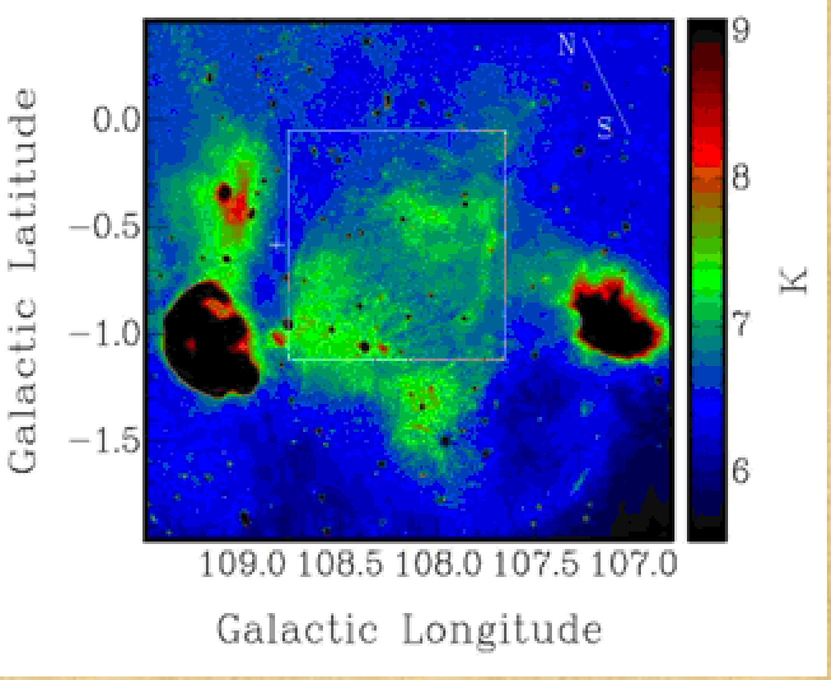
Multi-waveband study of Supernova remnants (SNRs)

Xiaohong Cui (NAOC)
崔晓红
Collaborators: Wenwu Tian & Hongquan Su(NAOC),
Zhiyuan Li & Bing Jiang (Nanjing University)
Randoll Smith (CFA)

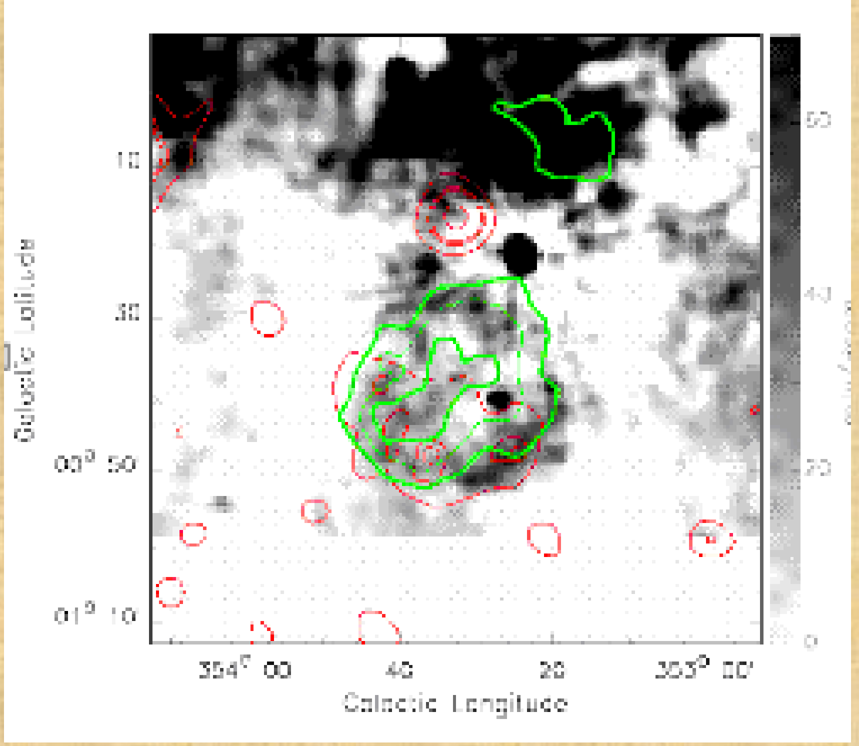
9th EAMA@ NCU, Taiwan Oct. 14-18, 2013

Discovery of SNRs in China

SNR G108.2-0.6 (Tian et al. 2007)

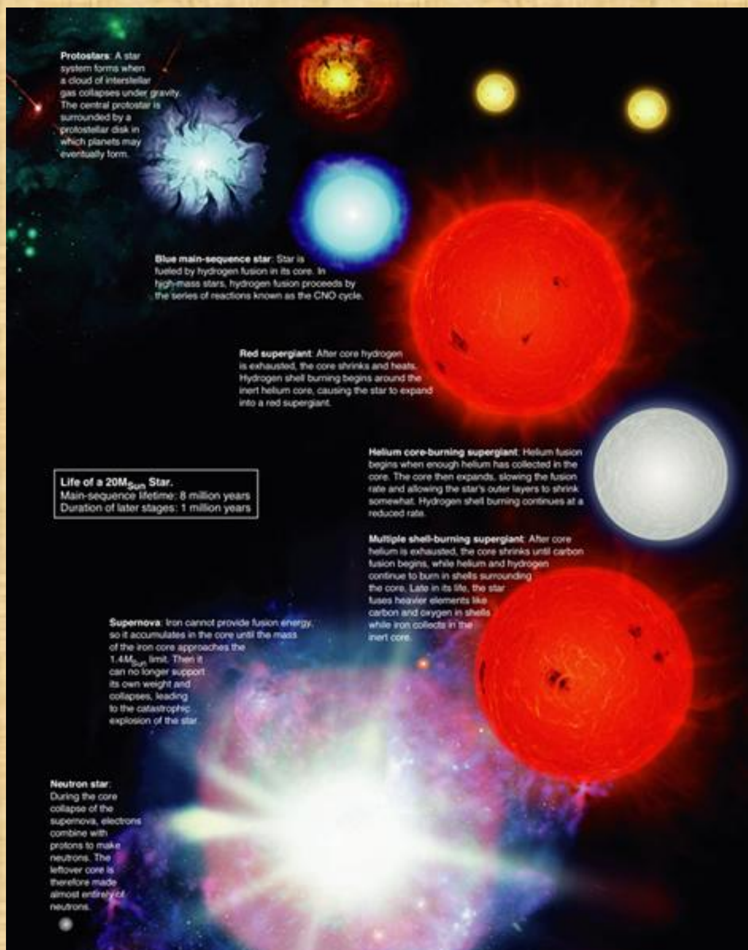


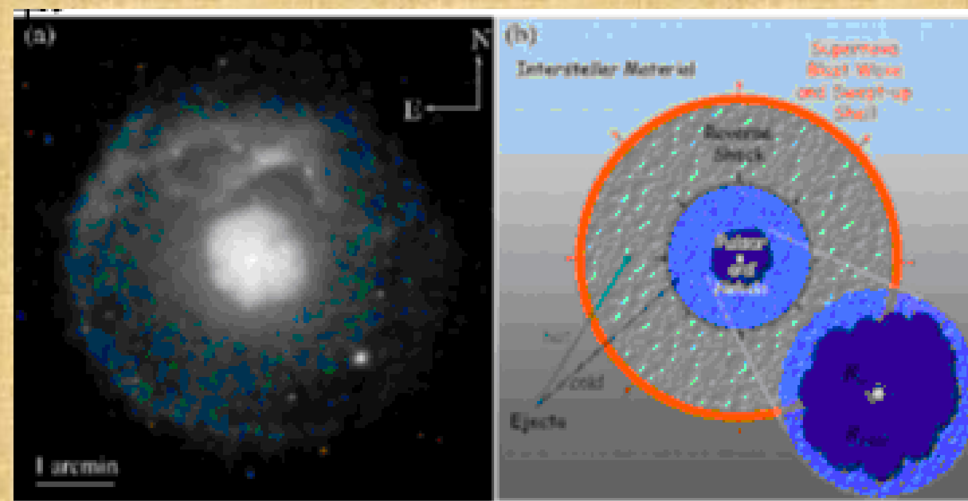
SNR G353.6-0.7/HESS J1731-347
(Tian et al. 2008)



SNRs: What?

Progenitor of an SNR has mass in 8-25 $M_{\odot}$: SNR G21.5-0.9 / PSR J1833-1034





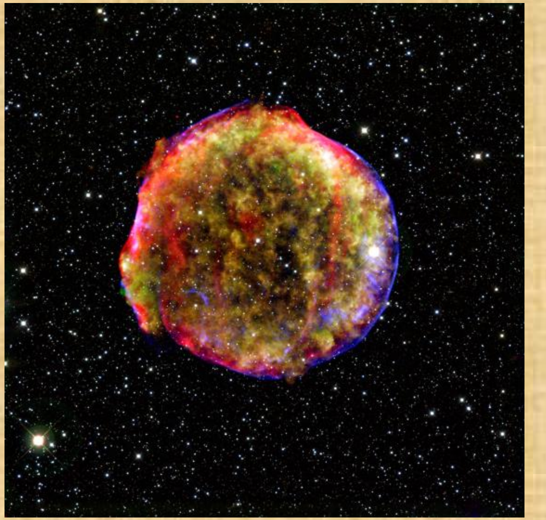
Evolution Phase	I	II	III
Mass swept up ($M_{\odot}$)	<5	tens	~1000
Velocity (km/s)	<10000	~200	~20
Radius (pc)	<1	~10	~30
Time (yrs)	<2000	~40000	~100,000

Phase IV represents disappearance of remnant

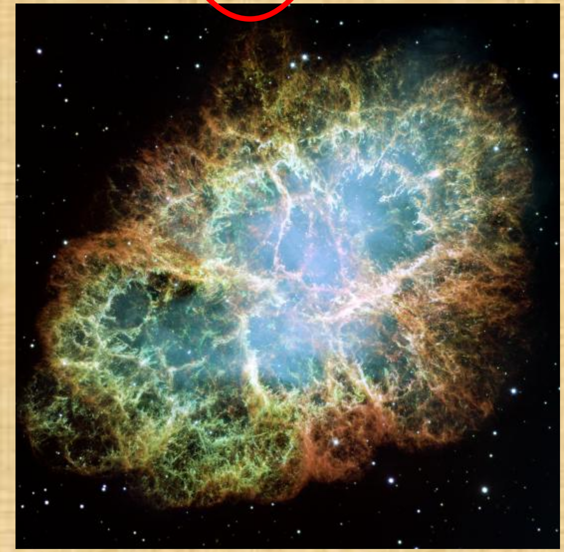
SNR classification

Environment!

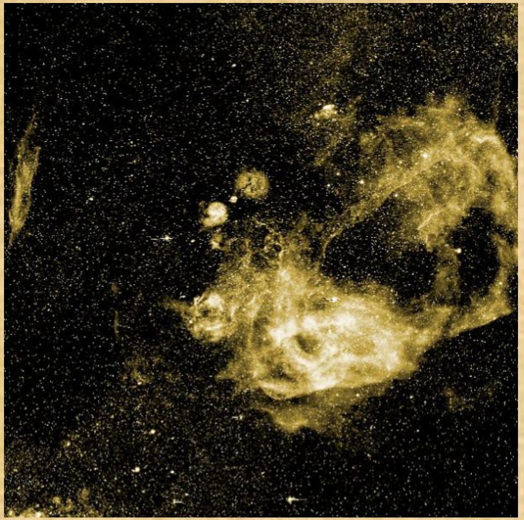
type	Radio	X-ray	SN ?	SNR evolution phase	Observed fraction	examples
shell	α~-0.5	Most thermal	Ia	Free expansion/Sedov	~90%	Tycho
plerions	α~-0.2—-0.1	Non-thermal	Ib/c, II		<10%	Crab
hybrid	Multi-compo nent	Non-thermal	Ib/c, II		<10%	Vela



Tycho



Crab



Vela

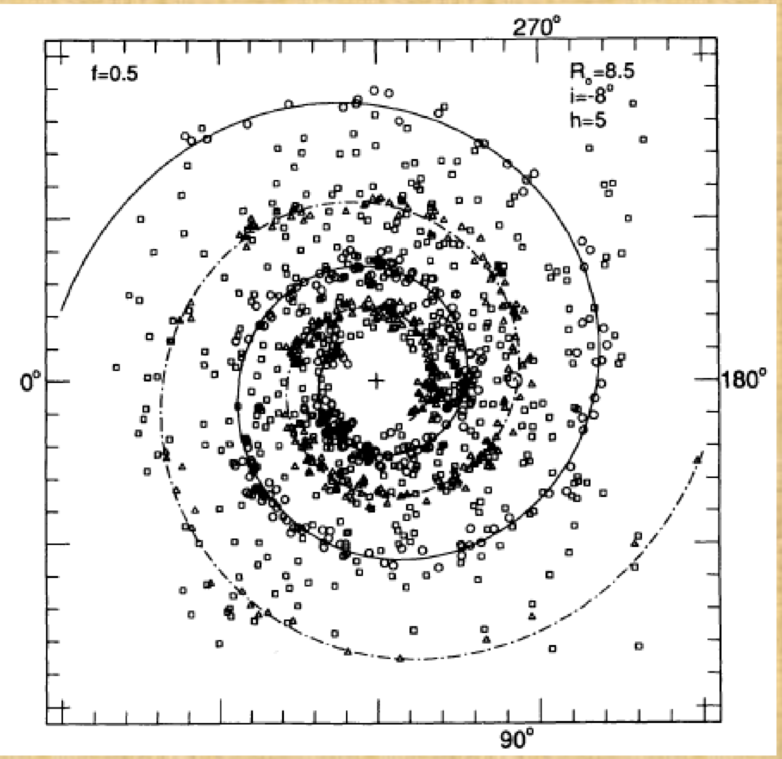
SNR deficiency

- Observations
  - PSR: 2213 (ATNF 2013)
  - SN: 726 (Li et al. 2011)

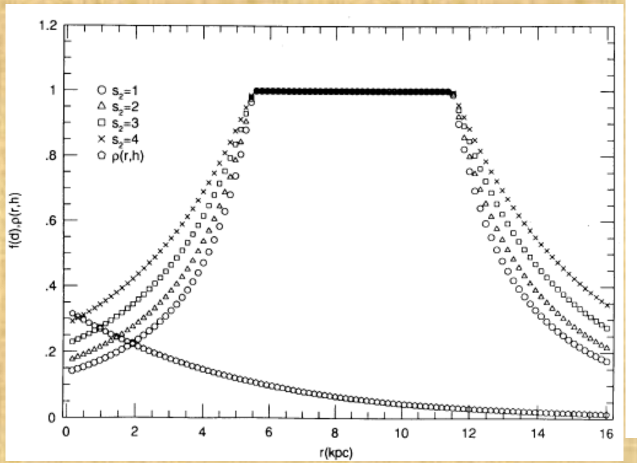
  274 Ia, 116 Ibc, 324 SNe II
  - SNR: 274 Galactic (Green 2009)

- Faint
- limit of coverage

- Prediction



~1000 SNR distribution (Li et al. 1991)



Selection effect function (Li et al. 1991)

Five-hundred-meter aperture spherical *radio telescope* (*FAST*)

Spherical reflector: Radius=300m, Aperture=500m, Opening angle=112.8°

Illuminated aperture: D_{ill} =300m

Focal ratio: f/D =0.4665

Sky coverage: zenith angle 40°, tracking time ~ 6h

Frequency: 70 MHz - 3 GHz (up to 8GHz, future upgrading)

Sensitivity (L-Band): A/T ~ 2000, system temperature T_{sys} ~ 20 K

Resolution (L-Band): 2.9′

Multi-beam (L-Band): beam number=19 (future focal plane array >100)

Slewing time: <10 minutes

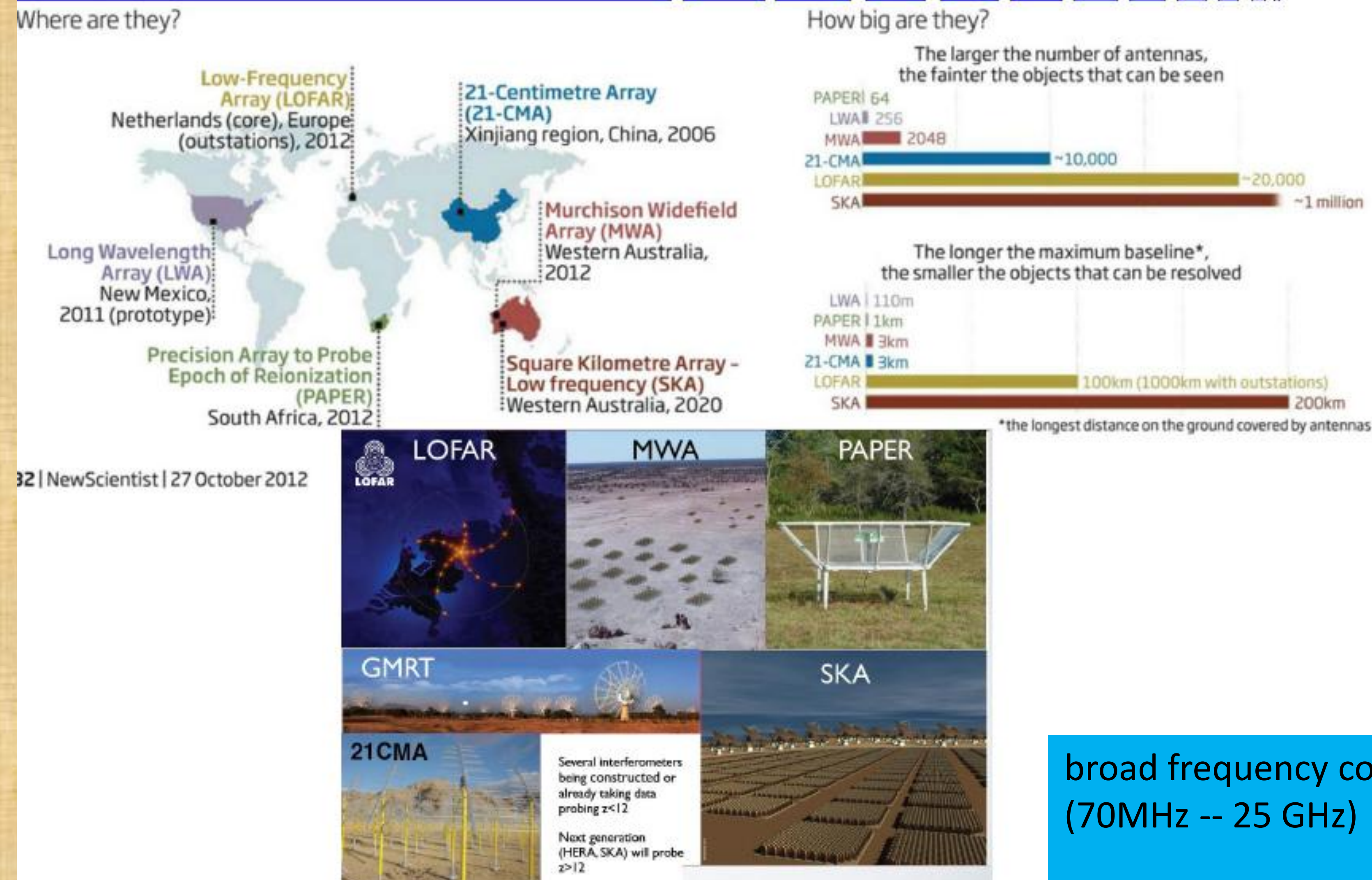
Pointing accuracy: 8″

(Nan et al. 2009)

1. How SNRs affect their environment and how the environment affect SNRs' evolution
2. How the magnetic fields of SNRs change their shapes with time?
3. Are SNRs responsible for the origination of Galactic cosmic rays

....

SKA Pathfinders



broad frequency coverage
(70MHz -- 25 GHz)

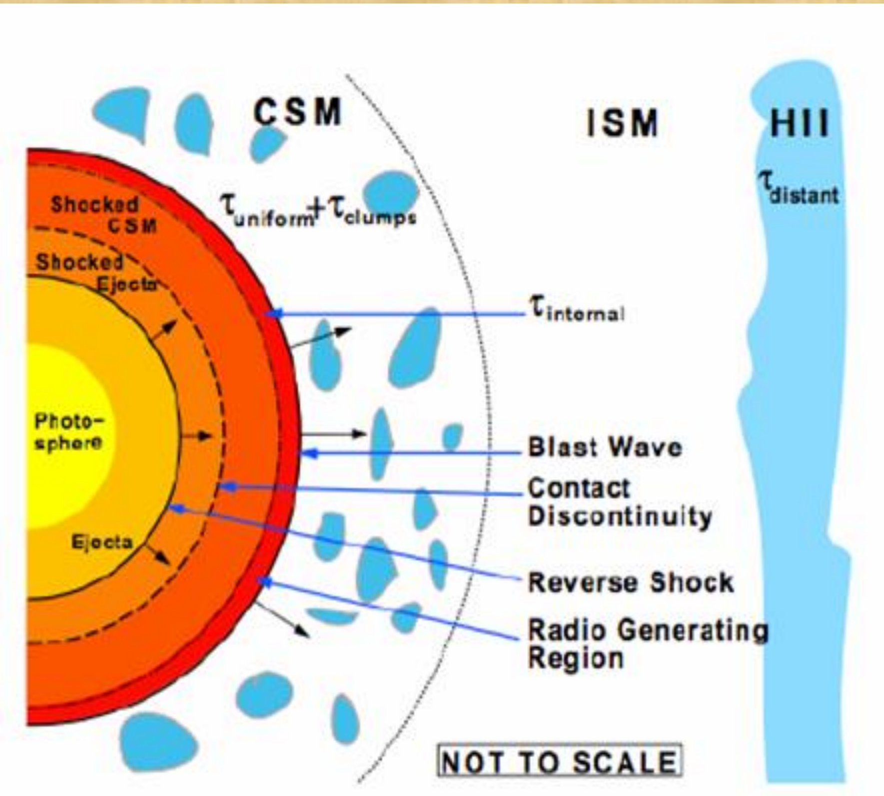
(Peter et al. 2009)

Peng, B. (2nd China-US Workshop on Radio Astronomy S & T, 2013)

Progenitor of SNIa (Poster 24—Wang et al.)

- Core collapses SNe

1. How do the massive progenitor stars of core collapse SNe evolve in the thousands of years prior to their explosion?
2. What are the physical processes of the absorbing medium of the early radio emission?
3. Do these SNe simply transition smoothly into SNRs or is there a fading as they overrun their CSM and later re-brightening as the blast wave begins to encounter the ISM

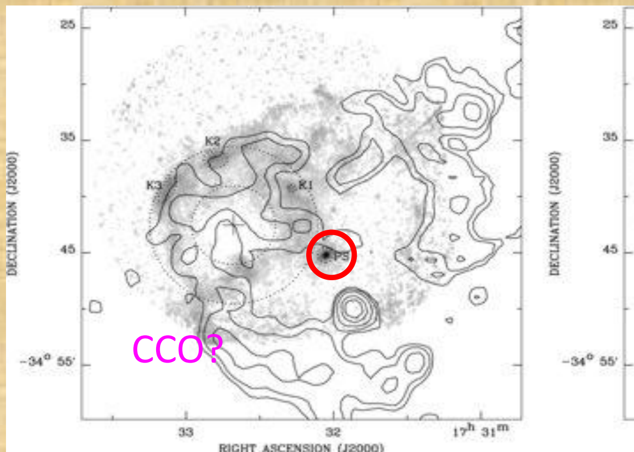


- Type Ia SNe

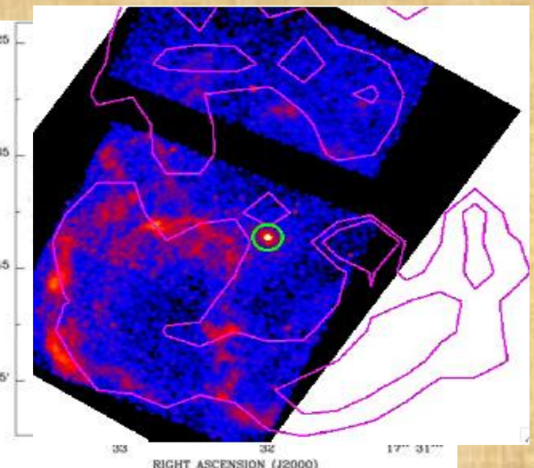
White dwarf + (from MS to RG) VS Double white dwarf

High sensitivity radio observation can help to answer these questions!

SNR G353.6-0.7: hard X-ray



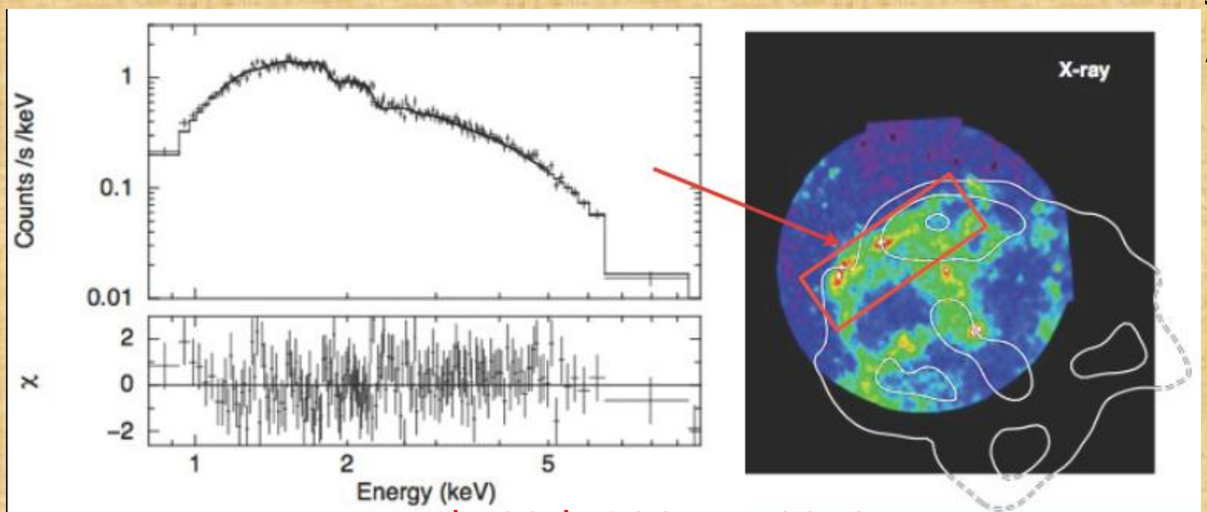
XMM-Newton, Tian et al. 2010



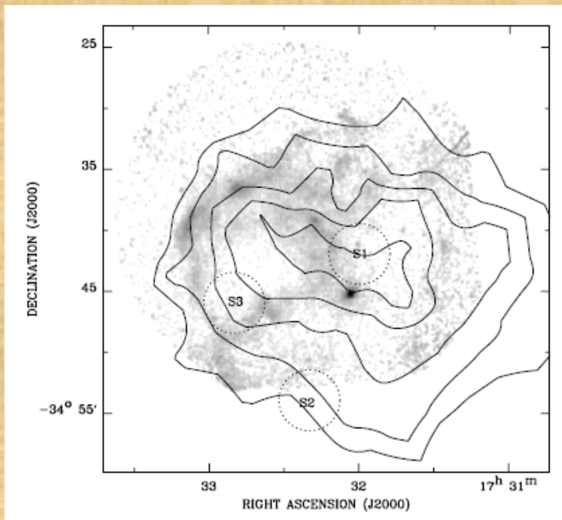
Chandra, Halpern & Gotthelf 2009

Suzaku : 33ks
XMM-Newton : 25 ks
Chandra : 30 ks
Non-thermal shell (power law with SI ~ -2.2) in radio, X-rays, Gamma-rays

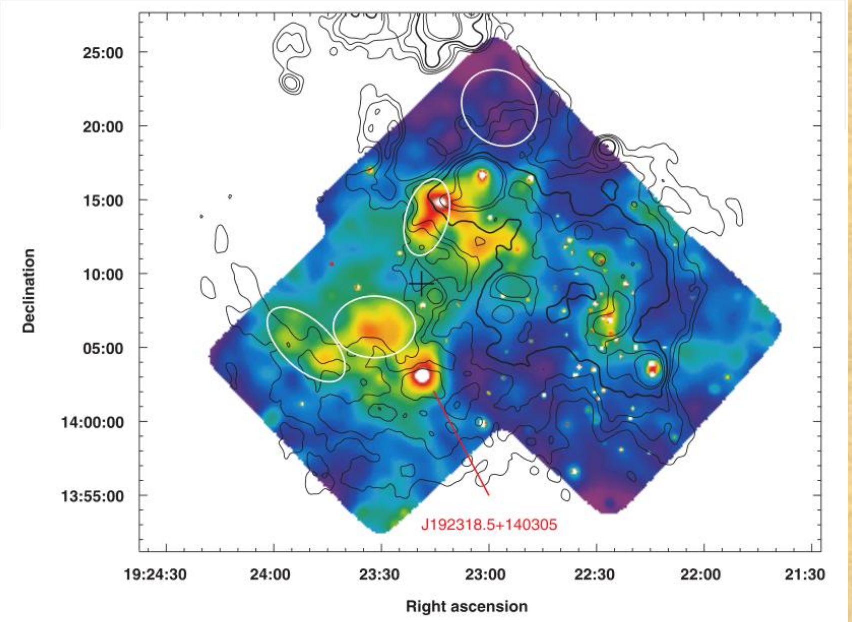
A compact source (XMMS J173203-344518) within the SNR: AXP



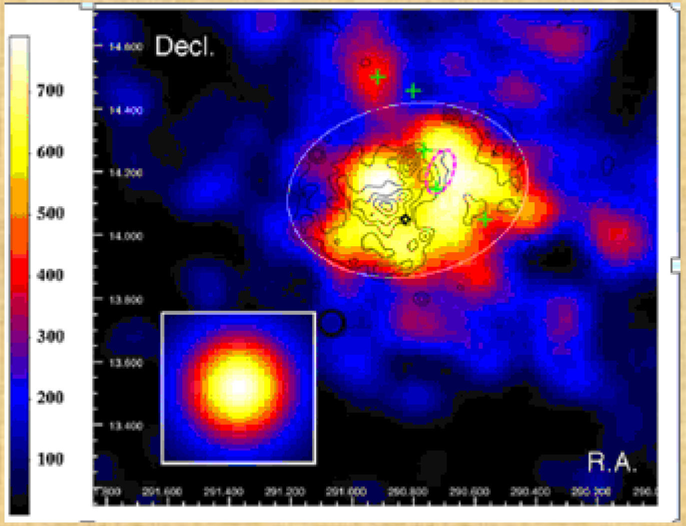
Acero et al., 38th COSPAR, 2010



SNR W51C:
Chandra ACIS image (0.5-8keV)



Fermi LAT counts map in 2–10 GeV around SNR W51C

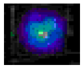


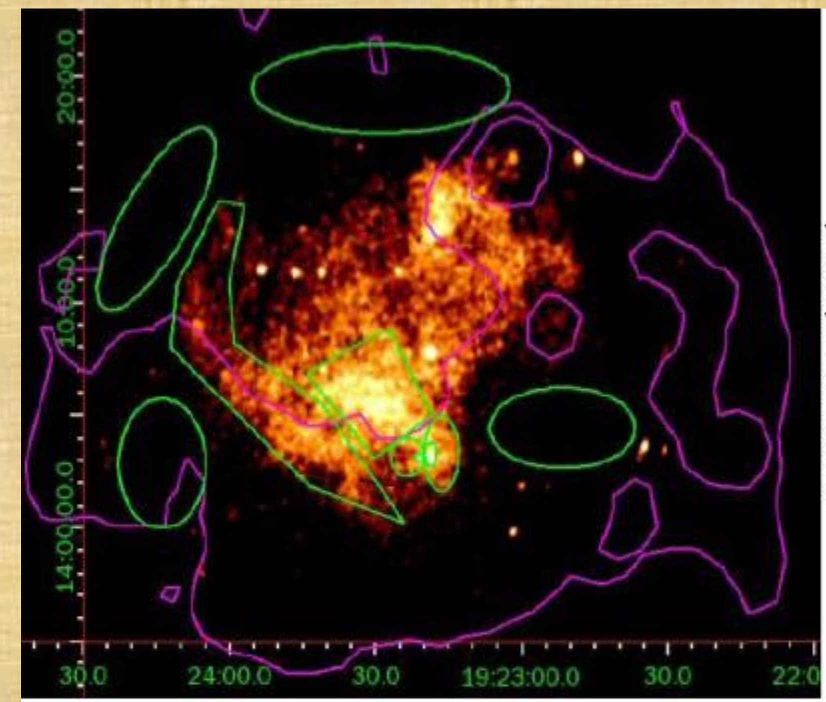
Addo et al. 2009

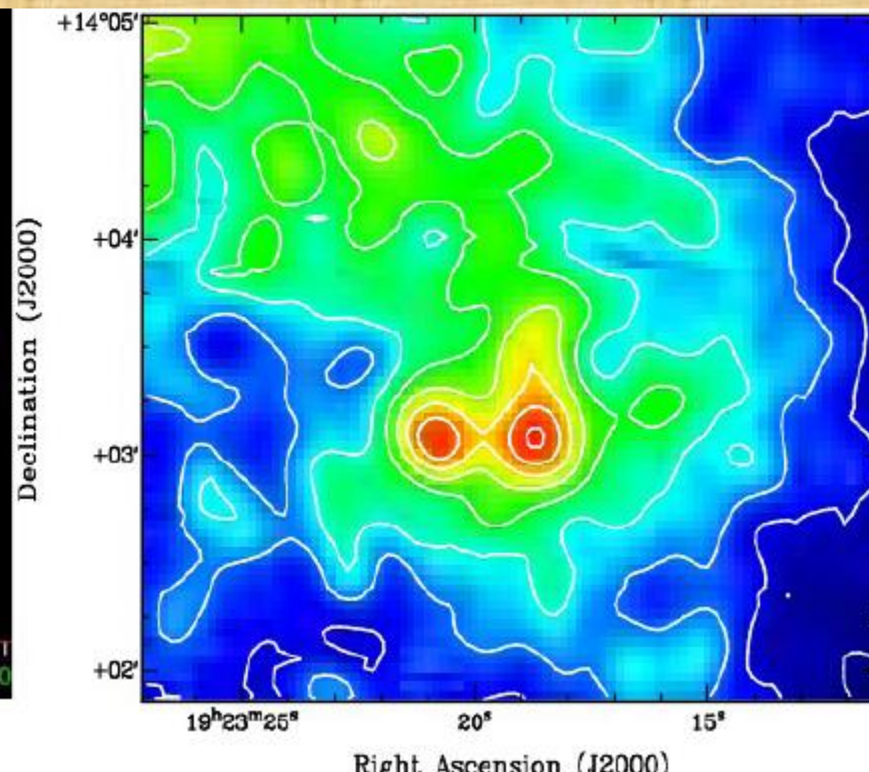
Sequence Number	Date	Instrument	Field Center ($\alpha_{2000.0}$, $\delta_{2000.0}$)	Exposure (ks)
500318..................................	2003 Jun 3	ACIS-I	(19 22 28.0, 14 05 00)	29.9
500319..................................	2002 Dec 8	ACIS-I	(19 23 00.0, 14 15 00)	11.76
500320..................................	2002 Dec 8	ACIS-I	(19 23 30.0, 14 05 00)	12.12

(Koo et al 2005)

XMM-Newton Observations W51C

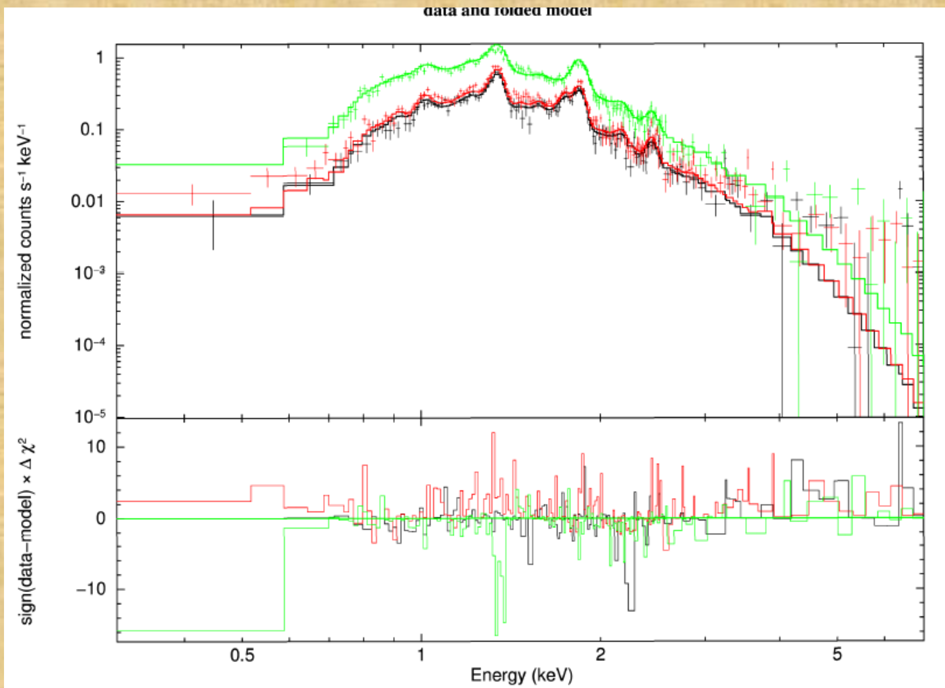
Obs.ID	EPIC	RGS	Target	RA	Dec	Start Date	End Date	Dur.	Target Type	PI name
0554690101			W51C center	19h 23m 31.84s	+14d 07' 19.70"	2009-04-08 12:42:39	2009-04-09 09:31:16	74917	SNR FILLED-CENTER TYPE II	Lee, Jae-Joon
0554690501	N/A	N/A	W51C center	19h 23m 31.84s	+14d 07' 19.70"	2009-04-08 10:58:21	2009-04-08 12:23:49	5128	SNR FILLED-CENTER TYPE II	Lee, Jae-Joon



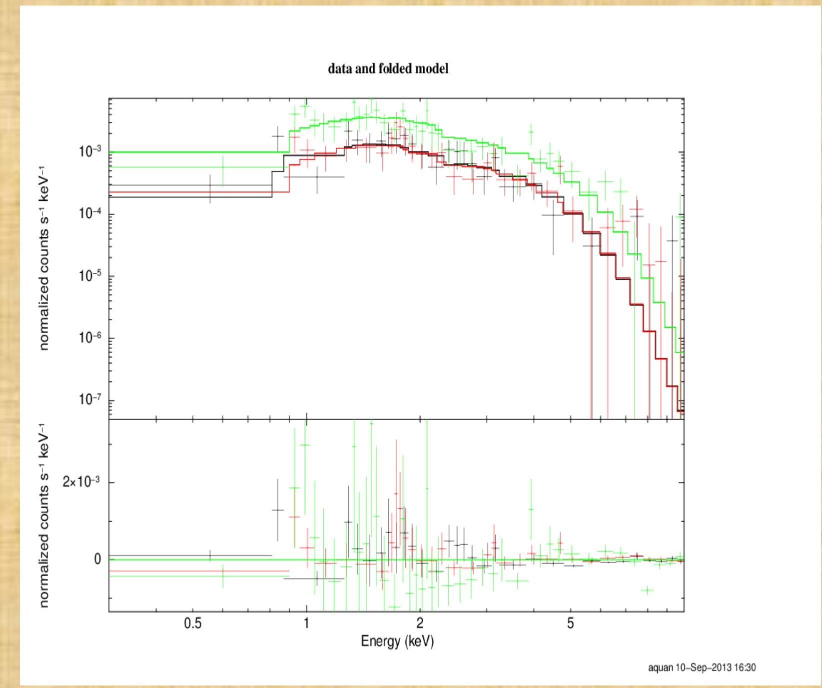


Spectra SNR W51C and new source

W51C

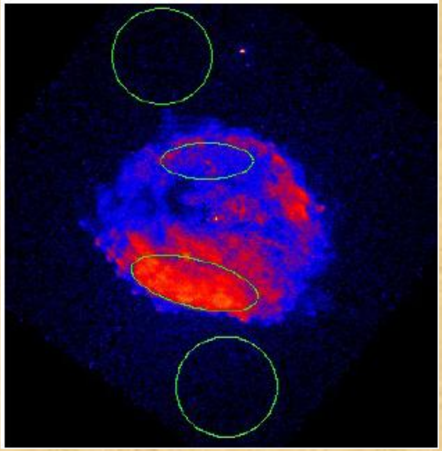


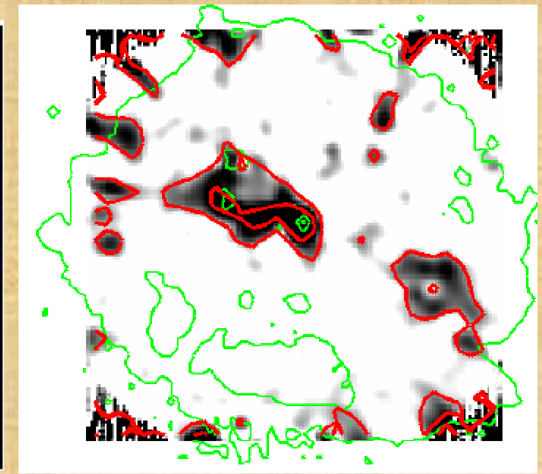
New source

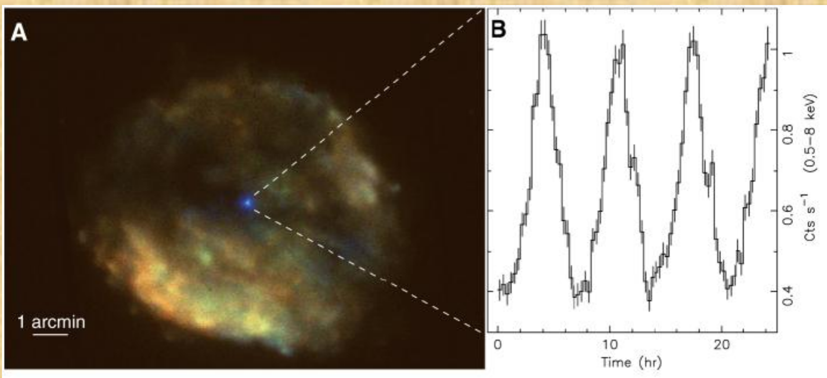


source	model	N_H ($10^{22} cm^{-2}$)	kT (keV)	$[Mg]/[Mg]_c$ [2]	$[Si]/[Si]_c$	$[Ni]/[Ni]_c$	re-χ^2	snr	phoIndex
SNR inner left	wabs*vequil	1.28±0.03	0.57±0.02	1.90±0.18	1.00	1.00	1.852	4.0	-
SNR inner right	wabs*vequil	1.48±0.03	0.57±0.01	1.75±0.12	1.63±0.11	4.54±0.90	1.813	4.0	-
SNR inner whole	wabs*vequil	1.41±2.74	0.57±0.01	1.72±0.10	1.41±9.52	3.06±0.72	2.031	4.0	-
SNR outer whole	wabs*vequil	1.53±0.14	0.90±0.07	1.00	1.00	1.00	1.042	2.0	-
CXO[1]	wabs*(vequil+PL)	1.48±0.03	0.57±0.01	1.75±0.12	1.63±0.11	4.54±0.90	1.005	4.0	1.70±0.16
New source	wabs*PL	0.94±0.27	-	-	-	-	0.911	3.0	2.09±0.35

SNR RCW 103



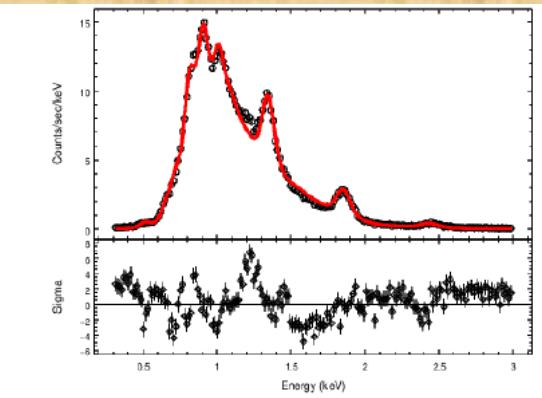


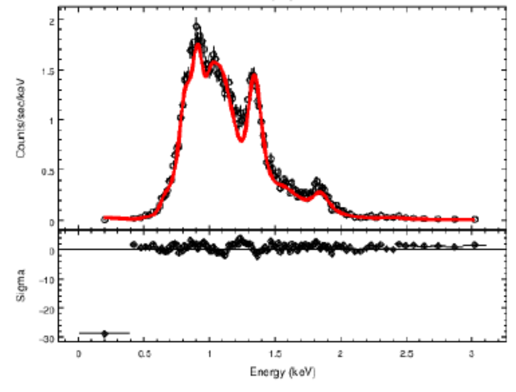


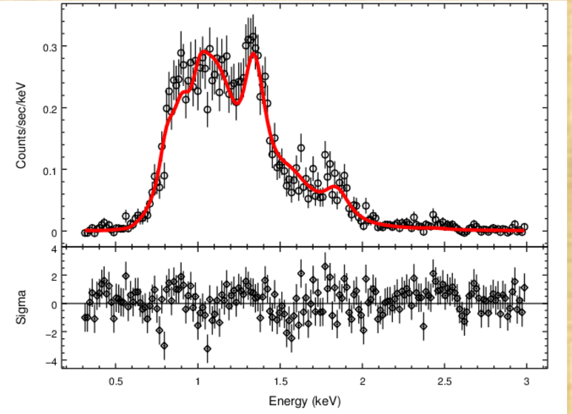
6.67-hour periodicity

(De Luca et al. 2006)

Chandra 2009 observations





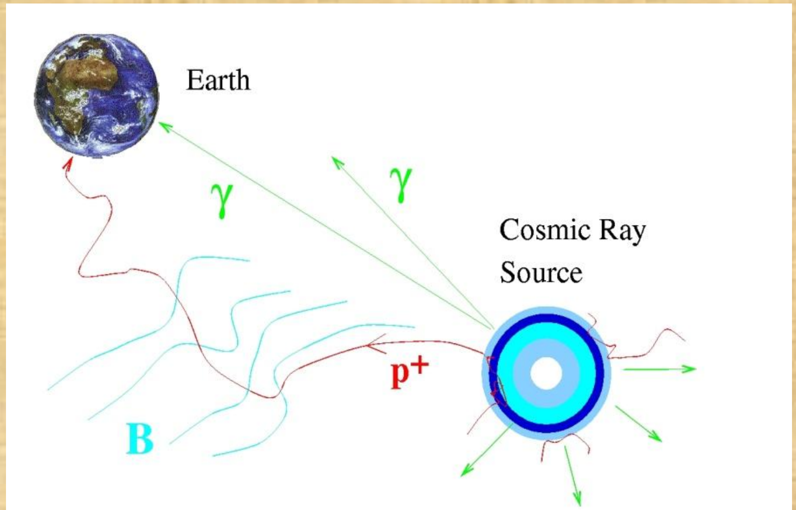


- Reduced statistic = 23.7101
- Change in statistic = 8.46608e+06
- abs1.nH 0.516173
- a1.kT 0.589954
- a1.norm 0.102177

- Reduced statistic = 2.56824
- Change in statistic = 1.12116e+08
- abs1.nH 0.835967
- a1.kT 0.286364
- a1.norm 0.0972665

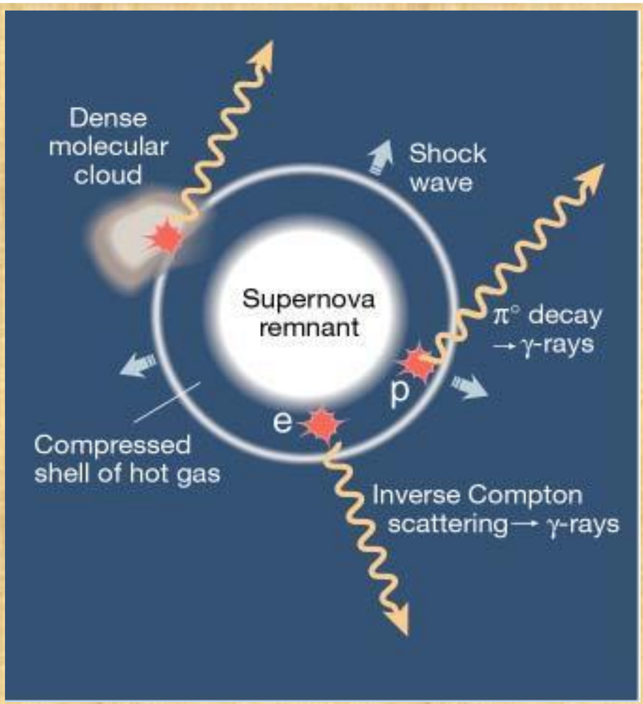
Reduced statistic = 2.00874
Change in statistic = 3.22511e+08
abs1.nH 1.05606
a1.kT 0.297875
a1.norm 0.0273112

VHE γ-ray observations: a key for CRs origin



γ-rays (its trajectories are unaffected by interstellar and Galactic magnetic fields) are an excellent tracer of CR accelerators.

Accelerated CRs produce γ-rays after interaction with interstellar material.



The key issue in SNR case: identification of γ-ray emission mechanisms:

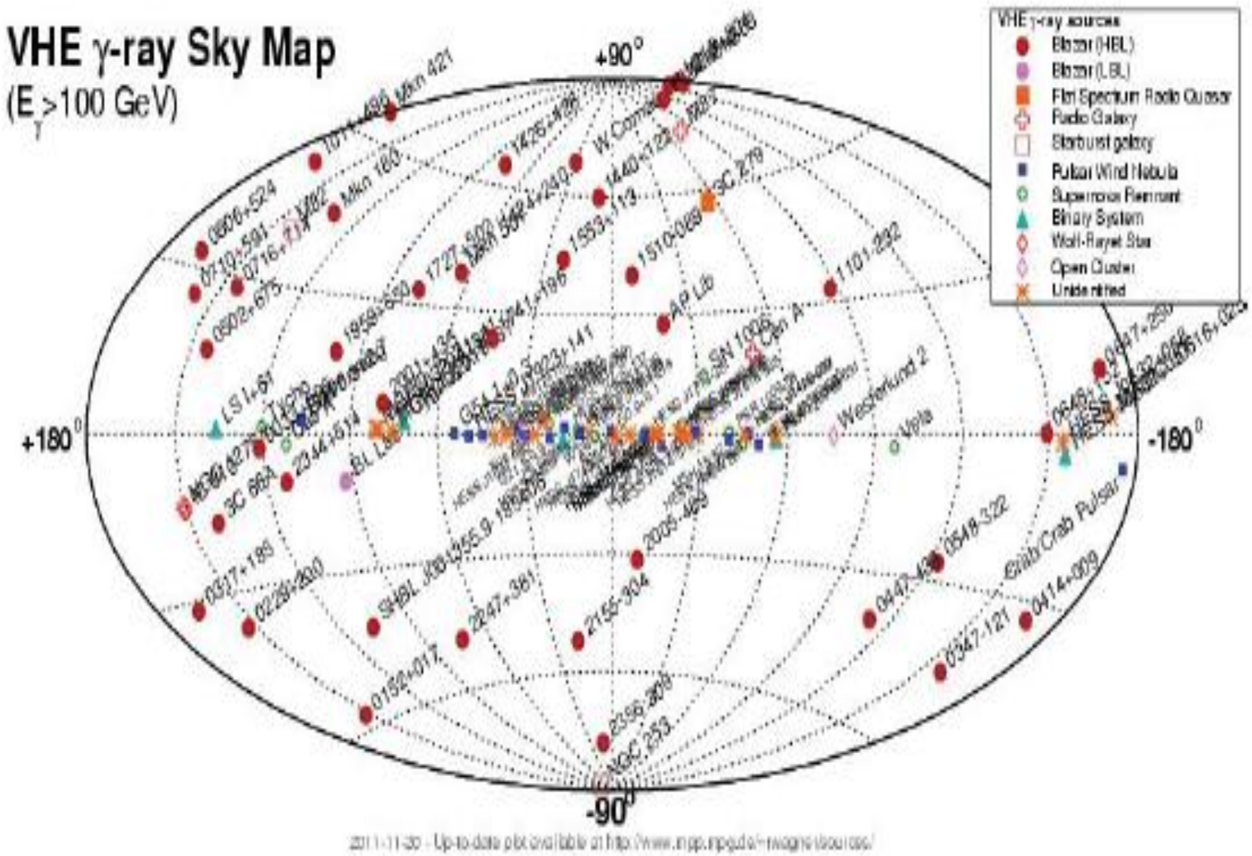
π0: hadronic origin of γ -ray

CRs + gas -> pp -> π0 -> 2γ

IC: leptonic origin of γ -rays

e γ -> e γ

High-energy Gamma rays

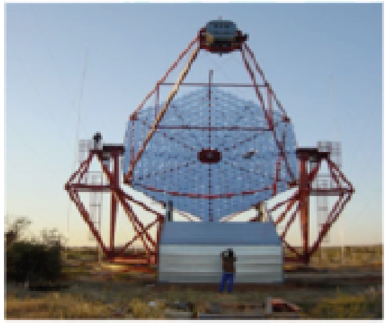


- Counterpart of accelerated electrons (inverse Compton scattering, Bremsstrahlung)
- Is there a counterpart of accelerated hadrons ? Few evidences with current data

Survey of the Gamma Sky

2 possible techniques

Cerenkov imaging of gamma-ray showers (IACT)



Ex: HESS, MAGIC, VERITAS then CTA

- High sensitivity (γ–hadron separation)
- Good spatial resolution

BUT

- Low duty cycle
- Limited field of view

Detection at ground of gamma-ray showers

Ex: ARGO, MILAGRO, Tibet-ASγ, HAWC

- 100% duty cycle
- Large field of View

BUT

Lower rejection power

LHAASO : Detection at ground of gamma-ray showers optimizing the rejection power with large collection surface and multi-parameter measures

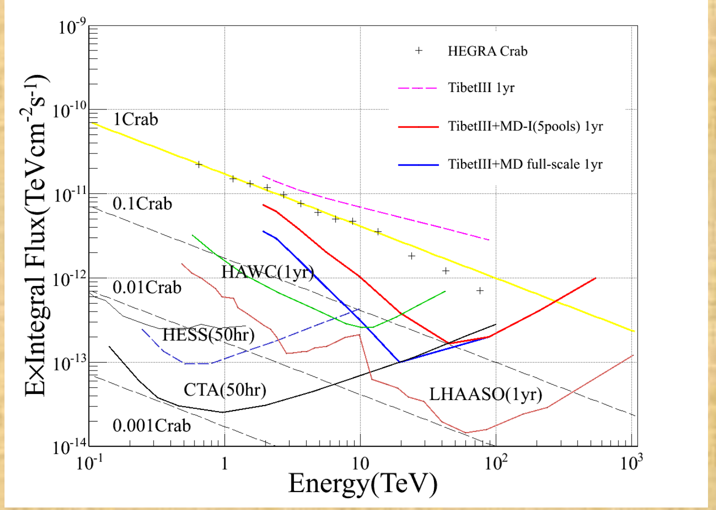
Olivier Deligny (Rencontres de Moriond 2013)

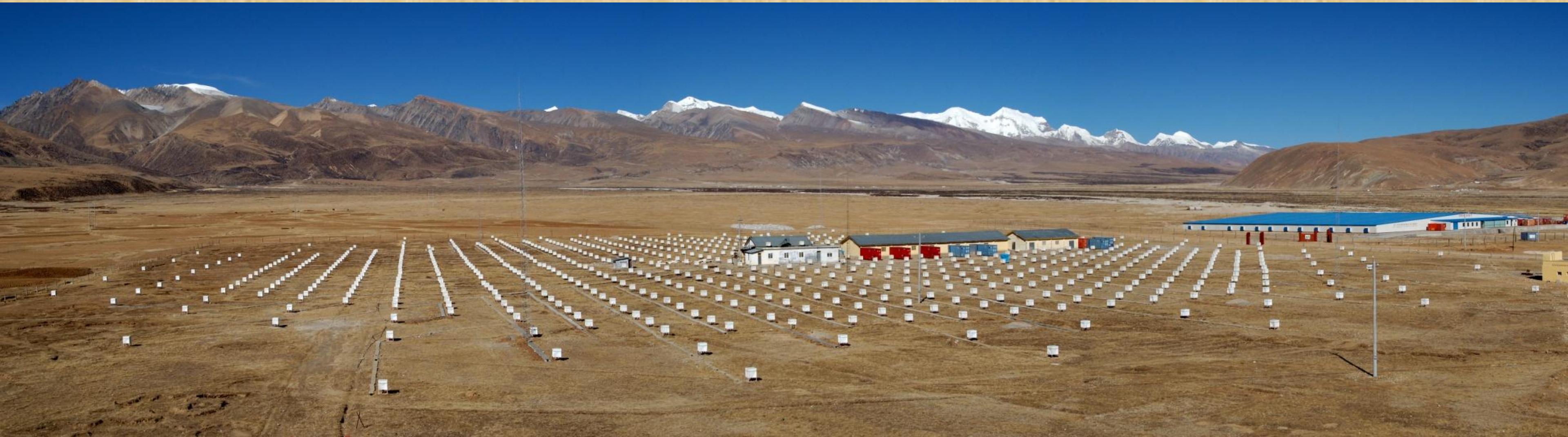
Tibet ASγ Experiment

Tibet China (90.522°E, 30.102°N) 4300 m a.s.l., since 1989

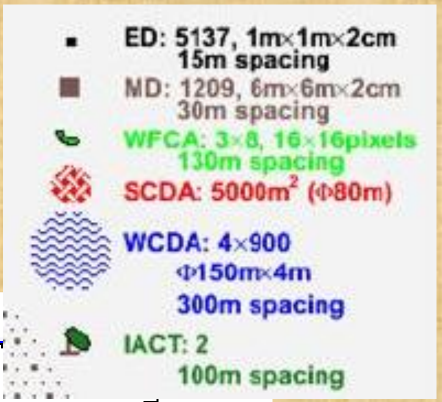
Number of Scinti. Det.	0.5 m^2 x 789
Angular Resolution for gamma rays	~0.9 deg.@3 TeV
	~0.5 deg.@10 TeV
	~0.2 deg.@100 TeV
Energy Resolution for gamma rays	~100% @3 TeV
	~60% @10 TeV
	~40% @100 TeV
F.O.V.	~2 sr

Effective Area for AS ~37,000 m^2





The Large High Altitude Air Shower Observatory (LHAASO)



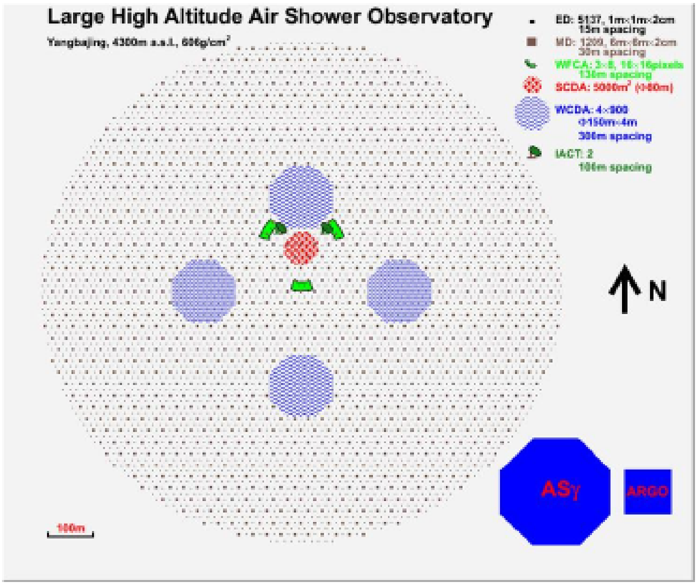


Fig. 1: Layout of the LHAASO array

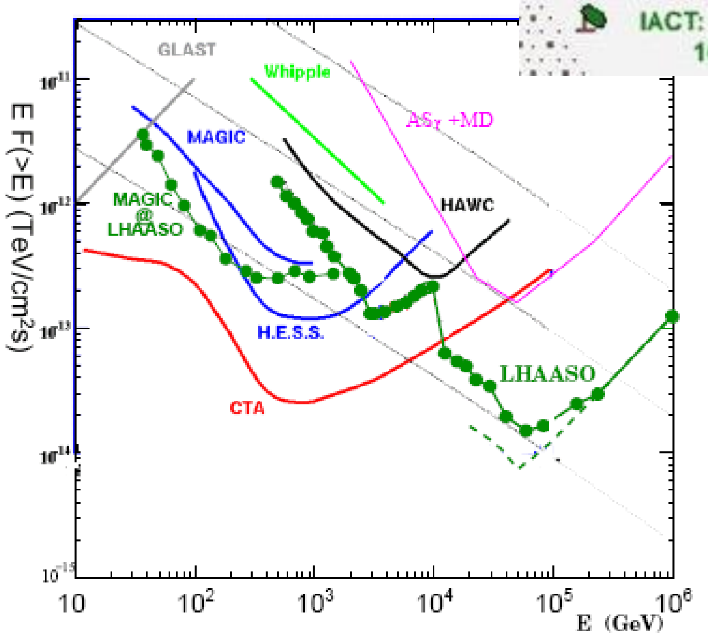
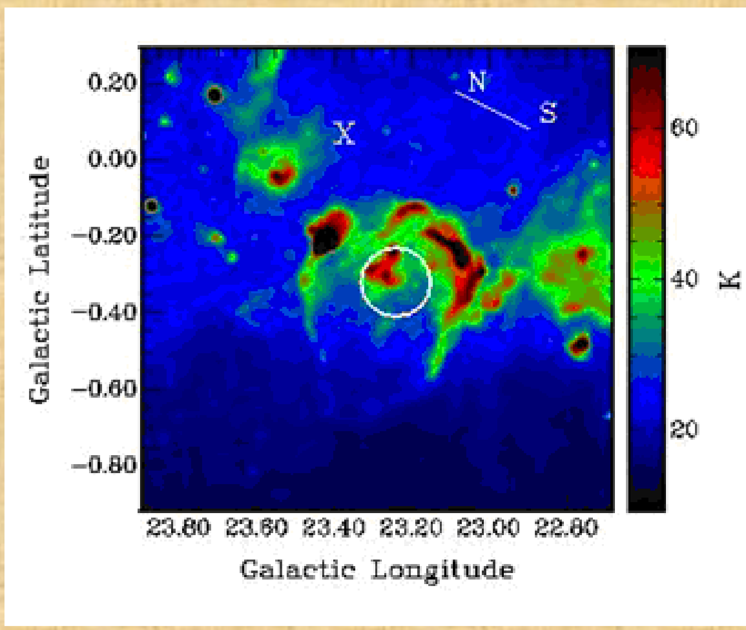


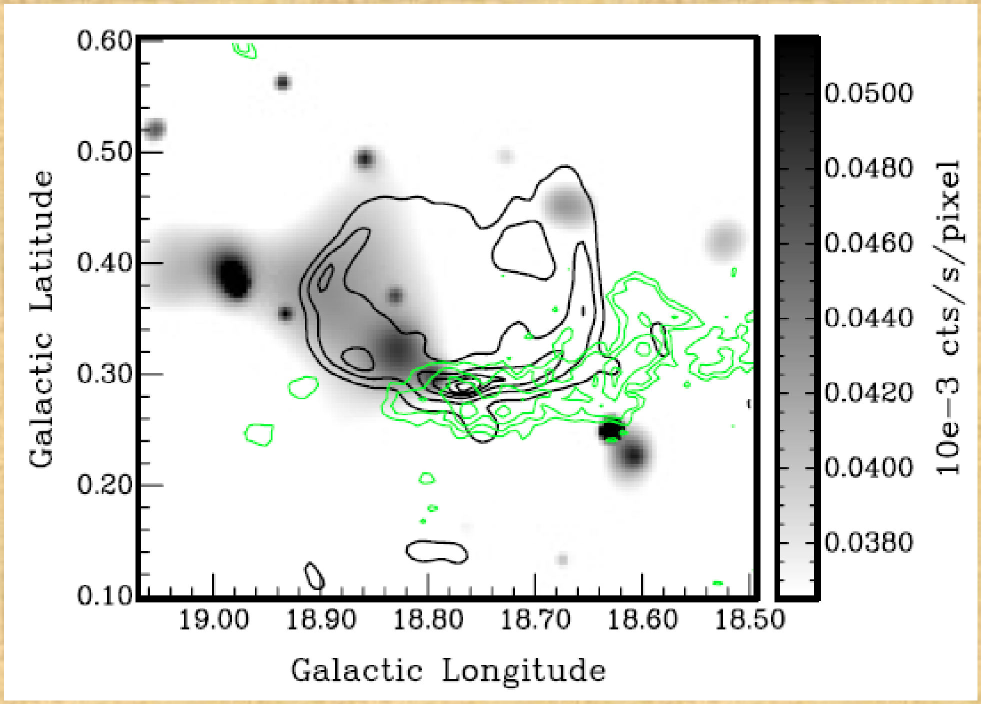
Fig. 2: The sensitivity of the major experiments and future projects for gamma ray astronomy

30TeV-10PeV (Cao et al. 2009)

TeV gamma-ray from the interaction between old SNR and MC



W41/HESS J1834-087 (Tian et al. 2007a)



SNR G18.3+0.3 (Tian et al. 2007b)

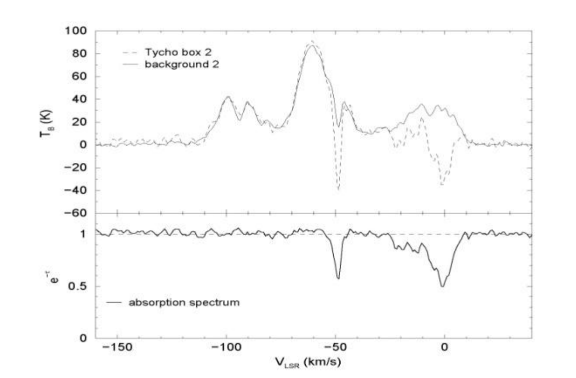
Testing SNR-MC interaction

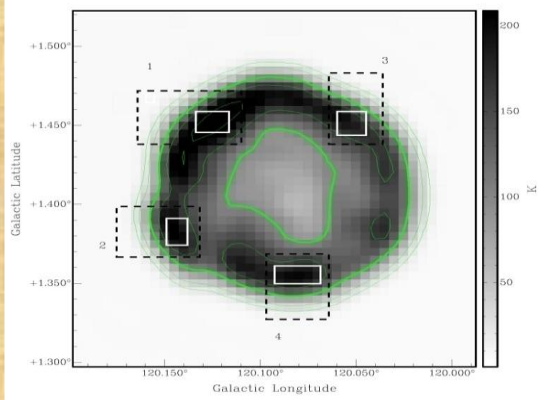
- Tycho 1572:

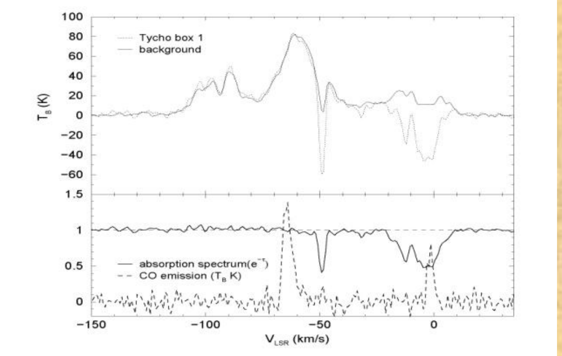
  a naked TeV Ia SNR

  (Tian & Leahy, 2011)

no interaction between Tycho shock and CO cloud

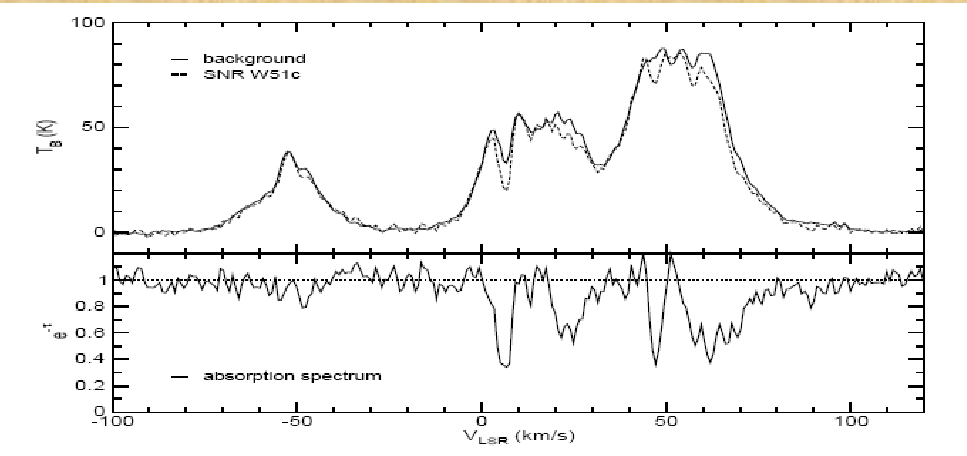


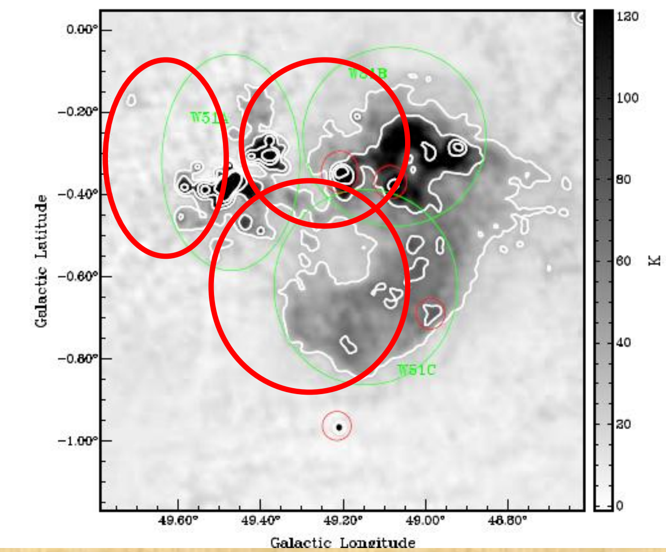




- W51C (TeV): not associated with HI

  Tian & Leahy, 2013



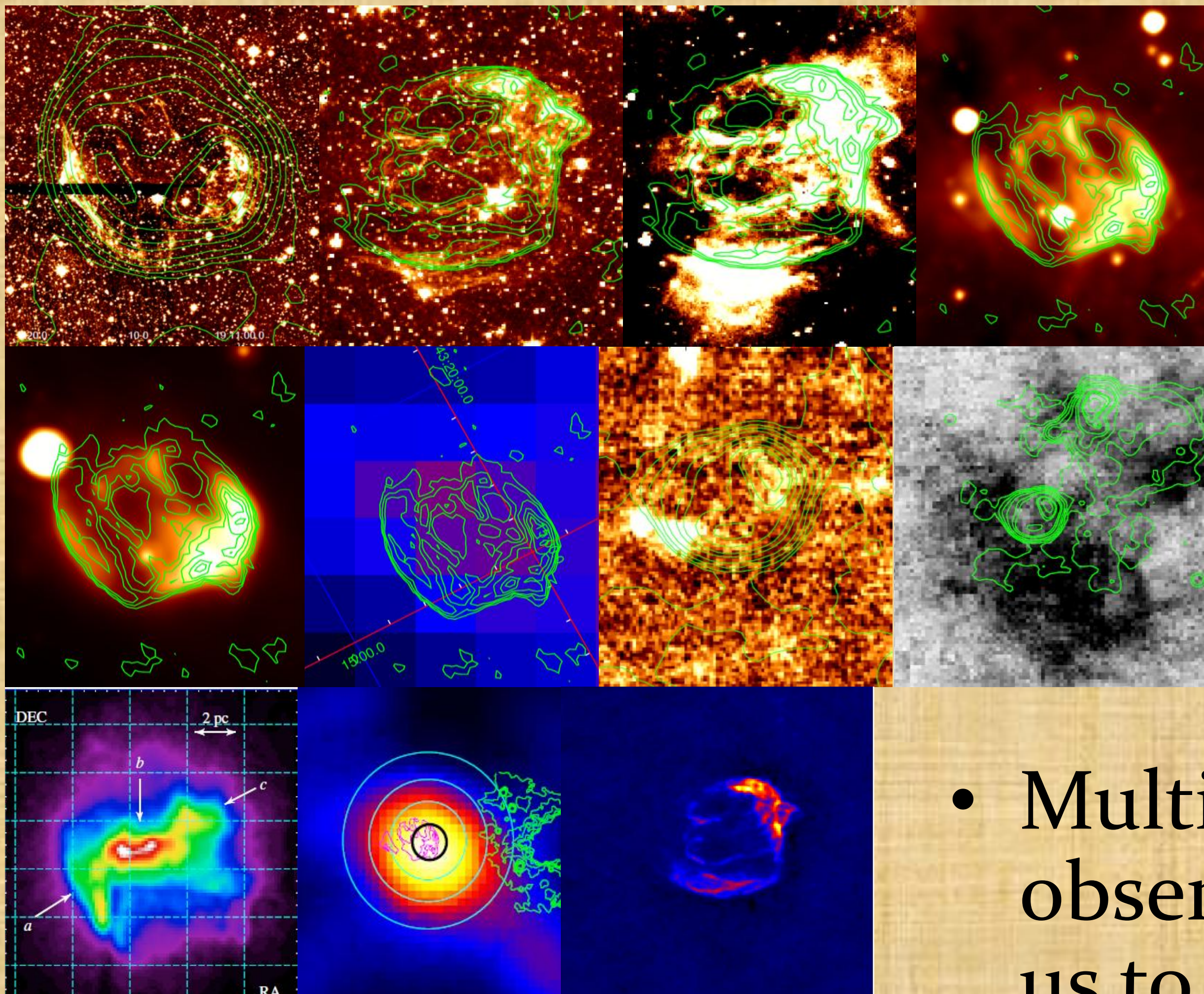


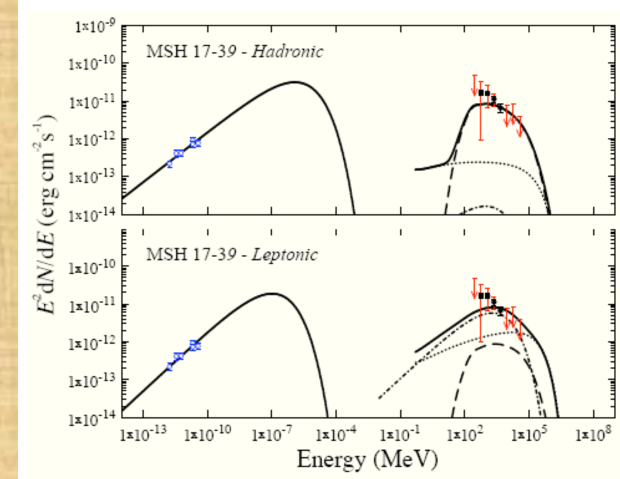
Expectation

- Galactic γ-Ray SNRs: 122 （Tian & Zhang 2013）
- Asγ candidate sources： 18

SNR ID Gal. name	Name (Gamma-ray)	Type	Age (kyr)	Distance (kpc)	Radio size	Gamma-Flux (Crab Units)	SNR/ MC
G23.3-0.3(W41)	HESS J1834-087(GT)	S? PWN?	100(S)	3.9-4.5(S)	27'	0.08(≥0.2TeV)(H,MA,F)	Y?
G25.5+0.0	HESS J1837-069(T)	PWN?				0.132(≥0.2TeV)(H)	
G40.5-0.5	HESS J1908+063,MGRO 1908+06(GT)	S	20(P)	3.2(P)	22'	0.17(≥1TeV)(H,V,MI,A,F)	Y?
G65.1+0.6	0FGL J1954.4+2838(GT)	S	4-14	9.2(S)	50'-90'	0.23(=35TeV)(MI,F)	
G75.2+0.1(Cisne)	MGRO J2019+37(T)	PWN?		≥10(S),4(P)		0.67(=35TeV)(MI)	
G78.2+2.1(gammaCygni)	VER J2019+407(GT)	S	6.6(S)	1.5(S)	60'	?(V,F)	Y?
G184.6-5.8	Crab(GT)	C? PWN	0.958	1.5-2.5(S), 2(P)	5' - 7'	1(H,V,MA,MI,A,F)	N
G189.1+3.0 (IC443)	MAGIC J0616+225(GT)	C PWN	30(S,P)	0.7 – 2(S)	45'	0.03(V,MA,MI,F)	Y
G195.1+4.3	Geminga(GT)	C? PWN		0.25(P)		0.23(35TeV)(MI,F)	
G26.8-0.2	HESS J1841-055(T)					0.37(0.54-80TeV)(H)	
G29.3+0.51	HESS J1843-033(T)					?(H)	
G34.7-0.4(W44, 3C392)	2FGL J1855.9+0121e(G)	C PWN	≥ 10(S), 20(P)	3(S,P)	27'-35'	0.436(F)	Y
G44.39-.07	HESS J1912+101(T)	PWN?				0.09 (1-10TeV)(H)	
G65.85-0.23	0FGL J1958.1+2848	PWN				0.21(Mi)	
G79.72+1.26	MGRO J2031+41(T)					0.39(=35TeV)(MI,A)	
G80.25+1.07	TeV J2032+4130(T)					0.03(=35TeV)(HE,W,MI,A)	
G201.3+0.51	0FGL J0631.8+1034	PWN		6.55(P)		0.29(Mi)	

Multi-wavebands study





Castro et al. 2013

From left to right and upper to bottom: 2.12um, 4.5um, 8um, 12um, 22um, 100um, 1.1mm, 2.6mm, 1-9KeV, 6-30GeV, 21cm CTA 46

- Multi-wavebands observation will help us to under the SNRs and the origin of CR.