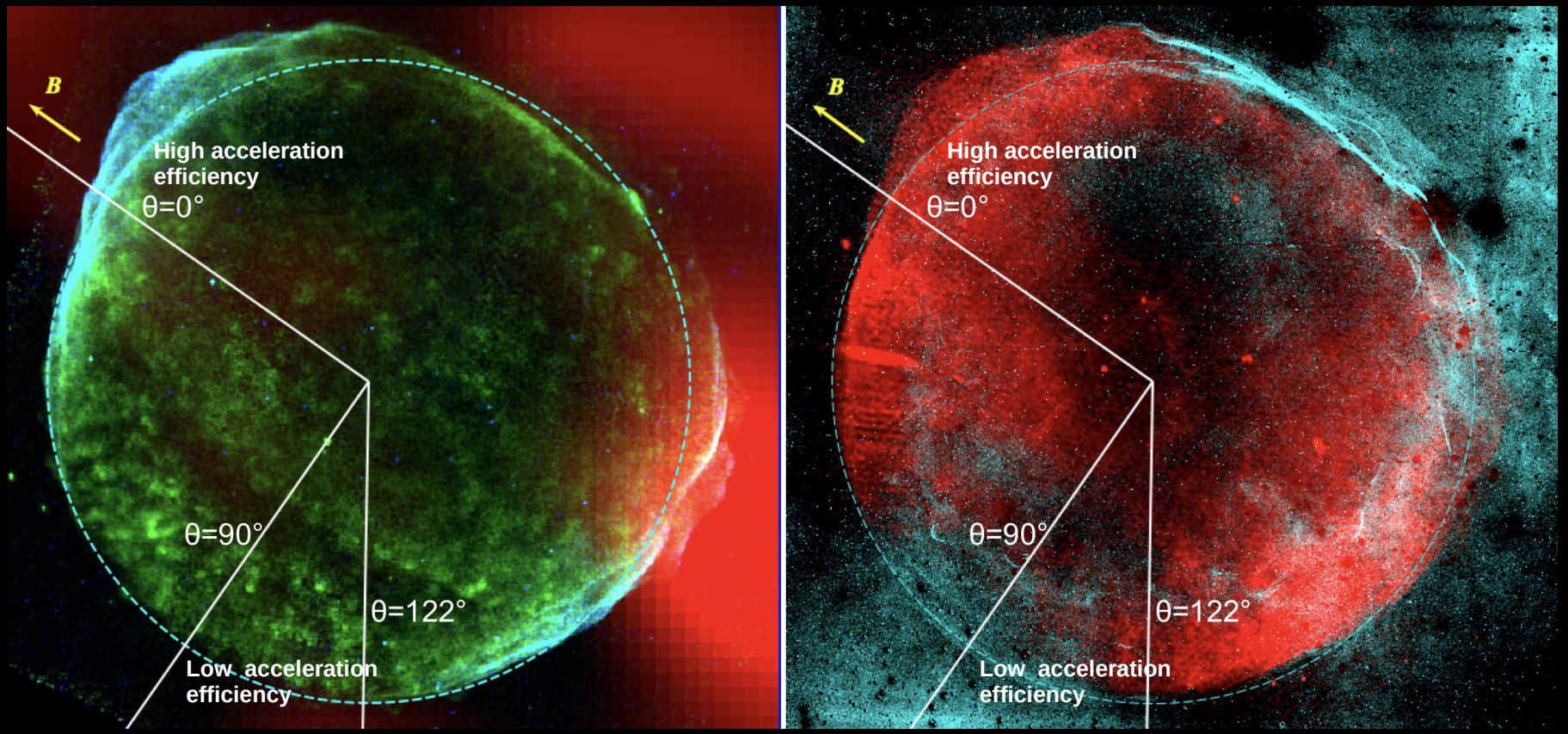
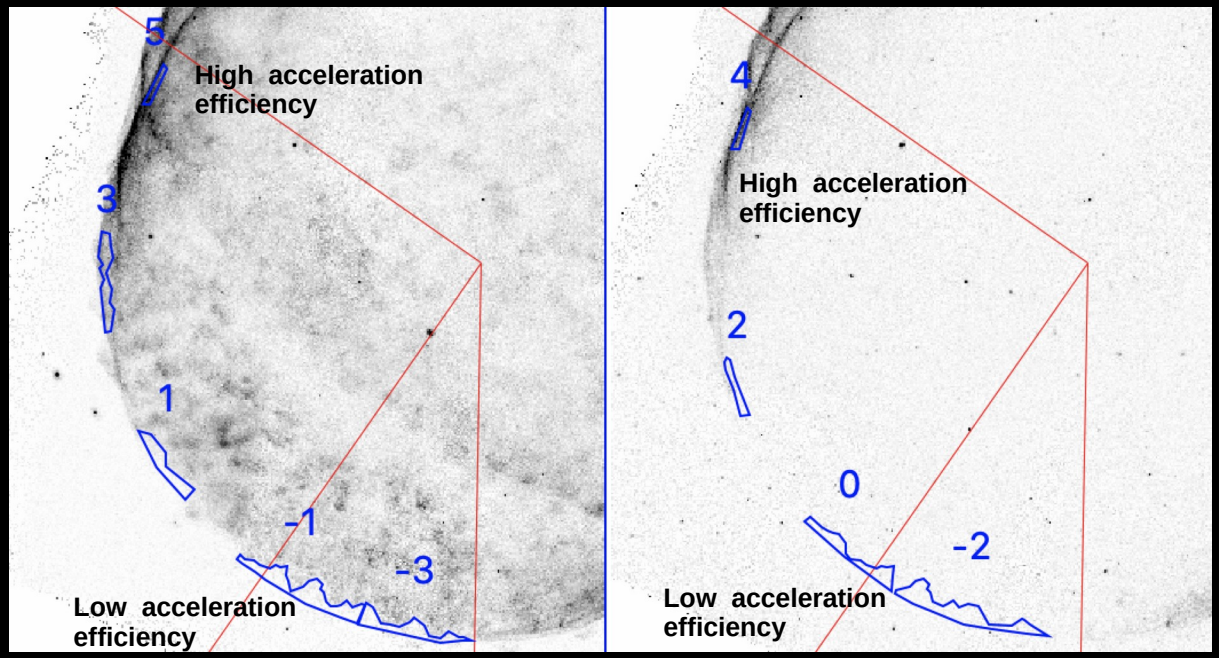


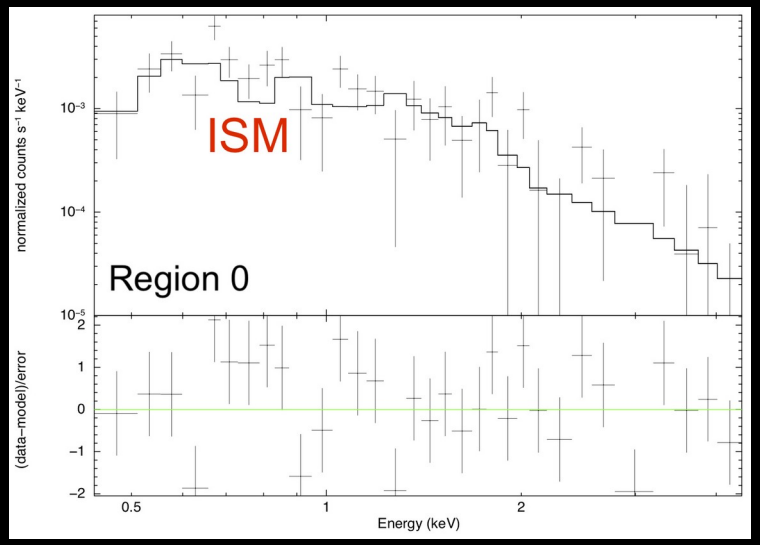
Giuffrida et al. under review

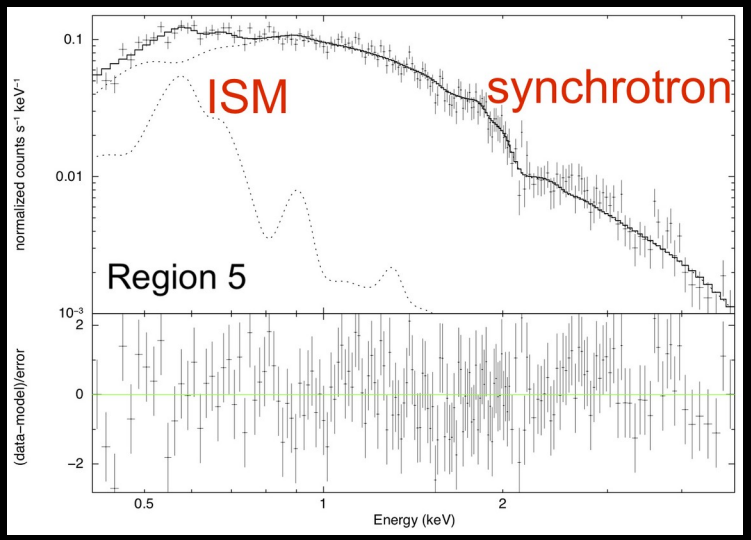
PARTICLE ACCELERATION IN SN 1006

Chandra analysis

Giuffrida et al. Under review







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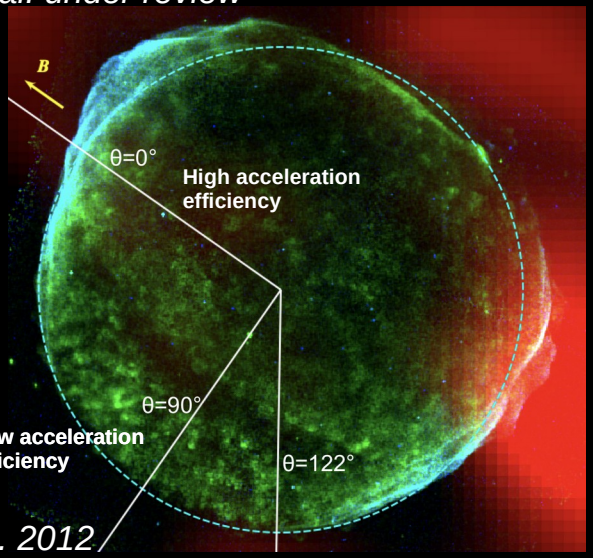
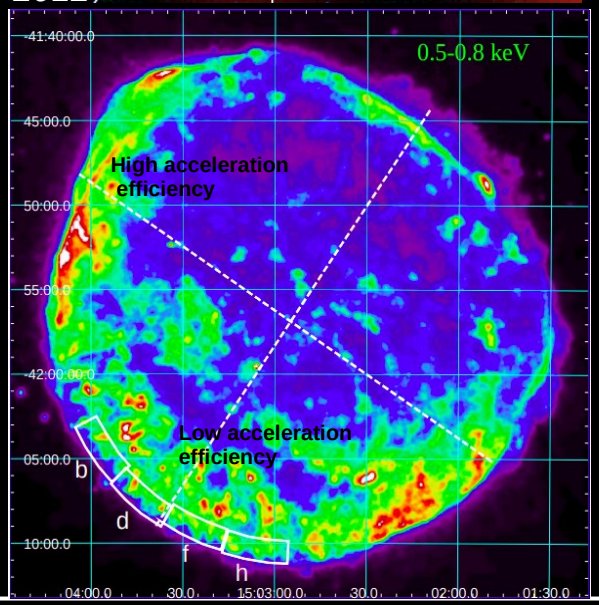
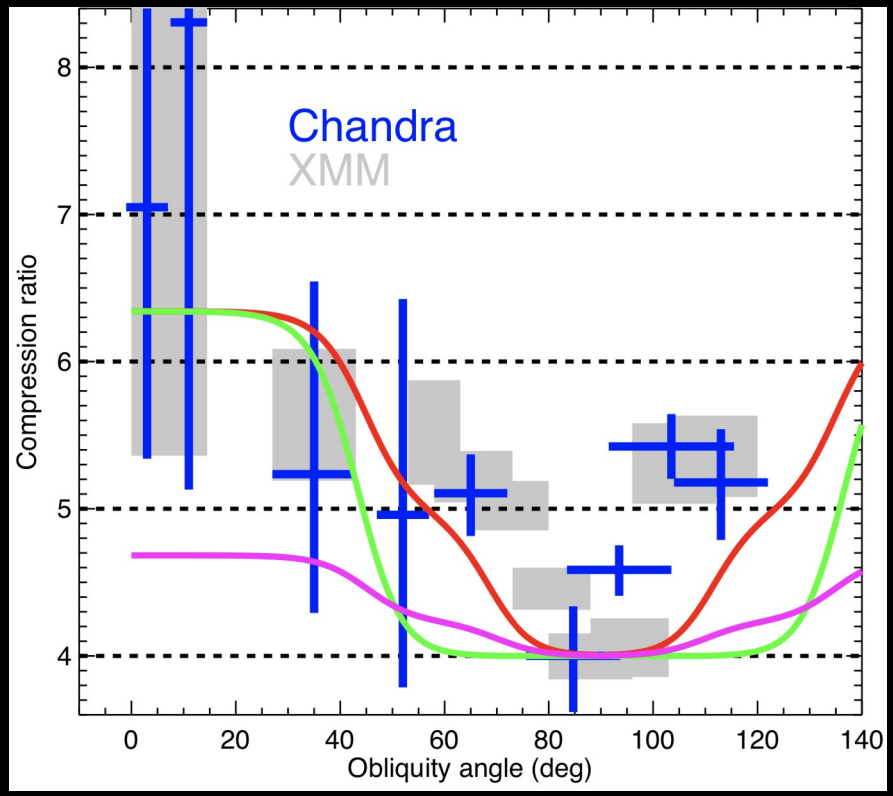
Giuffrida et al. under review



Miceli et al. 2012



Giuffrida et al. under review



ξ_p= 12 %
ξ_s= 6 %
ξ_B= 5 %

ξ_p= 18 %
ξ_s= 0 %
ξ_B= 5 %

ξ_p= 12 %
ξ_s= 6 %
ξ_B= 0 %

Caprioli et al. 2014, Caprioli et al. 2018, Haggerty et al. 2020, Caprioli et al. 2020

Particle acceleration causes shock modification.
SN 1006 is giving part of its kinetic energy to accelerate hadrons.


YES!

CONCLUSION

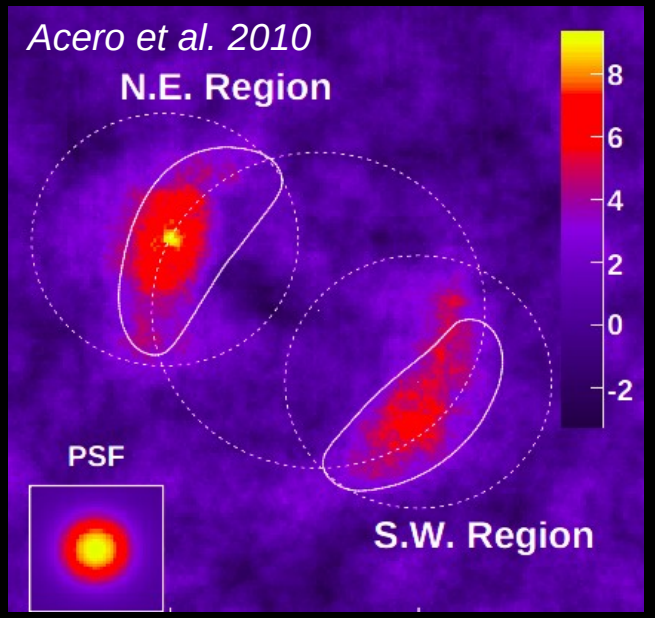
- Measure of post-shock ISM density in SE and NE limbs of SN 1006 and of the compression ratio
- Increase of compression ratio from the caracteristic value of 4 in thermal limb up to ~7 in nonthermal regions
- SN 1006 is affected by shock modification
- SN 1006 is giving >10% of its kinetic energy to accelerate CRs
- Comparison with simulation: 1) quasi parallel acceleration efficiency $\xi_p = 12\%$
  2) reaccelerated CRs with effciency $\xi_s = 6\%$
  3) presence of postcursor ⟶ magnetic field amplification $\xi_B = 5\%$

Thanks for your attention

FUTURE WORKS

γ−rays emission

- Leptonic scenario (Inverse Compton)
- Hadronic scenario (π^0 decay)



Miceli et al. 2016

- Inverse Compton
- hadronic contribution of the shocked cloud
- shocked ISM emission
- γ−ray spectrum observed with HESS
- Fermi− LAT upper limits