SNRs hitting Molecular clouds:

Fermi-LAT's view of SNR W28 and SNR HESS J1731-347

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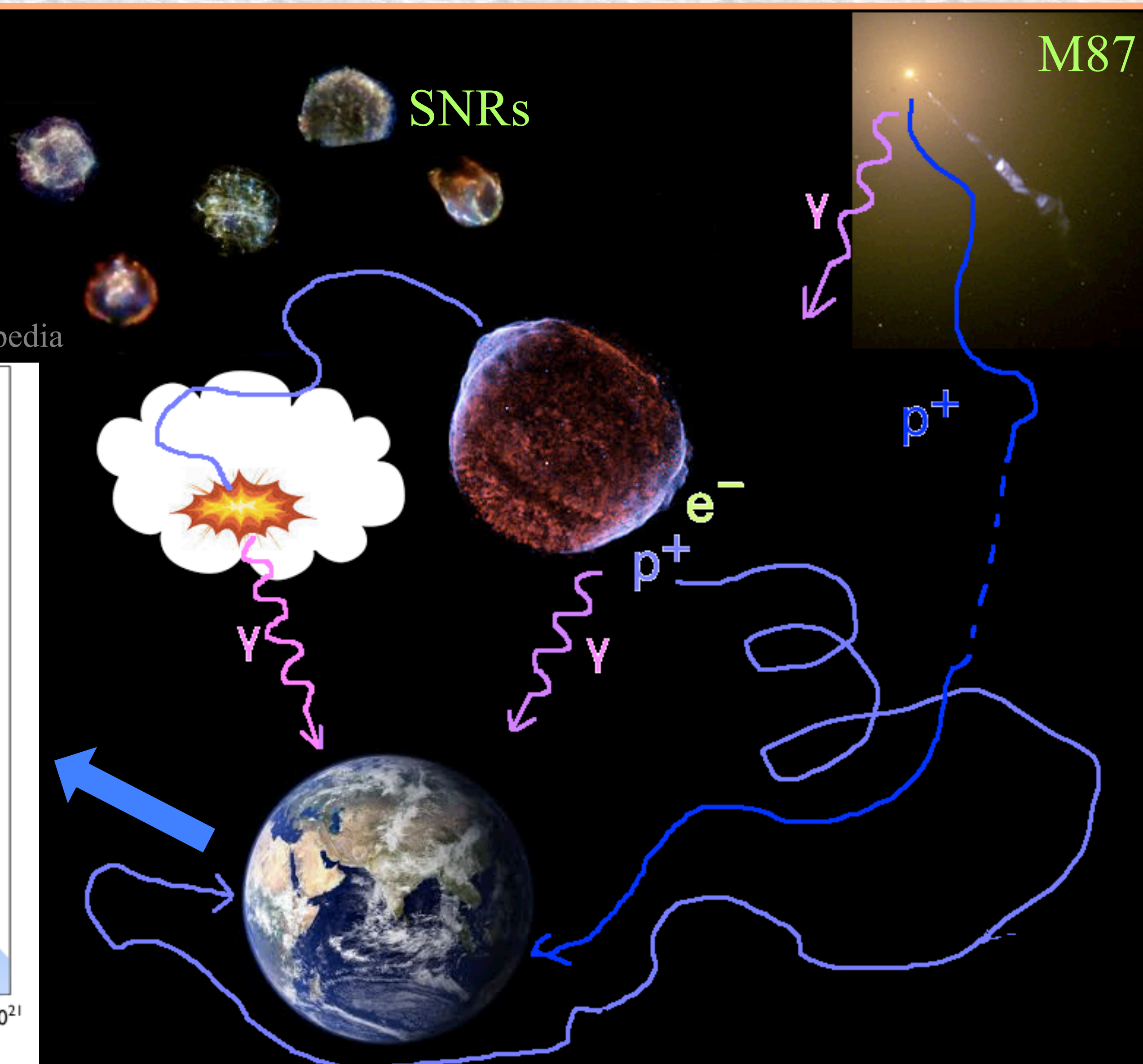
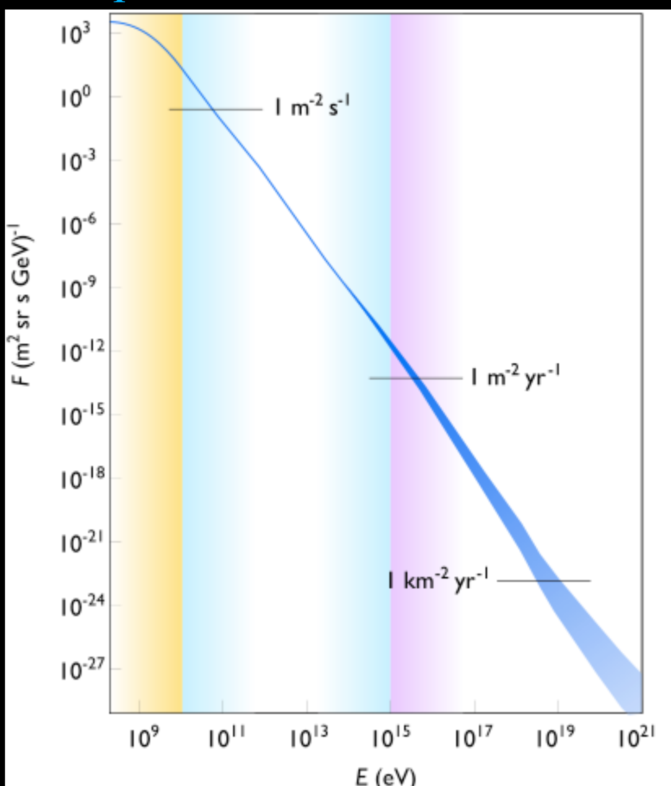
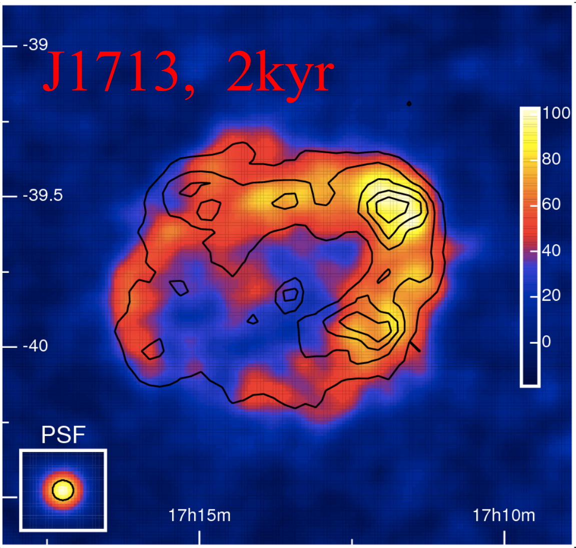
Cosmic ray (CR) sources



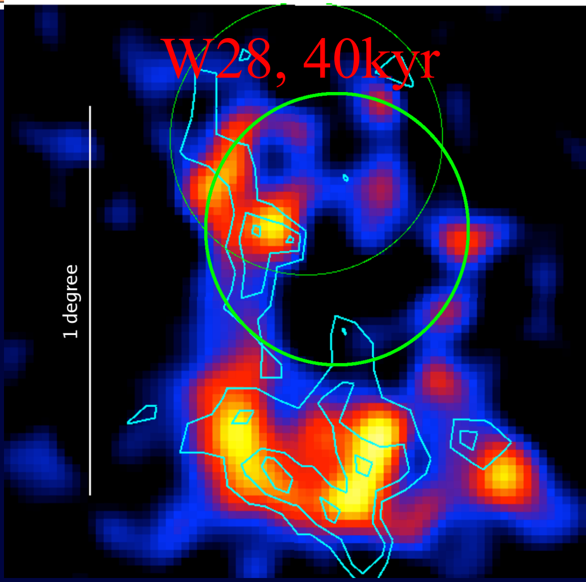
CR spectrum at Earth Credit Wikipedia



TeV SNRs - Young and middle-aged



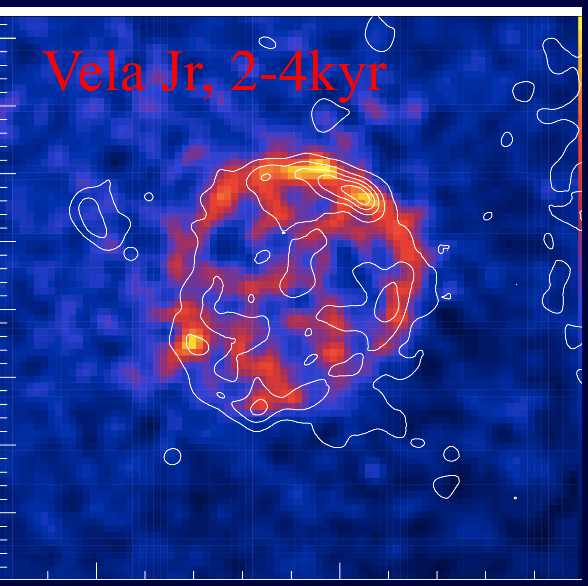
2006A&A...449..223A



2008A&A...481..401A

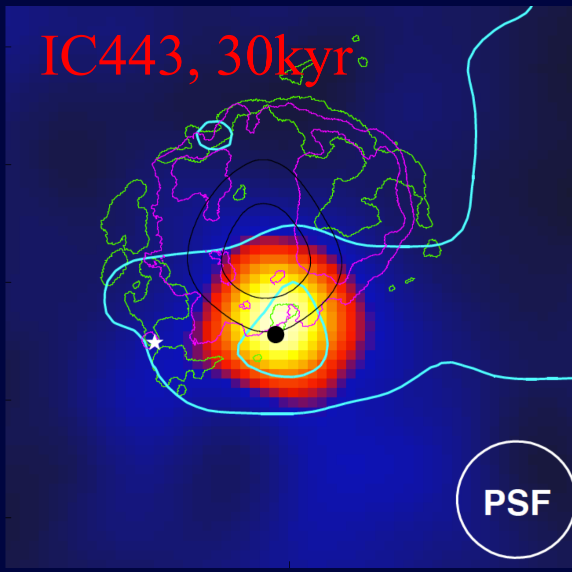
Active shock X-ray & γ-ray	No clear shock X-ray & γ-ray
Only highest energy CRs released	Most CRs released

VS



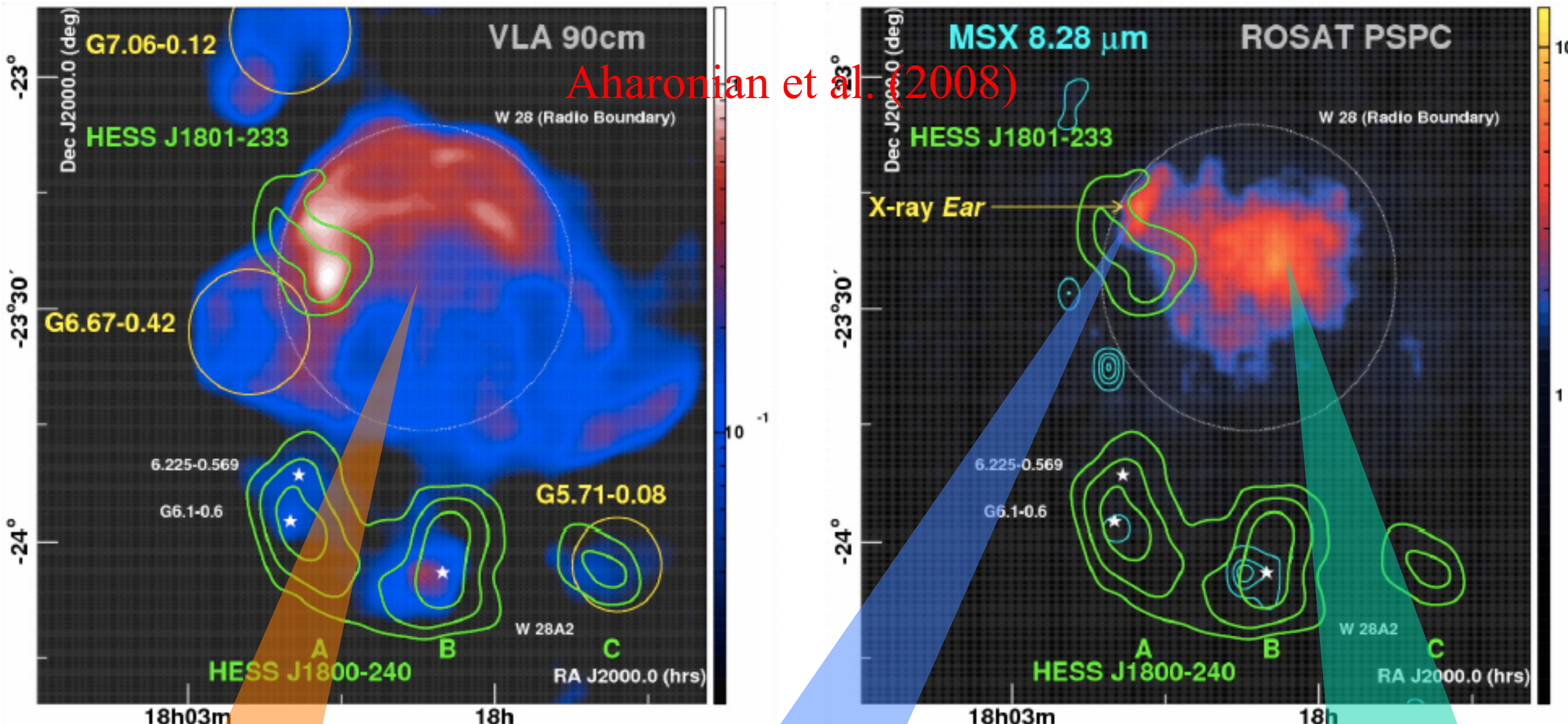
2007ApJ...661..236A

X-ray & TeV Matching	Cold gas & TeV Matching



2007ApJ, 664, L87

SNR W28 Radio & X-ray



Aharonian et al. (2008)

D~ 2kpc, with a radius of 13pc

~1keV 1Msun hot gas, ionization age ~>10 kyr, Zhou et. Al. 2016

~0.5keV 25Msun hot gas, ~ 30 kry, low elemental abundance. Zhou et al 2016

SNR W28 Masers

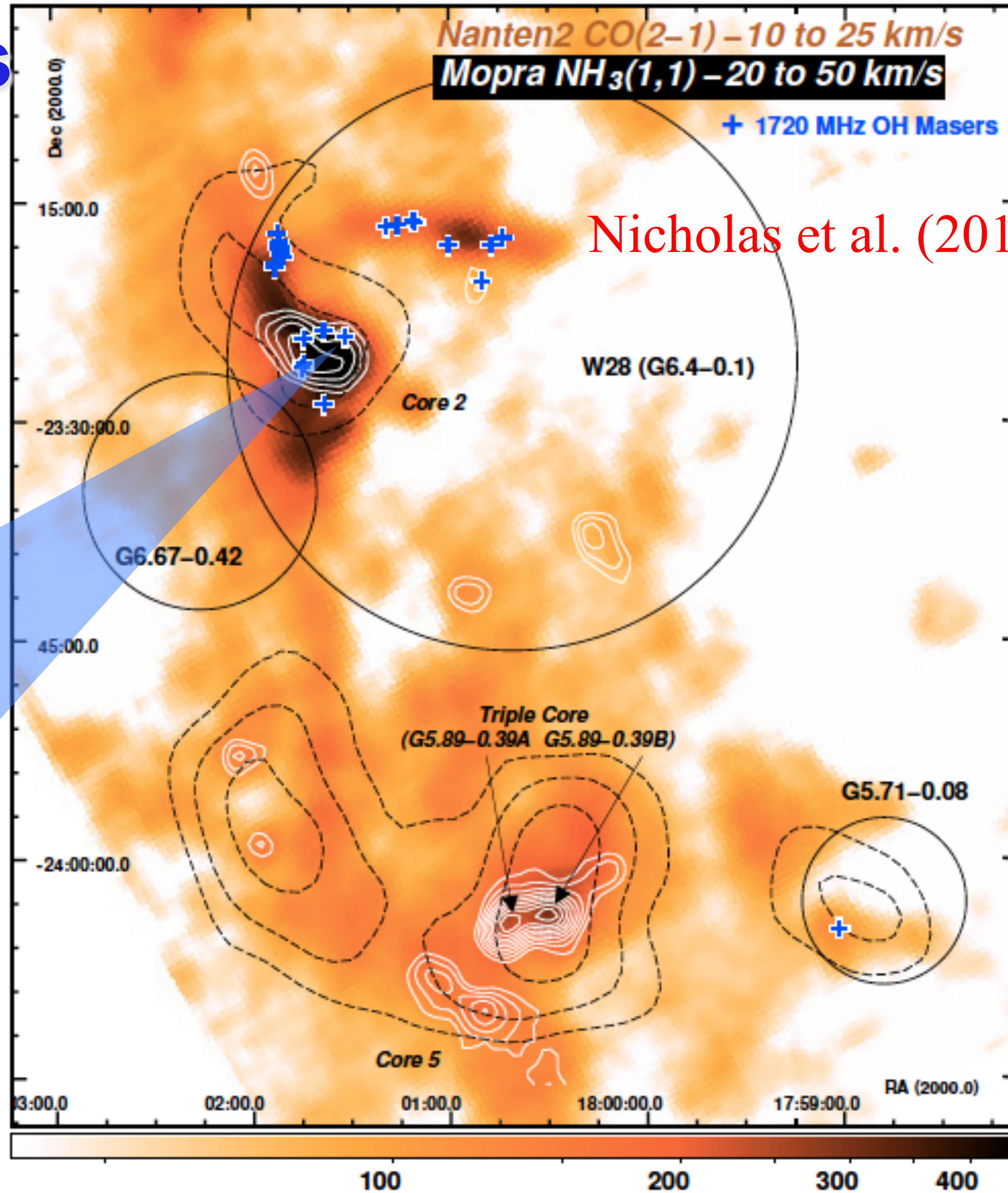
Clumps ~ $10^{3\text{-}5}$ cm^{-3}
Interclump medium ~ 5cm^{-3}

Masers as The shock-MC encounter evidence

& evidence of ionized MC by leaked <1GeV CRs

DCO^+/HCO^+ abundance ratios, with IRAM 30m telescope, by Vaupre2014, A&A,568, A50;

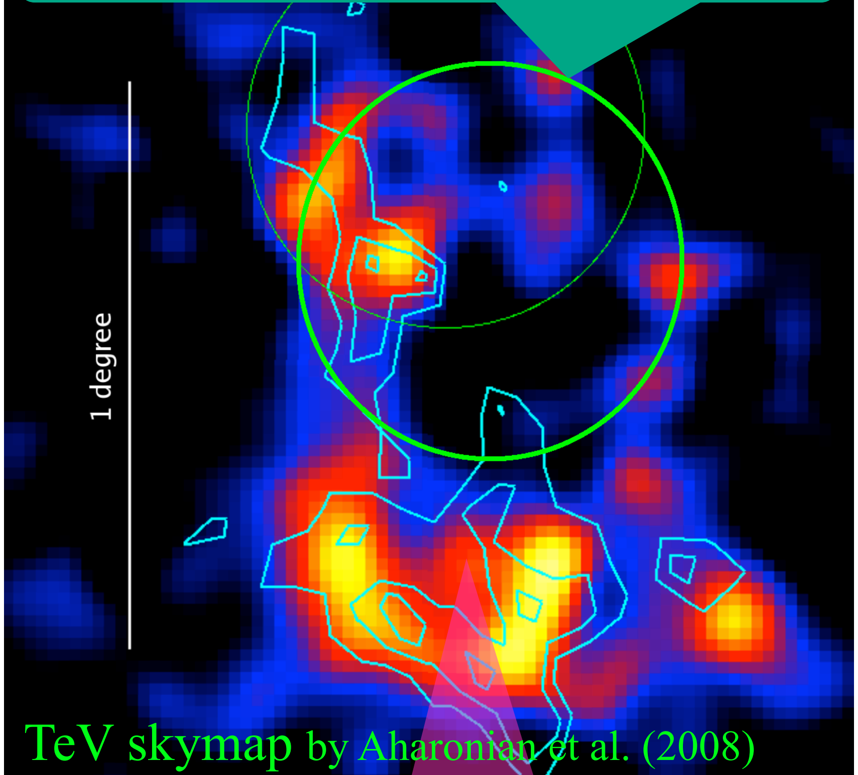
NH_3 lines, with Mopra radio telescope, by Maxted2016MNRAS462..532M;

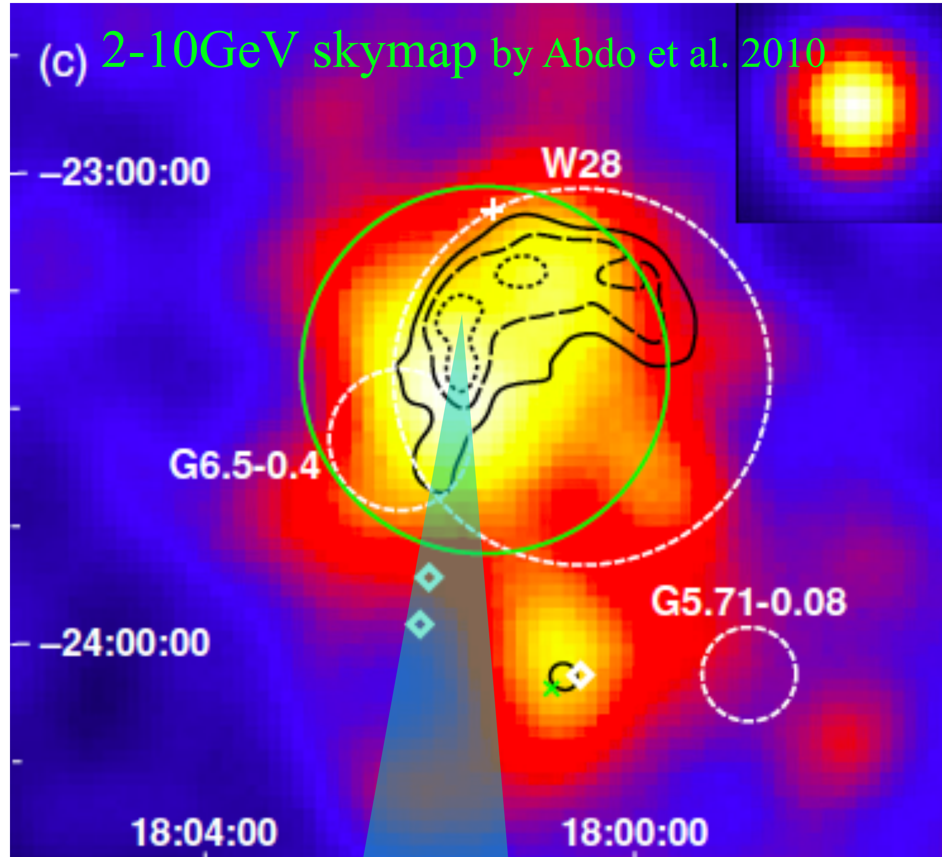


Nicholas et al. (2011)

SNR W28 TeV & GeV

Radio boundary of SNR W28

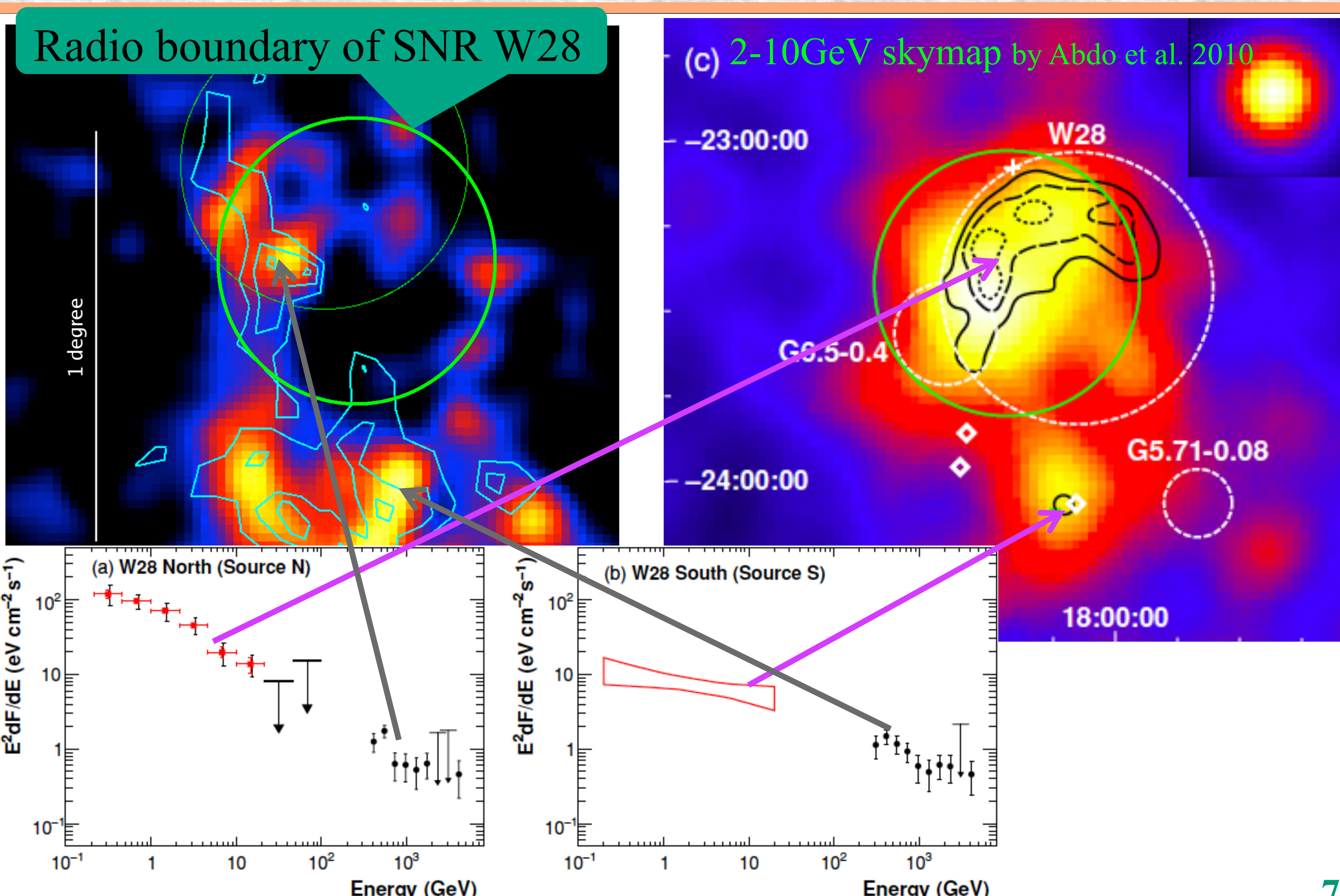


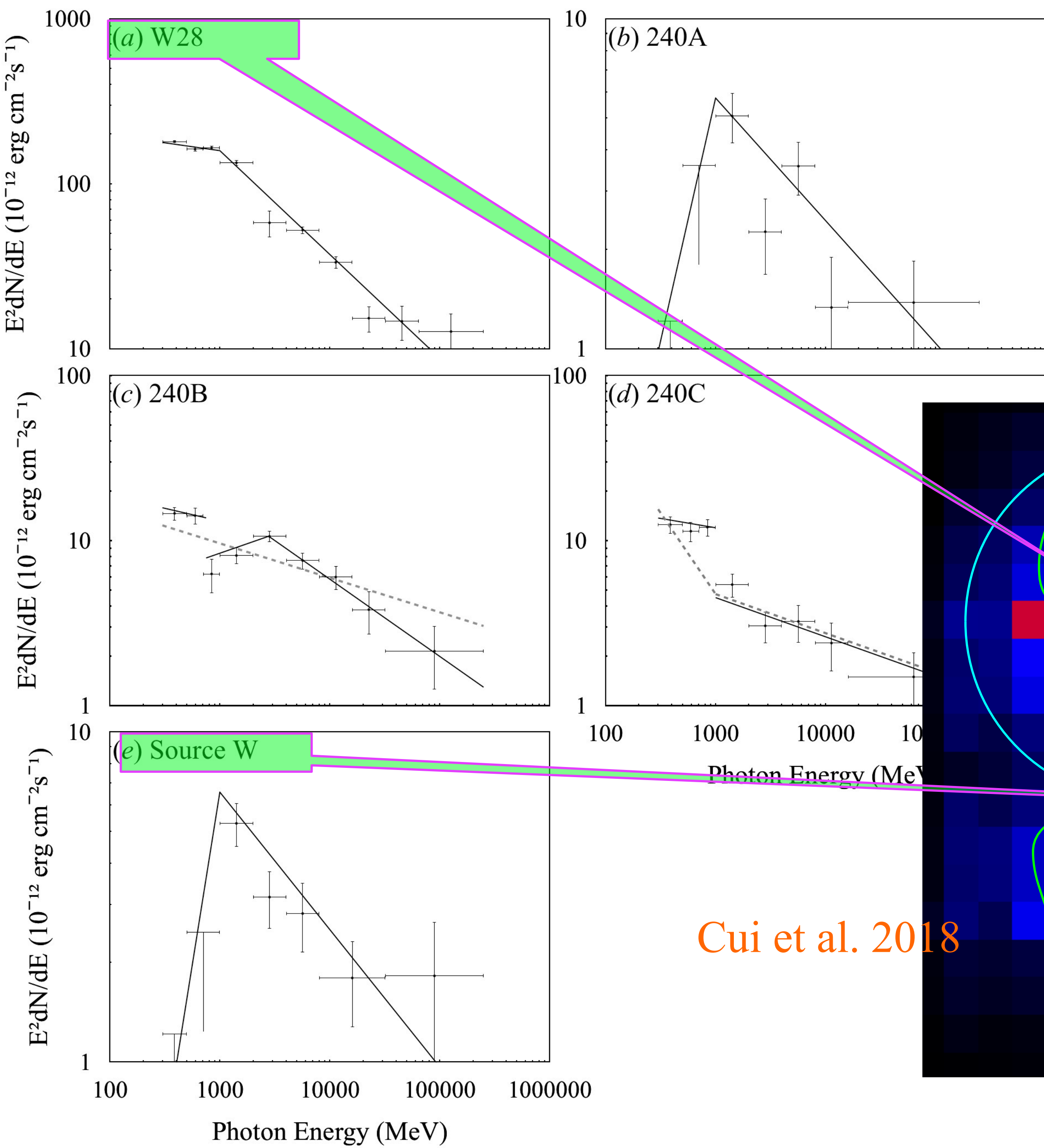


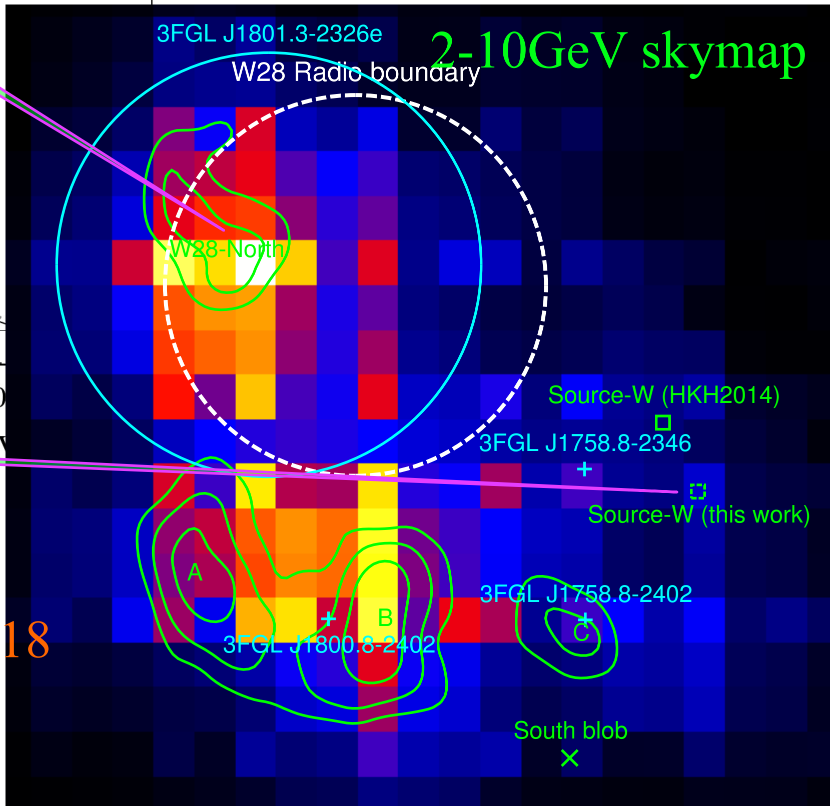
TeV CRs released in early stage diffuse Everywhere.

Part of the shock is stalled and the GeV CRs are leaking out.

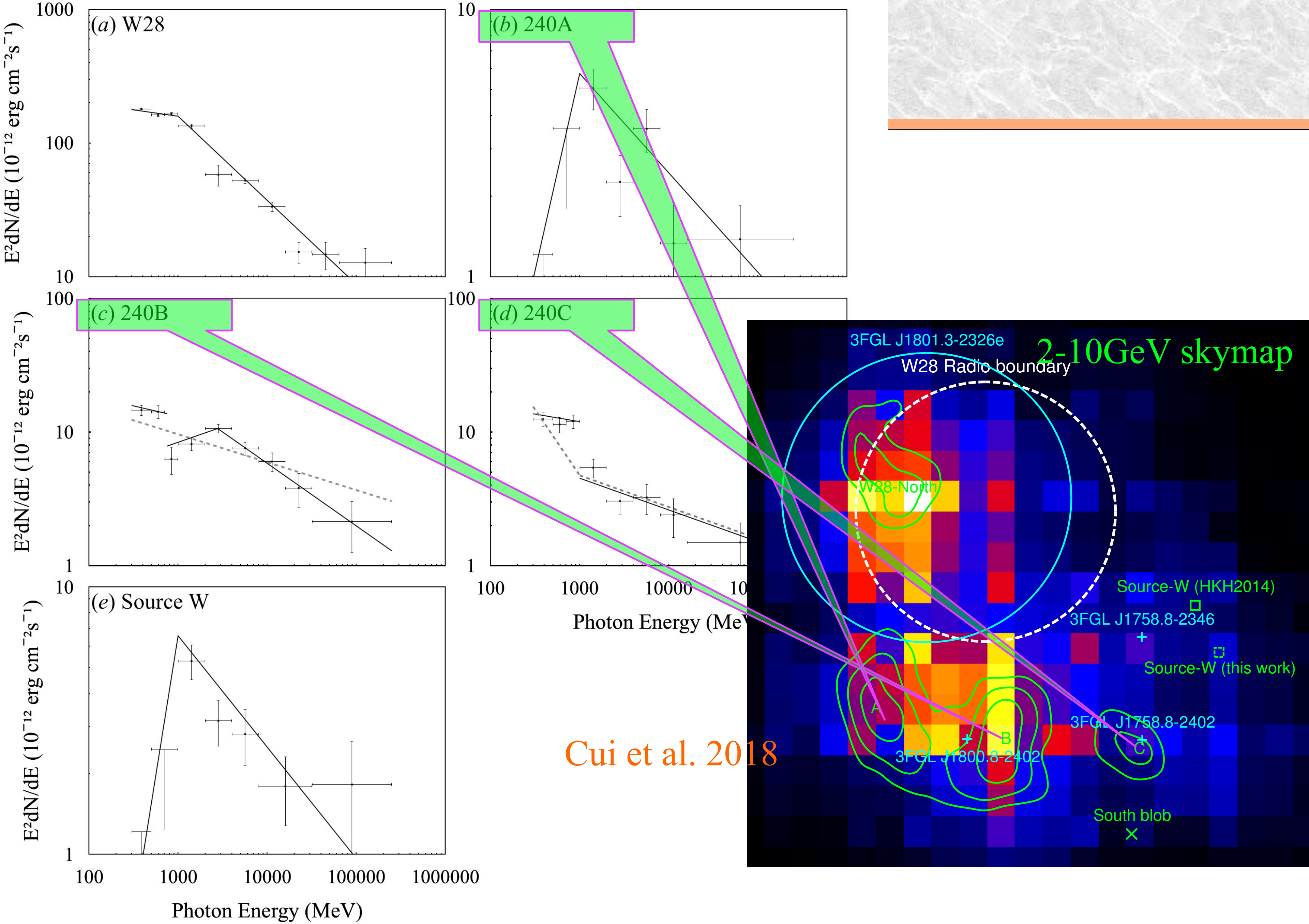
SNR W28 TeV & GeV



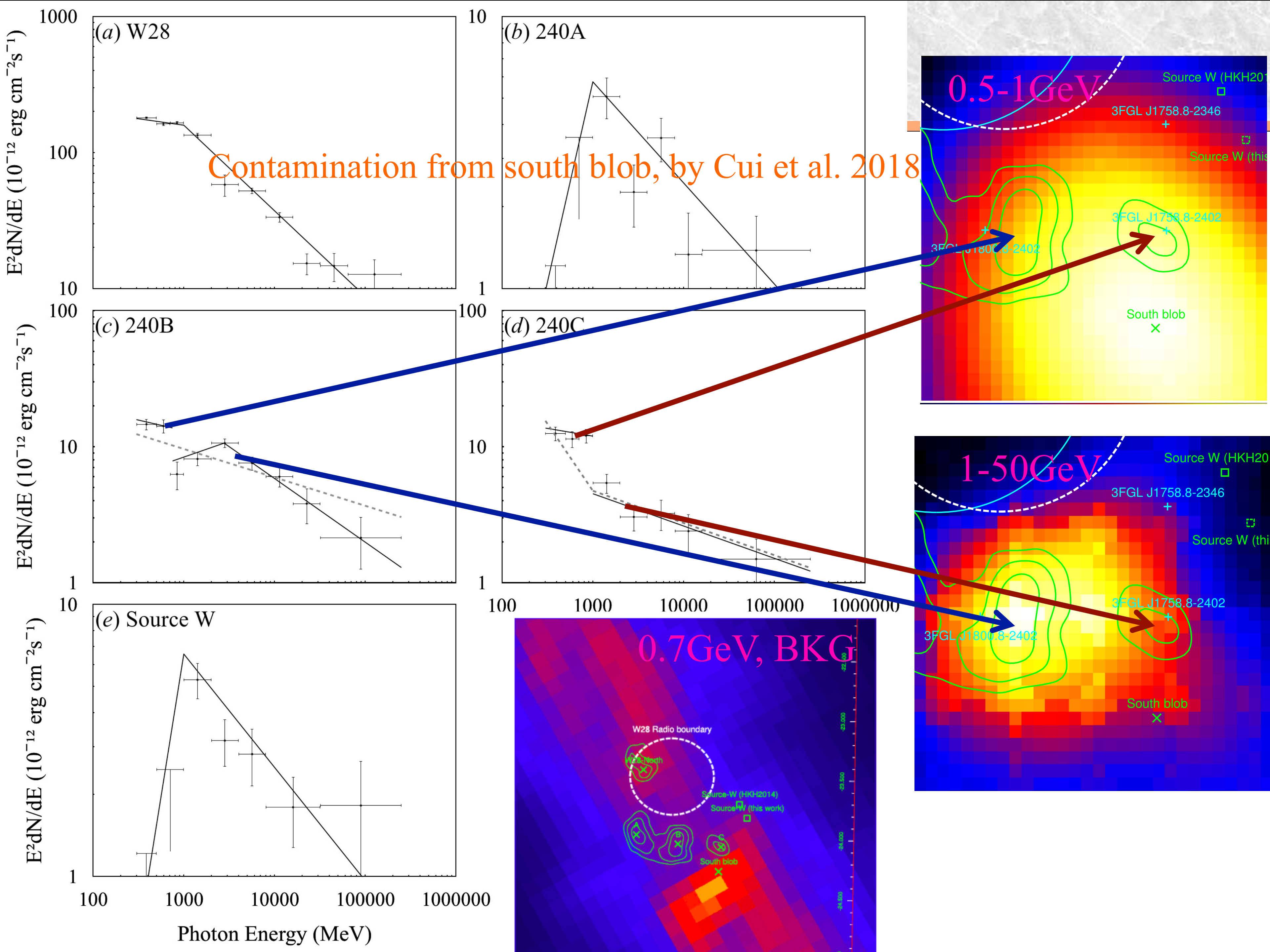




Cui et al. 2018

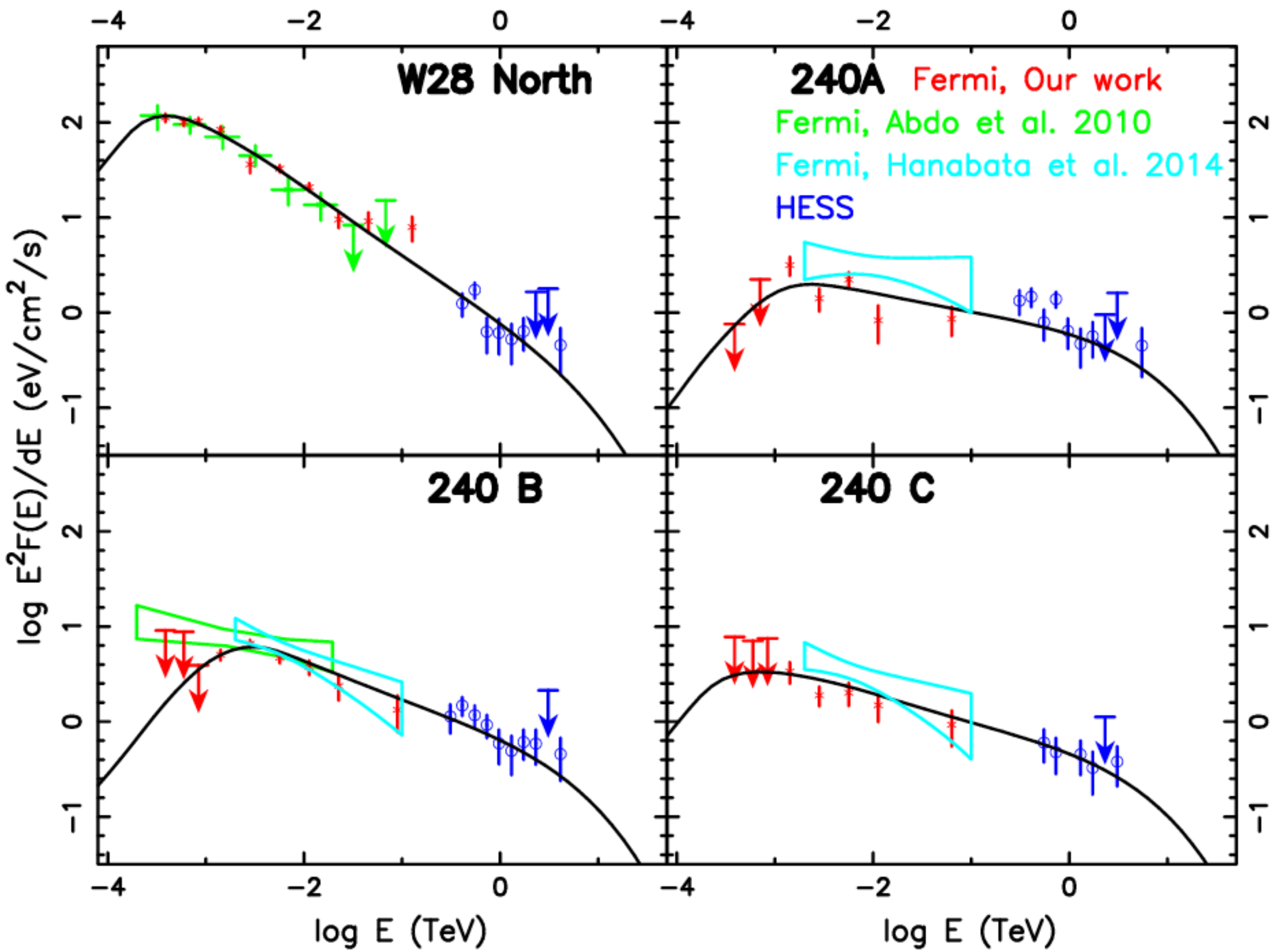


Cui et al. 2018



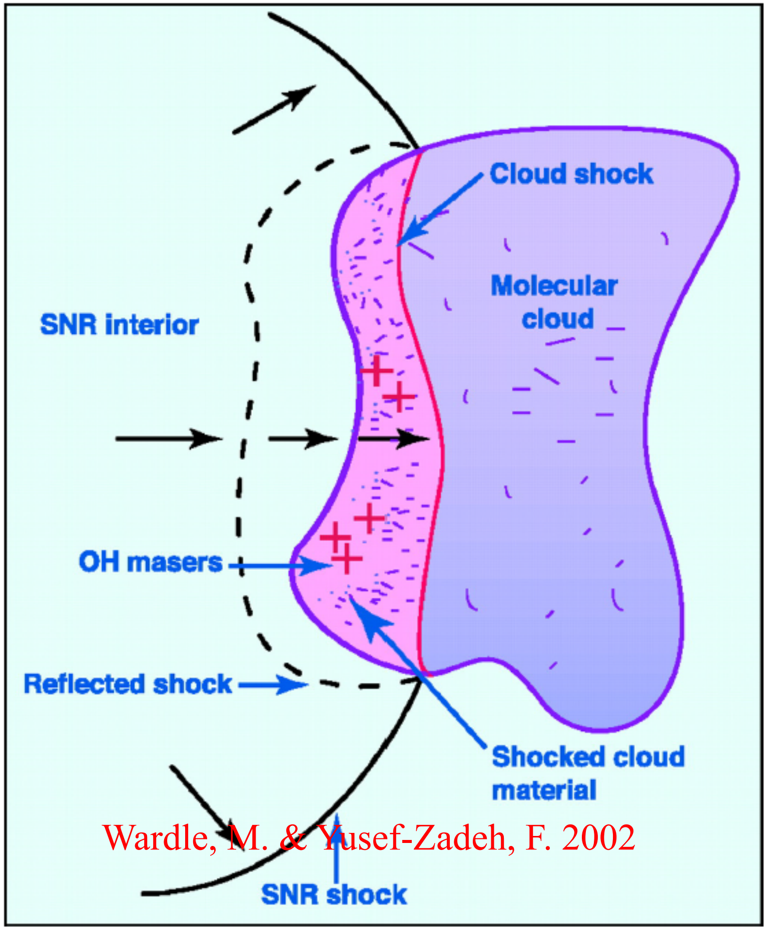
Contamination from south blob, by Cui et al. 2018
(a) W28
(b) 240A
(c) 240B
(d) 240C
(e) Source W
E²dN/dE (10⁻¹² erg cm⁻²s⁻¹)
Photon Energy (MeV)
100
1000
10000
100000
1000000
0.5-1GeV
1-50GeV
0.7GeV, BKG
Source W (HKH2014)
Source W (this work)
3FGL J1758.8-2346
3FGL J1758.8-2402
3FGL J1800.8-2402
South blob
W28 Radio boundary
W28-North

Compare & Pre-model fitting



Leaking model

Two main ways (models) for a CR to leave the SNR,
1. Escape from a strong shock as a high energy CR.
2. Set free when the strong shock is no more.



Wardle, M. & Yusef-Zadeh, F. 2002

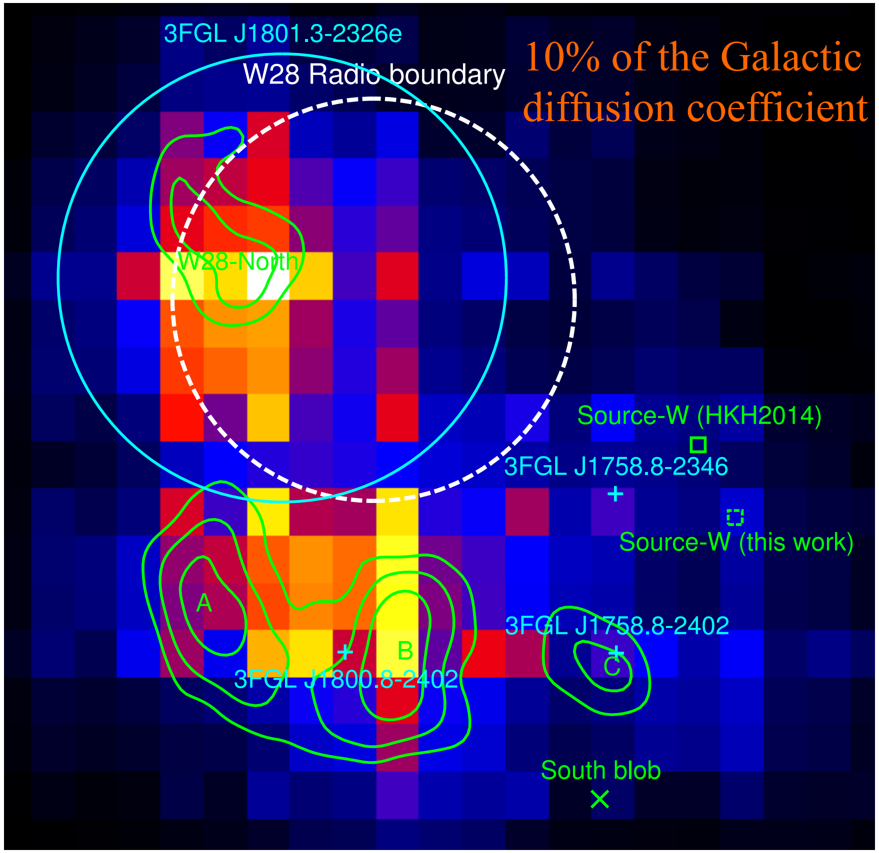
Gabici et al. (2010) , Li & Chen (2010) ,
Ohira et al. (2011) , and Tang (2017) :
Model 1 + spherical symmetric ➔
explain North & 240B (Abdo et al. 2010)
Ohira et al. (2011) :
Model 2 + spherical symmetric ➔
explain North & 240B

Hanabata et al. (2014) : the Fermi-LAT results at 240 A, C and Source W.

MC-N is partially colliding with SNR, and it is too big for the shock to swallow it unharmed.
When the shock at W28-North is stalled, the CRs down to <1GeV can be set free. X~10%

GeV-TeV CRs released from the SNR W28

	MC-N ($5\,M_4$[a])	MC-A ($4.3\,M_4$)	MC-B ($6\,M_4$)	MC-C ($2\,M_4$)
		Damping		
SNR center	13 pc	35 pc	31 pc	27 pc
W28-North	0~1 pc	37 pc	29 pc	28 pc
		Non-damping		
SNR center	13 pc	35 pc	28 pc	27 pc
W28-North	0~1 pc	33 pc	26 pc	25 pc

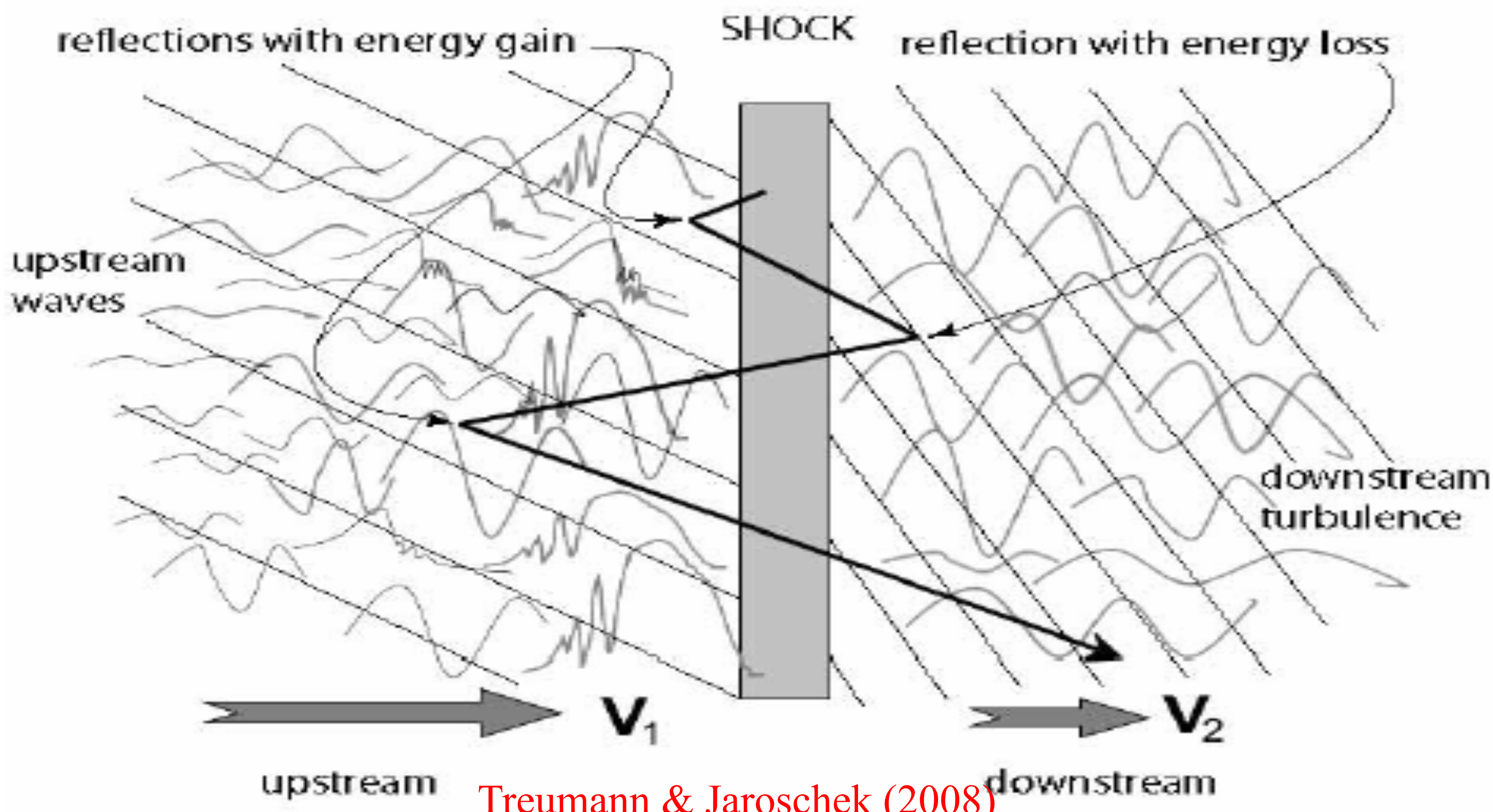


Run-away CRs from shock upstream ➔ dominating TeV band

Leaked CRs from W28-North 12kyr ago ➔ dominating GeV band (North)

Galactic CR sea at 5kpc from GC ➔ dominating <10GeV band for 240ABC

CR acceleration at collisionless shock



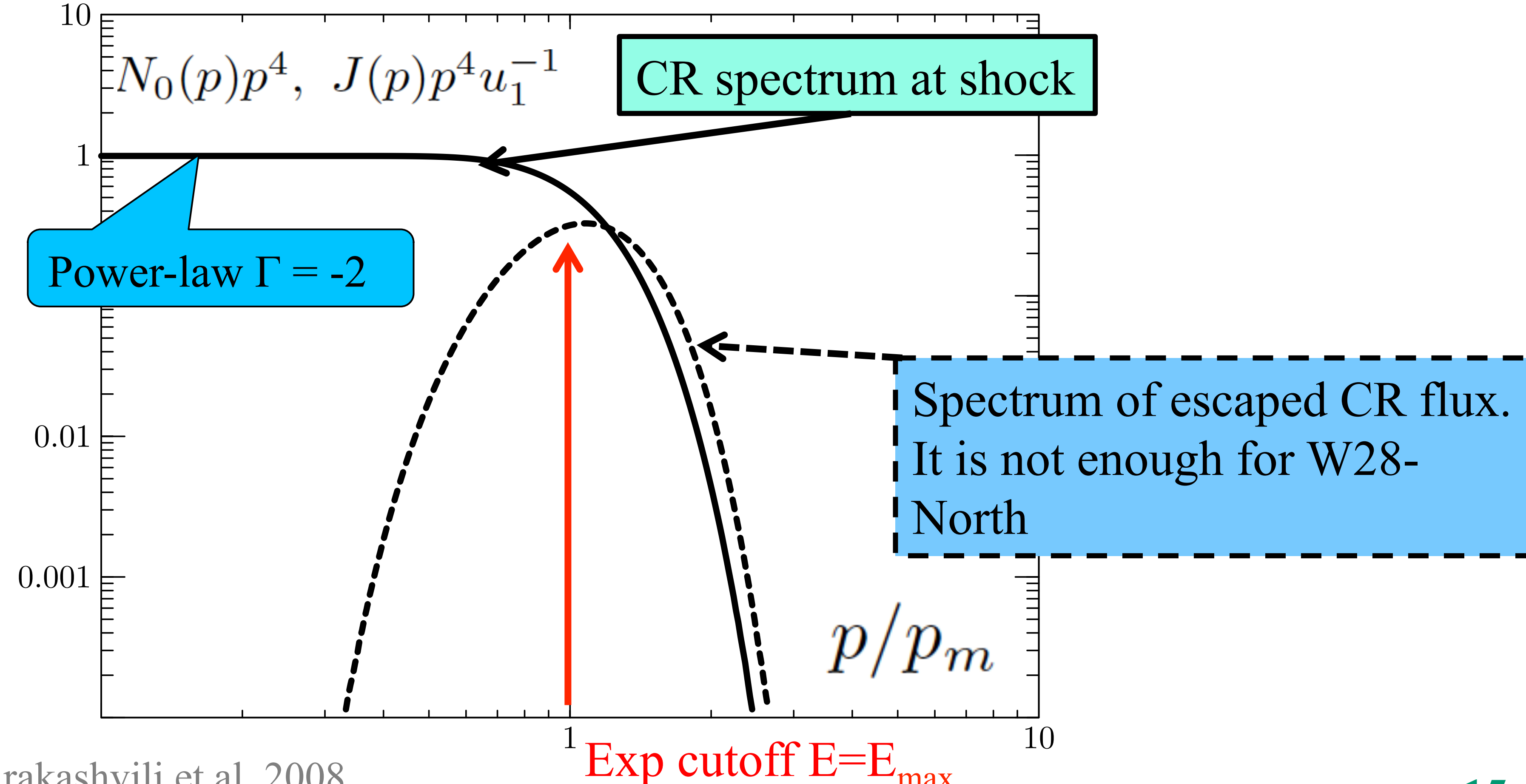
Treumann & Jaroschek (2008)

Particles swept away by the downstream flow ➔ power-law $\Gamma \sim -2$.
Particles escape from the upstream ➔ Exp cutoff E_{max} .
Big size + high velocity ➔ High E_{max}

Trapping the CRs at the shock

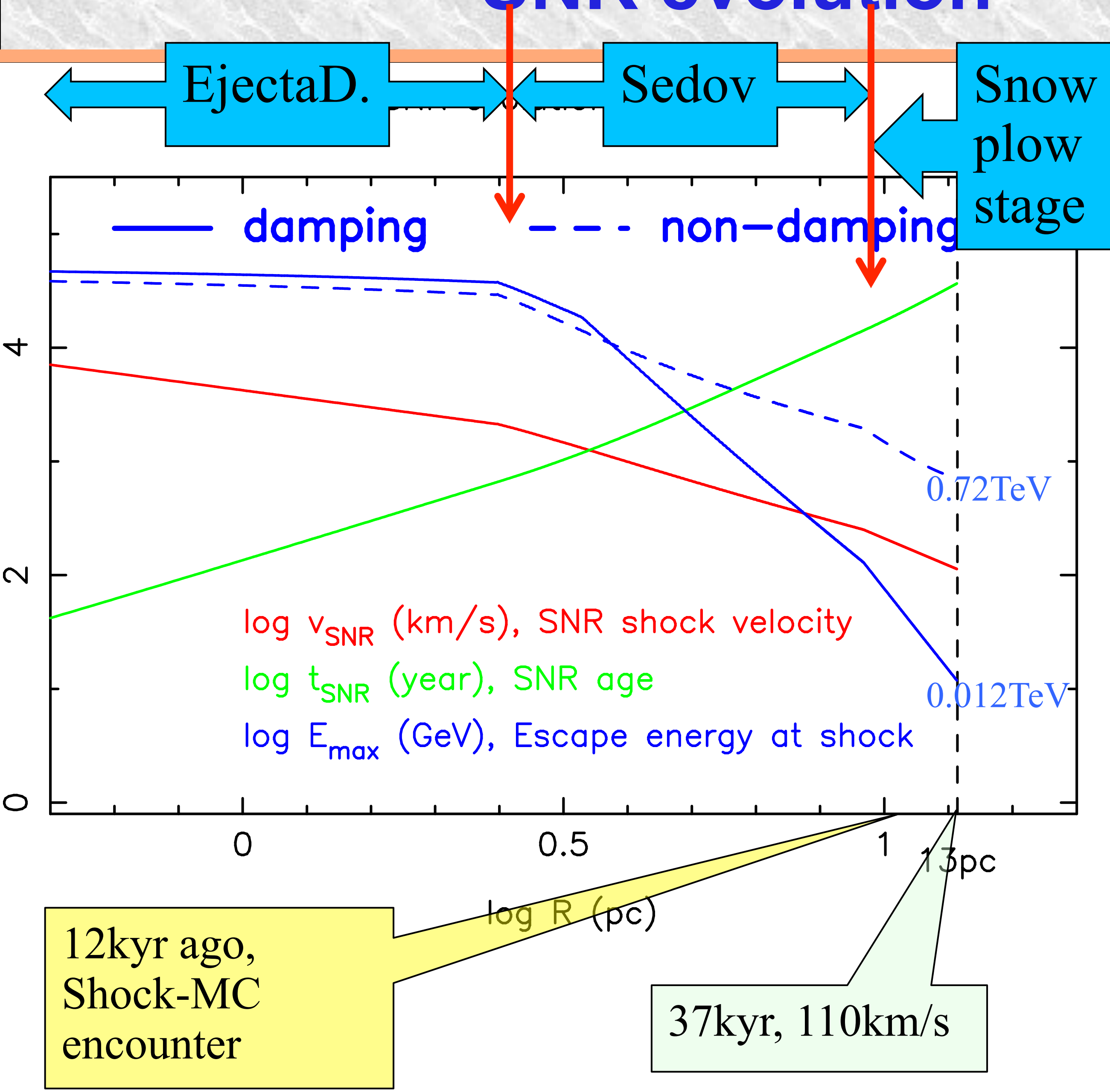
Non-resonant instability ➔ quickly amplify the magnetic turbulence in upstream

This theory is well established in both numerical simulation and analytical approximation. (Bell 2004; Zirakashvili & Ptuskin 2008)



Zirakashvili et al. 2008

SNR evolution

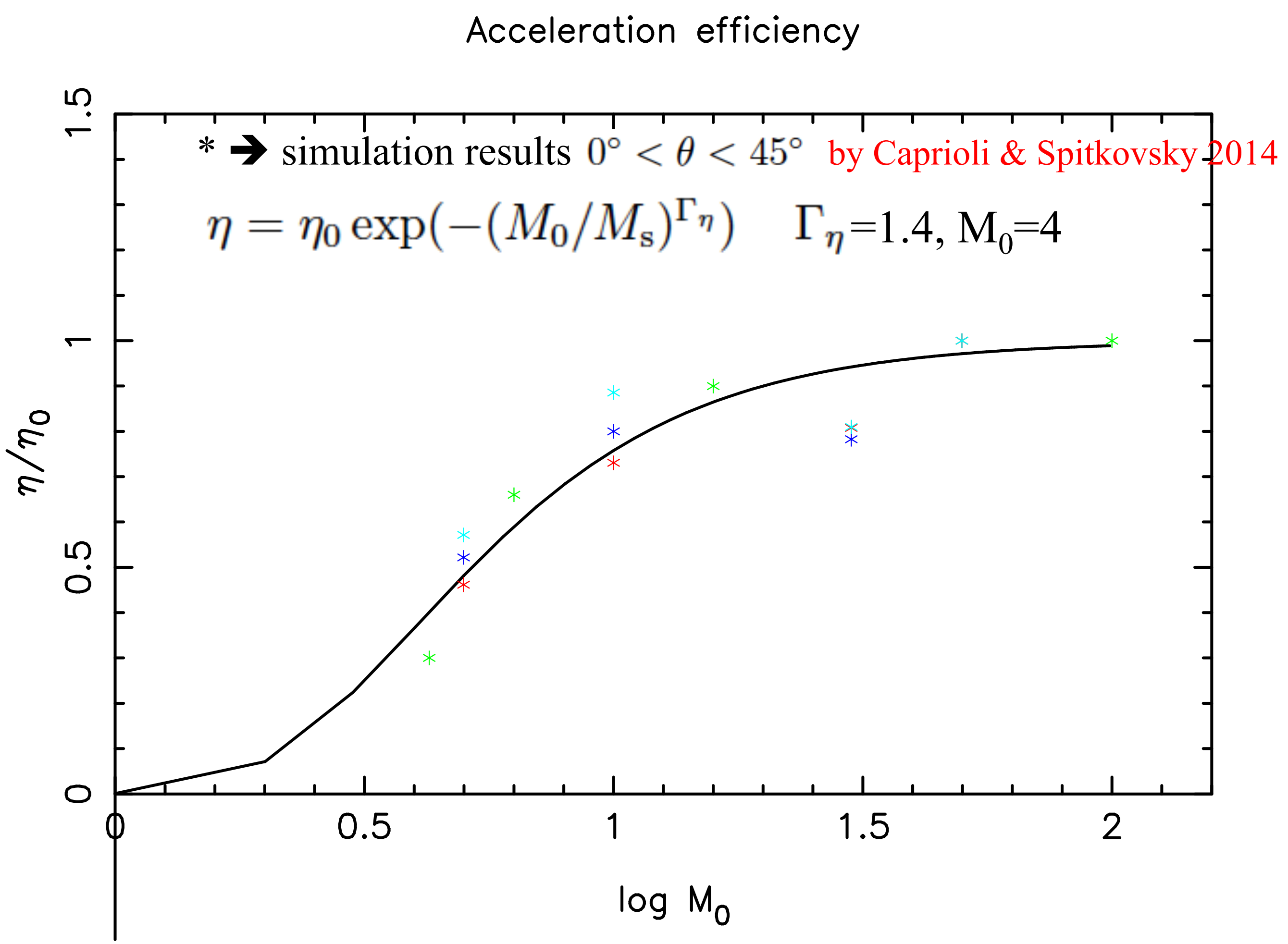


Assuming a typeIIP SN
8Msun scenario
6Msun ejecta mass

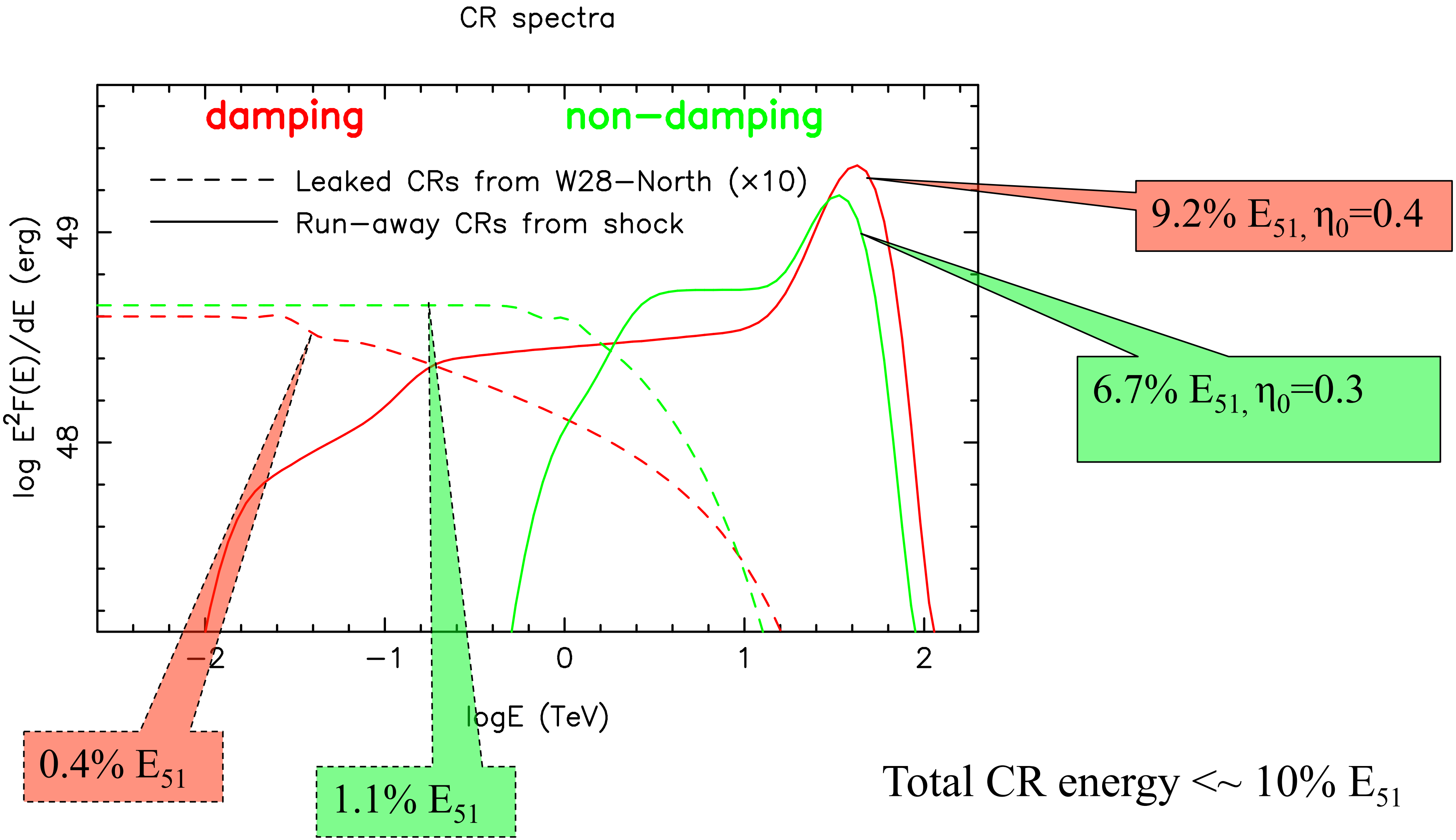
Expanding inside Interclump medium ~5cm^{-3}

Old SNR➔
Damping of the magnetic waves by neutrals at upstream.
We use a Relationship from O'C Drury et al. 1996, Zirakashvili et al 2017.

Old SNR ➔ lower acceleration efficiency

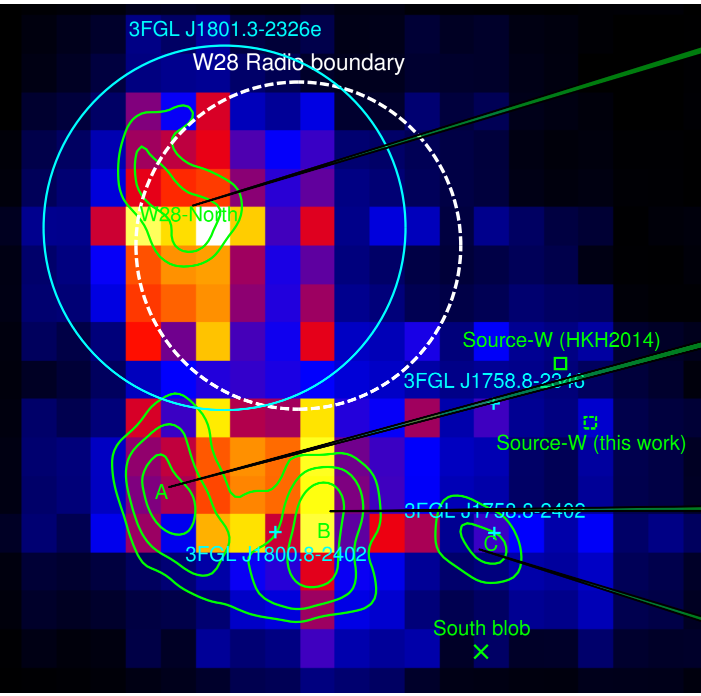


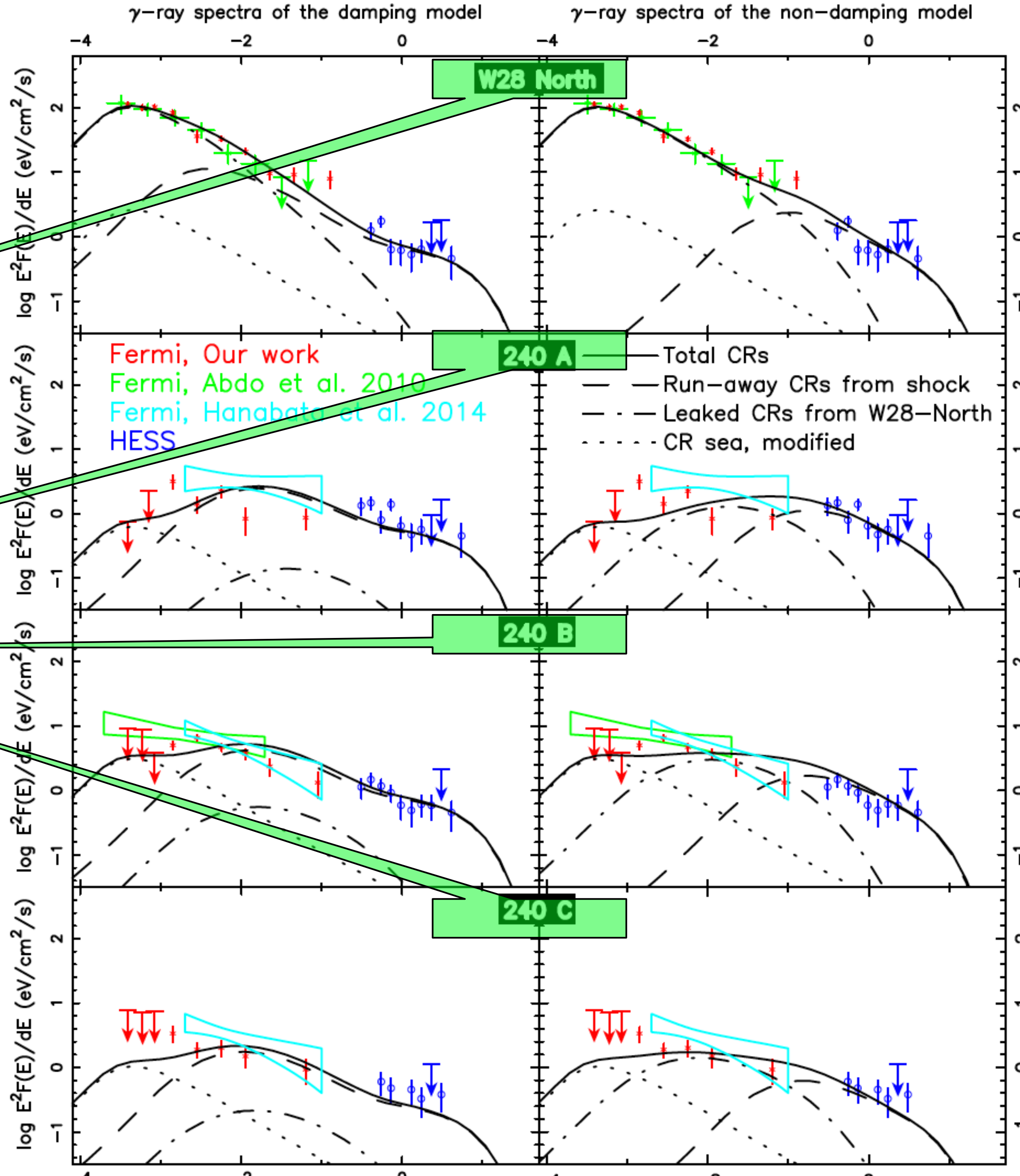
Run-away CRs VS Leaked CRs



Total CR energy <~ 10% E_{51}

Averaged CR sea

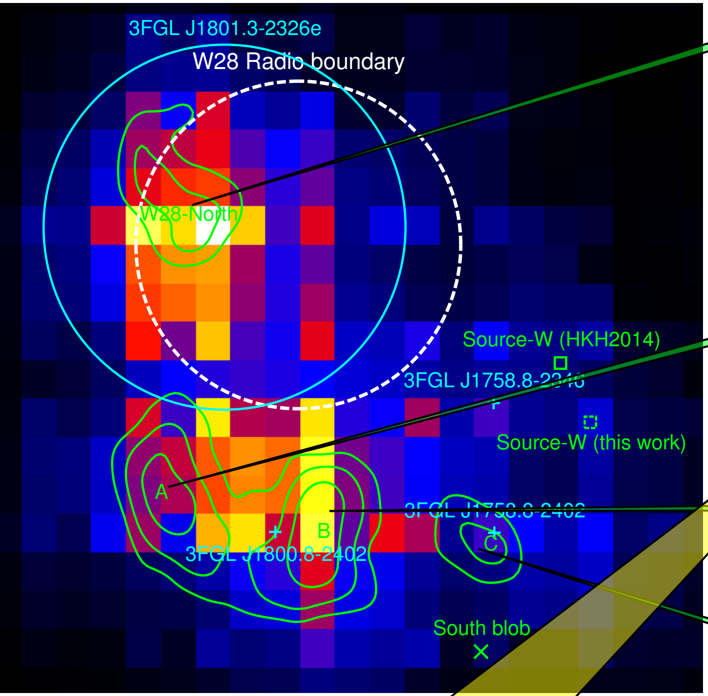


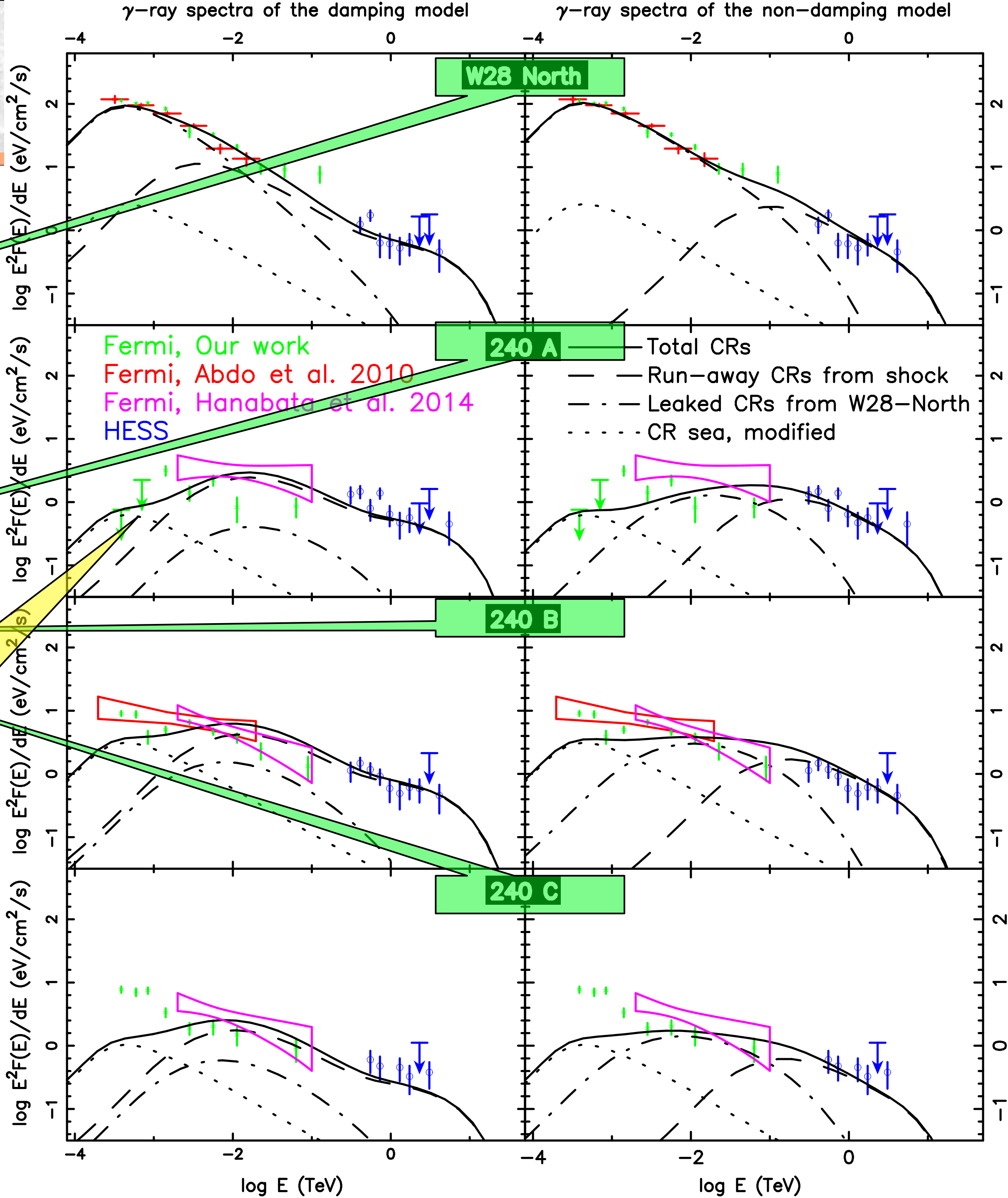


Homogeneous diffusion coefficient used here.

10% of the Galactic one.

Clumpy CR sea





240A need 14% of the averaged CR sea.
If we put MC-A further from Earth ➔ closer to GC ☹

Summary

1. >2GeV Fermi skymap match well the TeV skymap & <1GeV south blob found.

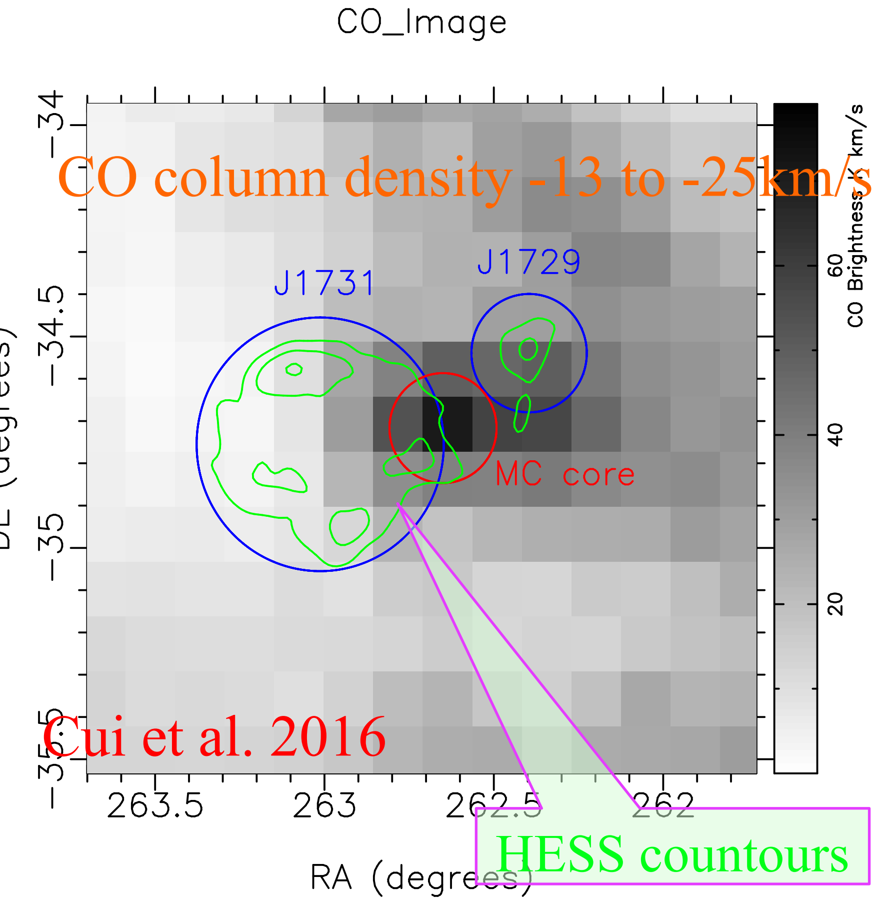
2. Under one SNR/environment model.

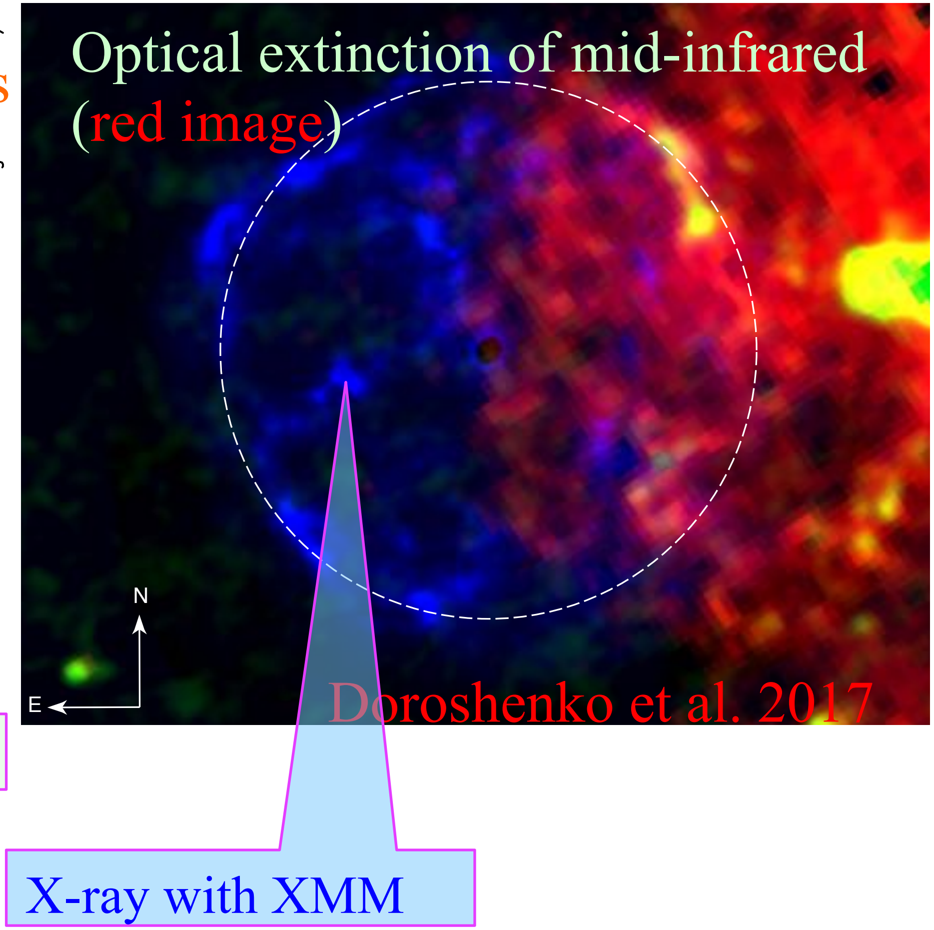
Leaked CRs from broken shell + escaped CRs from strong shock ➔ can roughly explain the GeV-TeV observation.

3. Low detection at 240 A assumes an inhomogeneous CR background. Or the uncertainty of the diffuse background?

We are applying this test to Young SNRs (Emax is high) .

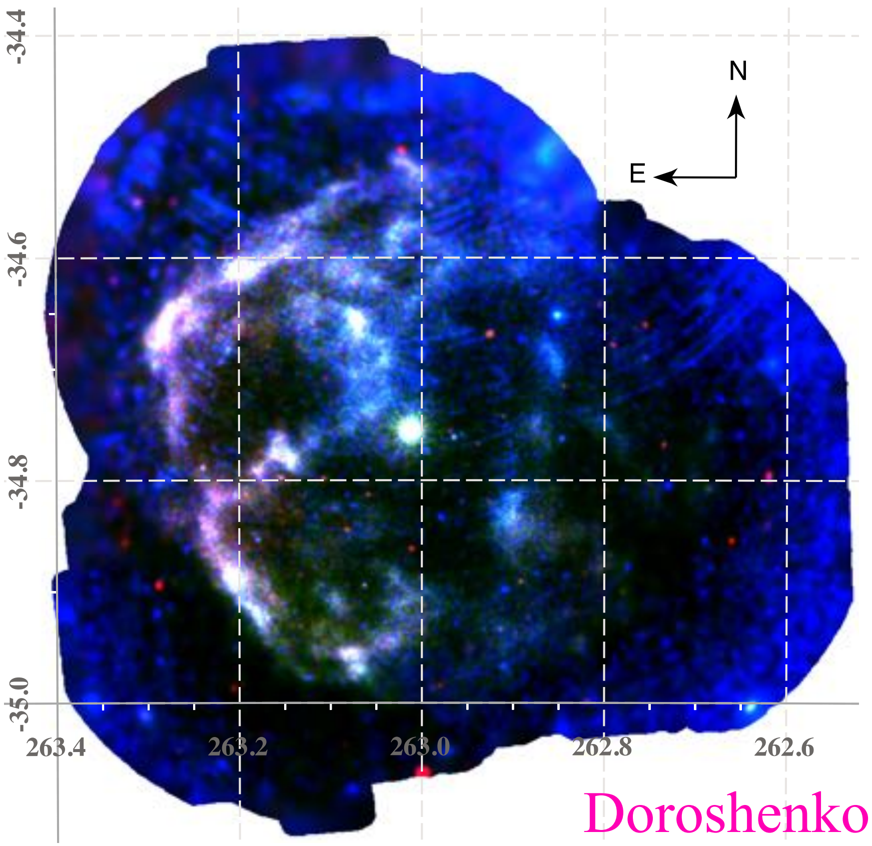
Giant Molecular cloud in front of the SNR

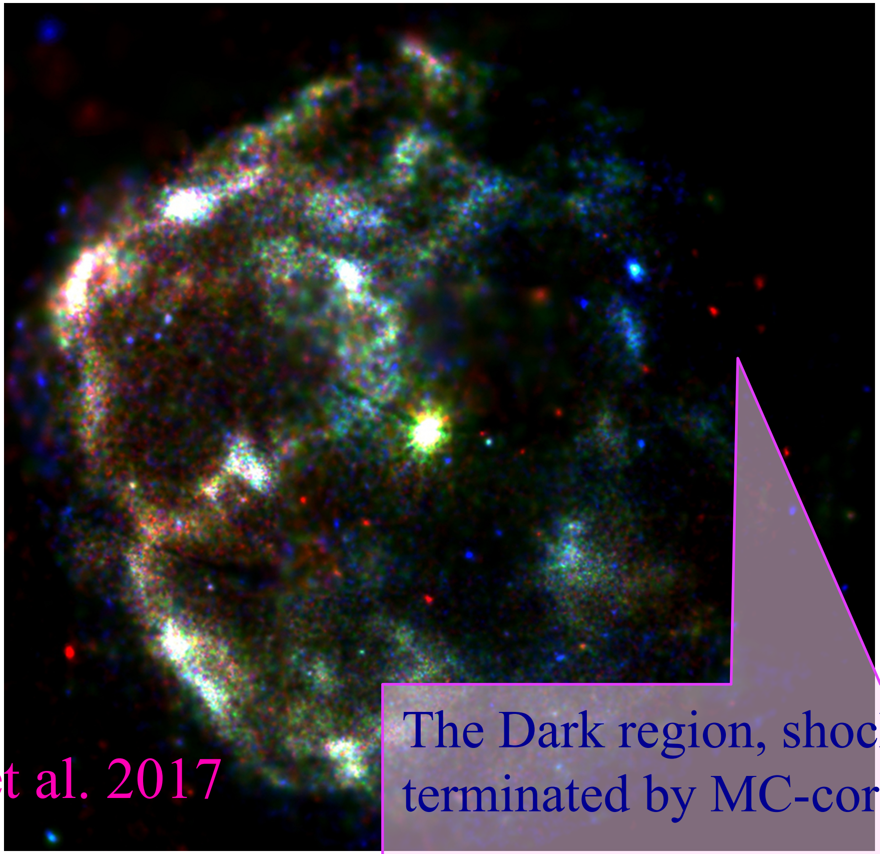




Correction of p+, stray light

0.4-1.8KeV, 1.8-2.8KeV, 2.8-10KeV

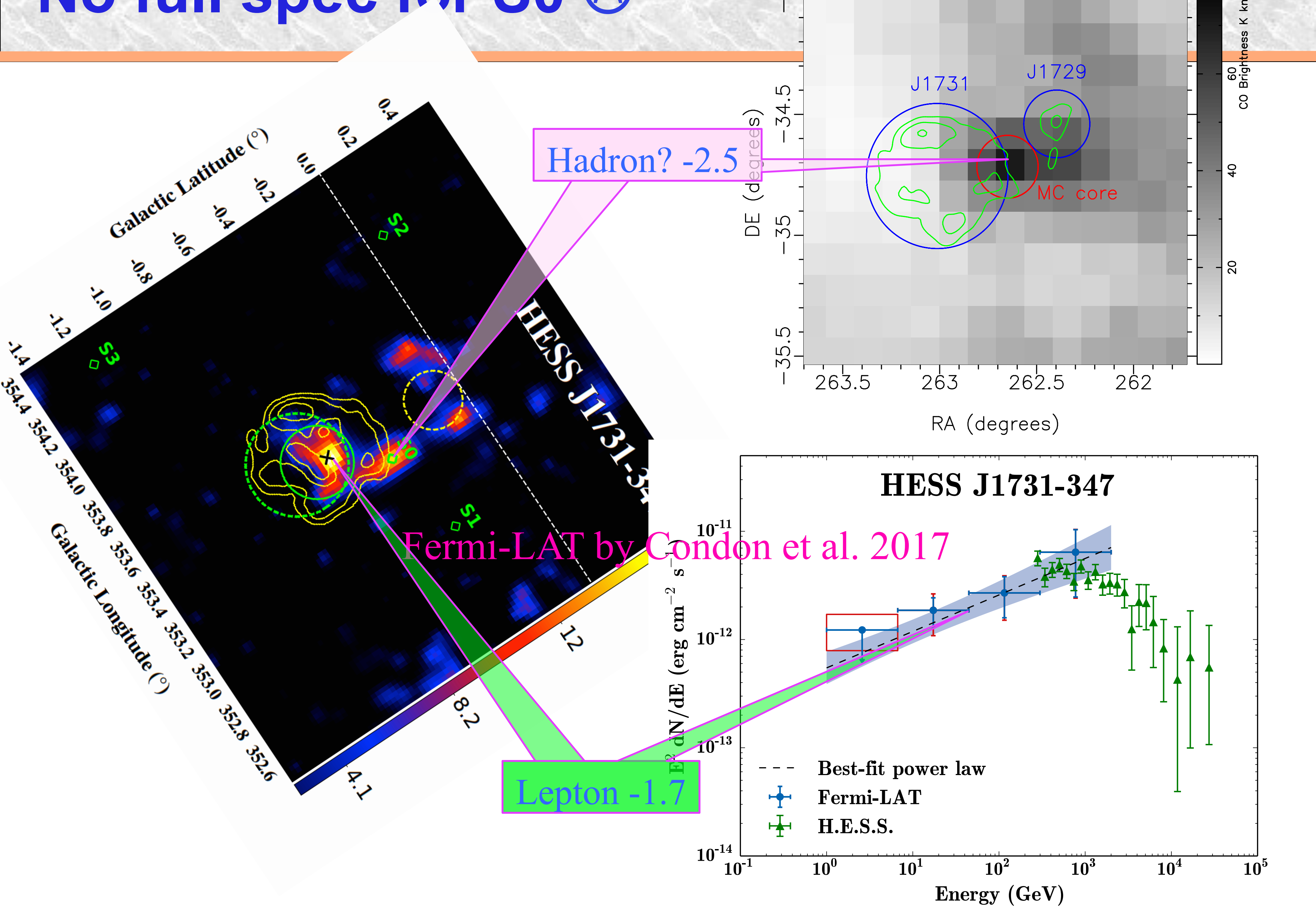




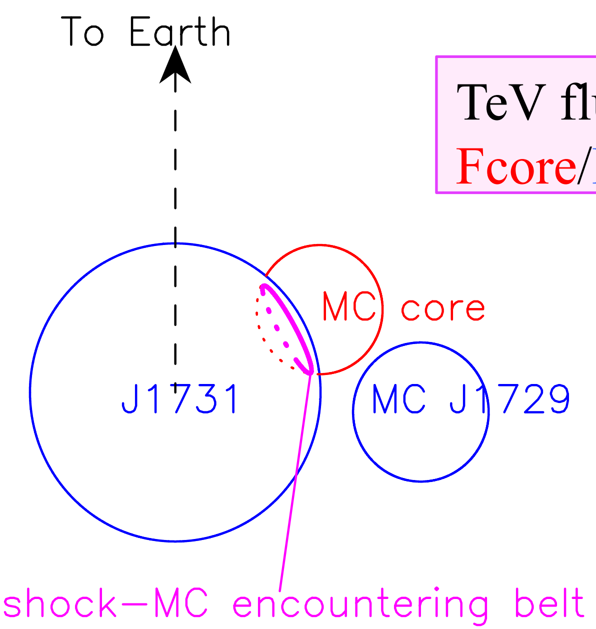
Doroshenko et al. 2017

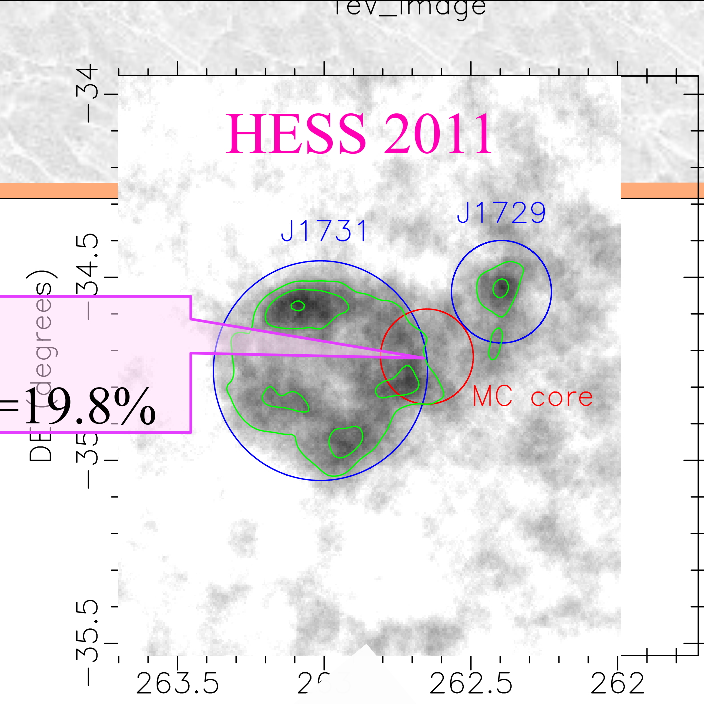
The Dark region, shock terminated by MC-core?

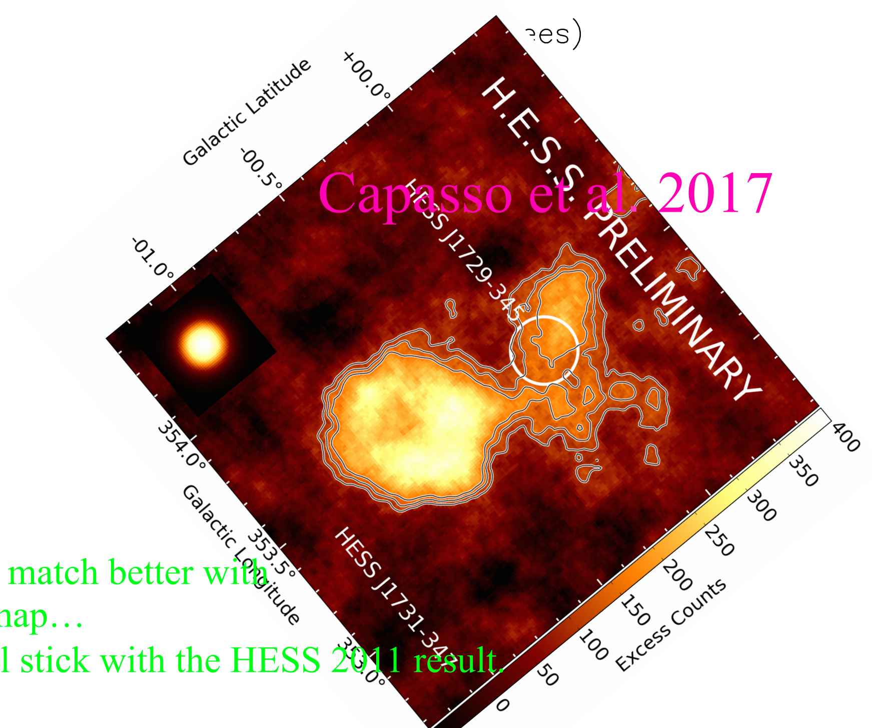
No full spec for S0 ☹



MC-core hitting SNR





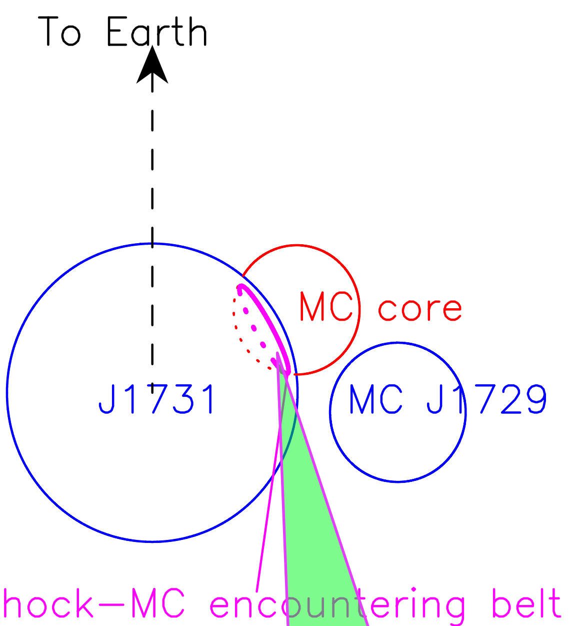


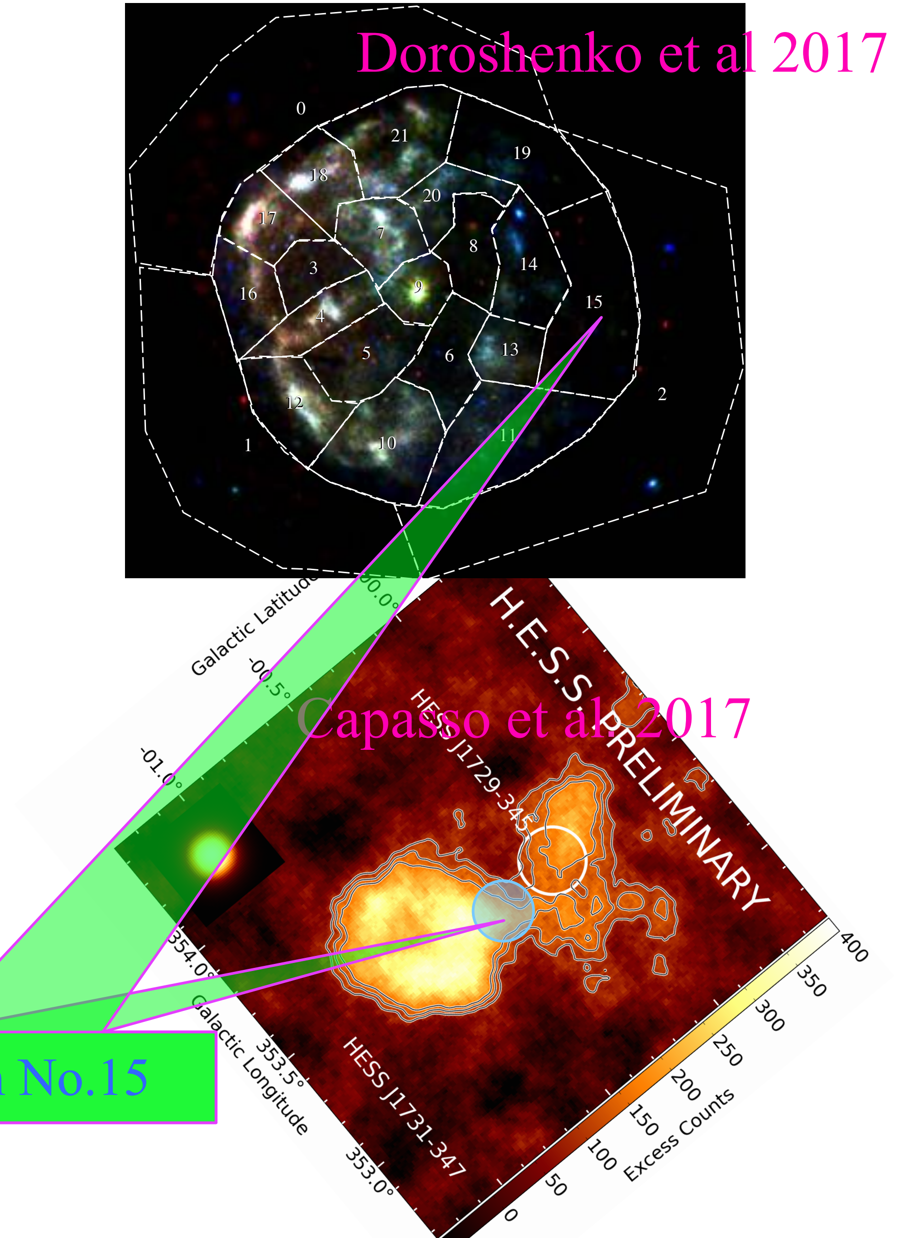
SNR J1731 is too young, <~5kyr, shock−MC encounter should NOT be seen as an instantaneous event.

SNR gradually swallows MC-core.
Encountering belt size slowly increase.
GeV CRs released at the encountering belt.

2017 HESS skymap match better with the CO and CS skymap…
But in paper, we will stick with the HESS 2011 result.

The Dark Region - No.15, but Shine brightly in GeV-TeV.





MC-core's size and shape are free parameters

The hadronic Region No.15

Any ionization proof in MC-core?

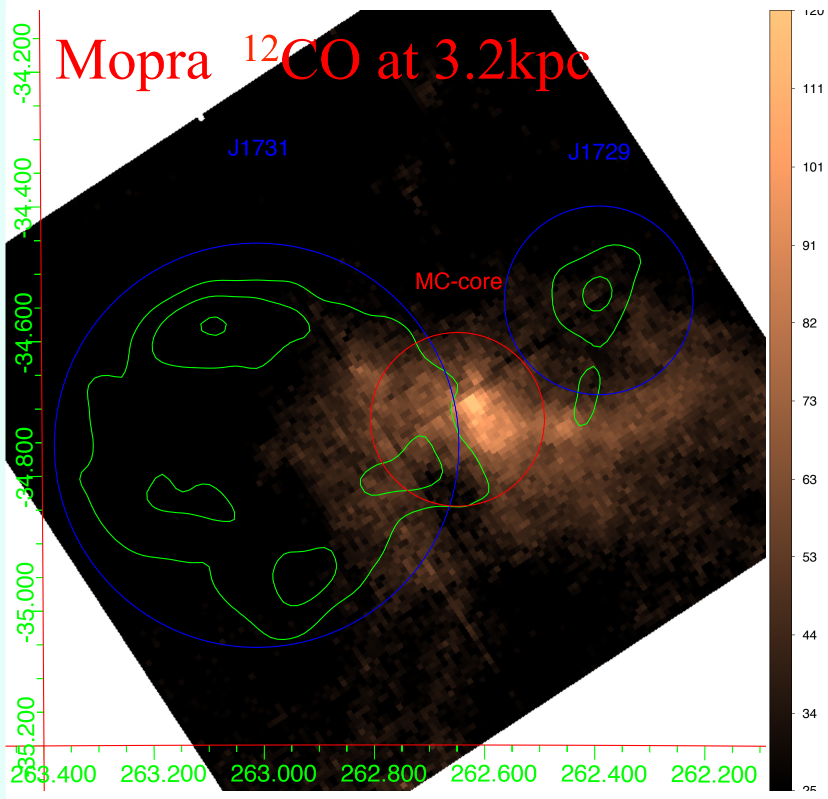
MeV - GeV Cosmic Rays could be injected into MC-core and ionize the molecular there.

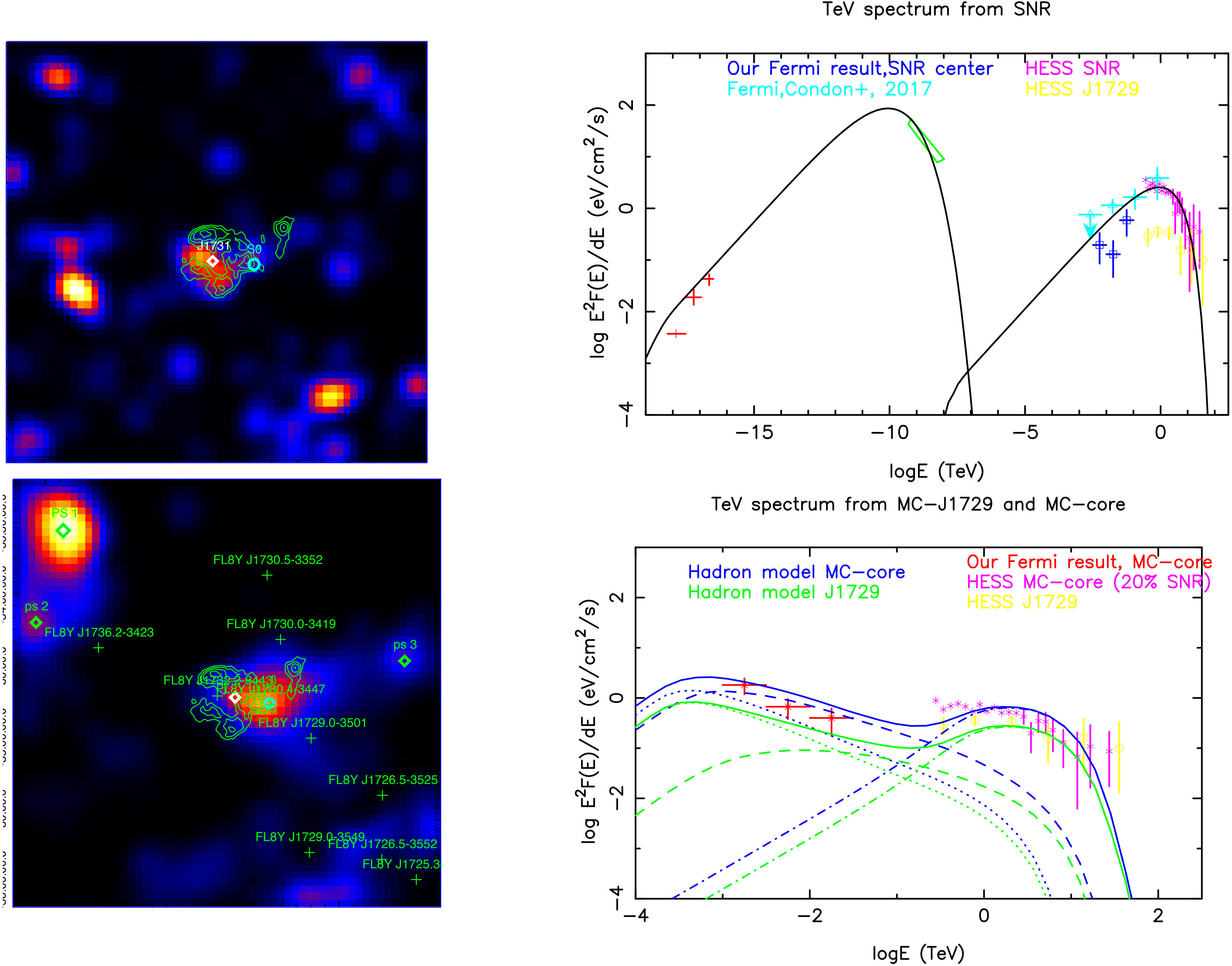
Other sources with successful ionization hunt

1. H_3^+ absorption features for SNR IC 443, with Near Infrared Echelle Spectrograph at the W. M. Keck Observatory, and the Infrared Camera and Spectrograph at the Subaru Telescope, by Indriolo 2010ApJ...724.1357I;

2. DCO^+/HCO^+ abundance ratios for SNR W28, with IRAM 30m telescope, by Vaupre2014, A&A,568, A50;

3. NH_3 lines for SNR W28, with Mopra radio telescope, by Maxted2016MNRAS.462..532M;



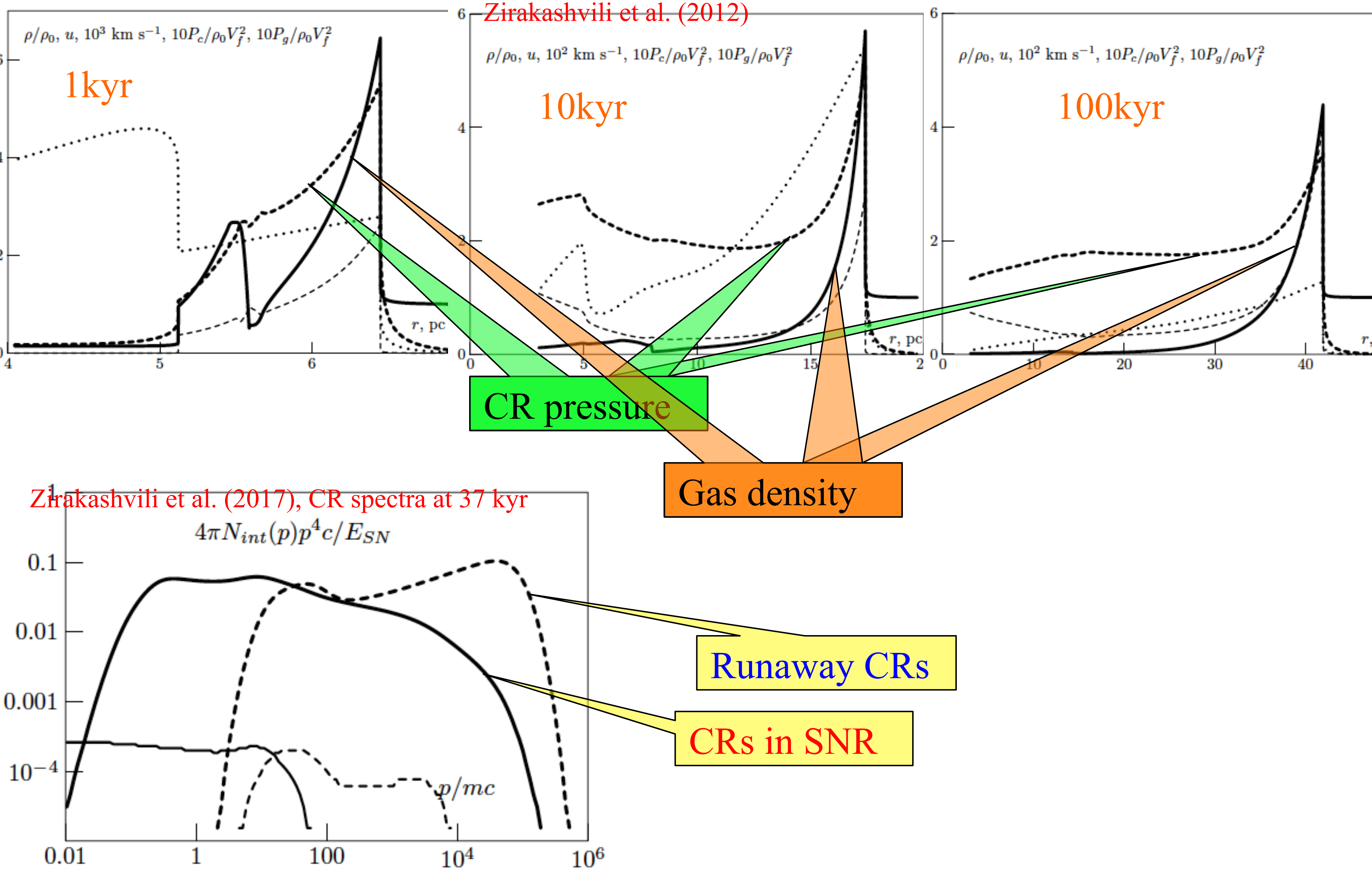

J1731
S0
PS 1
ps 2
ps 3
FL8Y J1730.5-3352
FL8Y J1736.2-3423
FL8Y J1730.0-3419
FL8Y J1730.4-3447
FL8Y J1729.0-3501
FL8Y J1726.5-3525
FL8Y J1729.0-3549
FL8Y J1726.5-3552
FL8Y J1725.3
TeV spectrum from SNR
Our Fermi result,SNR center
Fermi,Condon+, 2017
HESS SNR
HESS J1729
log E^{2}F(E)/dE (eV/cm^2/s)
logE (TeV)
−15
−10
−5
0
2
−2
−4
TeV spectrum from MC−J1729 and MC−core
Hadron model MC−core
Hadron model J1729
Our Fermi result, MC−core
HESS MC−core (20% SNR)
HESS J1729
log E^{2}F(E)/dE (eV/cm^2/s)
logE (TeV)
−4
−2
0
2

关于将来用LHAASO观测的一点总结

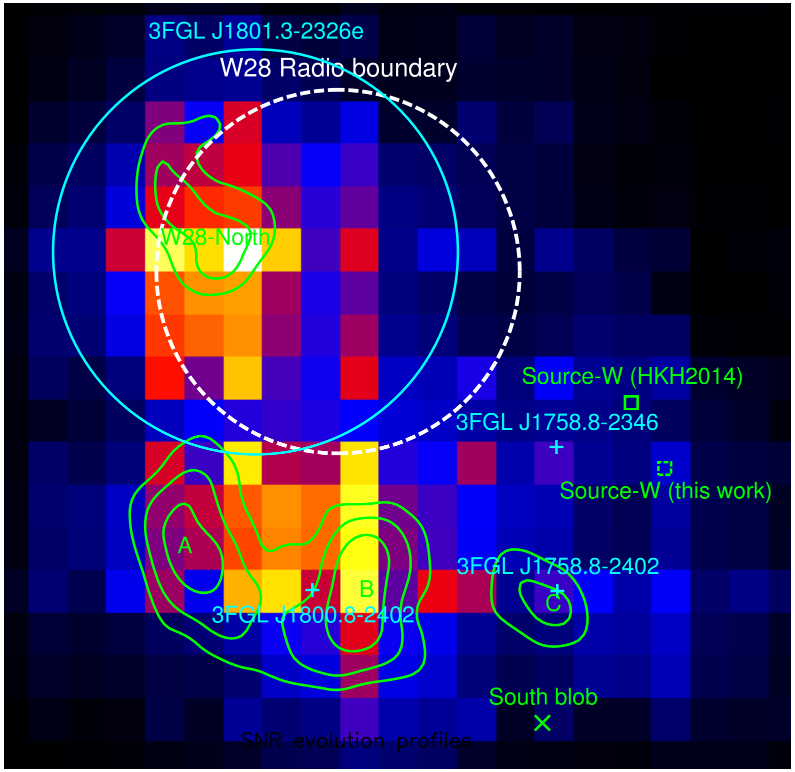
Lhaaso 10TeV 以上的探测优势。

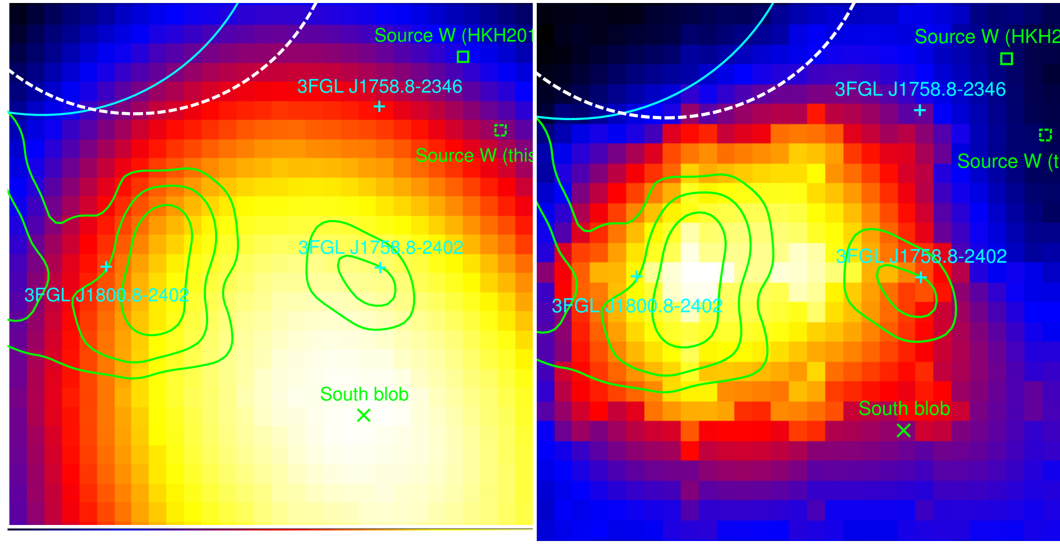
- ➔ 看银河系内。
- ➔ 年轻的超新星遗迹可以加速重子到>100TeV。
- ➔ 旁边最好有分子云。

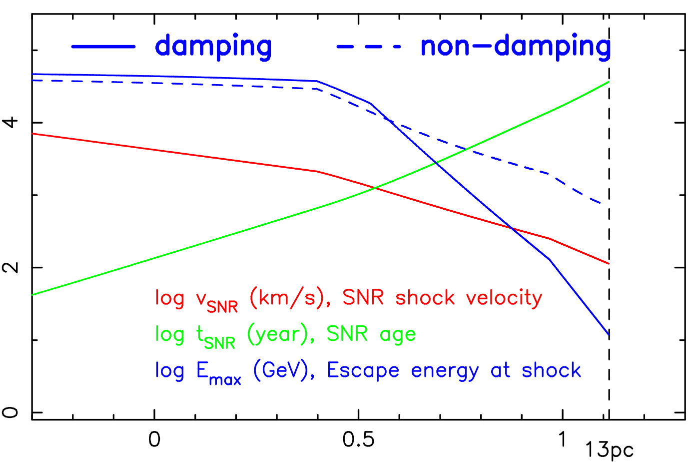
CR distribution inside the SNR



Summary







CR spectra