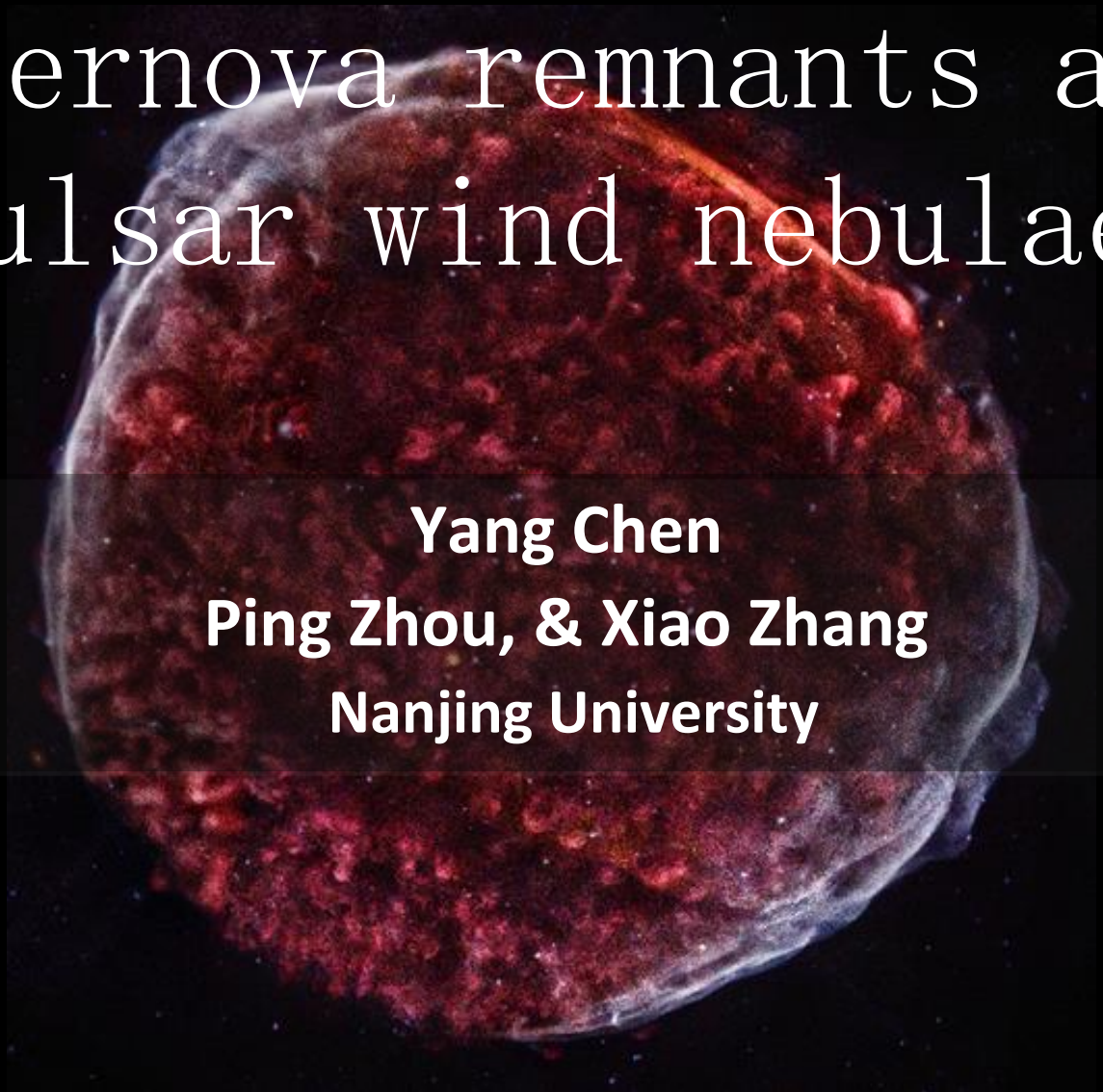
eXTP observation of supernova remnants and pulsar wind nebulae



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Importance of eXTP on the studies of SNRs and PWNe

SNRs are believed to be the main accelerators of cosmic rays up to 3PeV
Injection mechanism (for particles and energy) / acceleration efficiency / acceleration region size / *E*_max remain unclear.

eXTP is expected to address the following questions:

- What effect does the orientation of injection with respect to the direction of magnetic field have on the shock acceleration efficiency in SNRs?
- What is the intensity of the synchrotron radiation and the orientation of the magnetic field in the forward shock and, especially, the reverse shock in SNRs?
- What is geometry of the non-thermal X-ray emitting components with respect to that of the thermally emitting regions in SNRs?
- What is the configuration of the magnetic field in PWNe and what physical insight can we infer from that?

1. SNRs with Synchrotron X-rays

- Chandra discovered ~10 SNRs with non-thermal (synchrotron) X-ray boundaries.

Any more?

- In some SNRs, non-thermal X-rays are possibly blended with thermal ones, and are needed to be differentiated.

confirmed

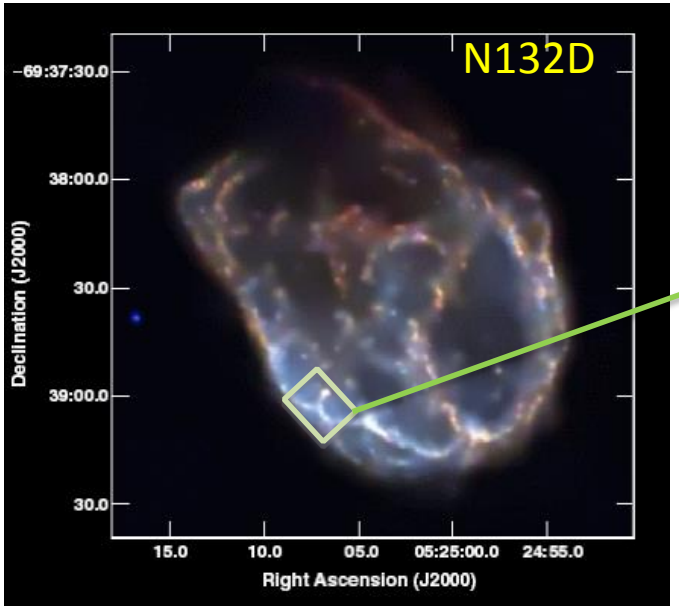
SNR	Size
G1.9+0.3	1.5′
Cas A	5′
Tycho	8′
SN1006	30′
RCW 86	42′
RX J1713-3946	65′ x55′
Vela Jr.	120′

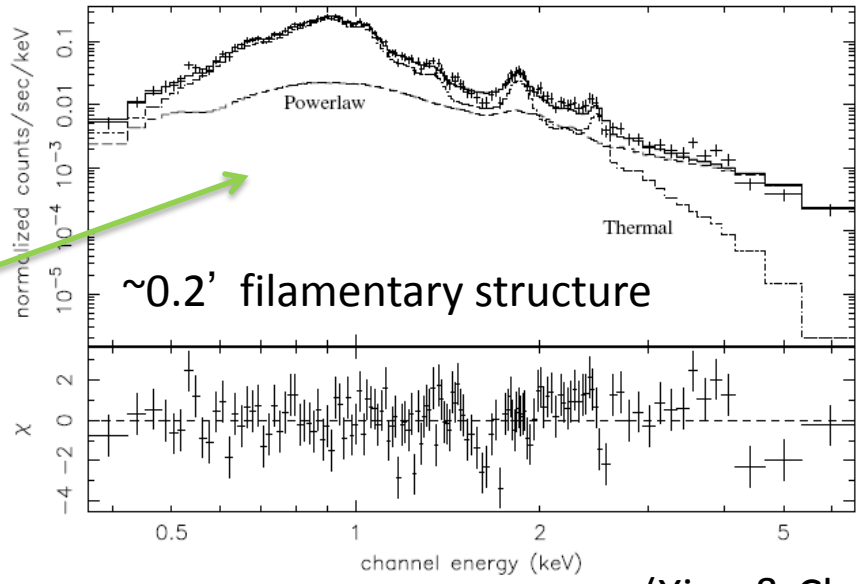
candidates

SNR	Size
N132D	2.5′ x2′
G32.4+0.1	6′
G28.6-0.1	13′ x9′
CTB 37B	17′
W28	48′
G156.2+5.7	110′
…	

Synchrotron X-rays from shell-type SNRs

A great advantage of eXTP for SNR studies:
able to tell the polarized synchrotron X-rays from the thermal X-rays.



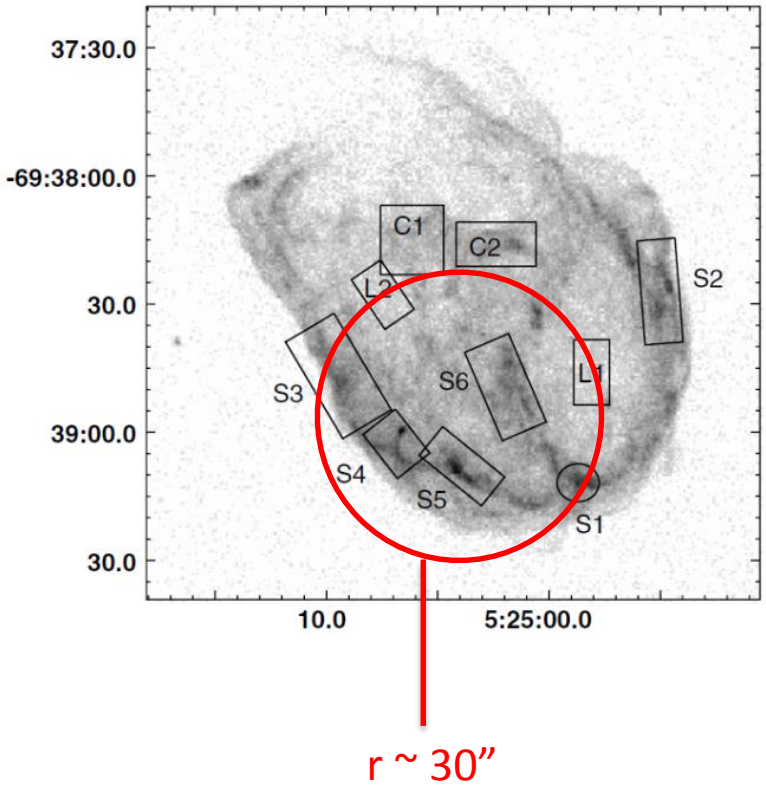


(Xiao & Chen 2008)

E.g.， in SNR N132D, thermal component + hard tail.

Is the hard tail synchrotron emission?

Distinguish the non-thermal and thermal emission



Model:

wabs*(vpshock+powerlaw)

Powerlaw component:

photon index Γ=3.42(+-0.02)

S4: F(2-10keV)=3E-13 erg/cm^2/s

Circle: F(2-10keV)= 4E-12 erg/cm^2/s

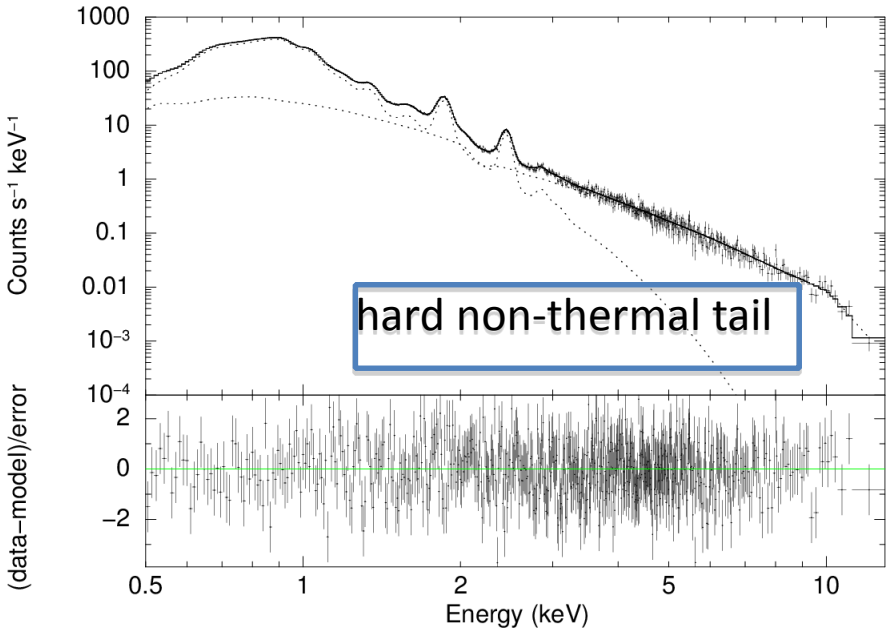
Entire: F(2-10keV)>~1E-11 erg/cm^2/s

If at *d* of Galactic SNRs (~10kpc)

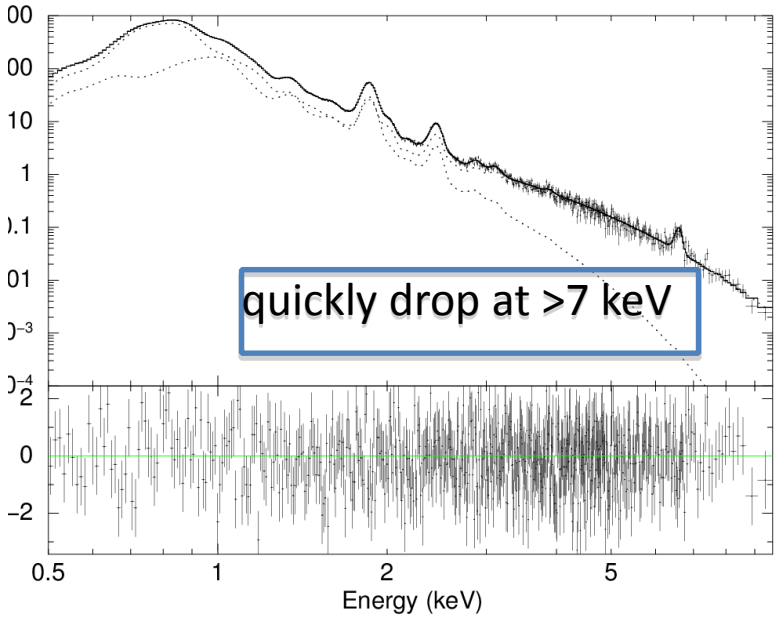
X-ray flux of order: 1E-10 to 1E-9erg/cm^2/s

Simulated SFA spectra

vpshock+powerlaw



vpshock+vpshock



vpshock: thermal model

exposure time=10 ks

F(2-10keV)=3E-12 erg/cm^2/s

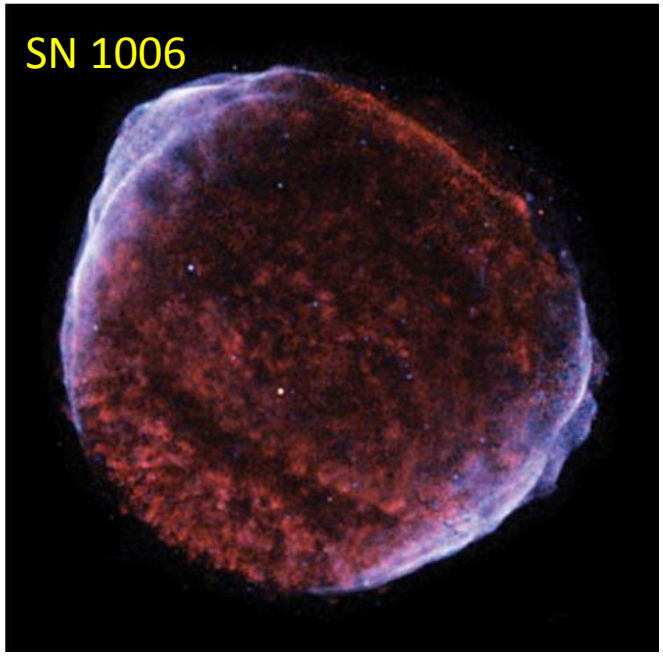
2. Role of B-field in diffusive shock acceleration (DSA)

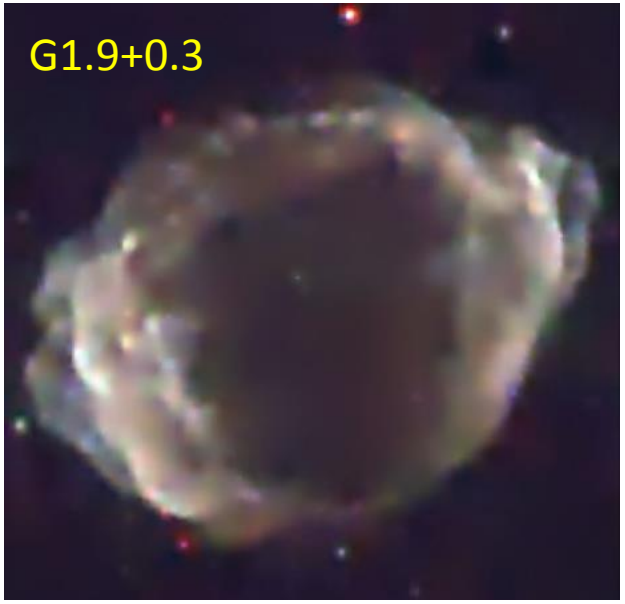
How does the orientation of injection with respect to the direction of B-field effect the acceleration efficiency?

“quasi-parallel scenario” vs. “quasi-perpendicular scenario”

(Fulbright & Reynolds 1990)

bilateral SNR, e.g. SN1006， “polar caps” or “equator”?



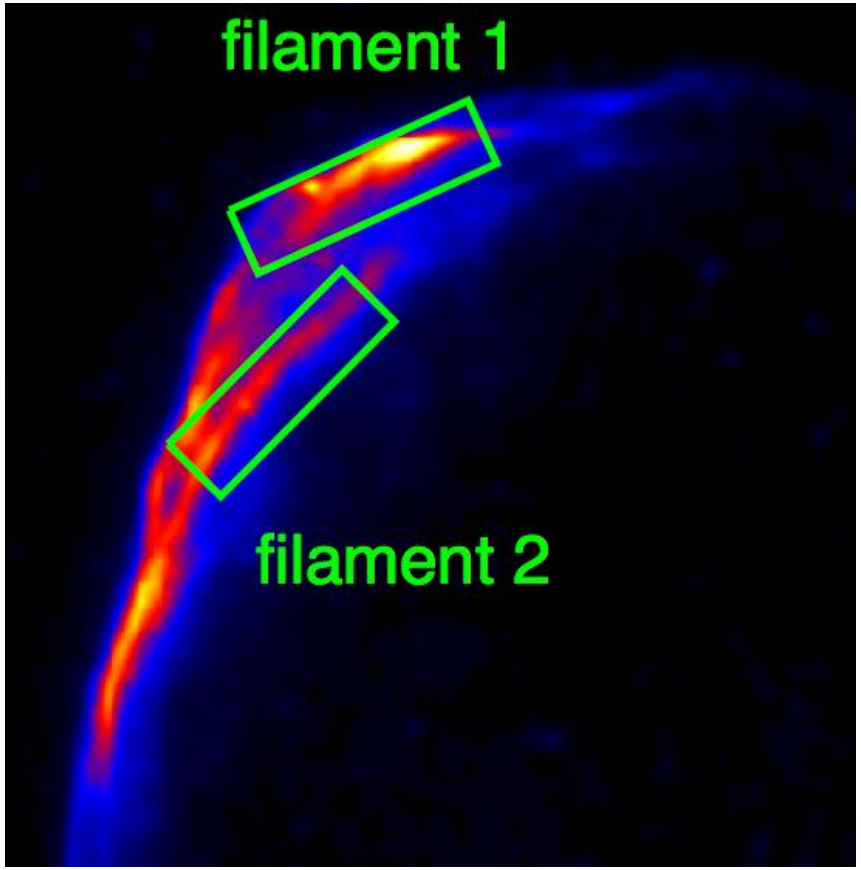


Long-standing debates up to now for SN1006, e.g.:

Quasi-parallel: Reynoso+2013, Schneiter +2015

Quasi-perpendicular: Matsumoto+2012, 2013; Caprioli & Spitkovsky 2014; West+2017

"Role of B"? 2-D Polarization Imaging



SN1006 2-8 keV image with GPD's resolution (15")

Assuming degree of polarization =17%
Exposure =1 Ms

errors of the PFA measurements

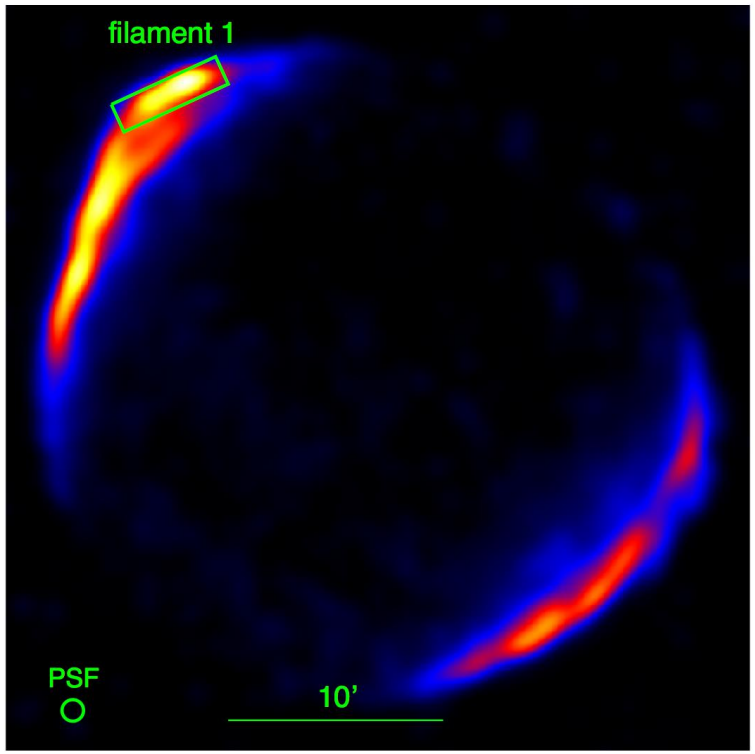
region	*flux (2-10 keV; ergs/cm^ 2/s)*	*σ_{dop} (%)*	*σ_{PA} (degree)*
filament 1 (5.3'x1.4')	*4.1E-12*	*1.7*	*3.0*
filament 2 (5'x1.5')	*3.4E-12*	*1.9*	*3.4*

dop: degree of polarisation
PA: position angle

Spatially resolved spectroscopy of SNRs

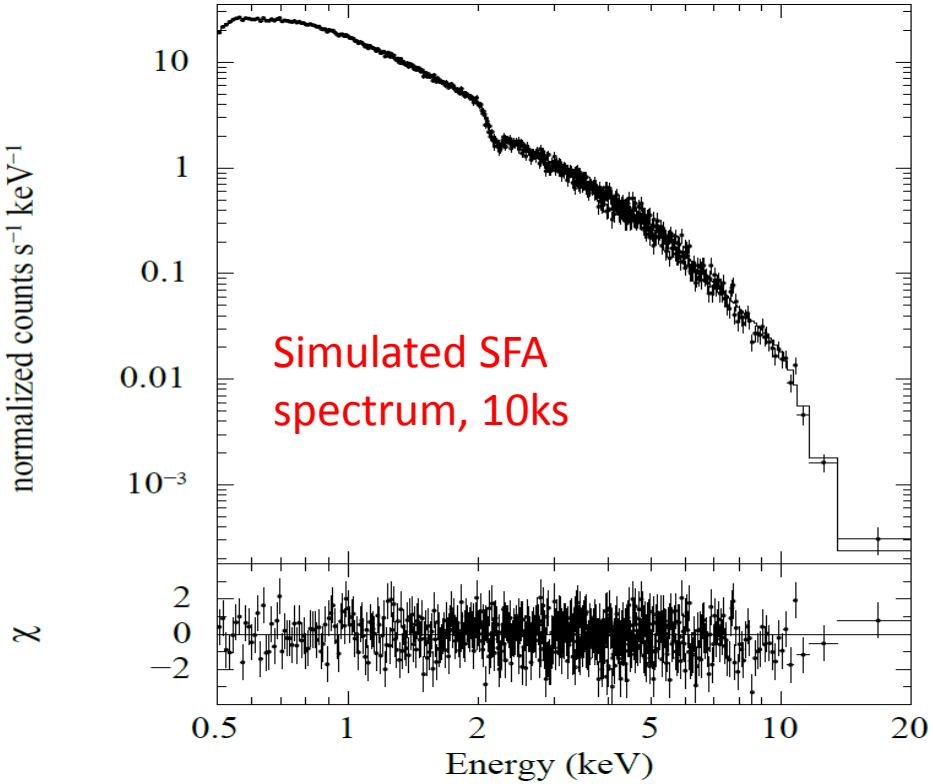
Study the maximum energy of the accelerated electrons (E_{max})

cutoff powerlaw: $N(E) \propto E^{-s} \exp(-E/E_{cut})$ (Miceli et al. 2013)



SN1006 2—8 keV image with 1' resolution

$$h\nu_{ch} = 13.9 \left(\frac{B_\perp}{100\,\mu G}\right)\left(\frac{E}{100\,TeV}\right)^2 keV,$$



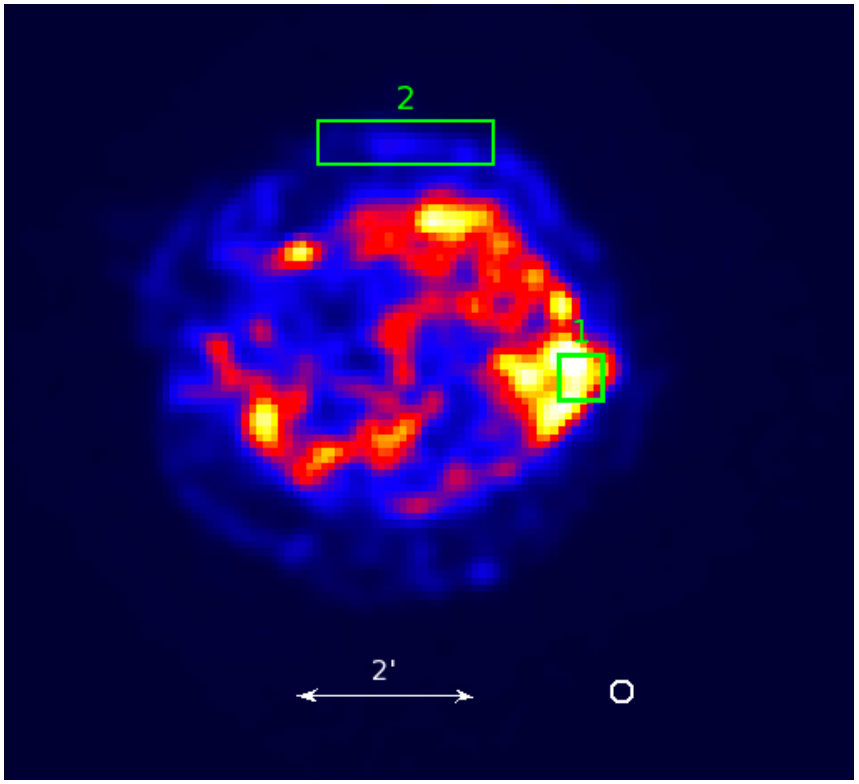
Model: phabs*srcut

NH=6.8e20, alpha=0.57 (fixed; Bamba et al.2008)

E_cut =1.11e17 Hz (+-1.8e15 Hz) or 0.46 keV

3. Synchrotron radiation and B-field in the forward shock and reverse shock

Acceleration at reverse shock: In Cas A, most synchrotron radiation comes from the reverse shock (Helder & Vink 2008; Uchiyama et al. 2008)



Cas A 2-8 keV image with GPD's resolution (15")

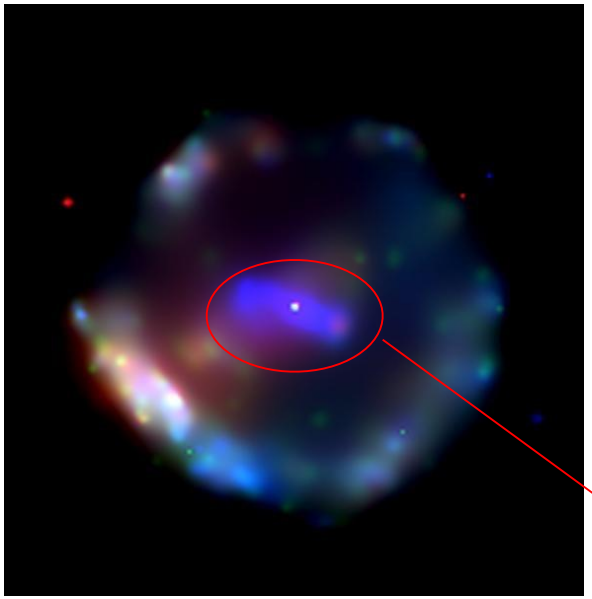
Assuming polarization degree=10%

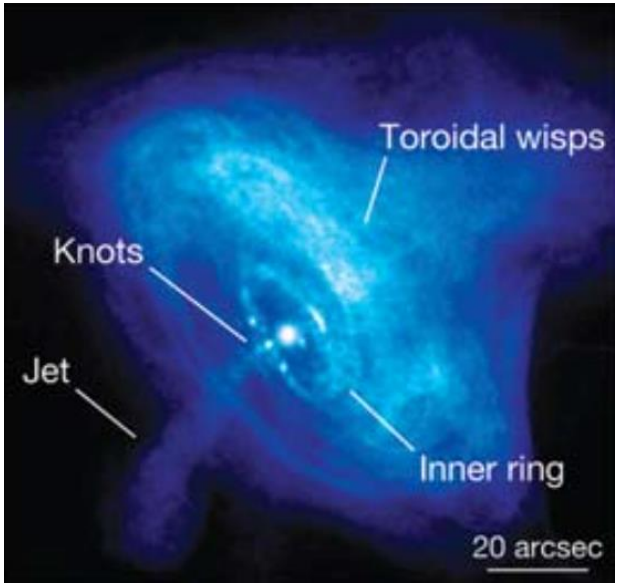
Exposure = 1Ms

errors of the PFA measurements

region	*flux (2-10 keV; ergs/cm^2/s)*	*σ_{dop} (%)*	*σ_{PA} (degree)*
1 (0.5') reverse shock	*3.5E-11*	*0.6*	*~1.9*
2 (2'x0.5') forward shock	*1.7E-11*	*0.8*	*~2.5*

4. Pulsar wind nebulae (PWNe)





PWNe harbored in SNRs has prominent polarized sync. X-rays (radio *P*-degree up to 50%, Reynolds 2012). $P = (s+1)/(s+7/3)$

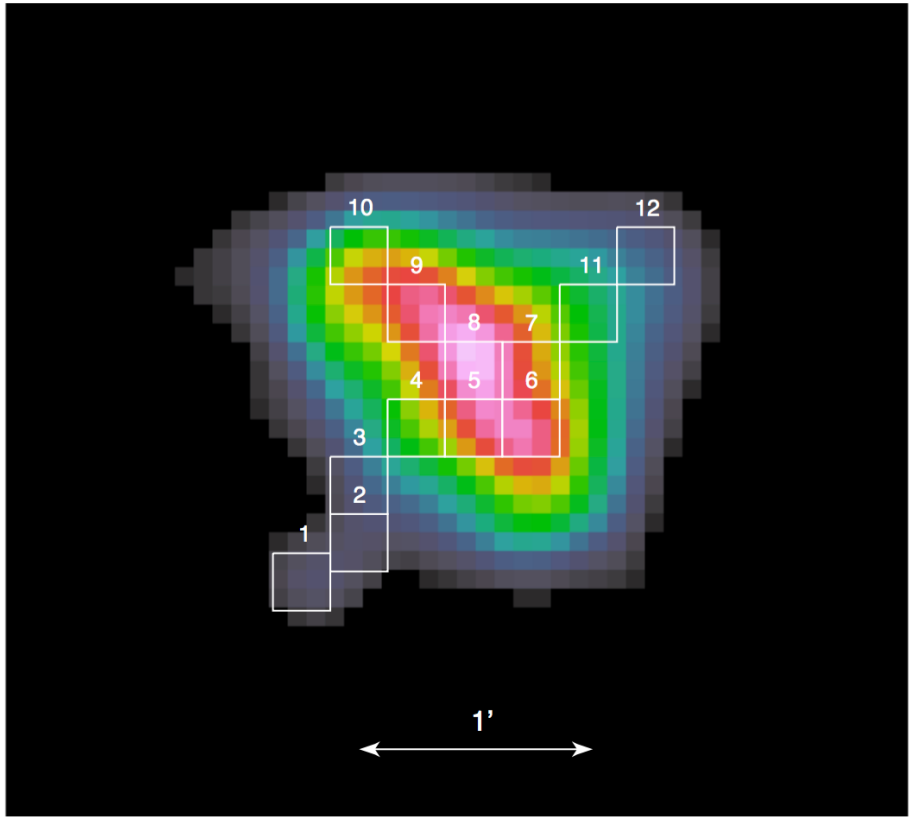
eXTP observation:

- beneficial to filtering/highlighting PWNe in SNRs, such as the PSR and PWN in the case like G11.2-0.3.

- obtains degree of polarization and distribution of magnetic field

eXTP spectroscopy and polarimetry of Crab

unprecedented measurement of polarization in PWNe (dop & B-field)



Crab 2-10 keV X-ray image with GPD's resolution (15")

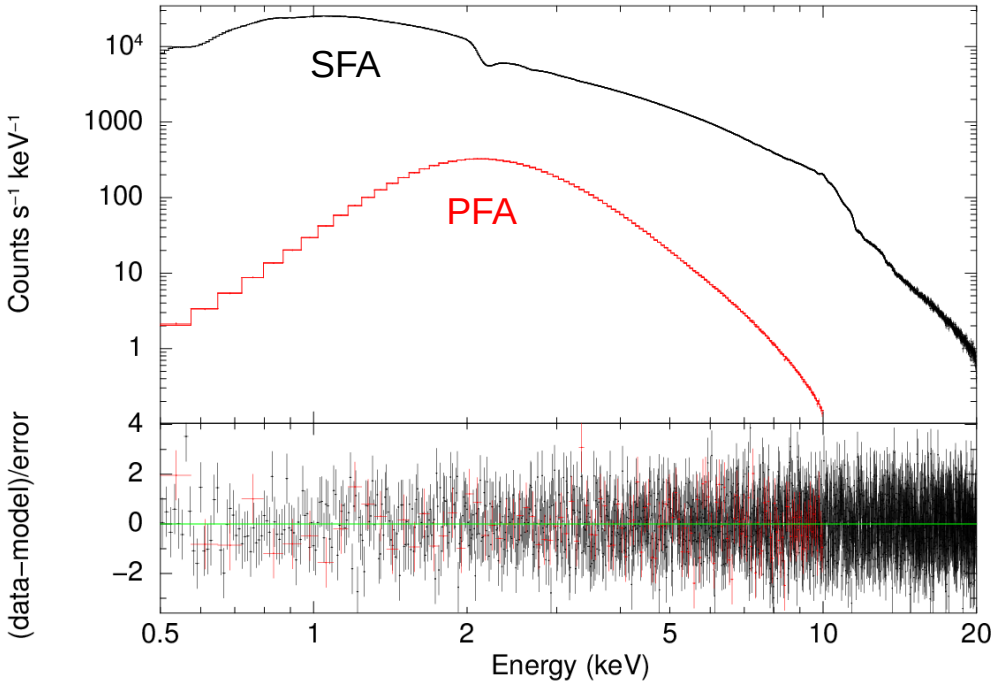
Assuming polarization degree=19%

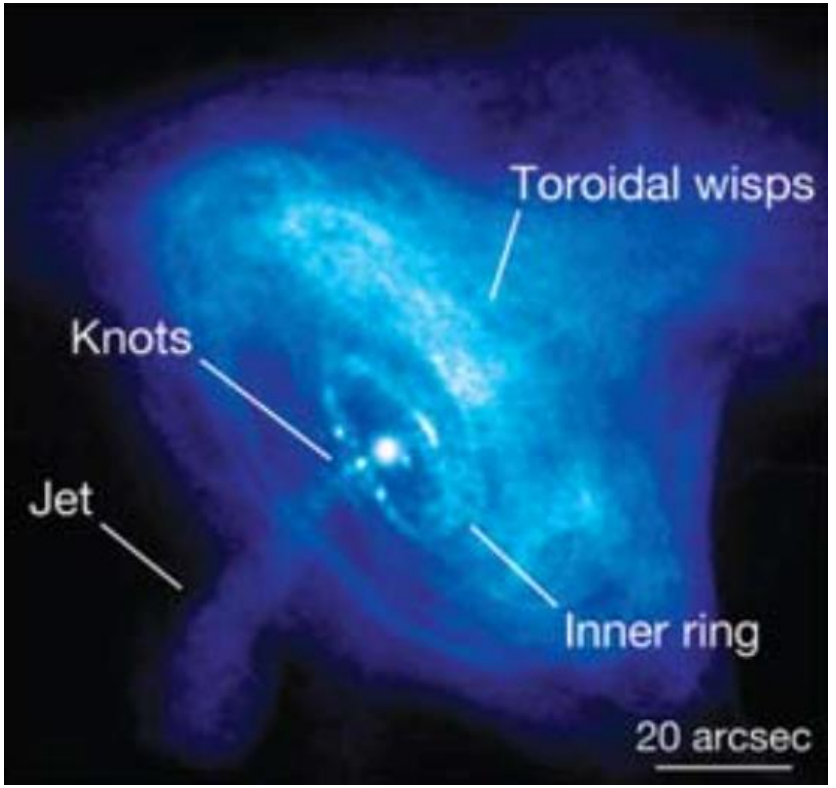
Exposure = 50 ks

errors of the measurements

region (15"x15")	*σ_{dop} (%)*	*σ_{PA} (degree)*
1	*1.9*	*3.5*
2	*2.1*	*3.5*
3	*1.7*	*2.7*
4	*0.9*	*1.4*
5	*0.7*	*1.2*
6	*0.7*	*1.1*
7	*0.8*	*1.3*
8	*0.6*	*1.0*
9	*0.7*	*1.1*
10	*0.8*	*1.3*
11	*1.1*	*1.7*
12	*1.6*	*2.6*

eXTP spectroscopy and polarimetry of Crab





Crab 10ks, Model: phabs*powerlaw

(Gaensler & Slane 2006)

Goals

- Survey of SNRs emitting synchrotron X-rays to study the CR electron acceleration
- Role of B-field in diffusive shock acceleration
- Forward/(Esp.) reverse shock synchrotron
- Pulsar wind nebulae (PWN) in SNRs and their B-field

Thank you!