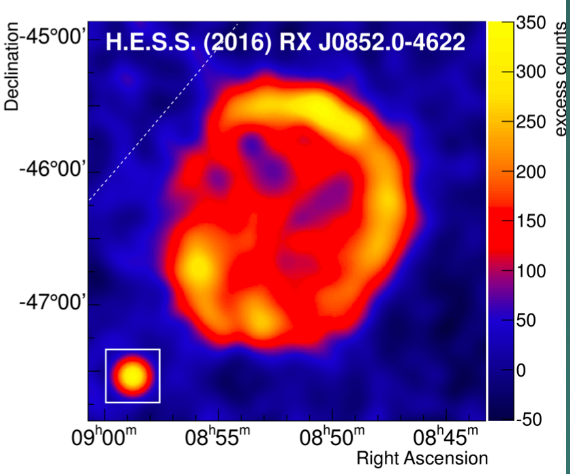
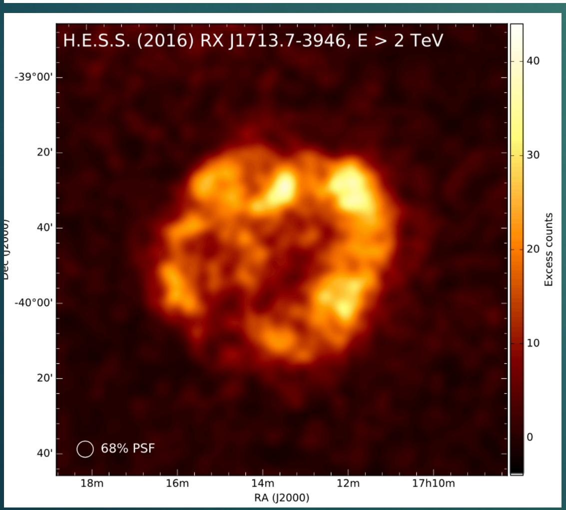
Broadband modelling the spectrum of the TeV-bright shell-type SNRs

张潇 @ 峨眉

TeV-bright shell-type SNRs

Abdalla et al. 2017

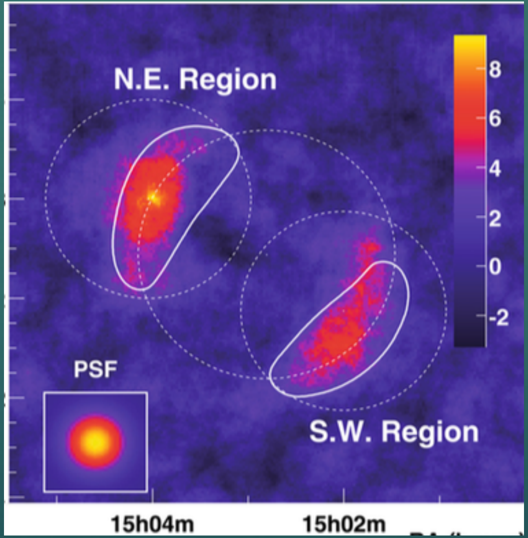


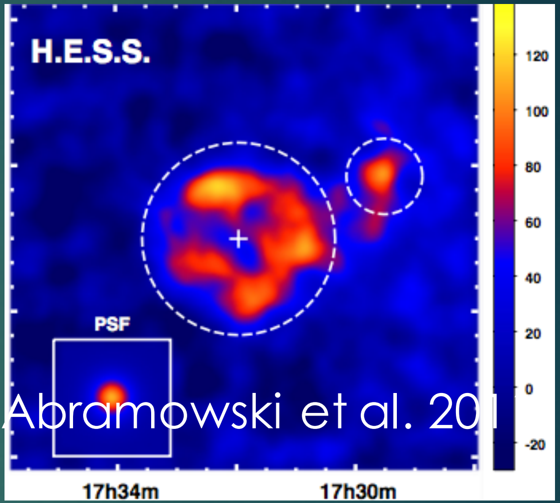


Abdalla et al. 2017

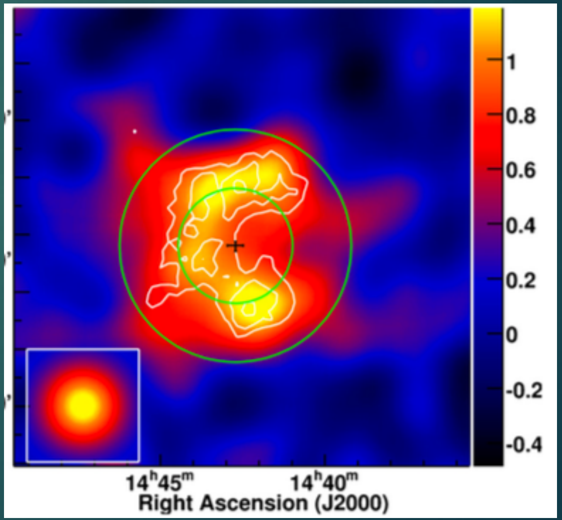
RX J0852.0
RX J1713.7
SN 1006
RCW 86
HESS J1731

Acero et al. 2010



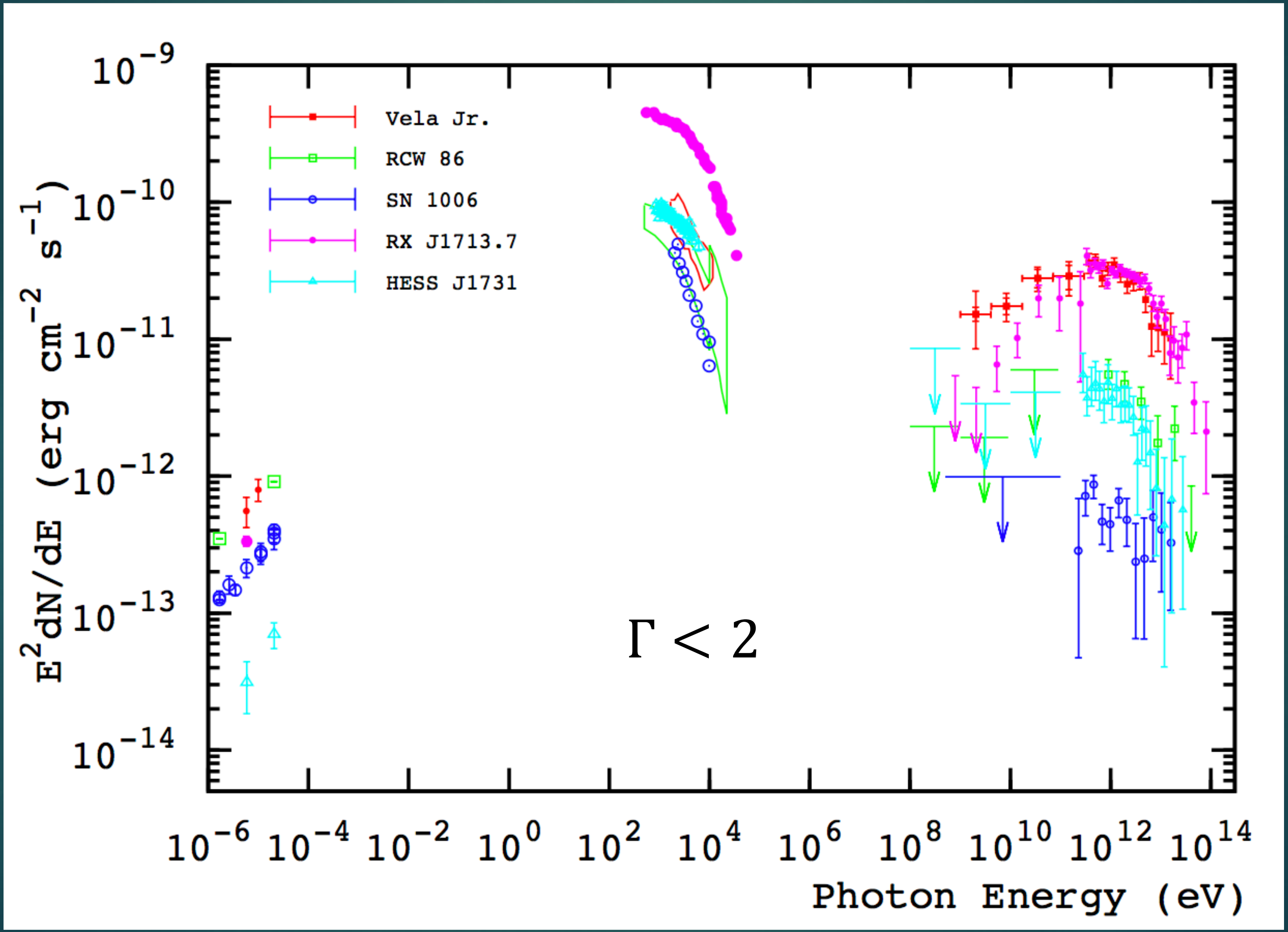


Abramowski et al. 201

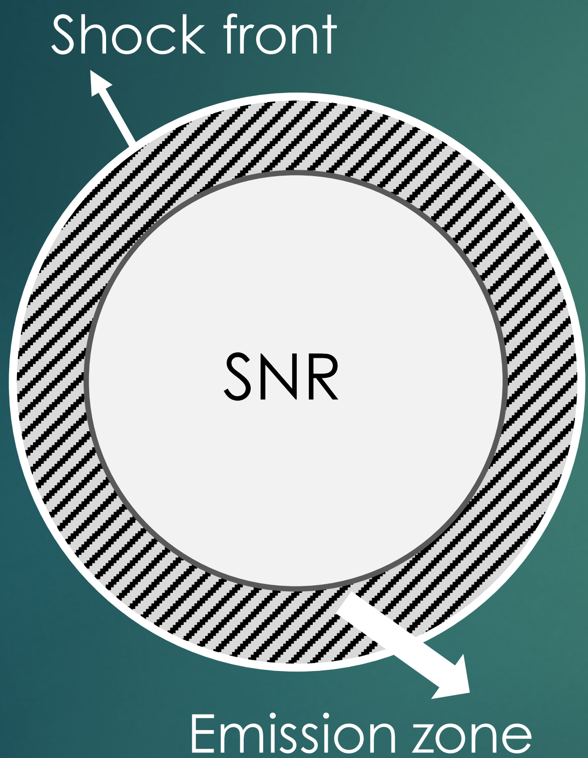


Ahronian et al 2009

Broad-band Spectra



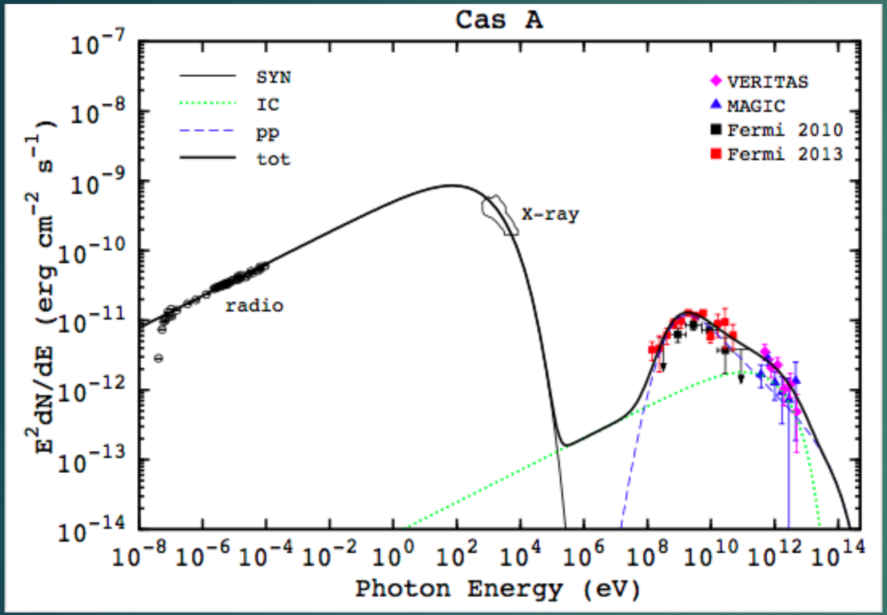
One-zone model



Single Power Law:

$$\frac{dN(E)}{dE} = A \cdot E^{-\alpha} \left[- \left(\frac{E}{E_{cut}} \right)^{\delta} \right]$$

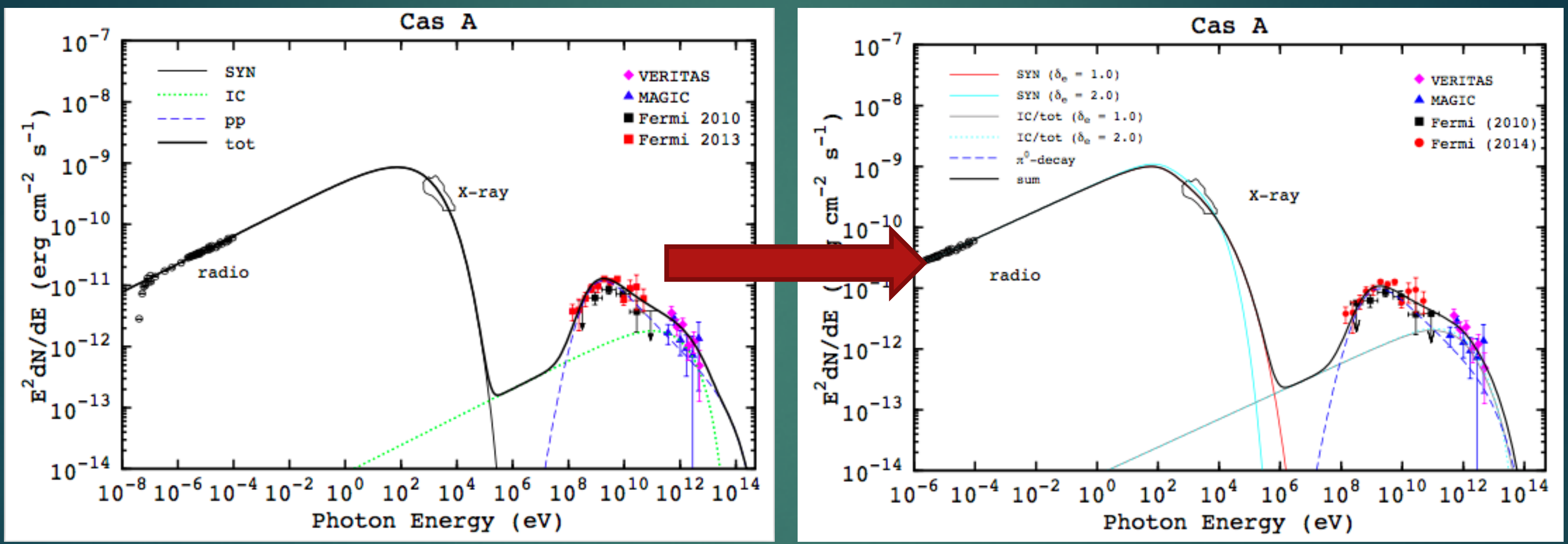
Example: Cas A



$$E_{e,cut} \sim 15 \text{ erg}; \;\; B \sim 100 \; \mu\text{G}$$

$$E_{bre} \sim 5 \text{ erg} < E_{e,cut}$$

Example: Cas A

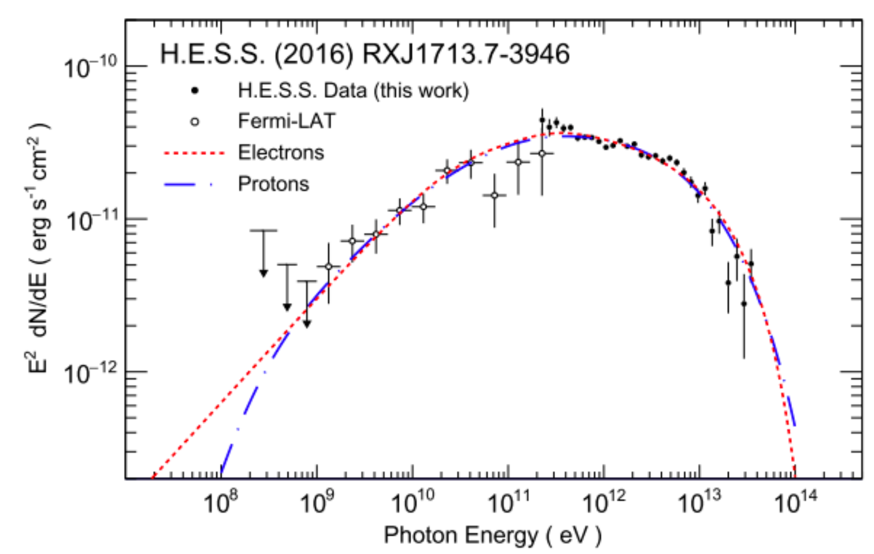


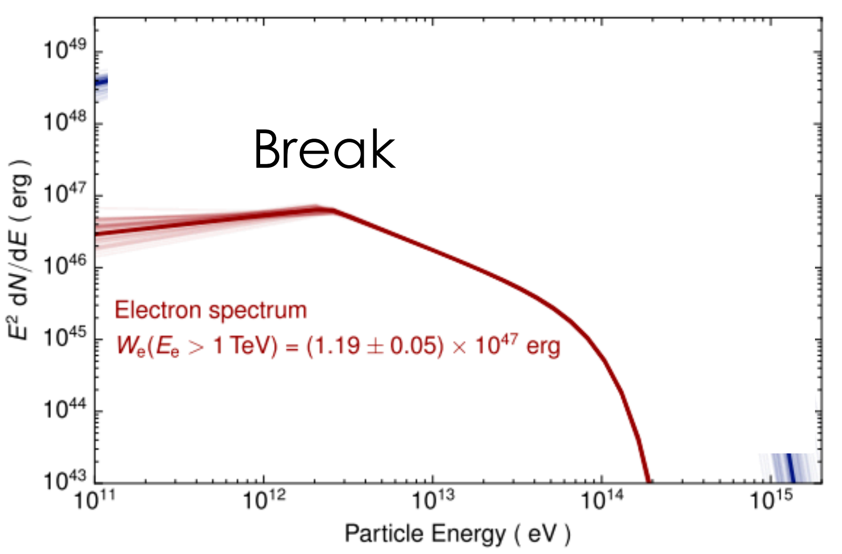
$$E_{e,cut} \sim 15 \text{ erg}; \;\; B \sim 100 \; \mu\text{G}$$

$$E_{bre} \sim 5 \text{ erg} < E_{e,cut}$$

Broken Power Law !

Example: RX J1713.7



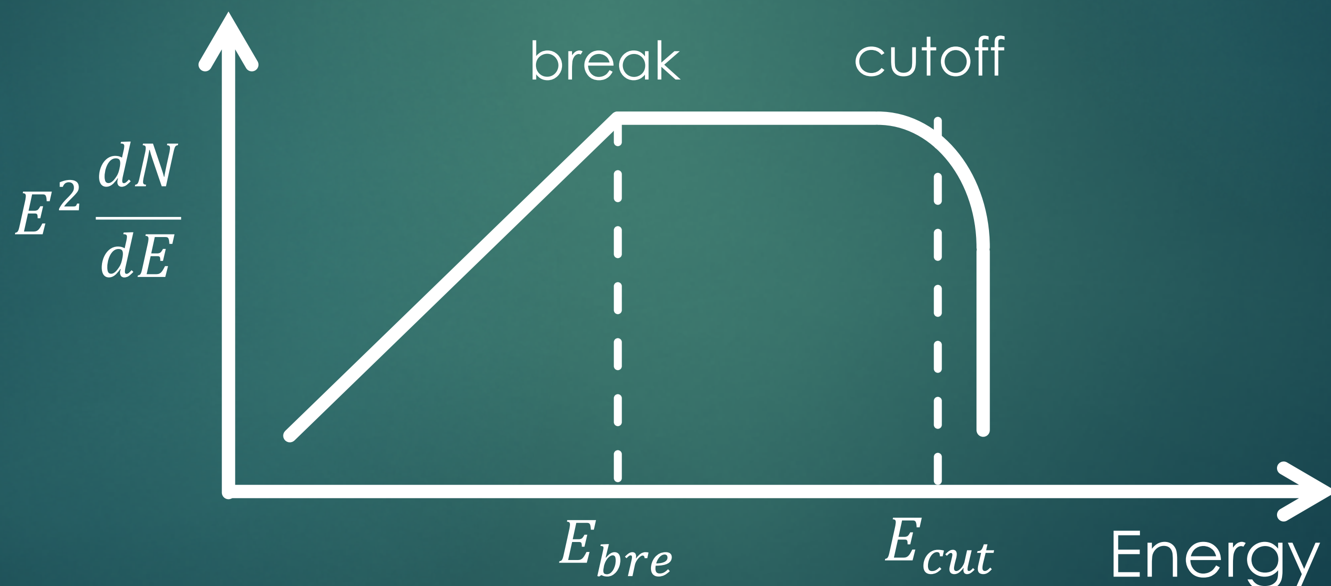


Model	Parameter	Full
Leptonic (X and γ-ray)	Γ_e^1	1.78 ± 0.12
	E_e^{break} (TeV)	2.5 ± 0.3
	Γ_e^2	2.93 ± 0.02
	E_e^{cutoff} (TeV)	88.4 ± 1.2
	W_e (10^{46} erg)	11.9 ± 0.5
	B (μG)	14.26 ± 0.16
	AIC (broken PL)	116.2
	AIC (simple PL)	345.5
	Relative likelihood (simple versus broken)	0

Broken Power Law !

Broken Power Law

$$\frac{dN(E)}{dE} = A \cdot E^{-\alpha} \left[1 + \left(\frac{E}{E_{bre}}\right)^{\sigma}\right]^{-\Delta\alpha/\sigma} \exp\left[-\left(\frac{E}{E_{cut}}\right)^{\delta}\right]$$



Timescale and Emax

$$\tau_{syn} = 1.25 \times 10^4 \ B^{-2} E^{-1} \ \mathrm{kyr}$$

$$\tau_{acc} = 1.1 \ E B^{-1} u_3^{-2} \ \mathrm{kyr}$$

加速区

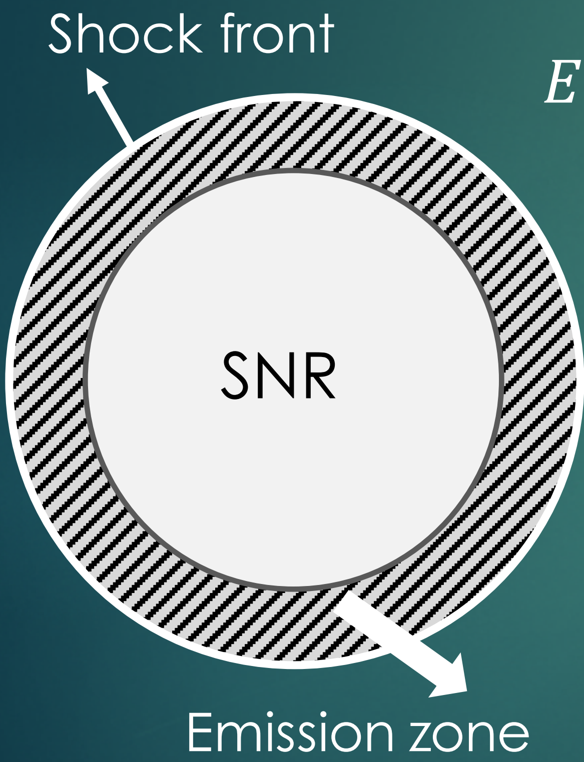
$$\tau_{acc} = \tau_{syn} \qquad E_{max,cool} = 110 \ B^{-1/2} u_3 \ \mathrm{TeV}$$

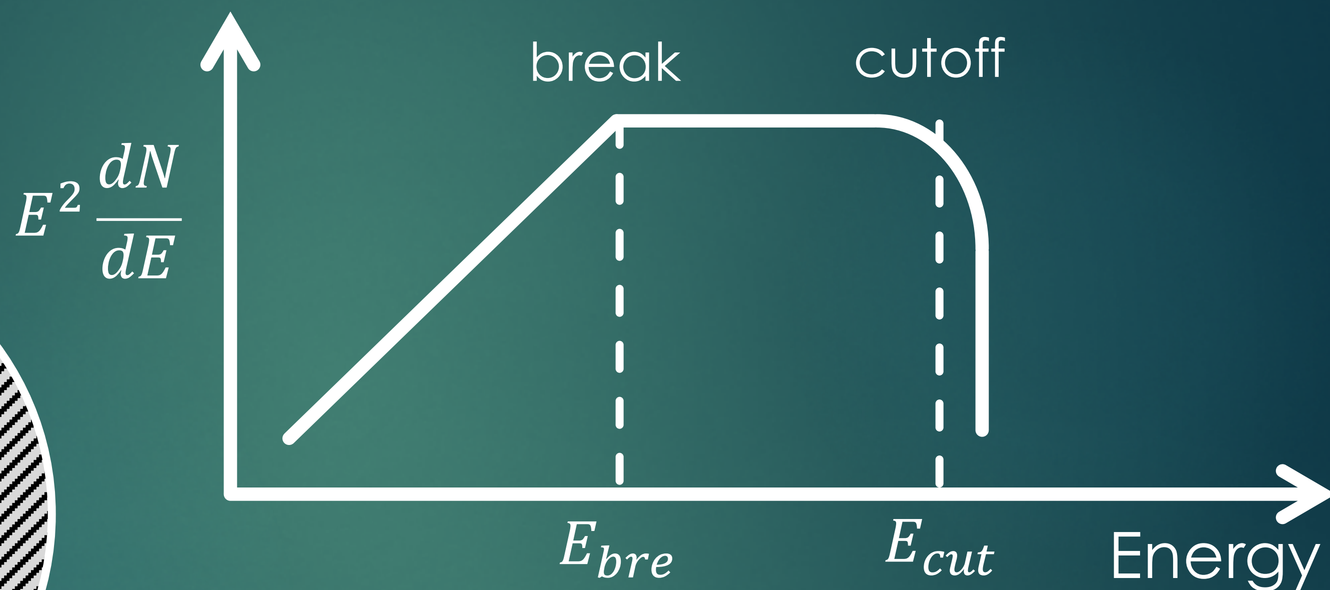
$$\tau_{acc} = t_{age} \qquad E_{max,age} = 1 \ B u_3^2 t_3 \ \mathrm{TeV}$$

发射区

$$\tau_{syn} = t_{age} \qquad E_{bre,cool} = 1.25 \times 10^4 \ B^{-2} t_3^{-1} \ \mathrm{TeV}$$

阶段一：双幂率

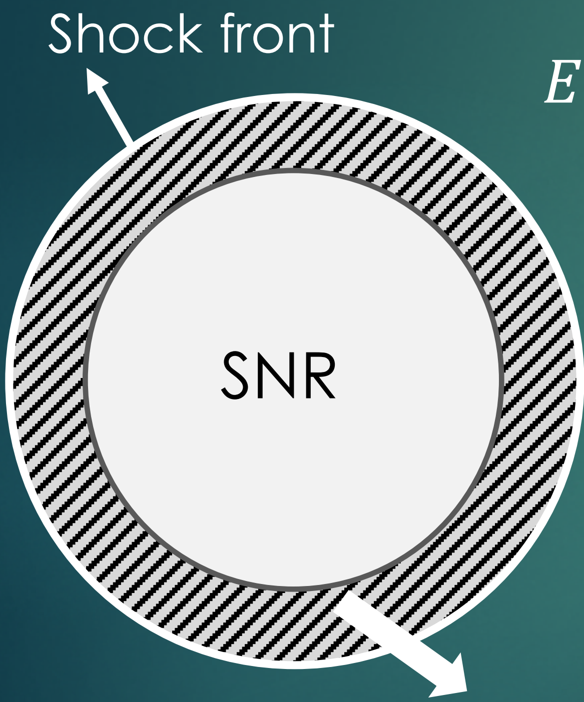


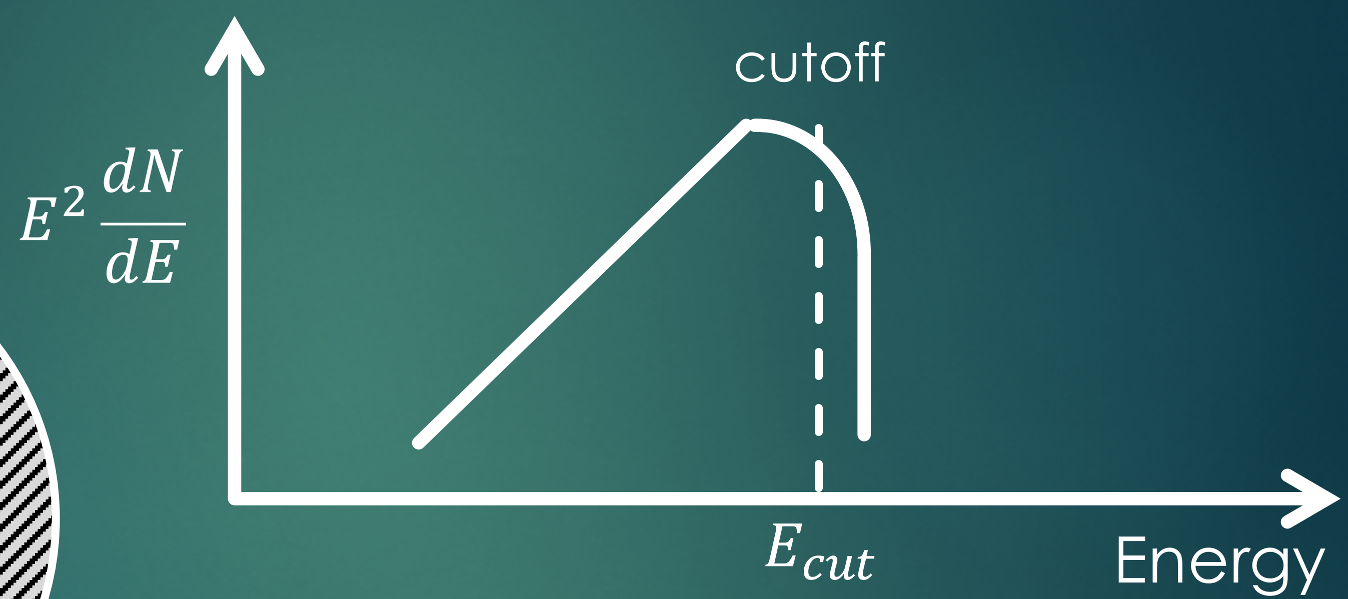


发射区 $E_{bre} = E_{bre,cool}$

加速区 $E_{cut} = E_{max,cool/age}$

阶段二：单幂率

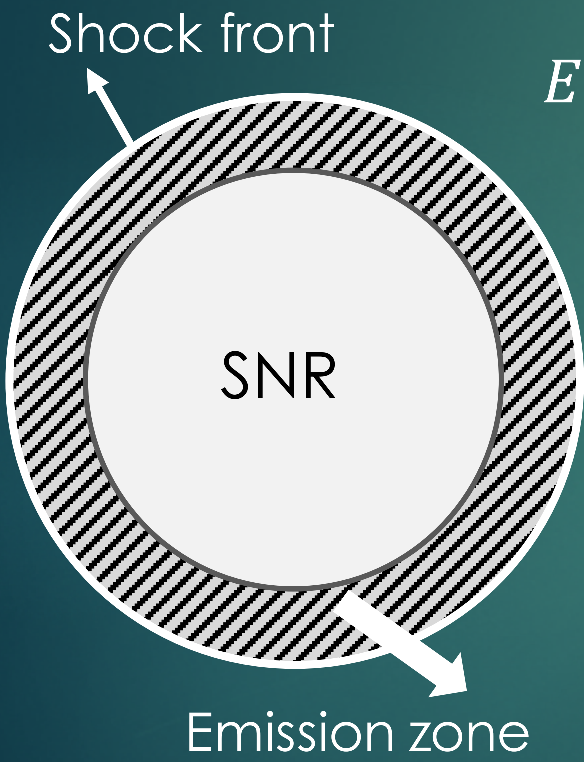


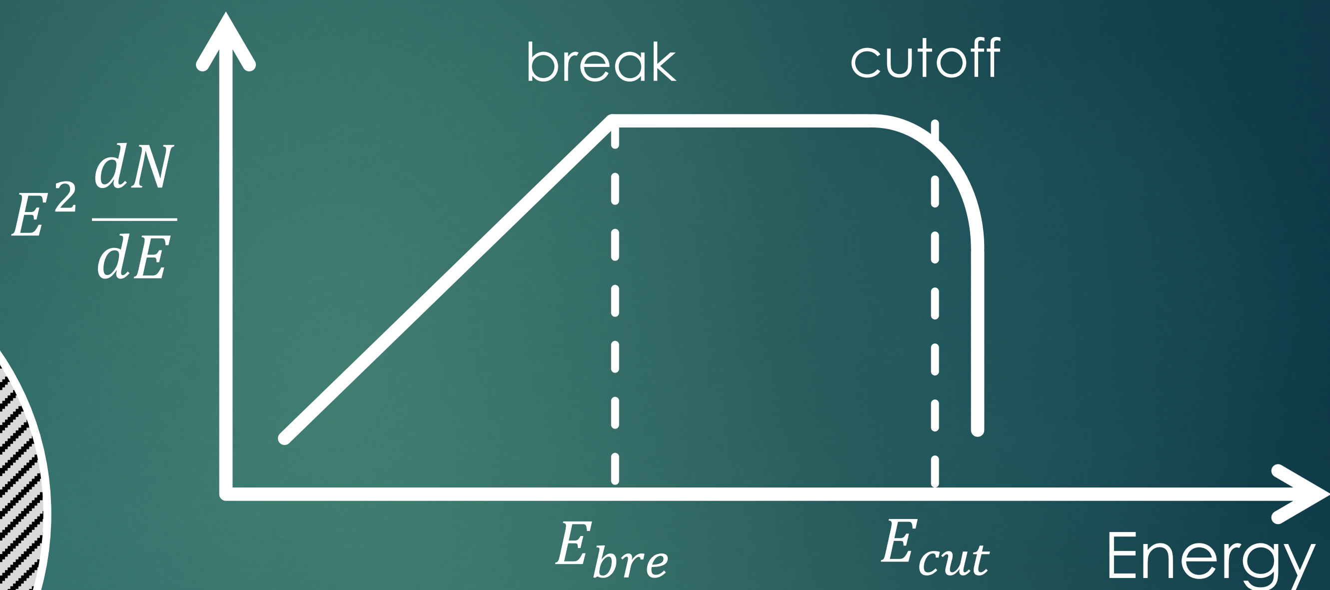


$$E_{cut} < E_{bre}$$

$$E_{cut} \sim E_{max,cool} \sim E_{max,age}$$

阶段三：双幂率



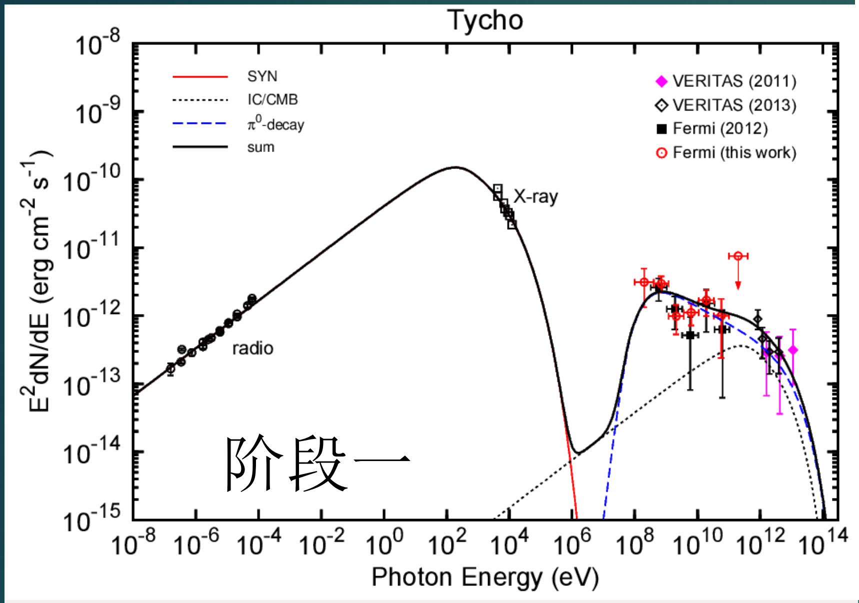


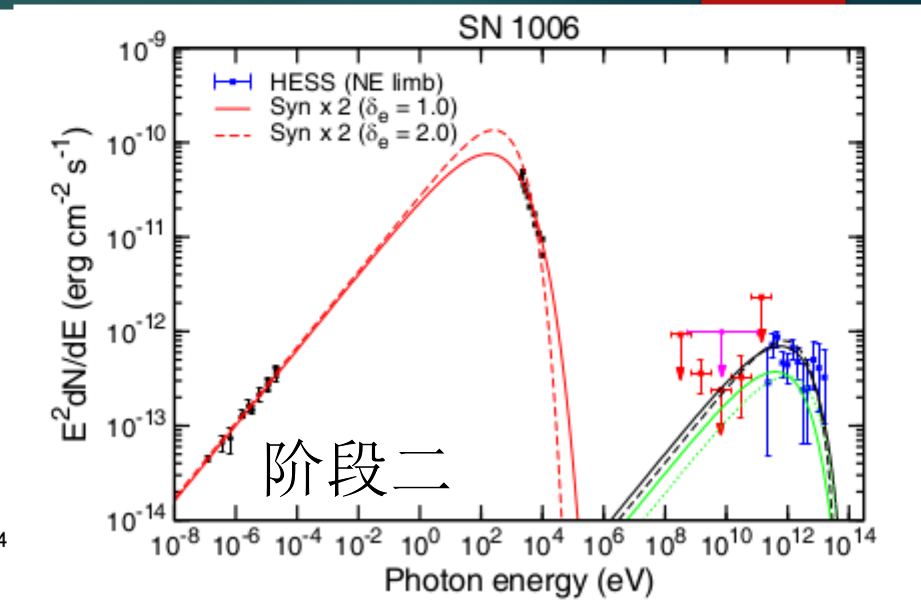
$$E_{bre} = E_{max,age}$$

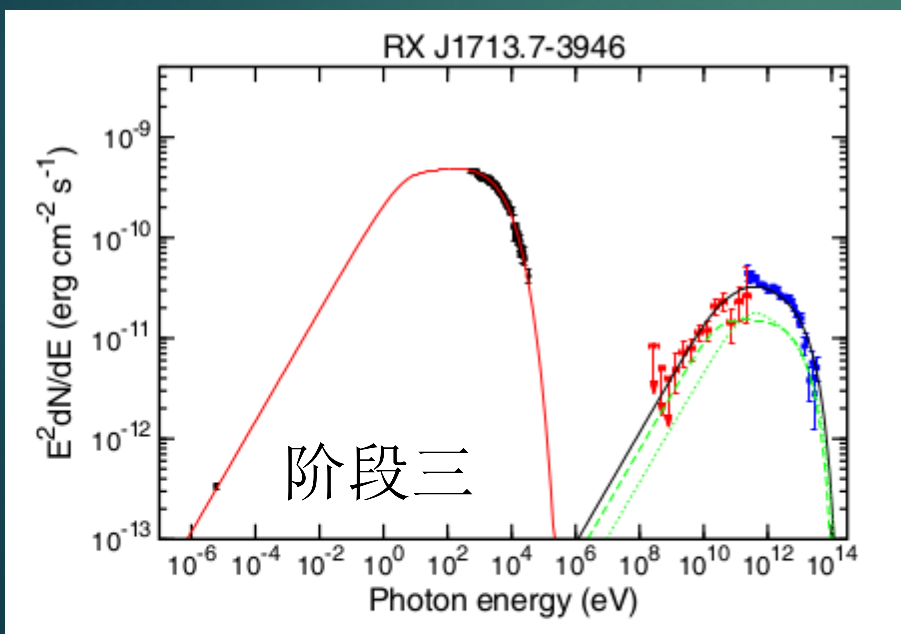
$$E_{cut} = E_{bre,cool}$$

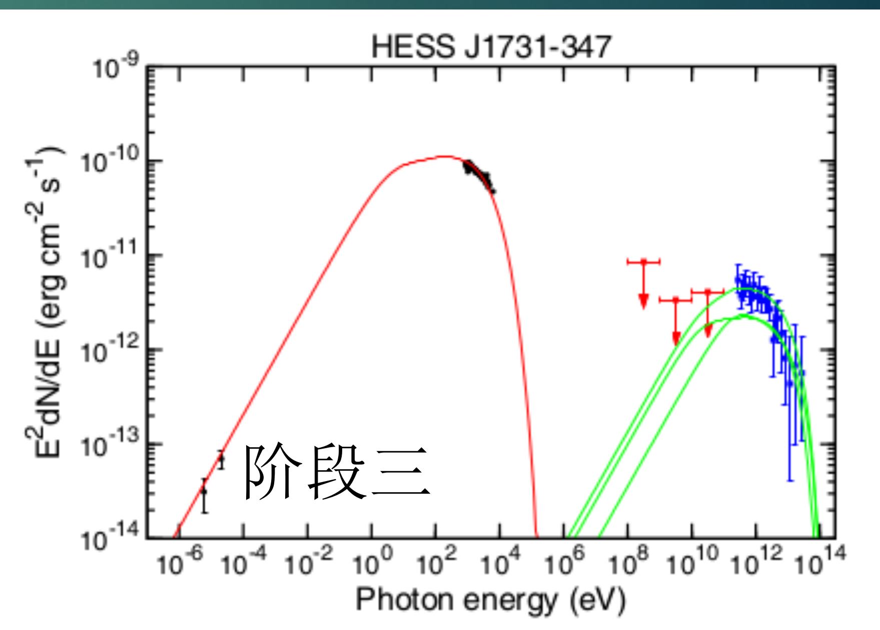
电子能谱演化

	阶段一	阶段二	阶段三	阶段四
	双幂率	单幂率	双幂率	单幂率
E_{bre}	$E_{bre,cool}$	—	$E_{max,age}$	—
E_{cut}	$E_{max,age}$ $E_{max,cool}$	$E_{max,age}$ $E_{max,cool}$	$E_{bre,cool}$	$E_{bre,cool}$

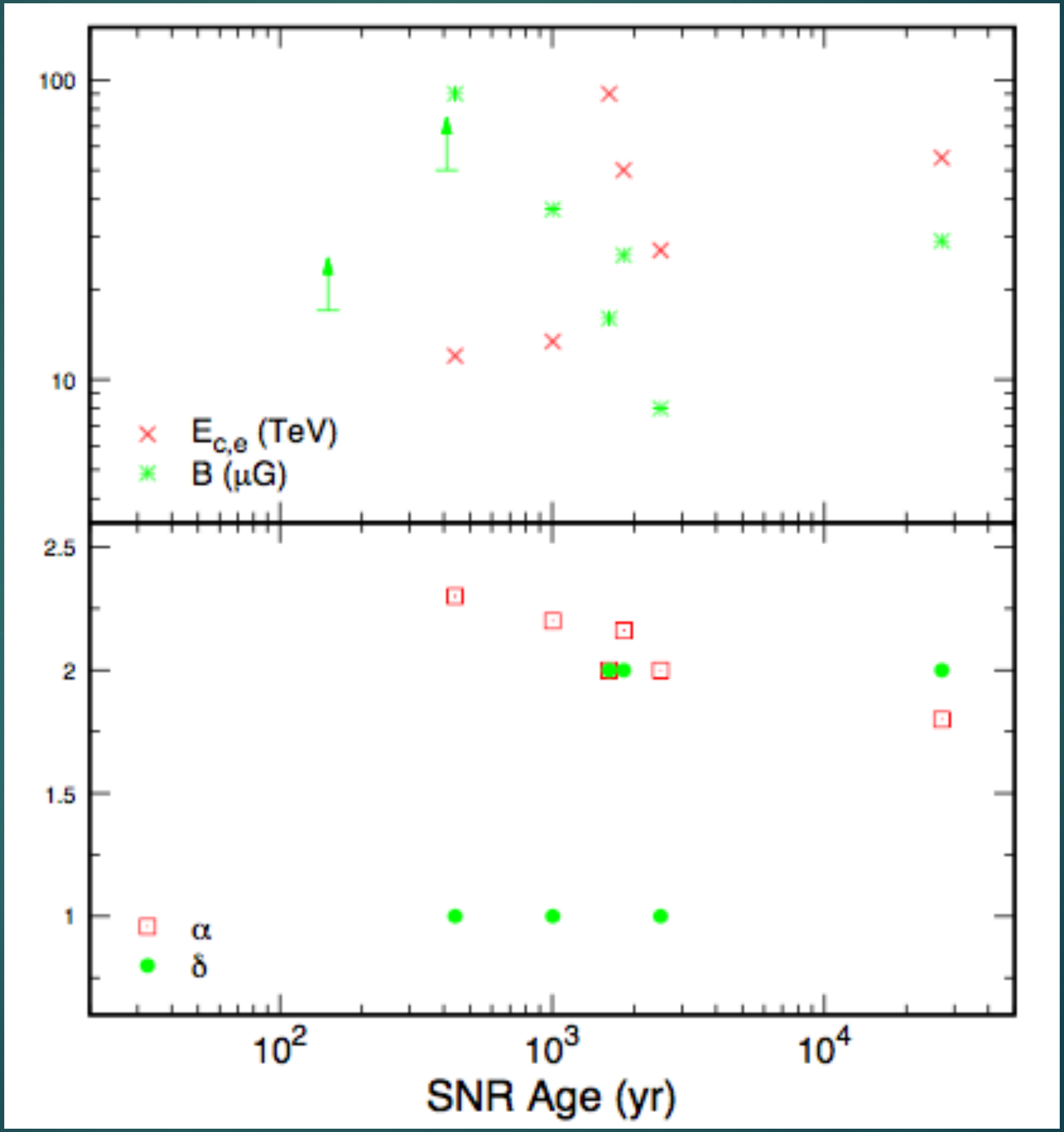

Tycho
SYN
IC/CMB
π^0-decay
sum
VERITAS (2011)
VERITAS (2013)
Fermi (2012)
Fermi (this work)
X-ray
radio
E^2dN/dE (erg cm^{-2} s^{-1})
Photon Energy (eV)
阶段一


SN 1006
HESS (NE limb)
Syn x 2 (δ_e = 1.0)
Syn x 2 (δ_e = 2.0)
E^2dN/dE (erg cm^{-2} s^{-1})
Photon energy (eV)
阶段二


RX J1713.7-3946
E^2dN/dE (erg cm^{-2} s^{-1})
Photon energy (eV)
阶段三


HESS J1731-347
E^2dN/dE (erg cm^{-2} s^{-1})
Photon energy (eV)
阶段三

参数演化



总结

- 遗迹发射区的电子能谱有：双幂率 → 单幂率 → 双幂率 (→ 单幂率) 的演化过程。

- 第二个双幂率要求注入粒子的数目随时间是增加的，这和目前超新星遗迹加速理论是一致的。

谢谢！

背景介绍

MCs near SNRs: a probe for accelerated CR protons