

the interplay of cosmic rays & gamma rays

tevpa
august 2013

daniel castro - mit

outline

why is the connection between cosmic rays and gamma rays important?

what are the possible **sources** of galactic cosmic rays?

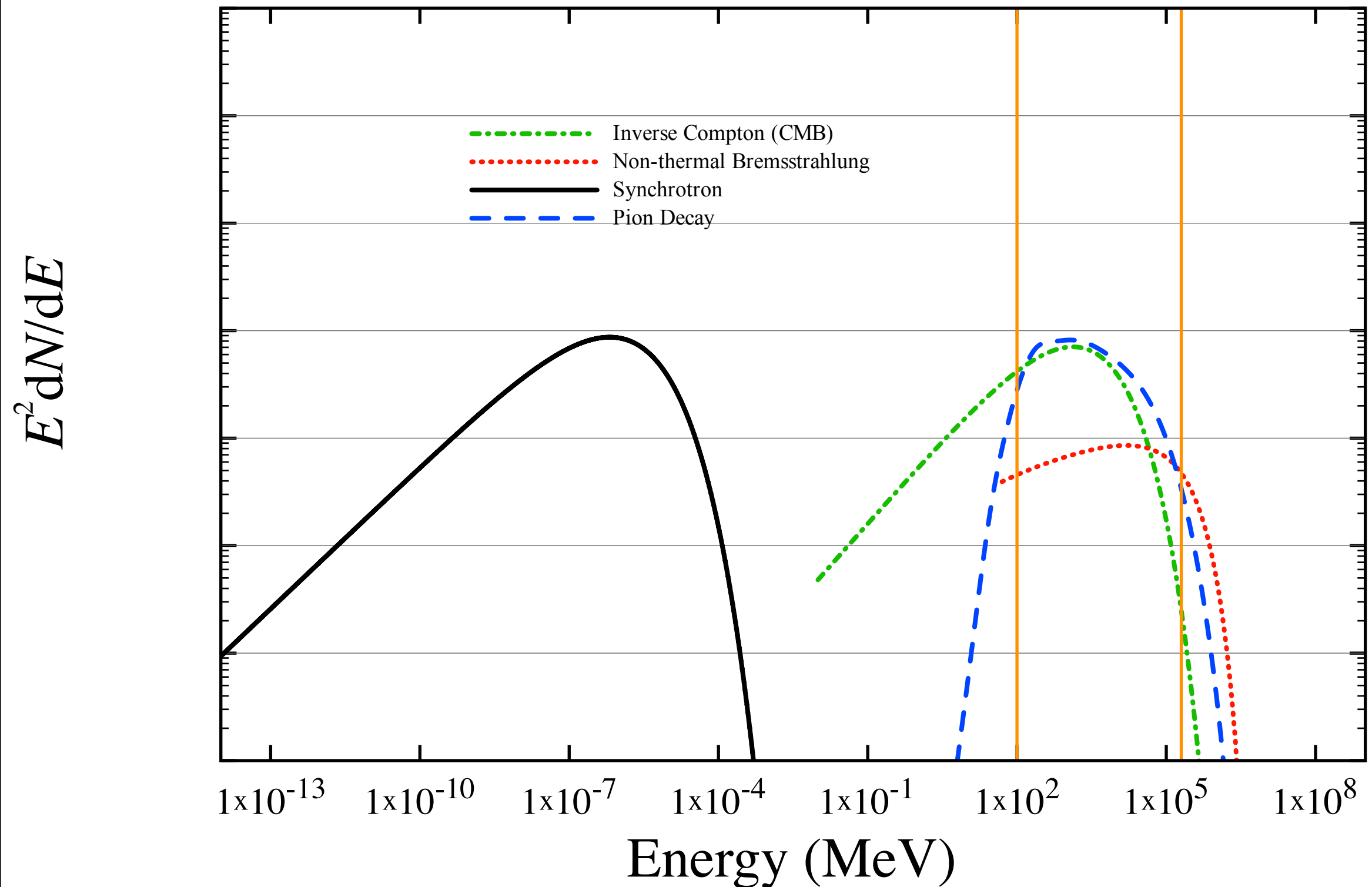
what have we learnt through **recent** research?

0. primer: cosmic rays -> gamma-rays

mechanisms through which cosmic rays produce gamma-rays

- inverse compton scattering
- non-thermal bremsstrahlung
- pion decay
- synchrotron

0. primer: cosmic rays -> gamma-rays

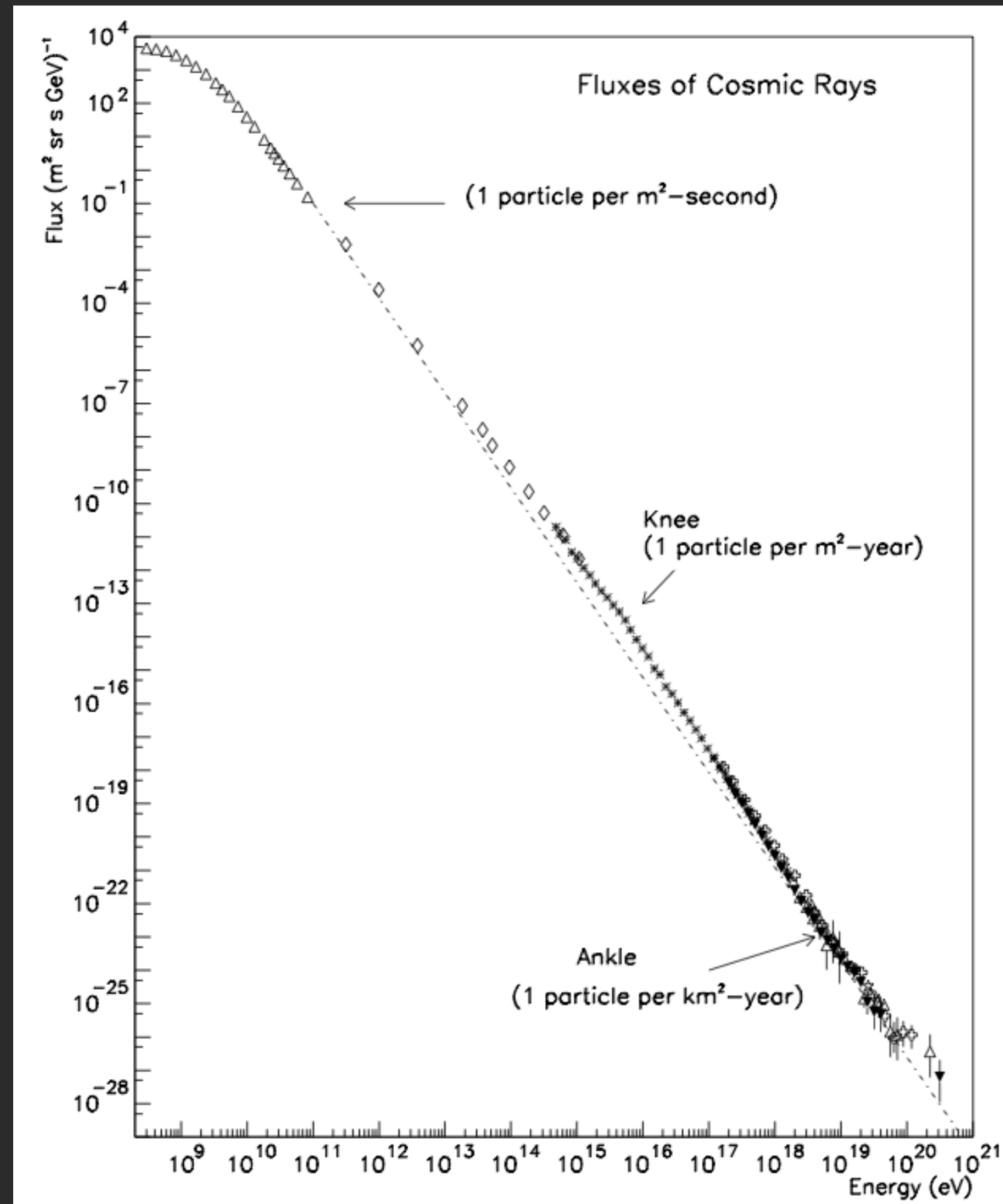


i. why?

why is the connection between cosmic rays and gamma rays important?

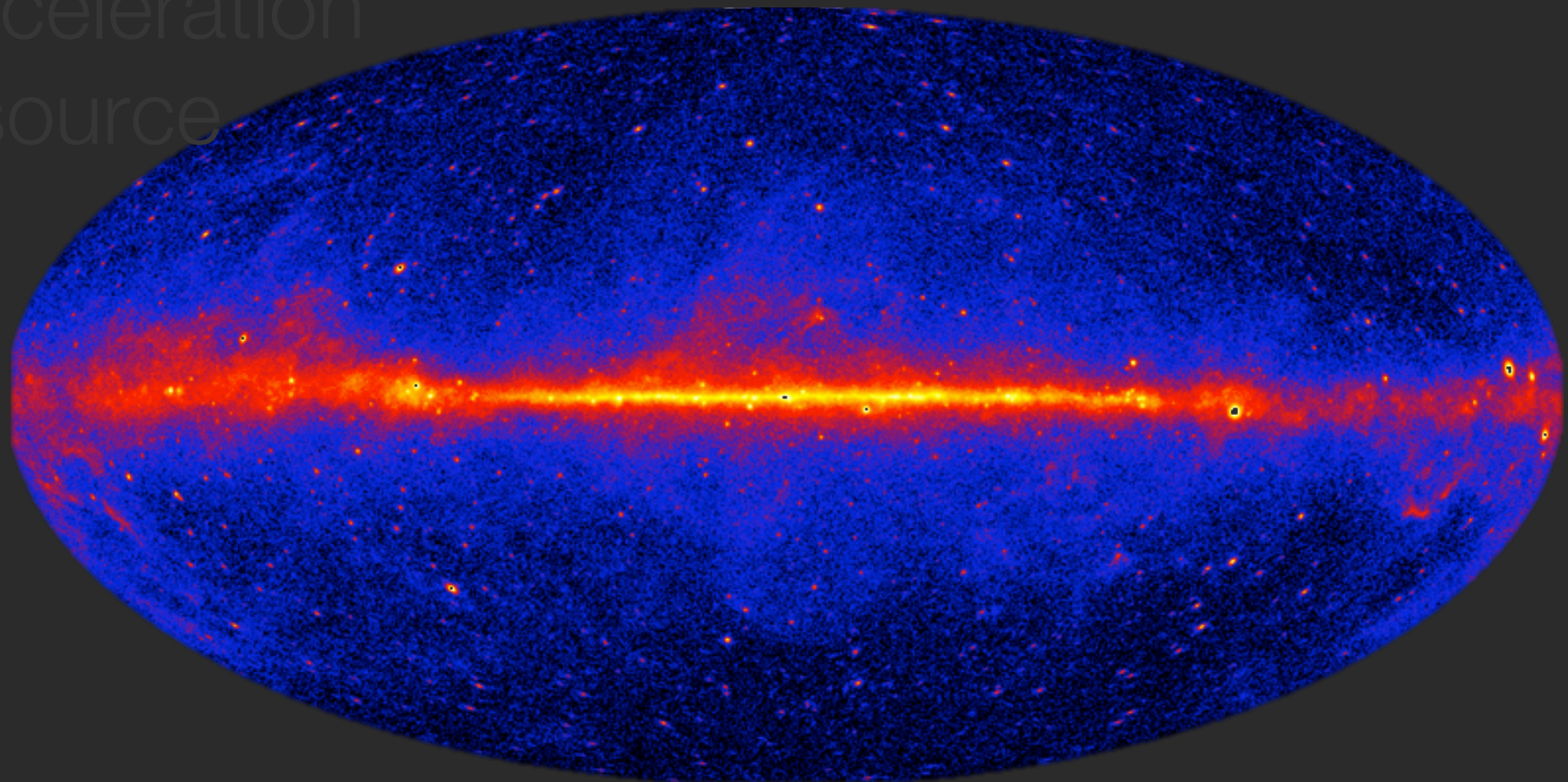
i. why?

- origin
- γ -ray background
- particle acceleration
- effect on source



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- origin
- γ -ray background
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ii. sources

what are the possible **sources** of galactic cosmic rays? – role of gamma-rays

ii. sources

what are the possible **sources** of galactic cosmic rays? – role of gamma-rays

yoshinuki inoue – wed 9.30 – extragalactic gamma-ray review

ii. sources

- supernova remnants (snr)
- stellar winds
- colliding winds
- pulsar winds
- novae
- protostar jets

ii. sources

- supernova remnants (snr)
- stellar winds – see walter binns talk – mon 5.18
- colliding winds
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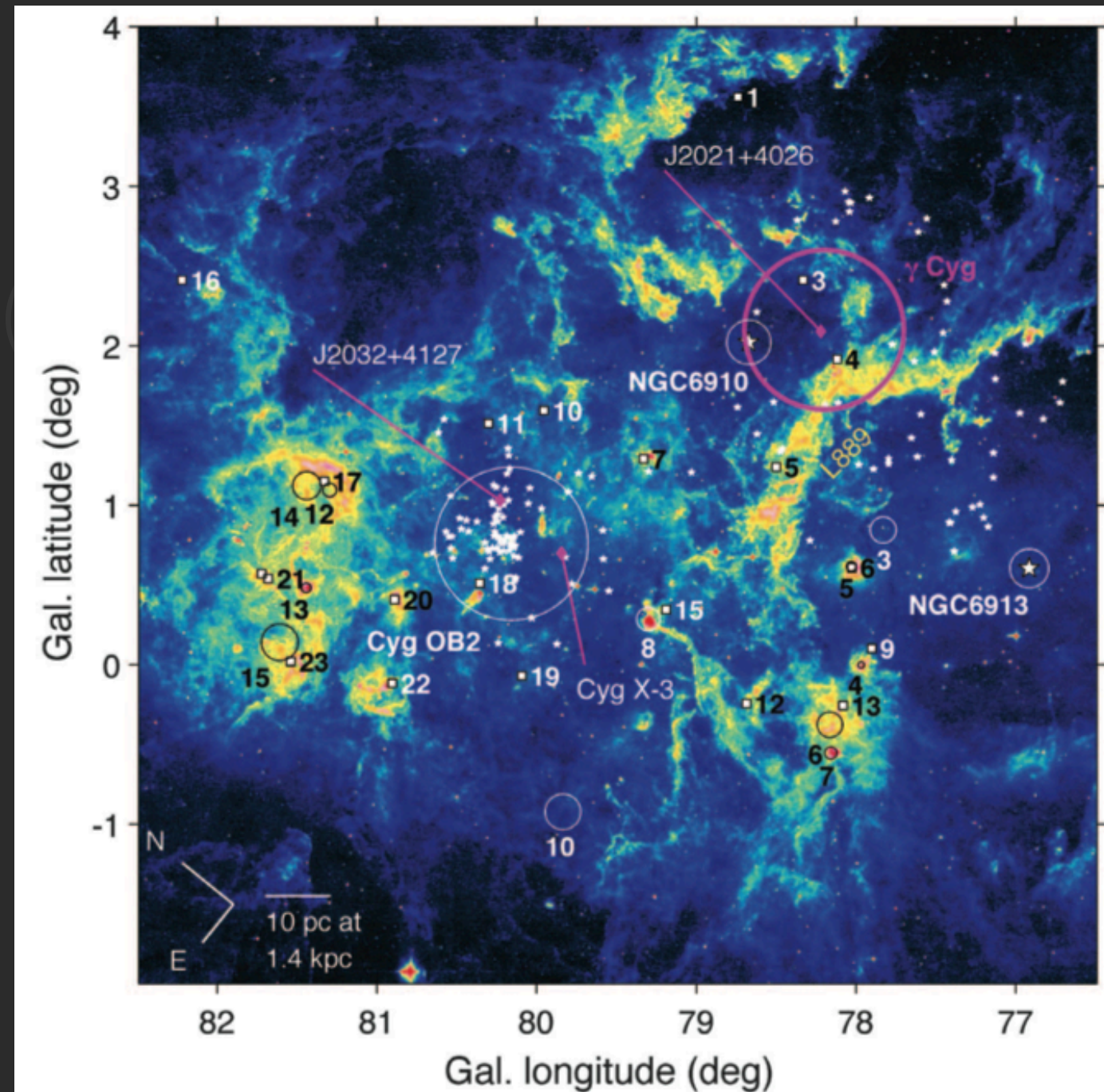
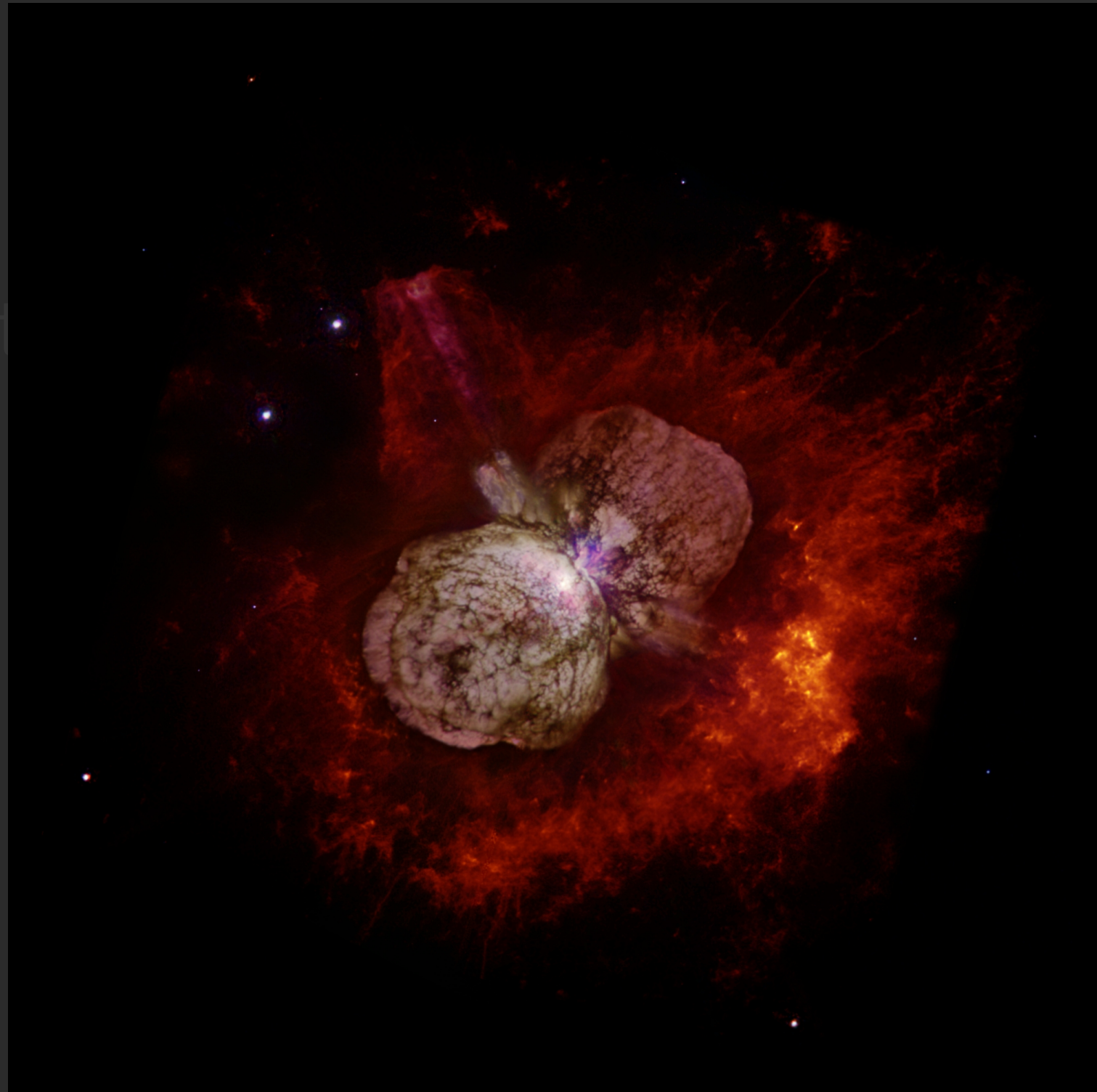


image: cygnus x – msx @8 micron – ackermann+ 2011

ii. sources

- supernova remnant
- stellar winds
- colliding winds
- pulsar winds
- novae
- protostar jets



see abdo+ 2010

ii. sources

- supernova remnants (snr)
- stellar winds
- colliding winds
- **pulsar winds** — b. rangelov — wed 6.06 — hess j1809-193
- novae
- protostar jets

ii. sources

- supernova remnants
- stellar winds
- colliding winds
- **pulsar winds**
- novae
- protostar jets

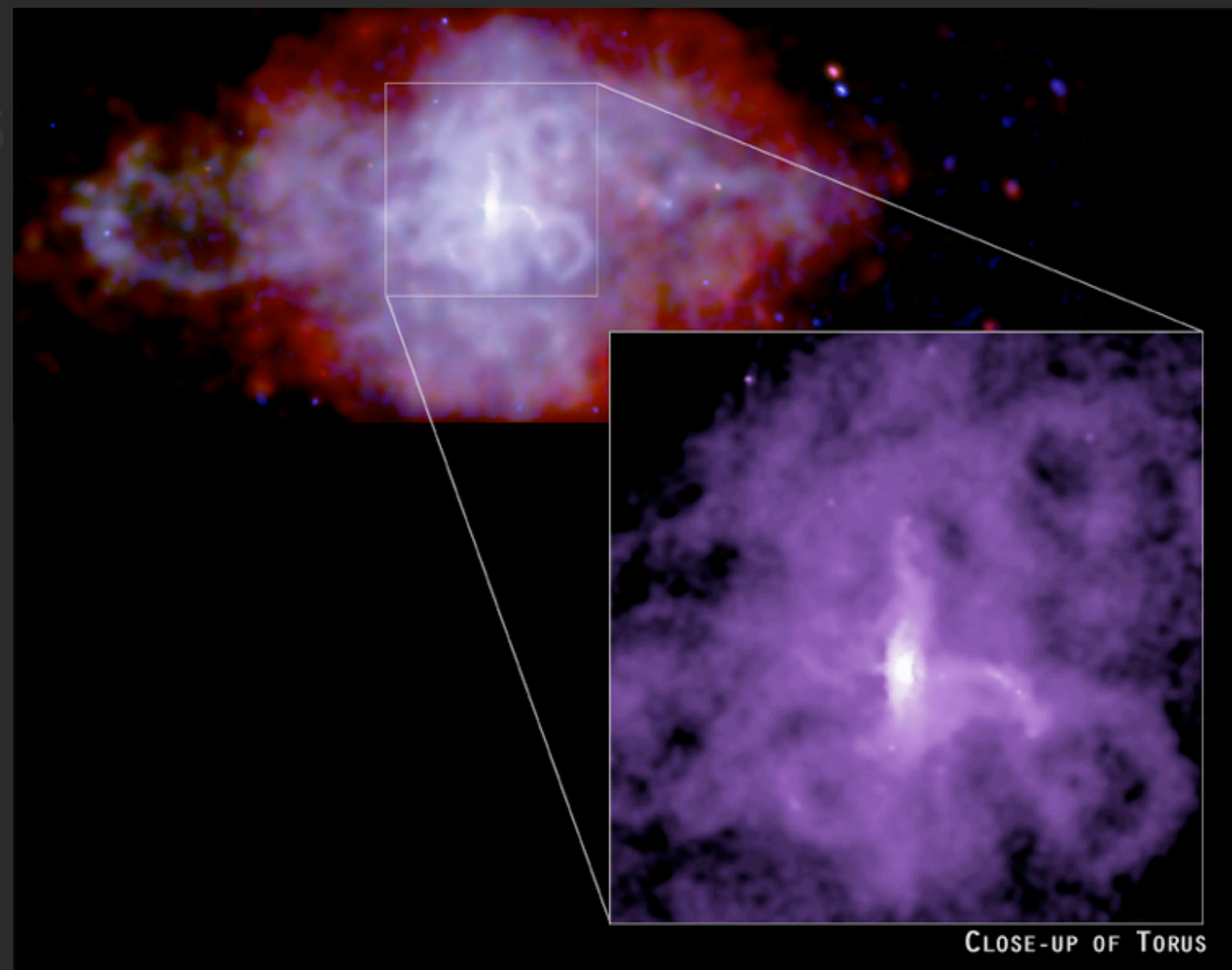
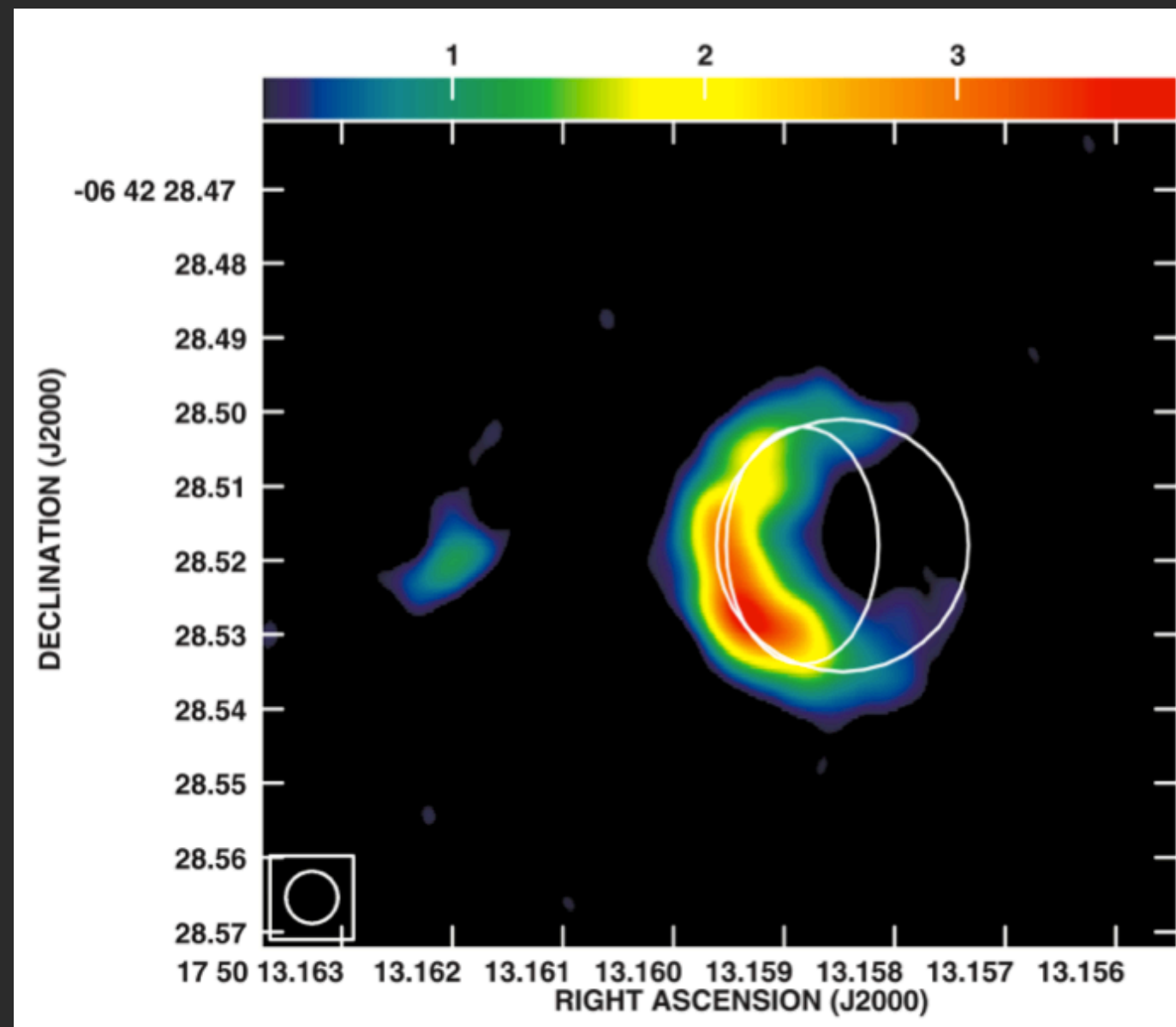


image: 3c 58 in x-rays – slane+ 2004

ii. sources

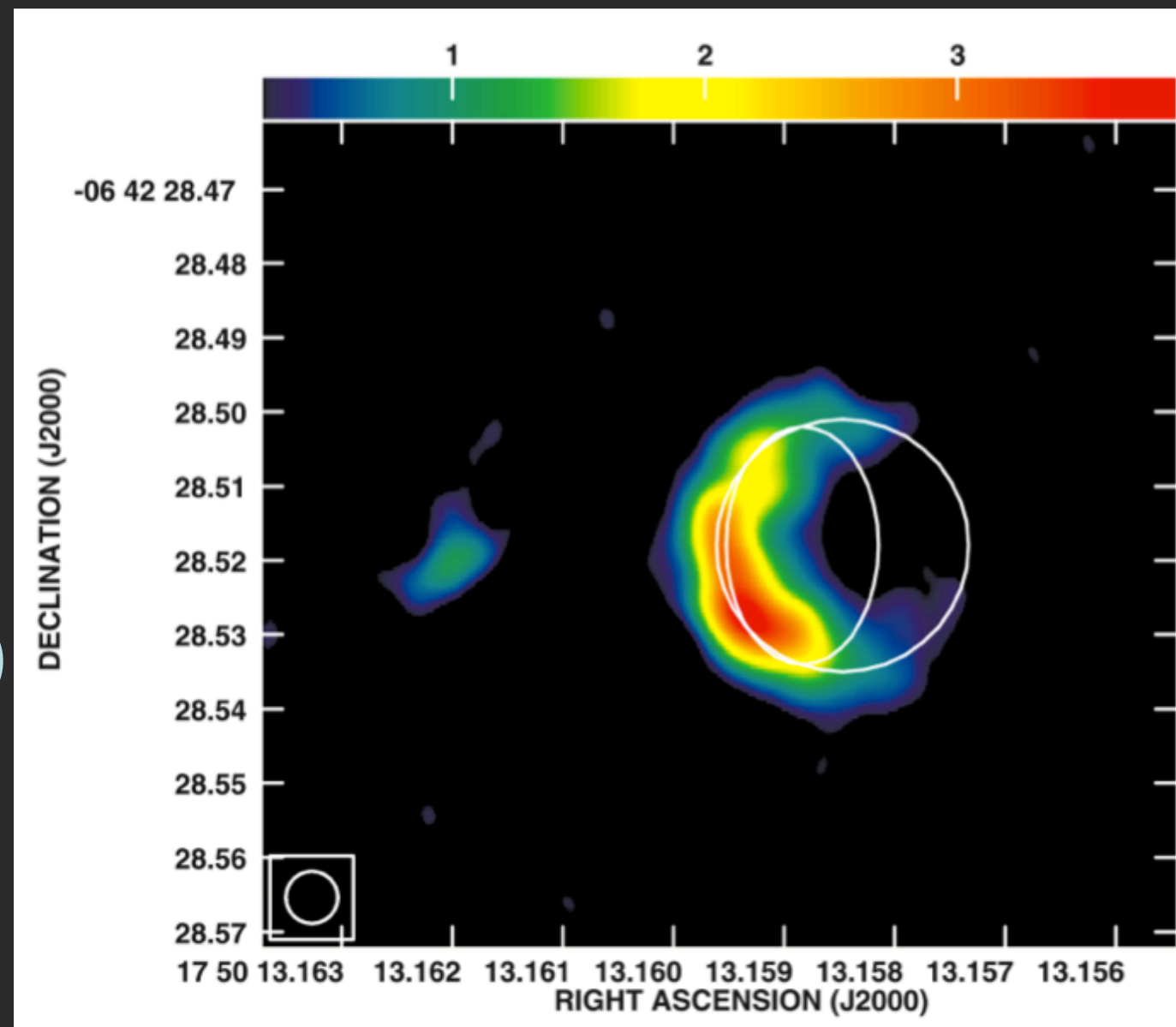
- supernova remnants
- stellar winds
- colliding winds
- pulsar winds
- novae
- protostar jets



rs oph at 5 ghz – rupen+ 2008

ii. sources

- supernova remnants
- stellar winds
- colliding winds
- pulsar winds
- novae - V407 Cyg (abdo+ 2010)
- protostar jets

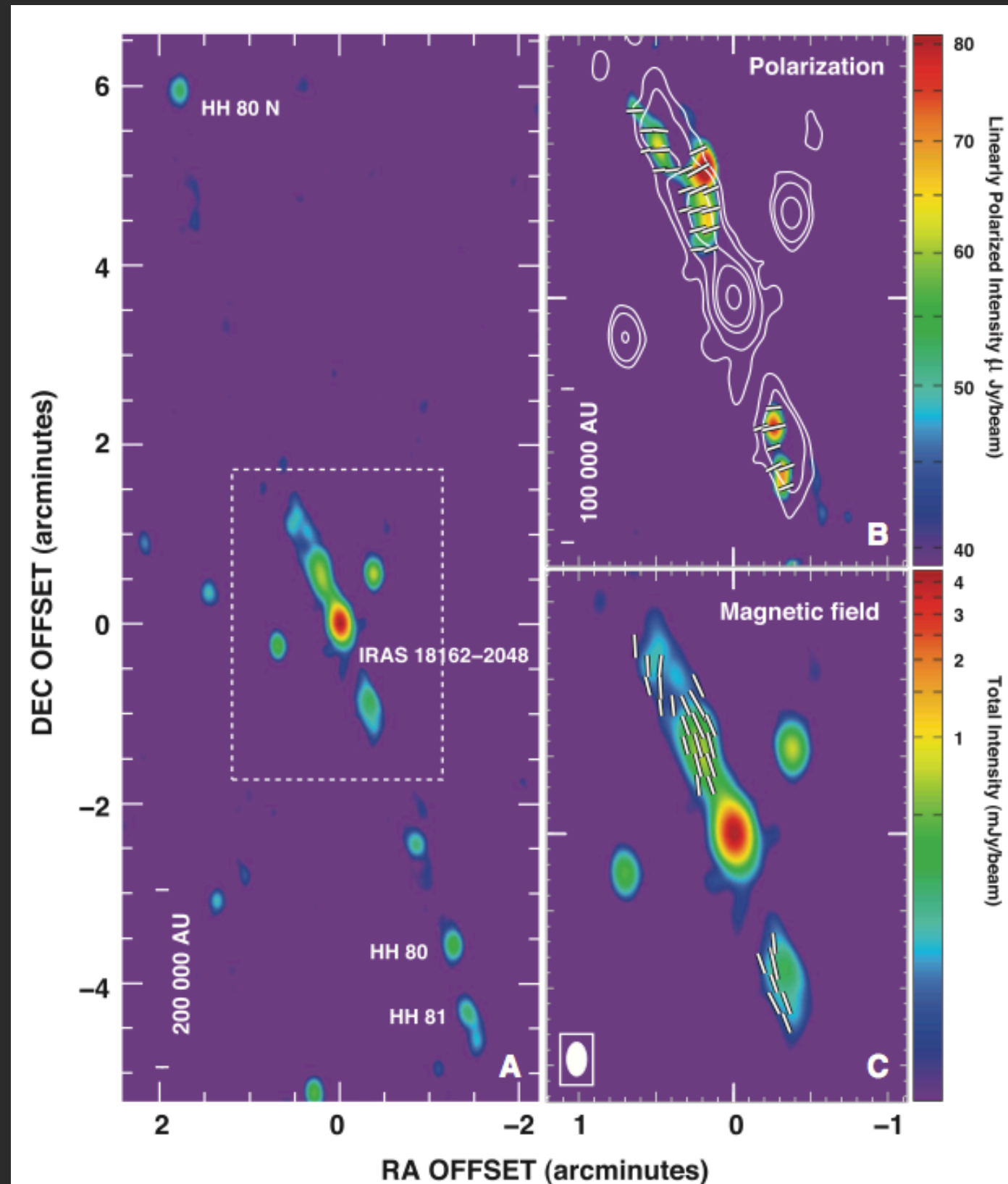


rs oph at 5 ghz – rupen+ 2008

ii. sources

- supernova remnants
- stellar winds
- colliding winds
- pulsar winds
- novae
- protostar jets

hh80-81@6cm– carrasco-gonzalez + 2012



ii. sources - snr

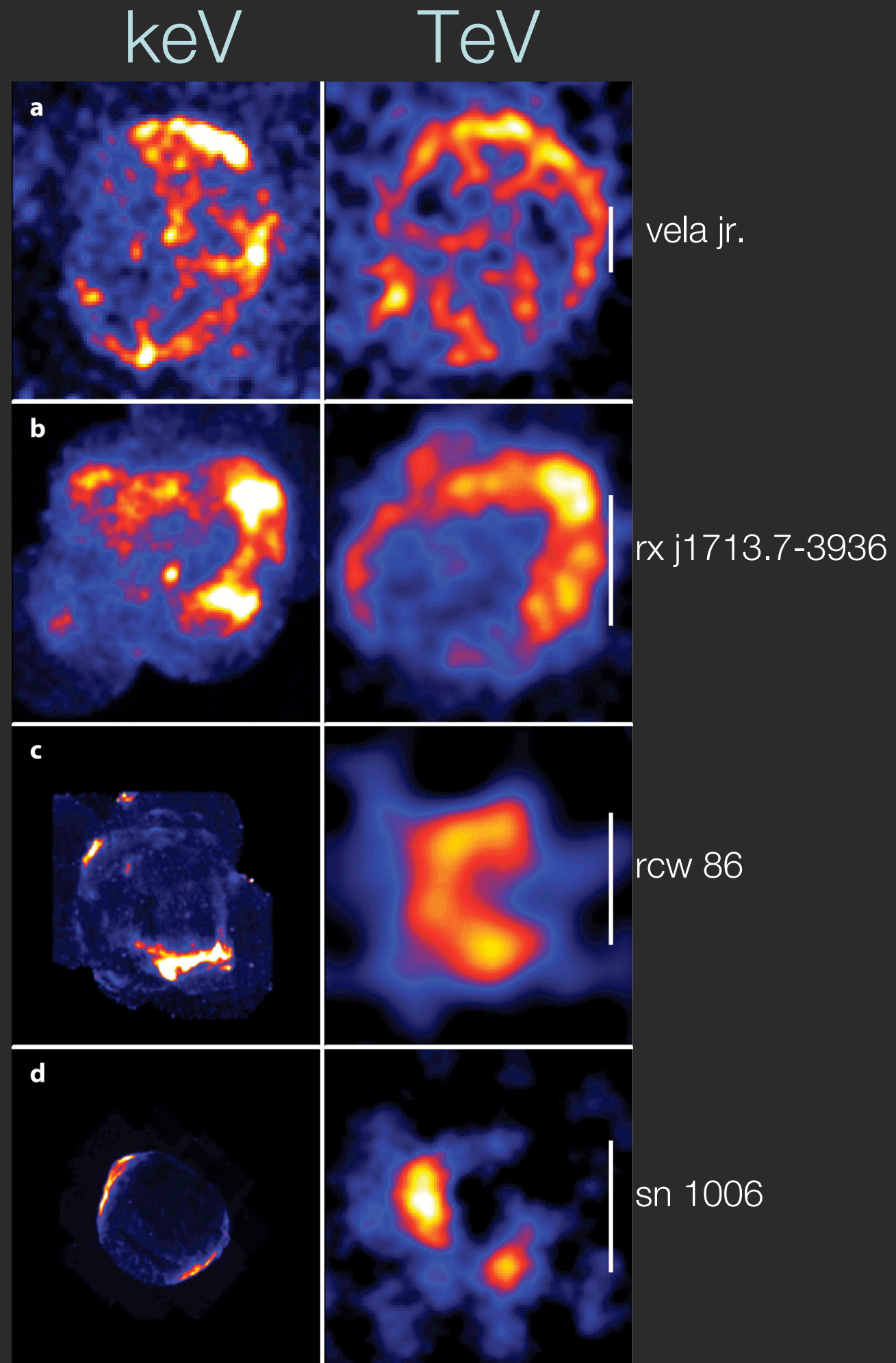
- non-thermal X-rays
- dynamical properties
- structure
- γ -ray emission

koyama+ 1995



ii. sources - snr

hinton & hofmann 2009
uchiama+ 2002
aschenbach 1998
vink+ 2006
aharonian+ 2006, 2007, 2008
naumann-godo+ 2006

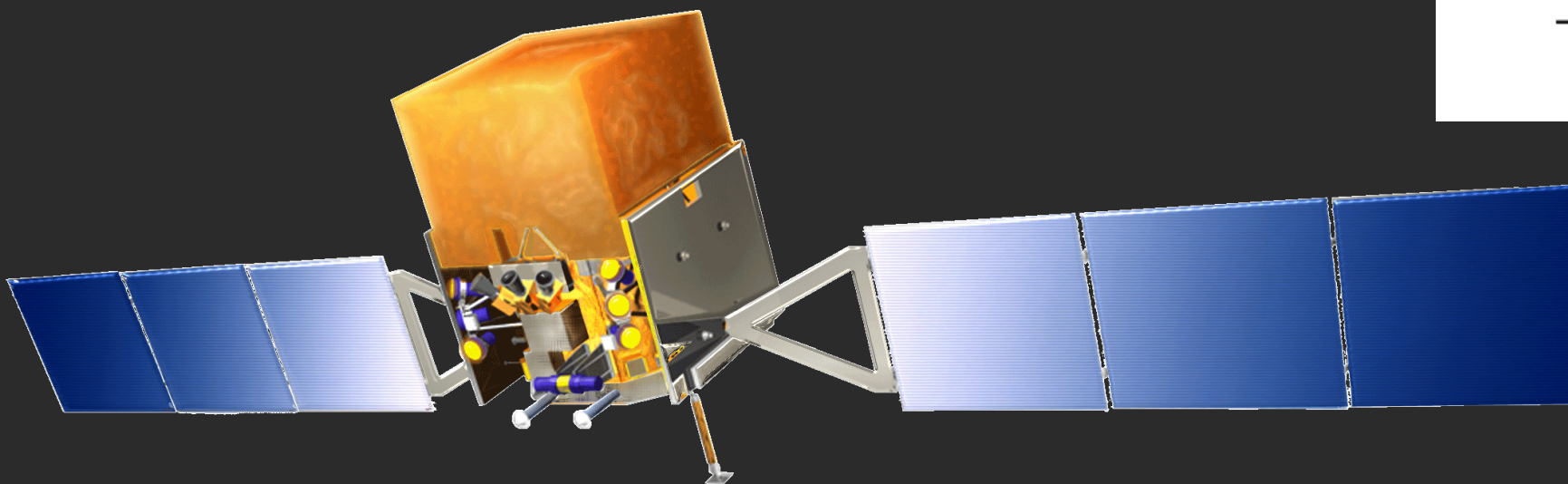


ii. sources - snr

Table 1
SNRs Observed with the *Fermi*-LAT

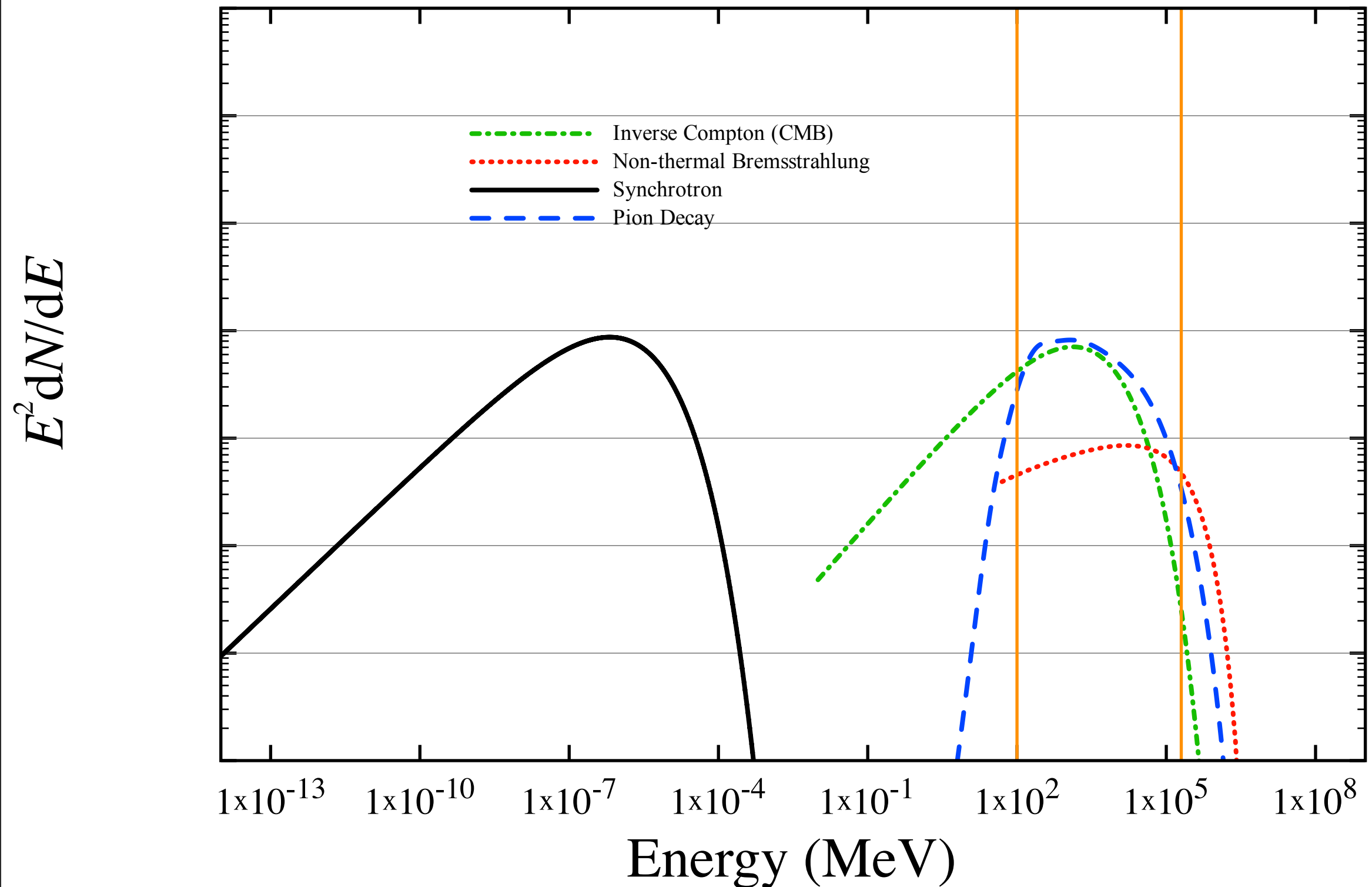
Galactic l (°) b (°)	Name	Reference
6.4 -0.1	W28	Abdo et al. (2010a)
8.7 -0.1	W30	Castro & Slane (2010)
23.3 -0.3	W41	Castro et al. (2013a)
31.9 0.0	3C 391	Castro & Slane (2010)
33.6 0.1	Kes 79	Auchettl et al. (2013) ^a
34.7 -0.4	W44	Abdo et al. (2010c)
43.3 -0.2	W49b	Abdo et al. (2009)
49.2 -0.7	W51C	Abdo et al. (2009)
74.0 -8.5	Cygnus Loop	Katagiri et al. (2011)
78.2 2.1	γ -Cygni SNR	Lande et al. (2012)
89.0 4.7	HB 21	Reichardt et al. (2012)
109.1 -1.0	CTB 109	Castro et al. (2012)
111.7 -2.1	Cas A	Abdo et al. (2010b)
120.1 1.4	Tycho	Giordano et al. (2012)
180.0 -1.7	S147	Katsuta et al. (2012)
189.1 3.0	IC443	Abdo et al. (2010d)
260.4 -3.4	Puppis A	Hewitt et al. (2012)
266.2 -1.2	Vela Jr.	Tanaka et al. (2011)
304.6 0.1	Kes 17	Wu et al. (2011)
337.0 -0.1	CTB 33	Castro et al. (2013a)
337.8 -0.1	Kes 41	Castro et al. (2013b) ^a
347.3 -0.5	RX J1713.7 3946	Abdo et al. (2011)
348.5 0.1	CTB 37A	Castro & Slane (2010)
349.7 -0.5	G349.7-0.5	Castro & Slane (2010)
357.7 -0.1	MSH 17-39	Castro et al. (2013a)

^a In preparation
Interacting with MCs



LAT SNR catalog (sometime in the next 12 months)

0. primer: cosmic rays -> gamma-rays



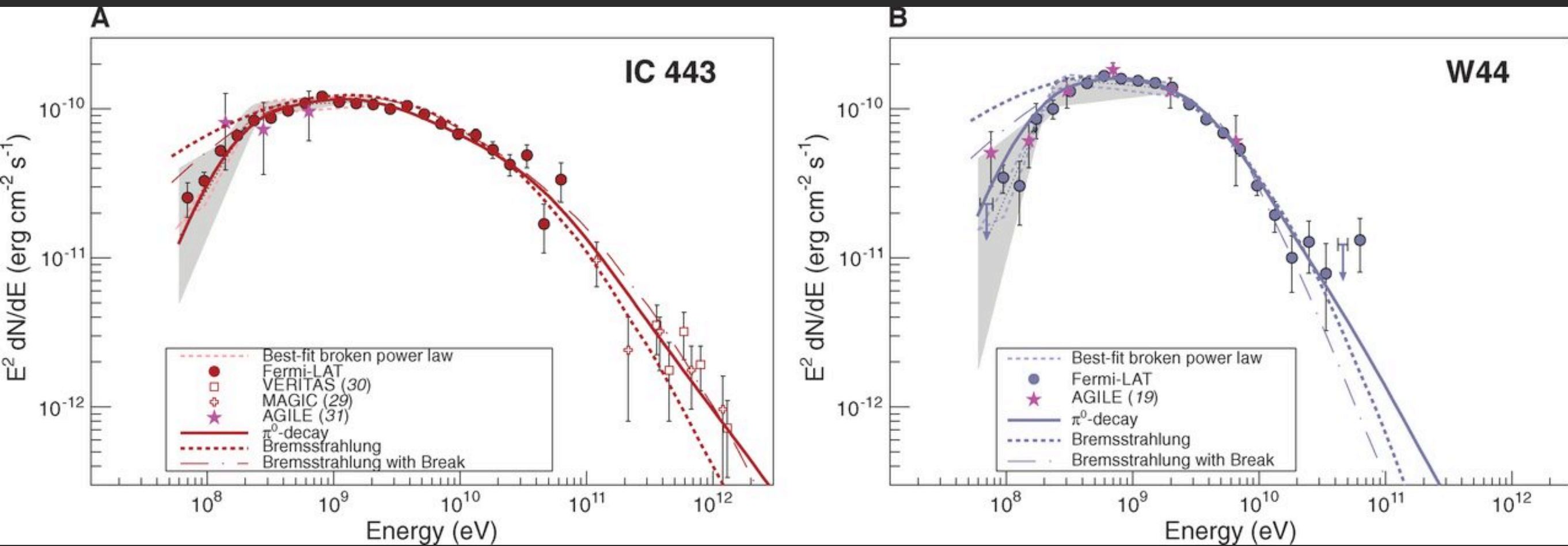
iii. recent

what have we learnt through recent research?

iii. other talks

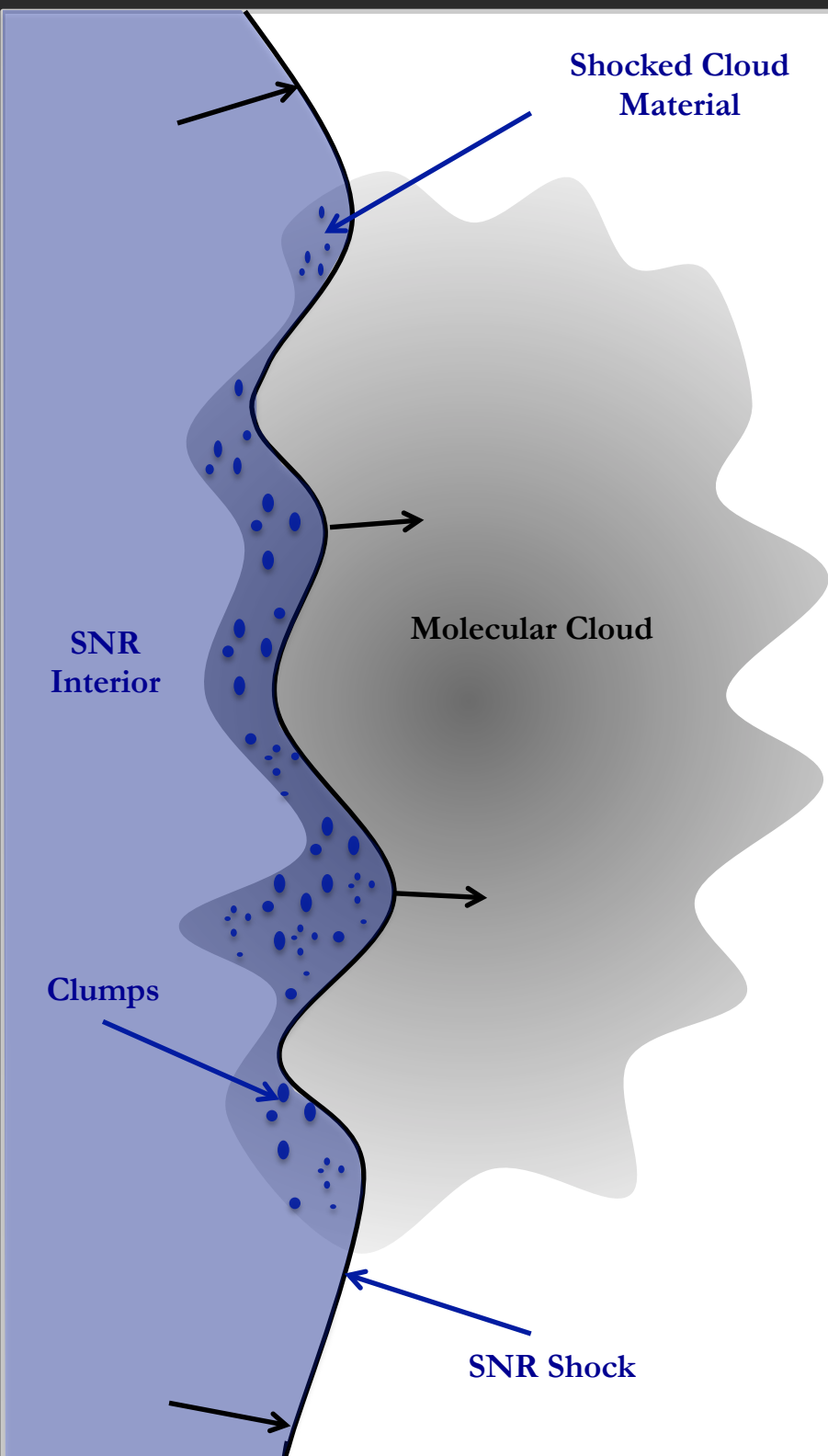
- farzaneh sheidaei – today 2.00 – veritas galactic
- christoph deil – today 2.24 – hess galactic
- denis leahy – today 2.48 – snrs in radio
- walter binns – today 5.18 – cr composition
- vladimir ptuskin – tue 2.00 – cr propagation (theory)
- terri brandt – wed 8.30 – galactic gev overview
- emma de ona wilhelmi – wed 9.00 – galactic tev overview
- ignacio taboada – wed 10.00 – hawc
- troy porter – wed 11.00 – cr propagation (observation)
- blagoy rangelov – wed 6.06 – hess j1809-193

iii. snrs



ackermann et al. 2013 (funk, tanaka, uchiyama)

iii. snr - molecular clouds

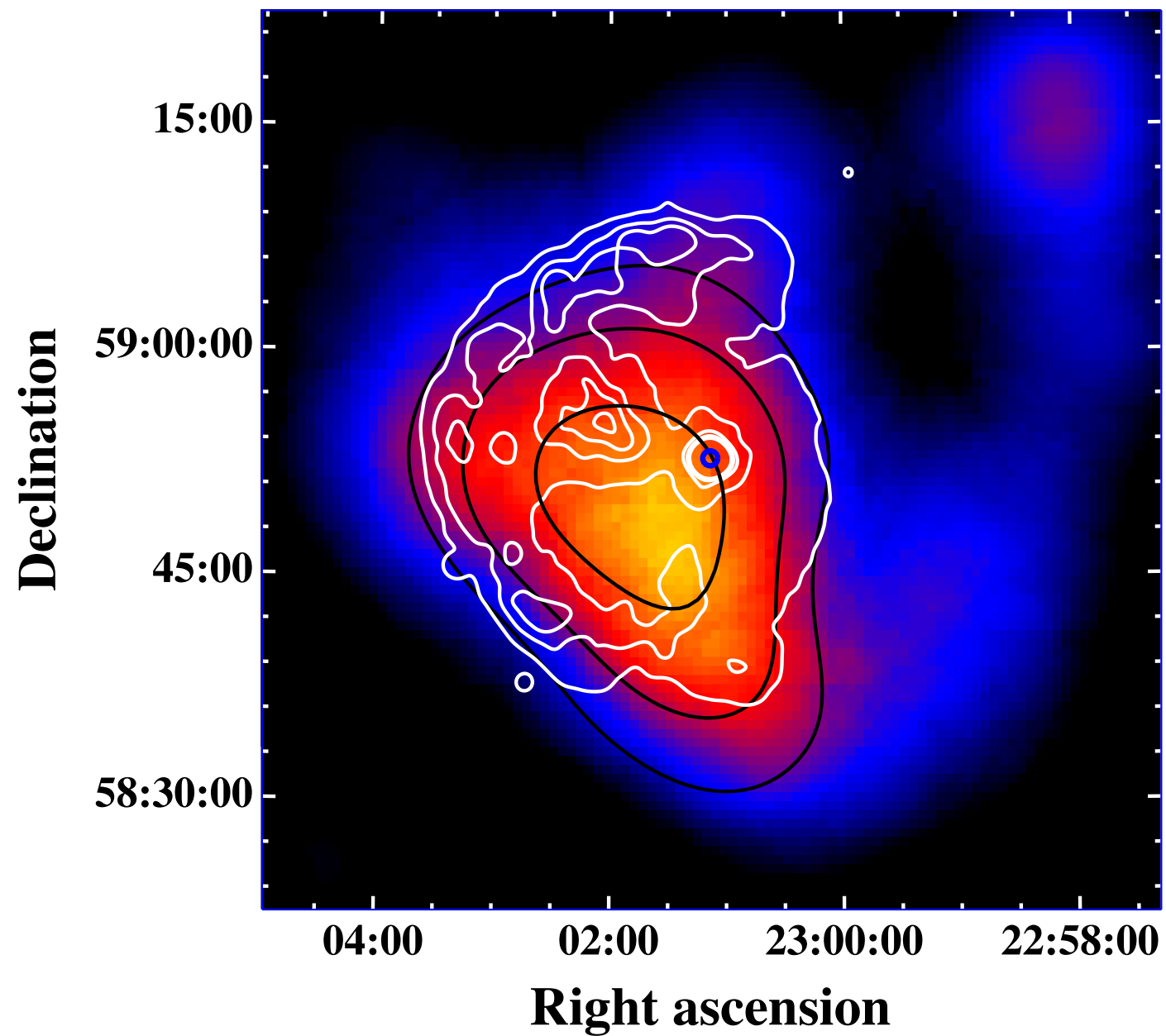
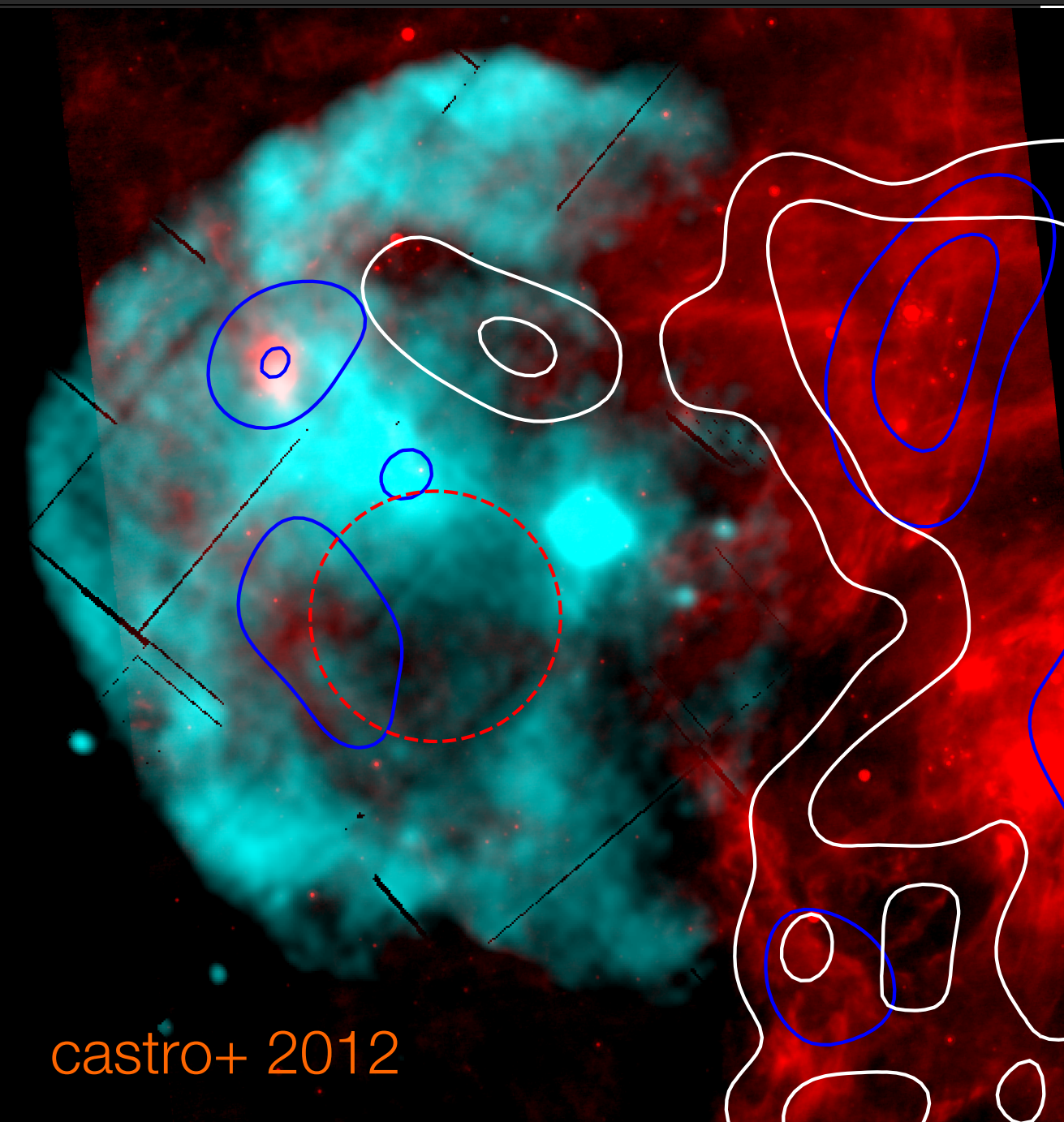


- [castro et al. \(2010,2013\)](#):
 - w30 + ctb 37a + g349.7-0.5 + 3c391
 - w41 + ctb 33 + msh 17-39
 - x-ray density \ll γ -ray density

see also:

- [uchiyama+ 2010](#) – reacceleration
- [inoue+ 2010](#) – diffusion
- [schuppan+ 2012](#) – ionization

iii. snr - molecular clouds

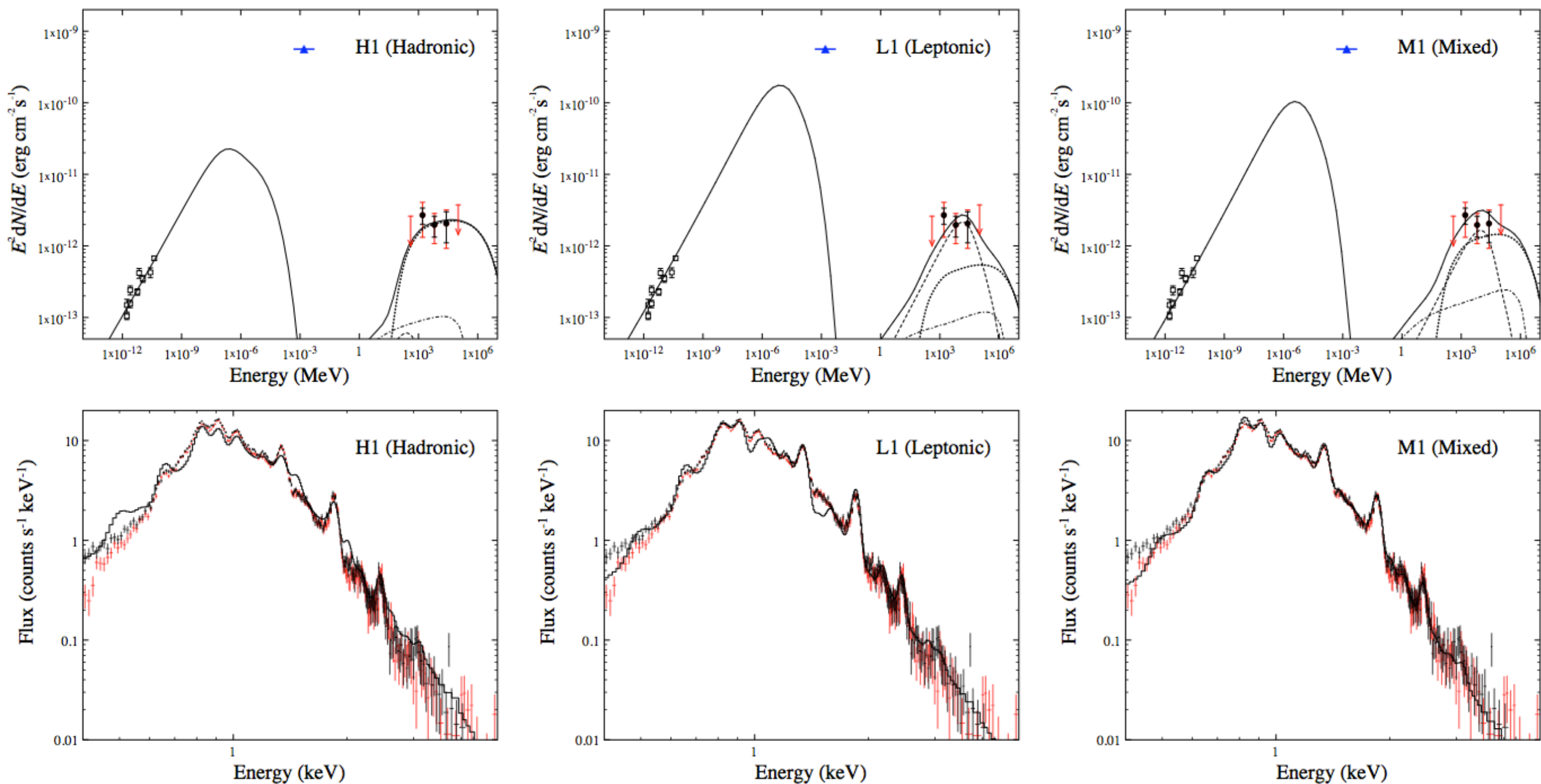


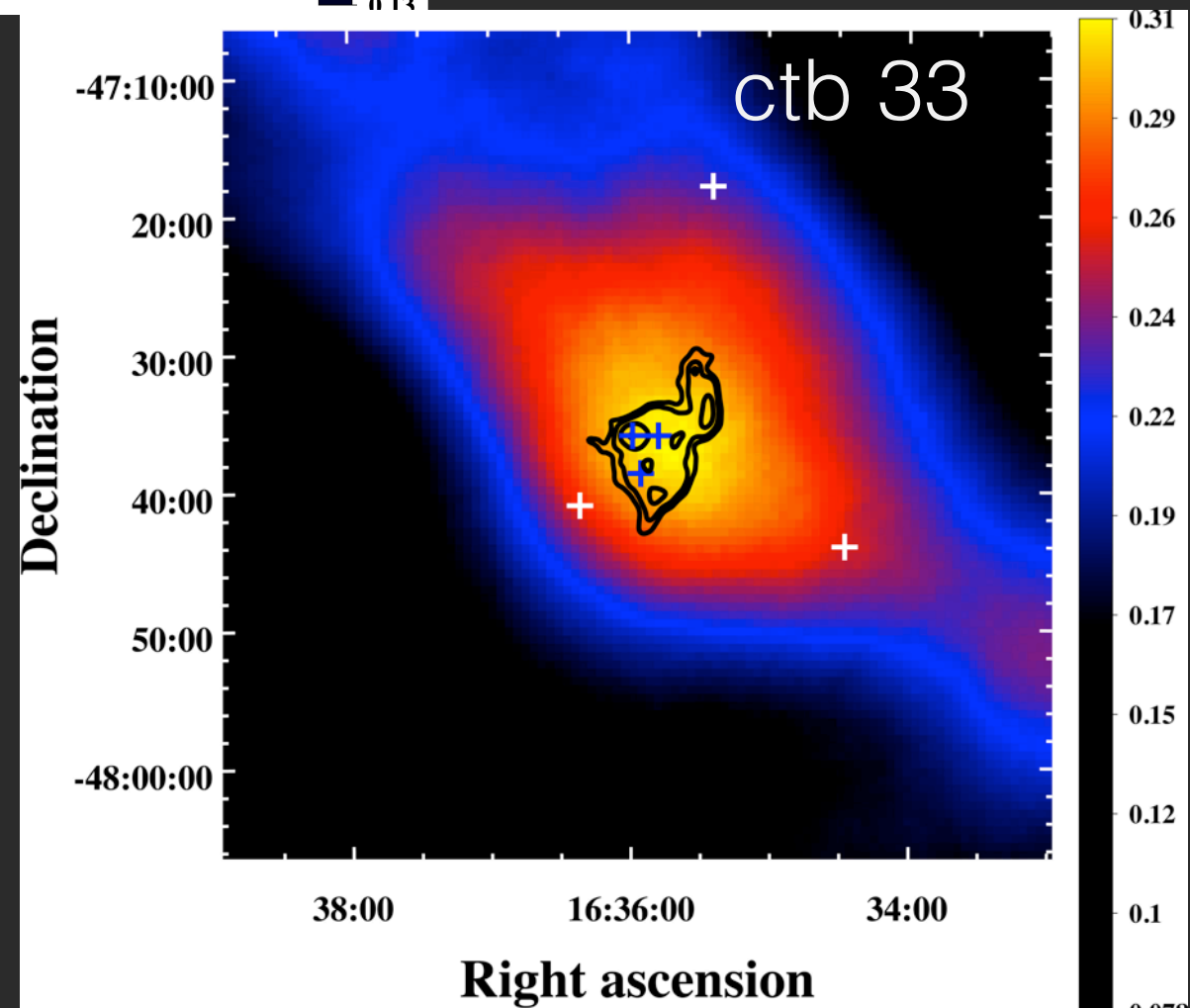
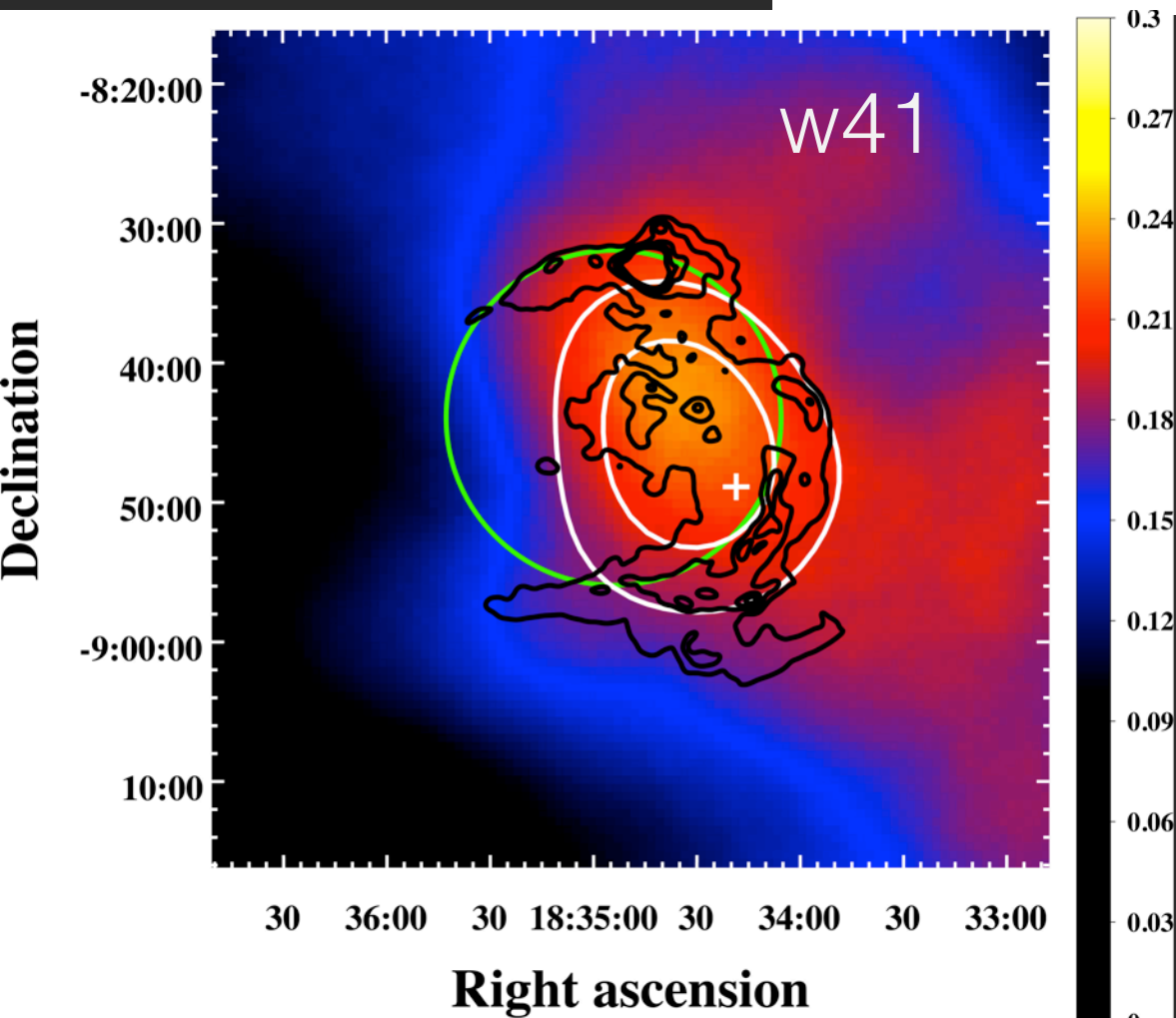
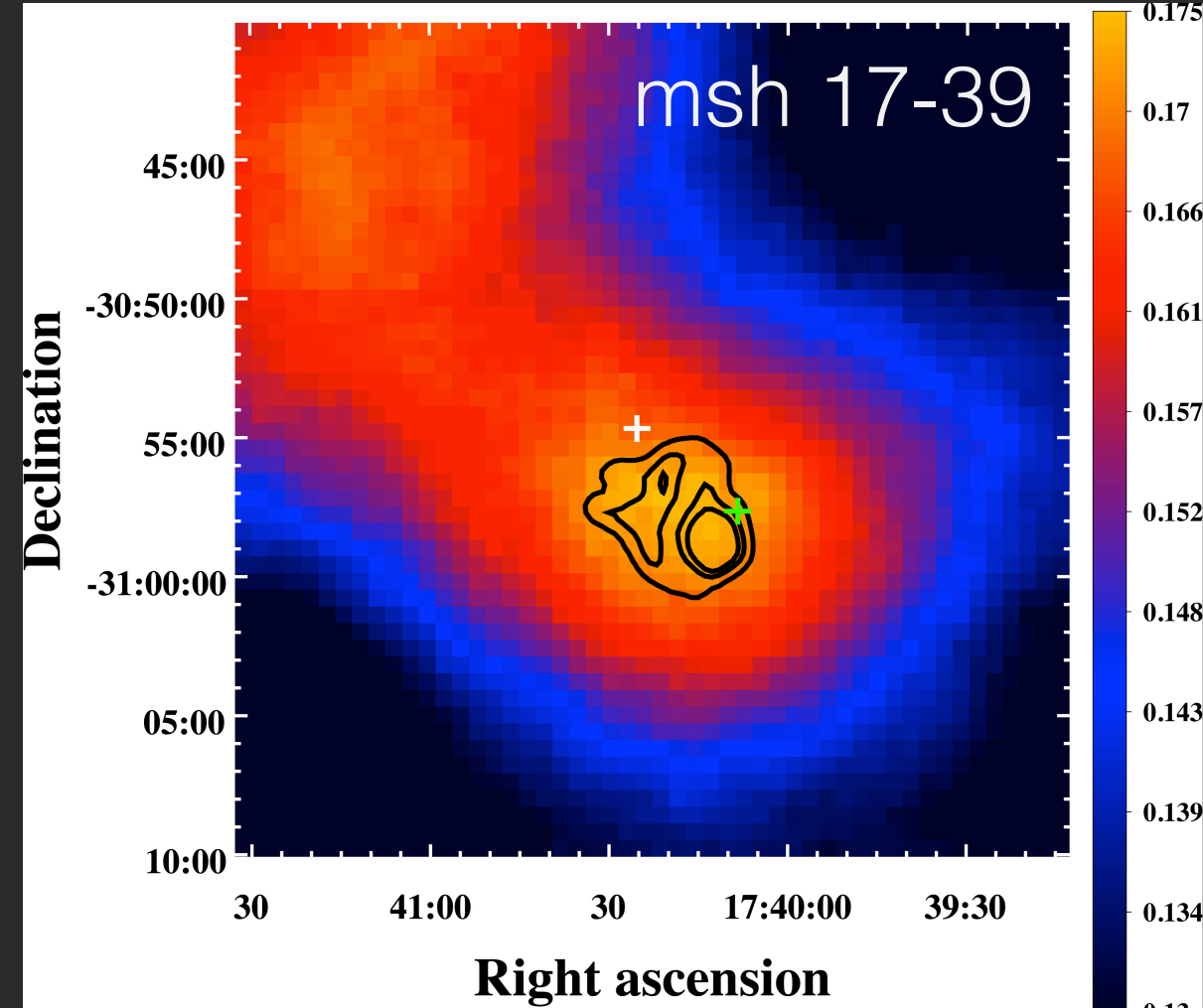
iii. recent/upcoming instruments

- **CTA** – more effective area, coverage to 10s of GeV (more SNRs + better sed) – see Dave Williams talk (today 11am)
- **NuStar + Astro-H** – hard x-rays = constraints on sed
- **Astro-H + Micro-X** – x-ray micro-calorimeters = detailed nature of shocked dense material
- **ALMA** – possibly synchrotron continuum + ionized molecular material
- **JWST** – synchrotron continuum? a lot more?

the end

iii. snr - molecular clouds

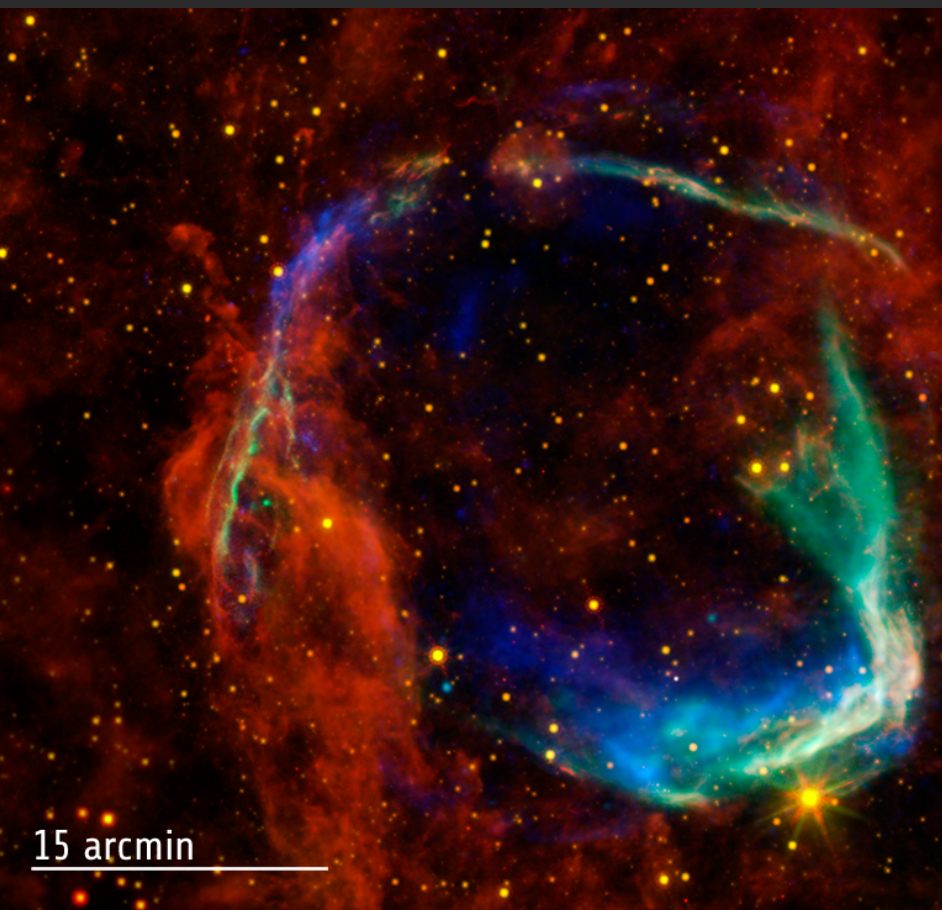




iii. molecular clouds

what happens when SNR shocks interact with dense clouds of material?

iii. magnetic field amplification



rcw 86

