



**「すざく」による広がったTeVガンマ線
放射VER J2019+368のX線観測
(*Suzaku Observation of the extended TeV
gamma-ray source VER J2019+368*)**

**September 25, 2015@JPS meeting
Tsunefumi Mizuno (Hiroshima Univ.)**

**H. Takahashi, J. Katsuta (Hiroshima Univ.),
K. Hayashi (ISAS/JAXA), R. Yamazaki (AGU)**



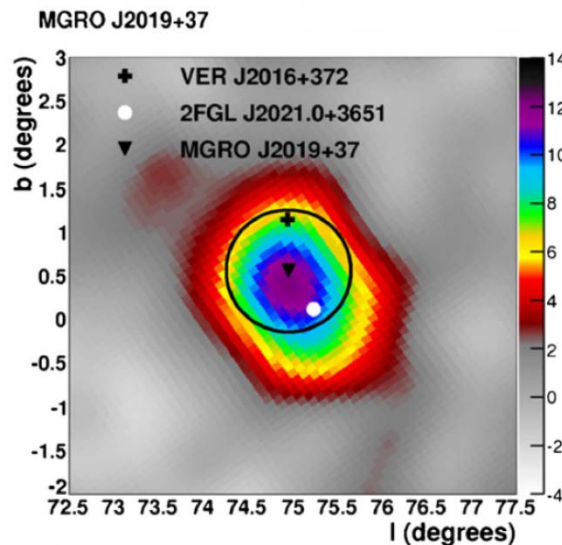
Contents

- Introduction
 - Past obs. in TeV γ -rays and X-rays
- Observations by *Suzaku*
- Data Analysis and Results
- Discussion
- Summary

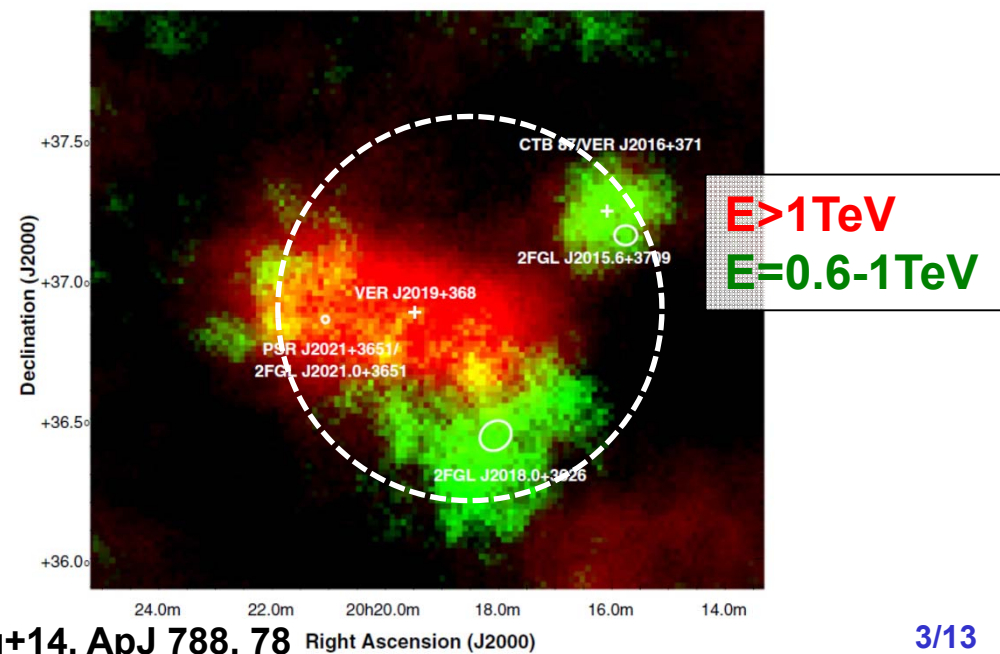


Past Obs. by Milagro & VERITAS

- Milagro reported an extended TeV γ -ray source MGRO J2019+37 in Cygnus-X direction ($\sigma=0.7$ deg)
- It was resolved into multiple sources by VERITAS. The most luminous one, VER J2019+368, has the following properties
 - $\sigma_{\text{major}}=0.34$ deg, positional coincidence with MGRO J2019+37, consistent spectrum in high energy => Main contributor



Abdo+12, ApJ 753, 159

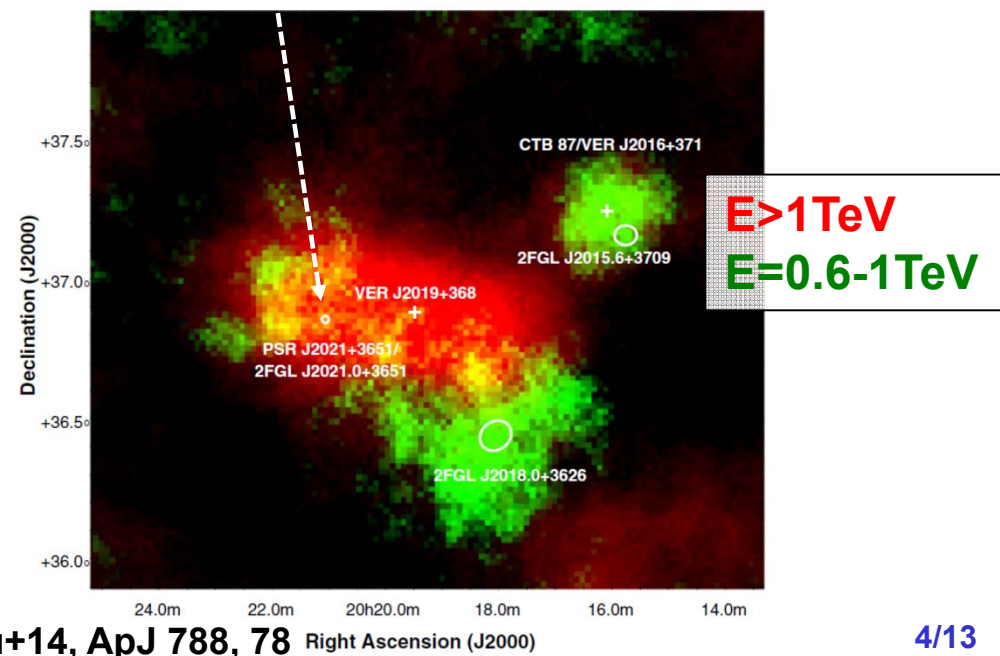
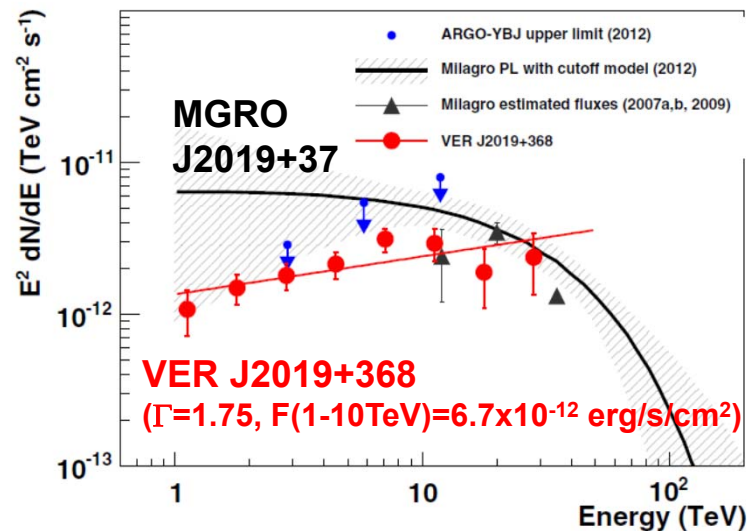


Aliu+14, ApJ 788, 78 Right Ascension (J2000)



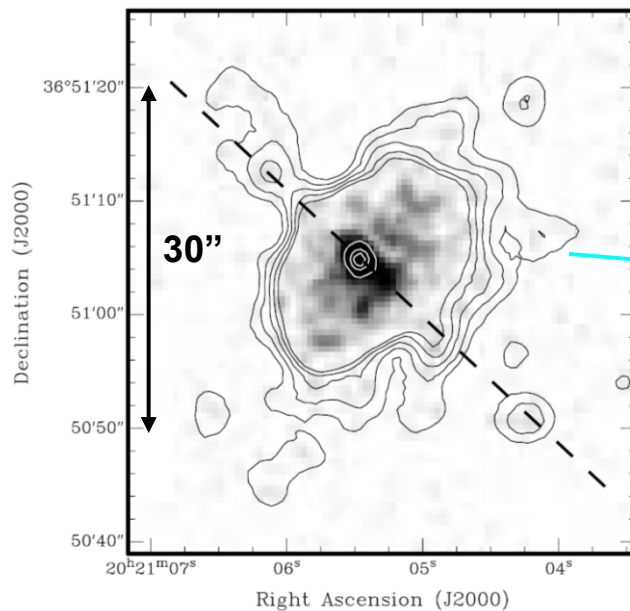
Past Obs. by Milagro & VERITAS

- Milagro reported an extended TeV γ -ray source MGRO J2019+37 in Cygnus-X direction ($\sigma=0.7$ deg)
- It was resolved into multiple sources by VERITAS. The most luminous one, VER J2019+368, has the following properties
 - $\sigma_{\text{major}}=0.34$ deg, positional coincidence with MGRO J2019+37, consistent spectrum in high energy => Main contributor
- Possible X-ray counterpart is PSR J2021+3651 & PWN G75.2+0.1

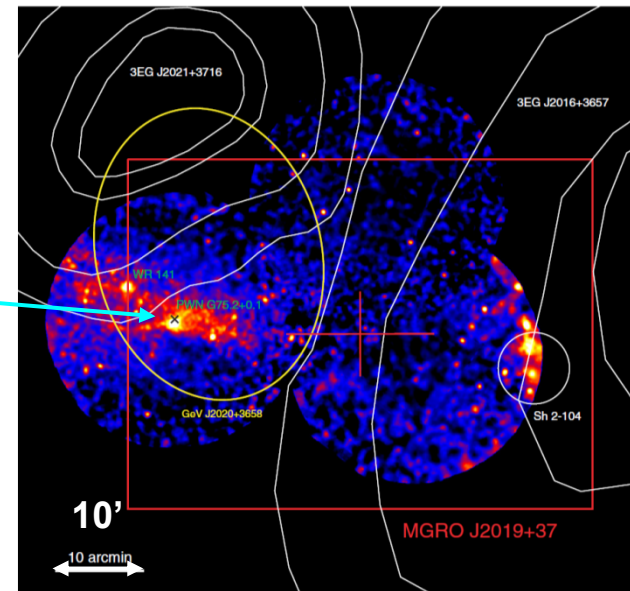


Past Obs. in X-Rays

- Possible X-ray counterpart is PSR J2021+3651 & PWN G75.2+0.1
 - PSR J2021+3651: young and energetic ($\tau=17$ kyr, $dE/dt=3.4 \times 10^{36}$ erg/s)
 - Chandra revealed a $\sim 20'' \times 10''$ pulsar wind nebula (PWN G75.2+0.1)
 - XMM reported faint emission of 5'-10' length in east (fainter) and west (brighter)




Hessels+04, ApJ 612, 389



Zabalza+10, J. of Mod. Phys. D. 19, 811



Problems of the PSR/PWN Scenario

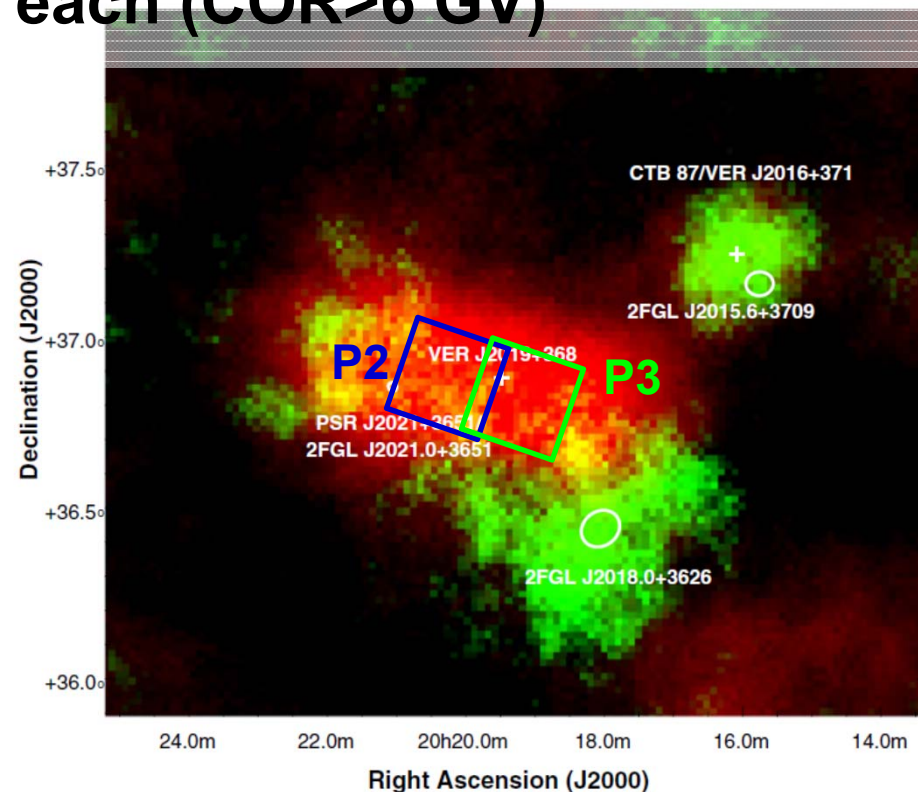
- Possible X-ray counterpart is PSR J2021+3651 & PWN G75.2+0.1
 - PSR J2021+3651: $\tau=17$ kyr, $dE_{\text{rot}}/dt=3.4 \times 10^{36}$ erg/s
 - PWN G75.2+0.1: revealed by Chandra and found to extend out 5'-10' in length in east (fainter) and west (brighter)
 - Several issues of the PSR/PWN scenario have been pointed out (e.g., Abdo+09, ApJ 799, 1059; Parades+09, A&A507, 241)
 - Large dispersion measure (370 pc/cm³) and rotation measure (524 rad/m²) indicate large distance to the source ($d > 10$ kpc).
 - γ -ray luminosity of PSR too high compared to dE_{rot}/dt
 - Source size (~90 pc for 0.5 deg at 10 kpc) too large for high-energy electrons to fill before cooling
 - X-rays from only small portion of TeV emission
- 
- Detailed study of the PWN properties (spectrum, morphology) and search for unknown extended emission by Suzaku-XIS



Suzaku Obs. of VER J2019+368

- Two observations conducted in 2014 November.
 - P2 covers region of the PSR/PWN and TeV centroid
 - P3 covers the west part of VER J2019+368, in which no strong X-ray sources are reported
- Net exposure is ~35 ks each (COR>6 GV)

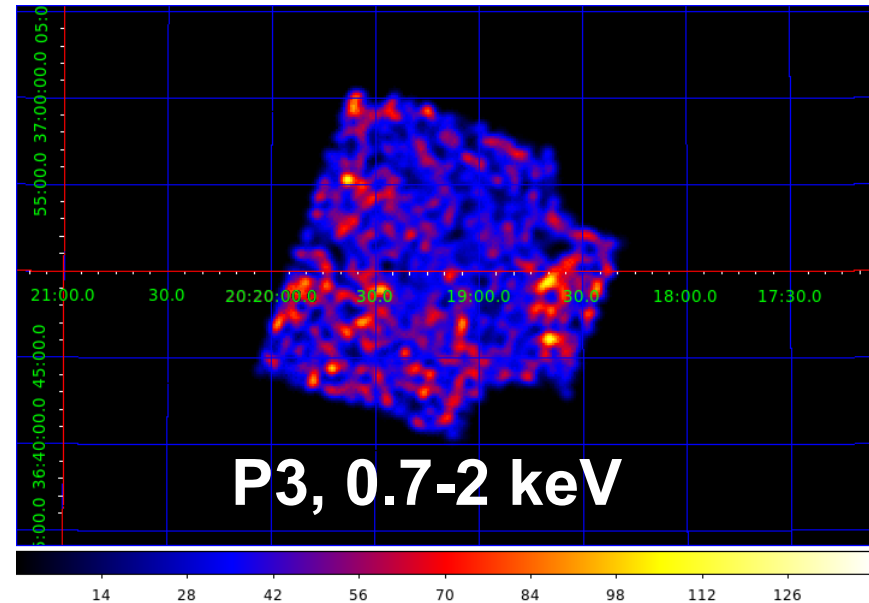
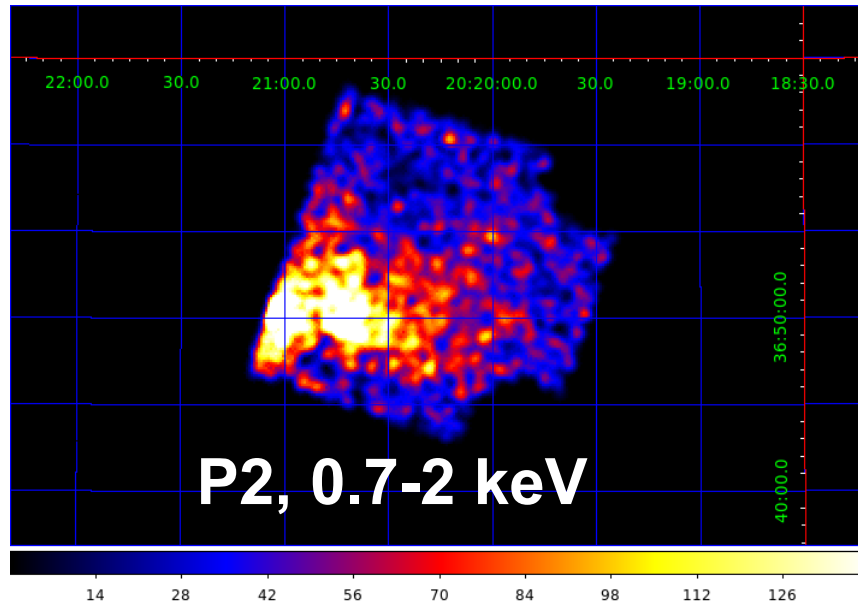
Position	RA (deg)	DEC (deg)	Net exp. (ks)
P2	305.07	36.85	35.0
P3	304.80	36.80	35.7





XIS Image (soft band)

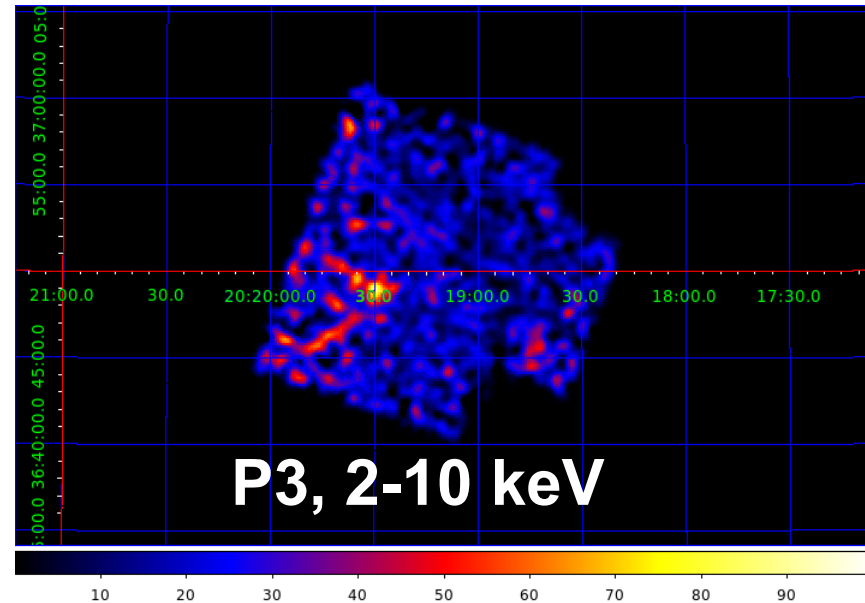
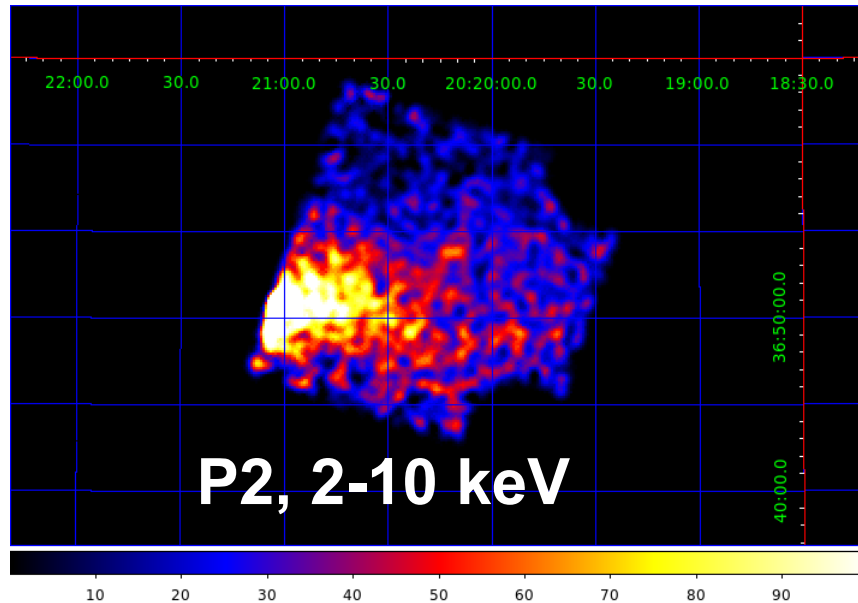
- Soft band (0.7-2 keV) intensity map (XIS3, in unit of photos/s/cm²/sr)
- PWN clearly detected in P2
- No obvious extended emission in P3 (detailed analysis to be done)





XIS Image (hard band)

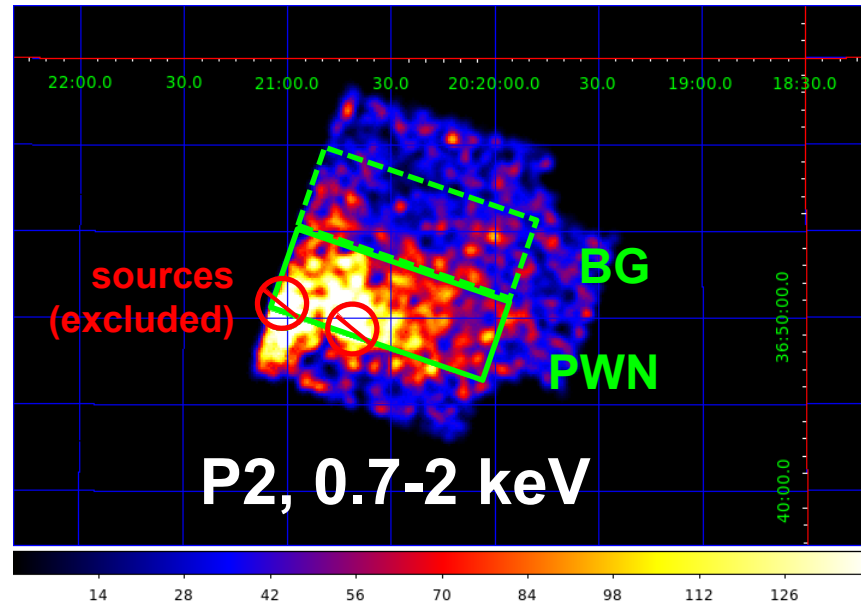
- Hard band (2-10 keV) intensity map
- PWN clearly detected in P2
- No obvious extended emission in P3
- Size of PWN similar to that in soft band (detailed analysis to be done)





PWN Spectrum (1)

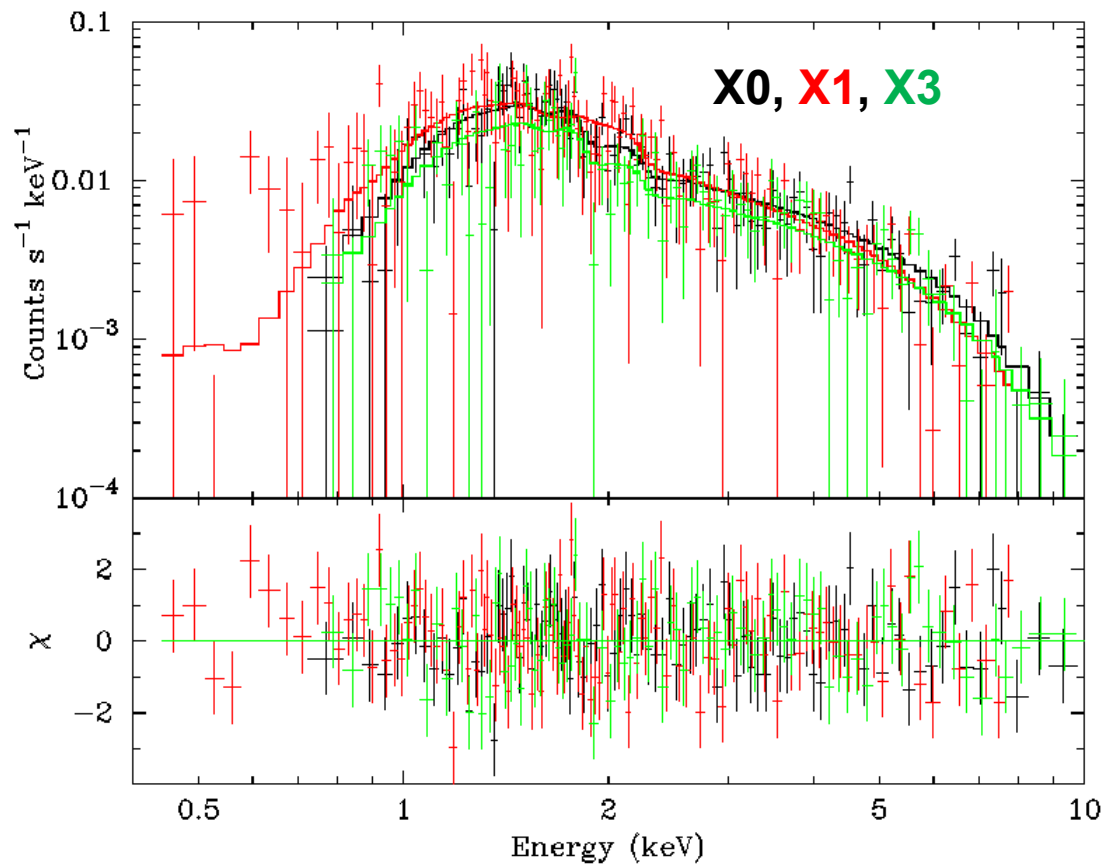
- **Source Region: 5' x 13' around the PWN**
- **(unusable area of XIS0 not used)**
- **BG region: the same size, next to the source region in north**
- **Bright sources excluded**





PWN Spectrum (2)

- Featureless spectrum, fitted by wabs*power-law



$\chi^2/\text{dof}=316.2/304$

$N(\text{H})=0.82(+0.15,-0.14)\times 10^{22}$

$\Gamma=2.21(+0.16,-0.15)$

$I(0.5-2 \text{ keV})=5.66\times 10^{-8} \text{ erg/s/cm}^2/\text{sr}$

$I(2-10 \text{ keV})=20.3\times 10^{-8} \text{ erg/s/cm}^2/\text{sr}$

$f(0.5-2 \text{ keV})=31.1\times 10^{-14} \text{ erg/s/cm}^2$

$f(2-10 \text{ keV})=112\times 10^{-14} \text{ erg/s/cm}^2$

Unabsorbed spectrum:

$$E^2F(E)=642\times 10^{-6} (E/\text{keV})^{-0.21} \text{ keV}^2/\text{s/cm}^2/\text{keV}$$



Discussion and Future Tasks

- **N(H) of the PWN $\sim 0.8 \times 10^{22} \text{ cm}^{-2}$, similar to the absorption of the pulsar (Hessels+04)**
 - Sources in Cygnus-X (d ~ 1.4 kpc) shows absorption of $(0.2-0.6) \times 10^{22} \text{ cm}^{-2}$ (Yoshida+11), whereas Galactic total absorption is estimated to be $(2-3) \times 10^{22} \text{ cm}^{-2}$ (Mizuno+15). \Rightarrow d ~ 3 kpc indicated. Then the size of the TeV emission (~ 0.5 deg) corresponds to ~ 25 pc.
- **F(2-10 keV) $\sim 1.1 \times 10^{-12} \text{ erg/s/cm}^2$ is obtained for the west part of the PWN**
 - F(1-10 TeV)/F(2-10 keV) ~ 6 . It will be further reduced if we include the whole emission of the PWN
- **Aliu+14 proposed an offset PSR(and PWN) scenario, born at the TeV centroid and traveled to the east**
 - Detailed study of PWN properties (energy dependence of morphology) and search for (or constraint on) unknown extended emission are important and underway.
 - Analysis of XMM data is also crucial (point source contribution, overall emission from the PWN)



Summary

- VER J2019+368 is an extended ($\sigma_{\text{major}}=0.34\text{deg}$) and hard ($\Gamma=1.75$) TeV γ -ray source in Cyg-X direction
- PSR J2021+3651/PWN G75.2+0.1 is a possible counterpart, but several issues are pointed out (distance, morphology)
- We conducted deep X-ray observations by Suzaku-XIS
 - PWN clearly detected ($N(\text{H})=8\times 10^{21} \text{ cm}^{-2}$, $\Gamma=2.2$, $f(2\text{-}10 \text{ keV})=1.1\times 10^{-12} \text{ erg/s/cm}^2$)
 - distance is likely to be $\sim 3 \text{ kpc}$, $F_{\text{TeV}}/F_{\text{X}}\sim$ a few if we include the whole PWN emission
 - Detailed analysis/discussion underway

Thank you for your Attention



Reference

- **Abdo+12, ApJ 753, 159**
- **Aliu+14, ApJ 788, 78**
- **Hessels+04, ApJ 612, 389**
- **Zabalza+10, J. of Mod. Phys. D. 19, 811**
- **Parades+09, A&A 507, 241**
- **Yoshida+11, PASJ 63, S717**
- **Mizuno+15, ApJ 803, 74**
- **Abdo+09, ApJ 700, 1059**