Temporal evolution of high energy radiation in type IIn Supernovae

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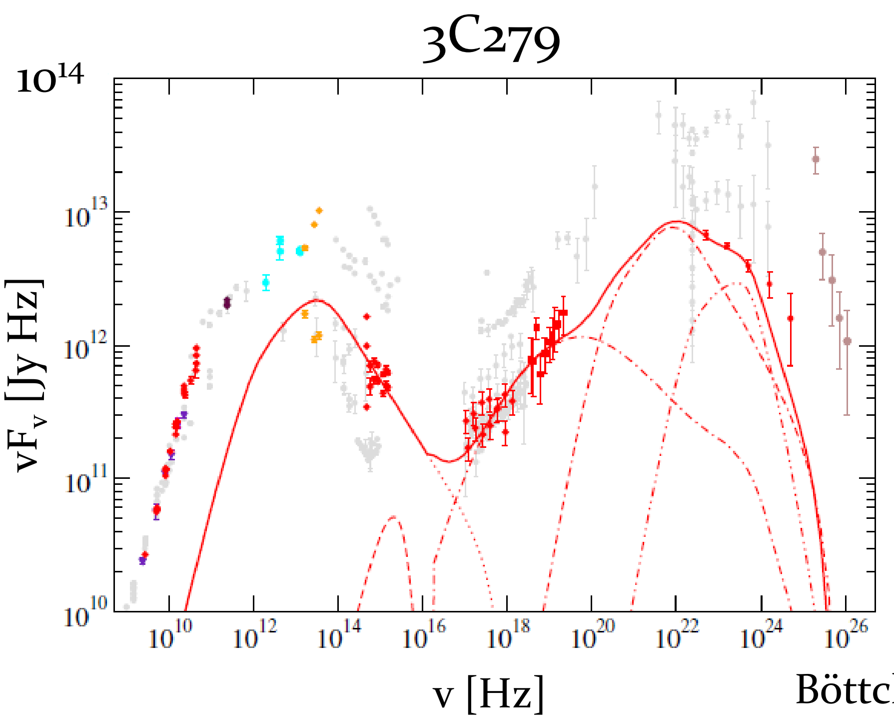
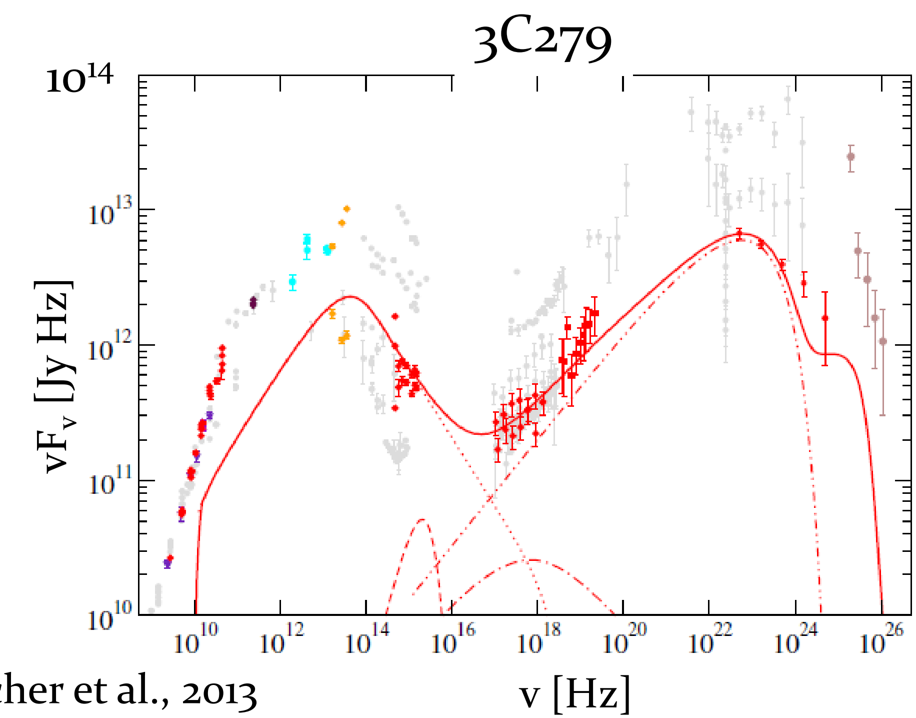
Motivation

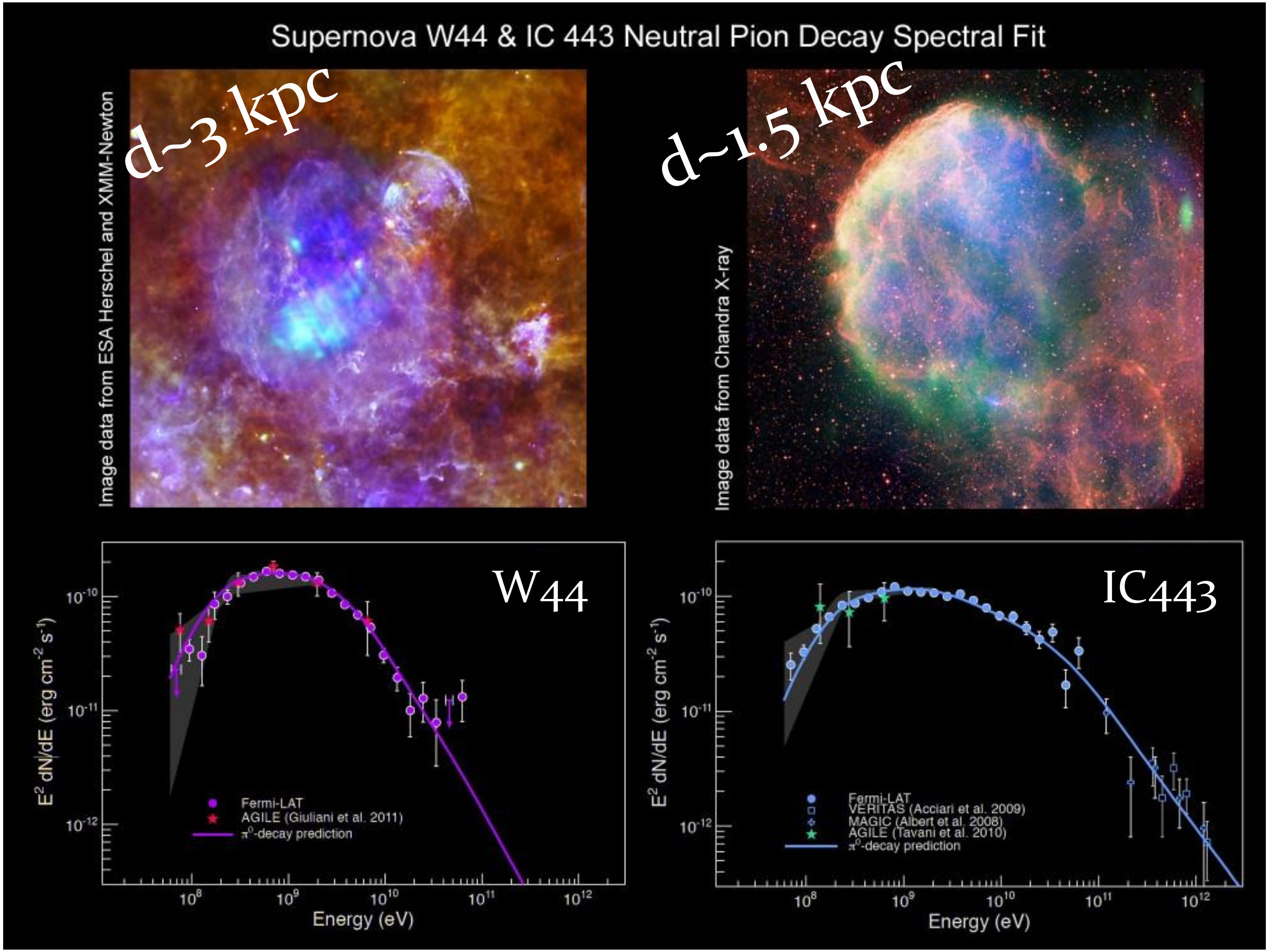
Leptonic Model	Hadronic Model





Böttcher et al., 2013

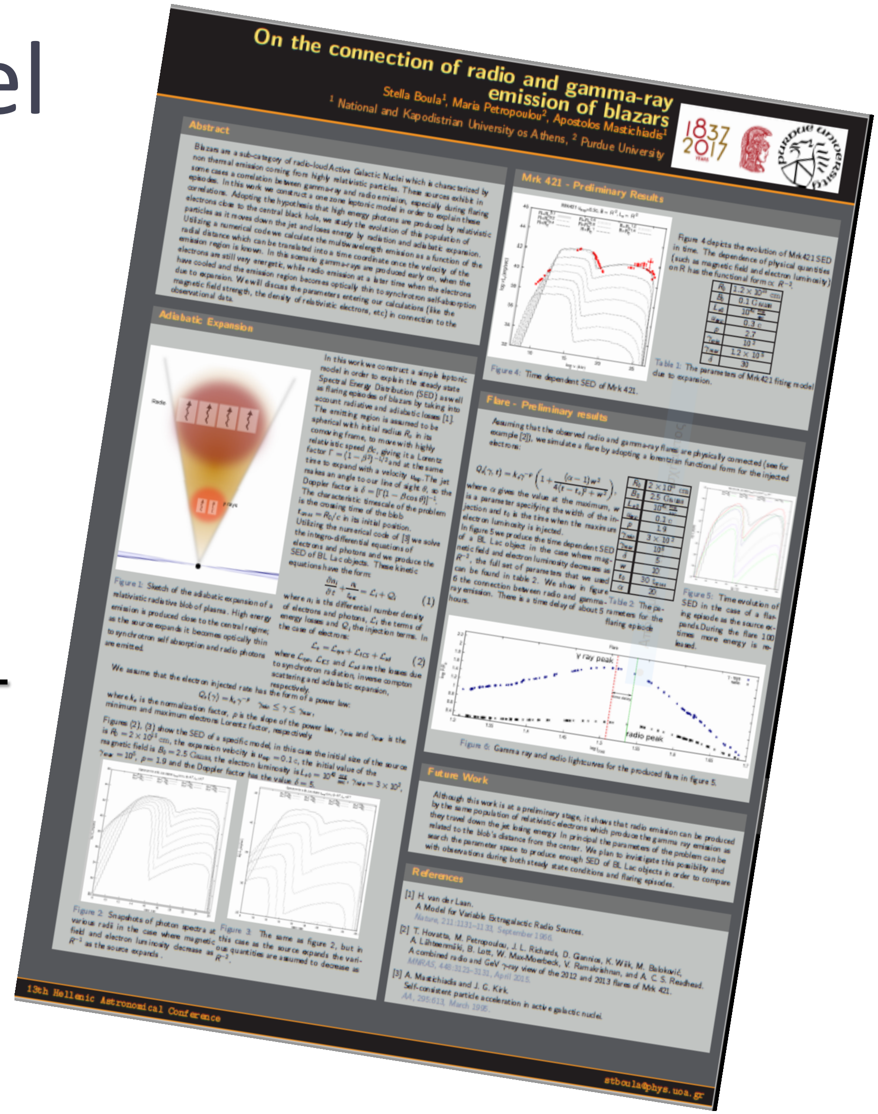
Also: **On the flaring γ-ray activity of quasar 3c279, *A. Mastichiadis et al.***

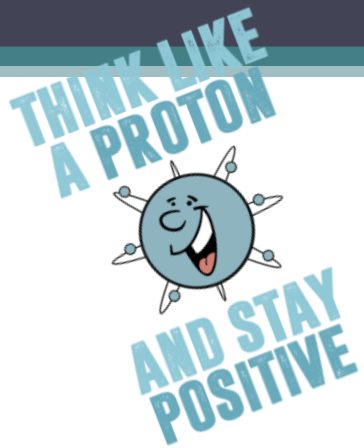

Supernova W44 & IC 443 Neutral Pion Decay Spectral Fit
d~3 kpc
d~1.5 kpc
Image data from ESA Herschel and XMM-Newton
Image data from Chandra X-ray
W44
IC443
E² dN/dE (erg cm⁻² s⁻¹)
Energy (eV)
Fermi-LAT
AGILE (Giuliani et al. 2011)
π⁰-decay prediction
Fermi-LAT
VERITAS (Acciari et al. 2009)
MAGIC (Albert et al. 2008)
AGILE (Tavani et al. 2010)
π⁰-decay prediction

Leptonic Model

- electrons
- ICS
- low B

- See poster: On the connection of radio and γ-ray emission of blazars, *S. Boula et al.*





Hadronic Model

- protons/nuclei
- π^0 decay
- CR acceleration +
- high energy –
- neutrinos …

- See poster: Modeling the rapid flare of 3C279 June 2015, *I. Florou et al.*


Modelling the June 2015 rapid flare of 3C279

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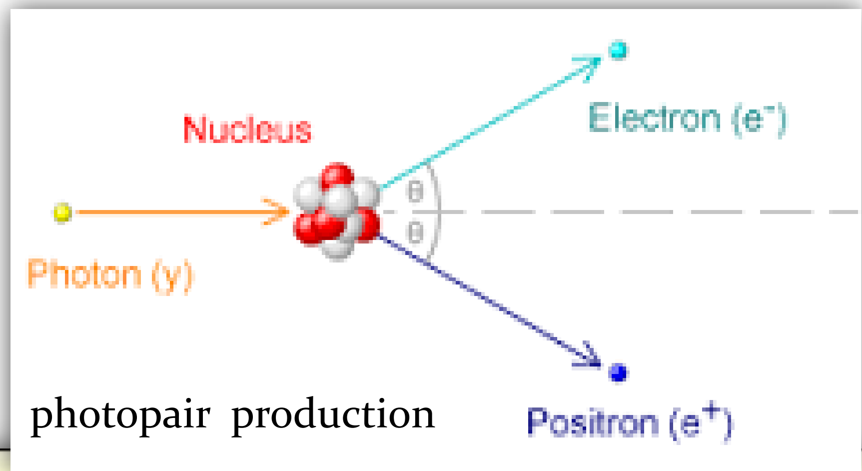
Abstract

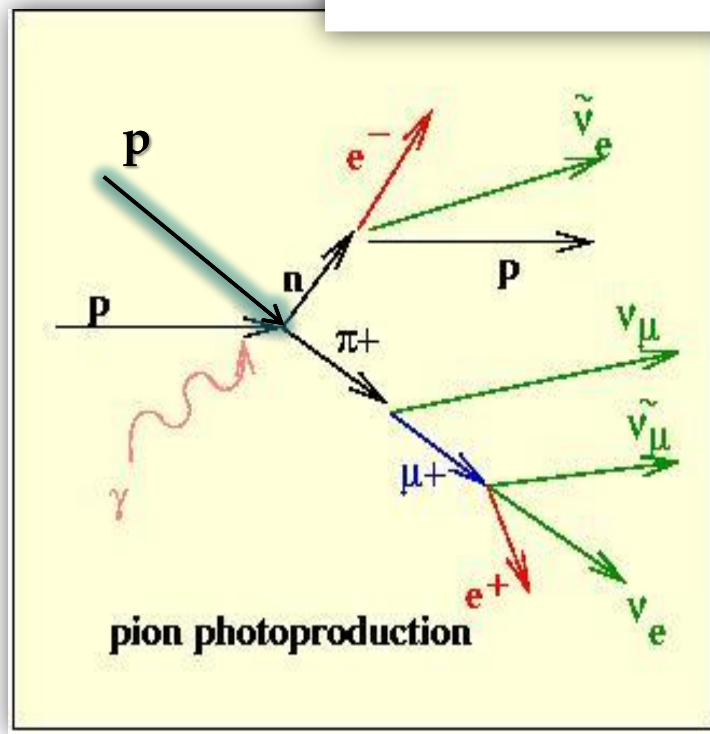
Model Assumptions

Numerical Results

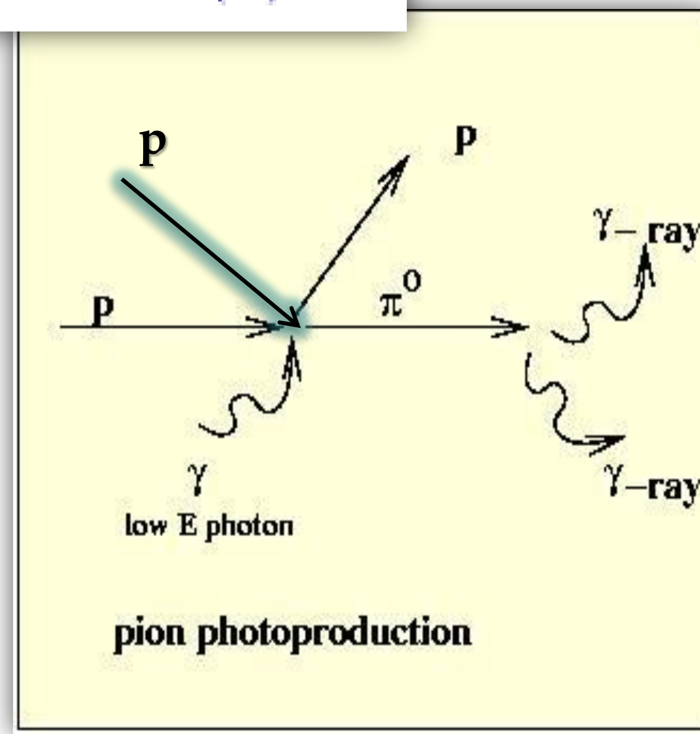
Conclusions

References





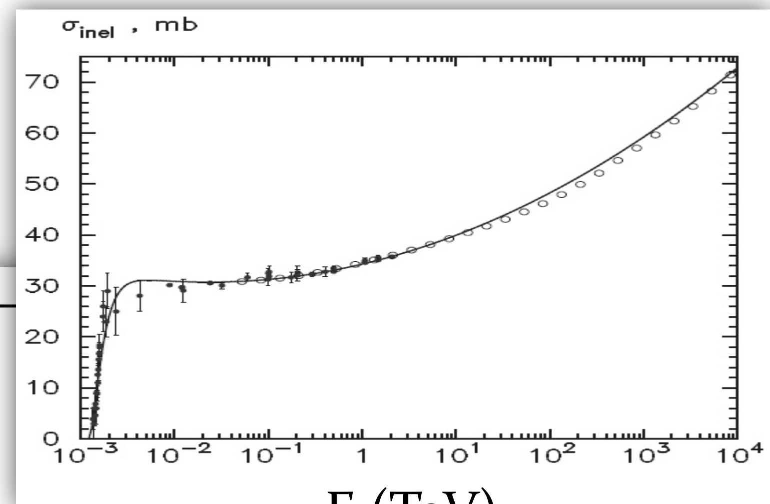
2.6×10^{-8} sec & 2.2×10^{-6} *sec*



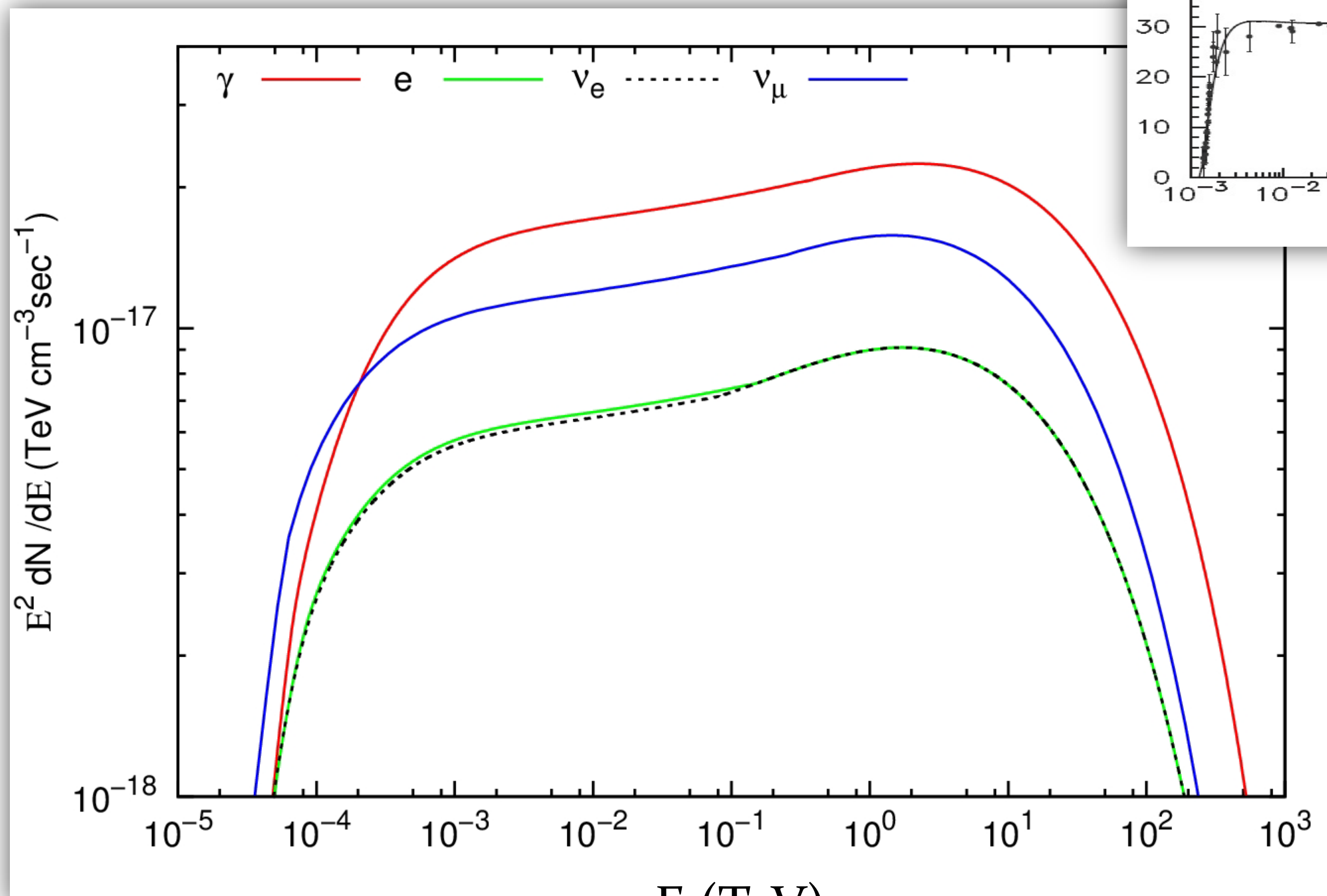
9×10^{-17} *sec*

Kelner et al., 2006

pp collisions



E (TeV)



E (TeV)

The kinetic equation approach

Protons:

$$\frac{\partial n_p}{\partial t} + L_p^{BH} + L_p^{photopion} + L_p^{psyn} + L_p^{pp} + \frac{n_p}{t_{p,esc}} = Q_p^{inj} + Q_p^{photopion}$$

Electrons:

$$\frac{\partial n_e}{\partial t} + L_e^{syn} + L_e^{ics} + L_e^{ann} + L_e^{tpp} + \frac{n_e}{t_{e,esc}} = Q_e^{ext} + Q_e^{BH} + Q_e^{\gamma\gamma} + Q_e^{photopion} + Q_e^{tpp} + Q_e^{pp}$$

Photons:

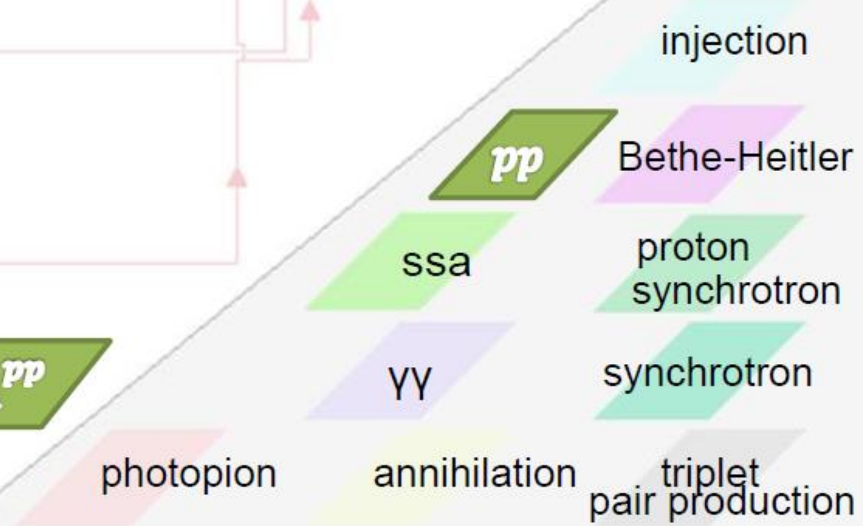
$$\frac{\partial n_\gamma}{\partial t} + \frac{n_\gamma}{t_{\gamma,esc}} + L_\gamma^{\gamma\gamma} + L_\gamma^{ssa} = Q_\gamma^{syn} + Q_\gamma^{psyn} + Q_\gamma^{ics} + Q_\gamma^{ann} + Q_\gamma^{photopion} + Q_\gamma^{pp}$$

Neutrinos:

$$\frac{\partial n_\nu}{\partial t} + \frac{n_\nu}{t_{esc}} = Q_\nu^{photopion} + Q_\nu^{pp}$$

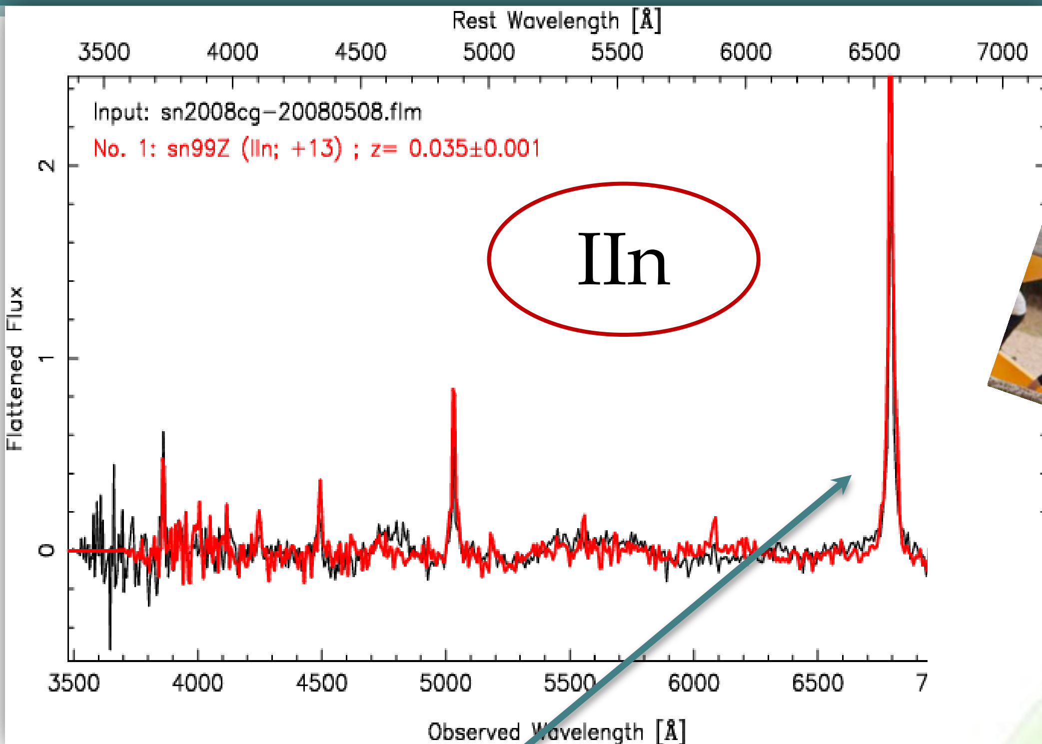
Neutrons:

$$\frac{\partial n_n}{\partial t} + L_n^{photopion} + \frac{n_n}{t_{esc}} = Q_n^{photopion} + Q_n^{pp}$$



Mastichiadis & Kirk, 1995

Dimitrakoudis et al., 2012 +



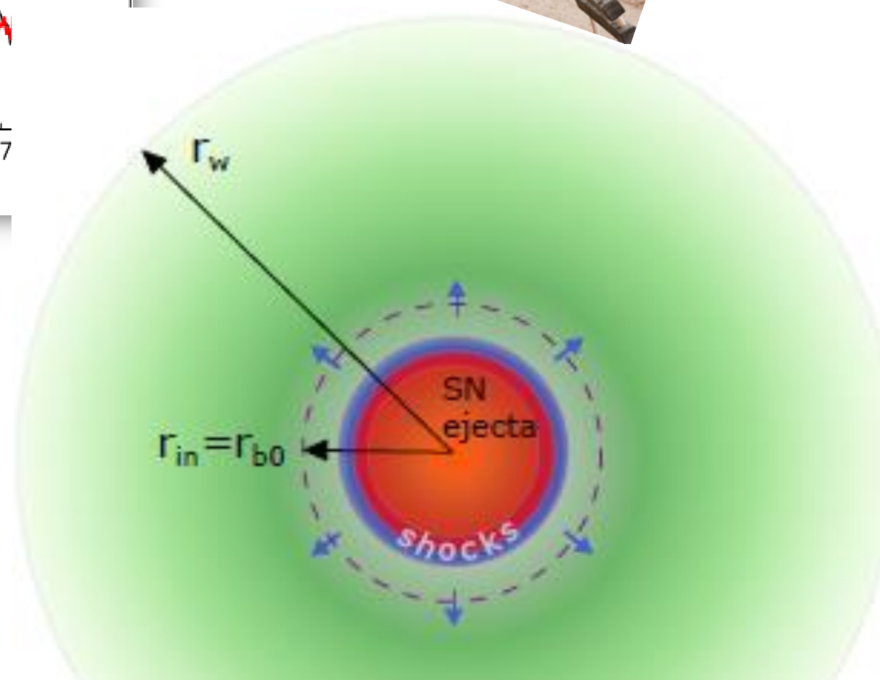
$\dot{M} \geq 0.1\ M_{\odot}/yr$ [1]

$v_w \sim 100\ km/sec$ [2]

$R_w \sim 10^{16}\ cm$ [2]

$v_{sh} \sim 10000\ km/sec$ [3]

$n \sim 10^{7} - 10^{12}\ cm^{-3}$ [2],[3]

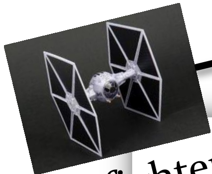


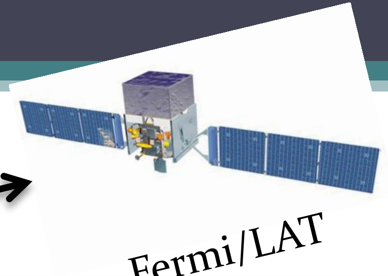
Petropoulou et al., 2016

[1]Smith et al., 2008, [2]Fasia et al., 2000, [3]Murase et al., 2014

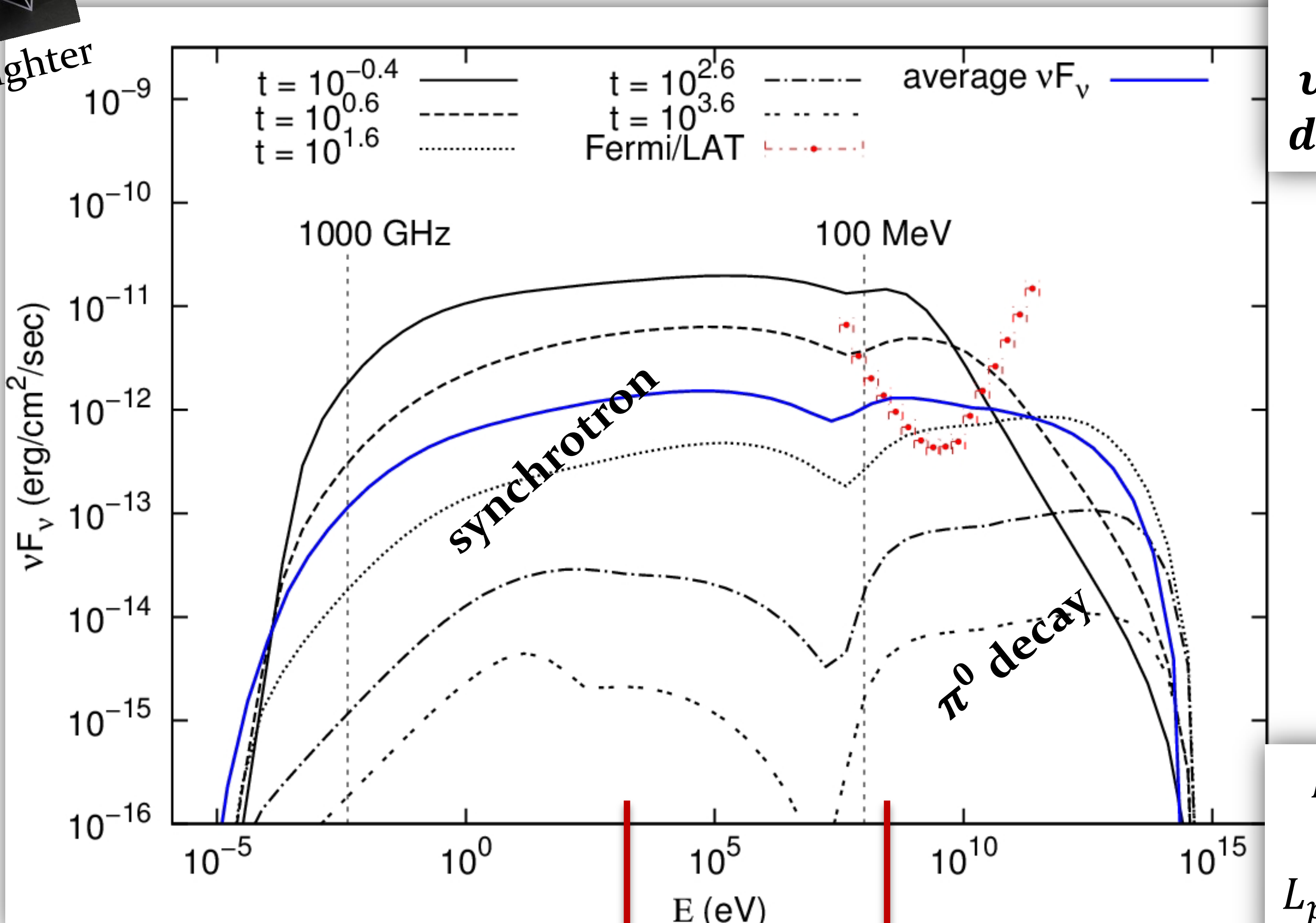
Application to SN IIn

- $n(R) = n_0 \left(\frac{R_0}{R}\right)^2$
  - $n_0 \approx 2 \times 10^{12} \left(\frac{R_0}{10^{14}\ cm}\right)^{-1} \left(\frac{v_s}{0.03\ c}\right)^{-1} cm^{-3}$
- $B(R) = B_0 \left(\frac{R_0}{R}\right)^{a_B}$
  - $B_0 \approx 460 \left(\frac{\varepsilon_\mathrm{B}}{0.01}\right)^{1/2} \left(\frac{v_s}{0.03\ c}\right)^{1/2} \left(\frac{R_0}{10^{14}\ cm}\right)^{-1/2} \mathrm{G}$





$B_0 = 46\ G$
$\alpha_B = 1$
$\upsilon \approx 0.03c$
$d = 5\ Mpc$



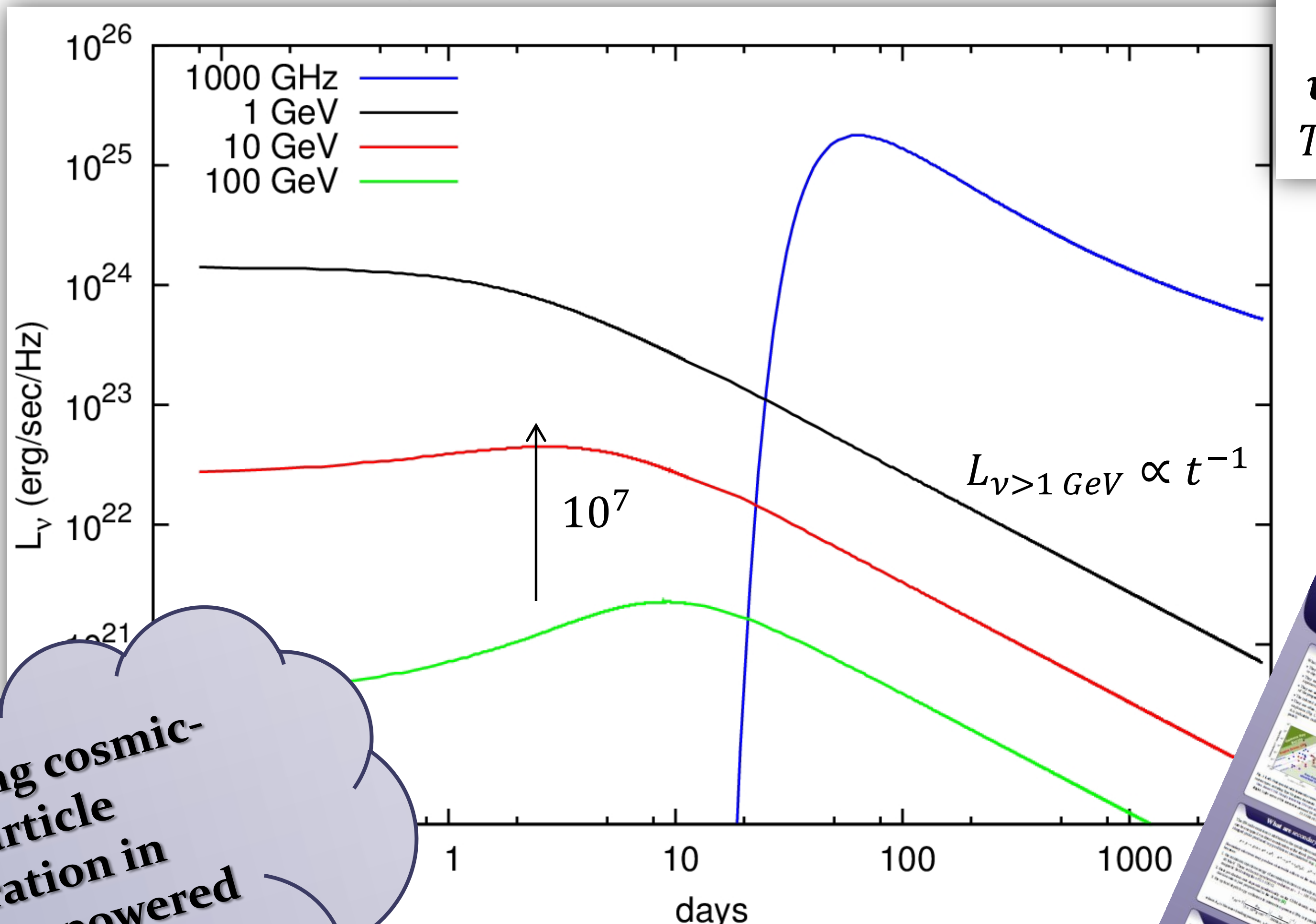
$\sim 1\ keV$ $\sim 500\ MeV$

$R_0 = 10^{14}\ cm$
$p = 2$
$L_p = 10^{41}\ erg/s$
$L_e = 0.01\ L_p$
$[t] = days$

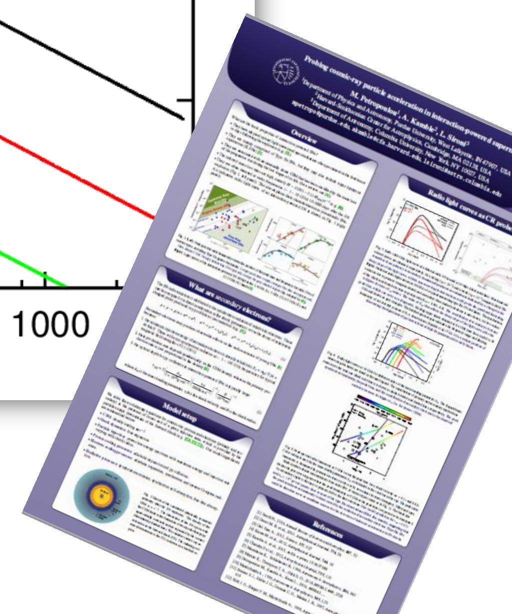
Kantzas et al. 2016 | arXiv:1607.05847

Kantzas et al. 2016 | arXiv:1607.05847

$B_0 = 46\ G$
$\alpha_B = 1$
$\upsilon \approx 0.03c$
$T = 10^5\ K$



Also: **Probing cosmic-ray particle acceleration in interaction-powered supernovae, M. Petropoulou et al.**



Take Home Note

- pp → γ-rays, e & ν
- photon – photon absorption
- $d < 10\ Mpc$ or $n_0 > 10^{10} cm^{-3}$

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- neutrinos

  (e.g. Aartsen et al. 2015 & Petropoulou et al.,2017)