Study on TeV γ Ray Emission from Cygnus Region Using the Tibet Air Shower Array

- 1. Brief introduction to Cygnus region
- 2. The Tibet AS γ Experiment
- 3. The known extended source MGRO J2019+37 observing and its energy spectrum measurement
- 4. Preliminary Results
- 5. Conclusions

Tibet ASγ collaboration

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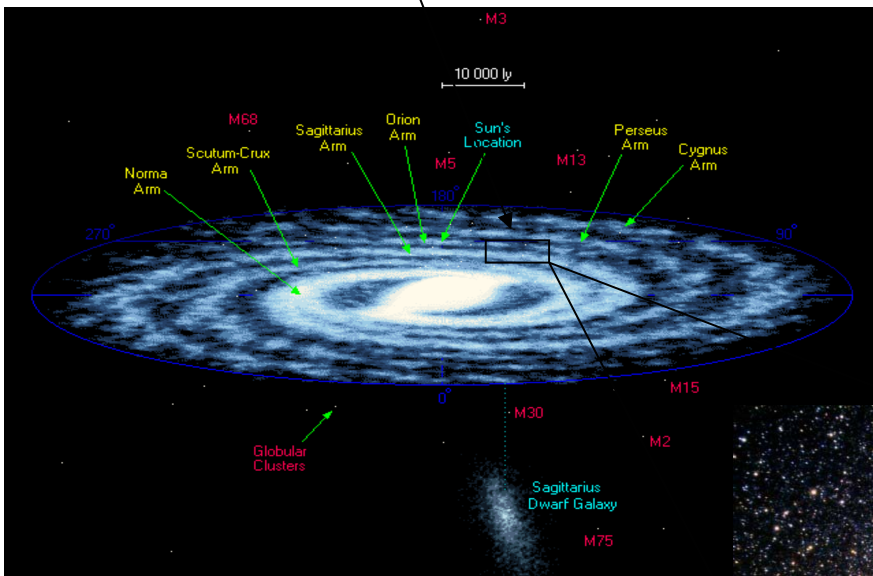
Brief Introduction about Cygnus region

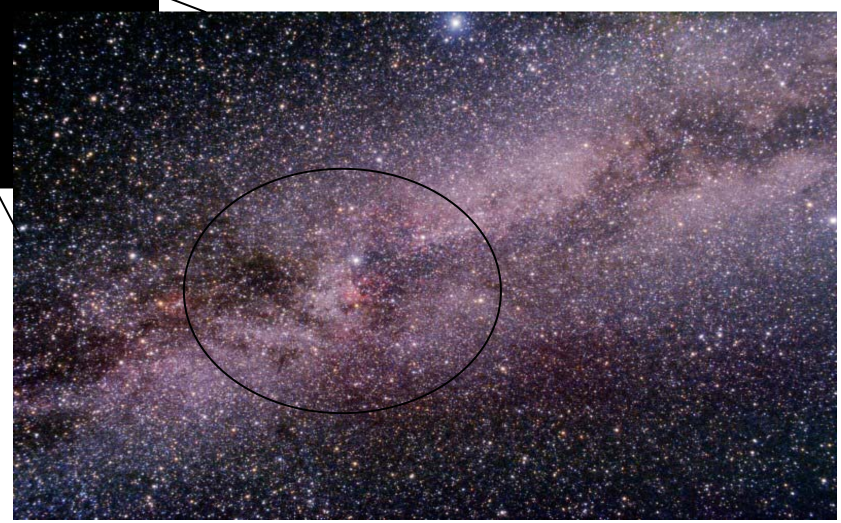
$65^\circ < l < 85^\circ$, $-3^\circ < b < 3^\circ$, d:1~2kpc



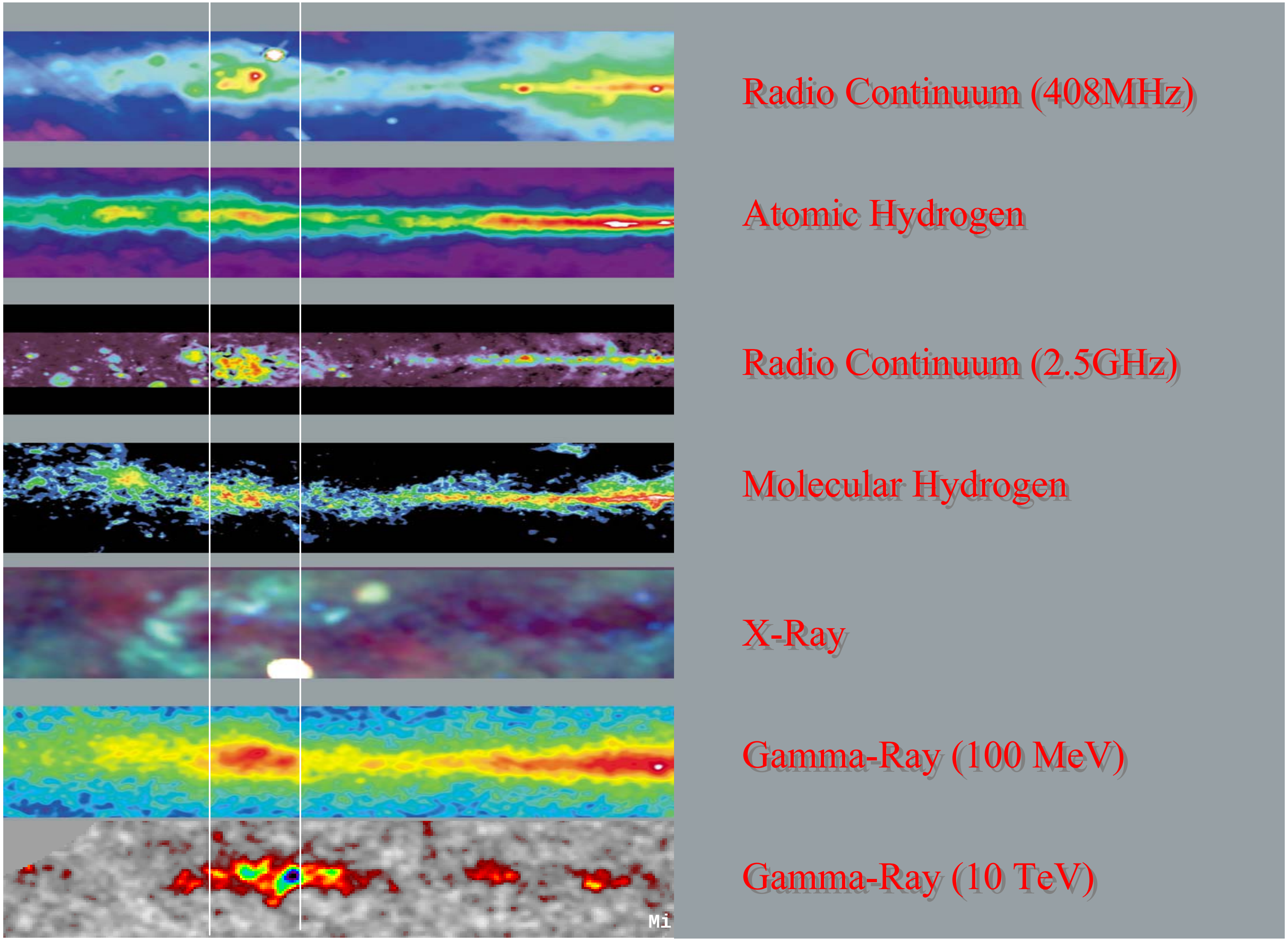
NN
EB
IC
......

γ

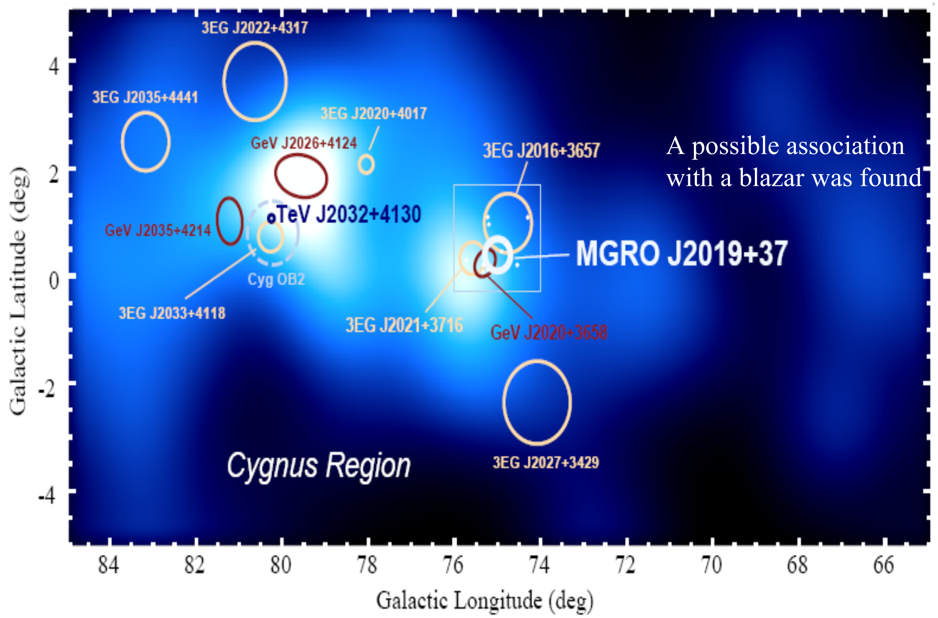
this region contains a great deal of molecular clouds and was one of the richest star formation region



Multi-wave bands observation in Cygnus region



One of the interested region–part of the Cygnus region



❖ IACTs

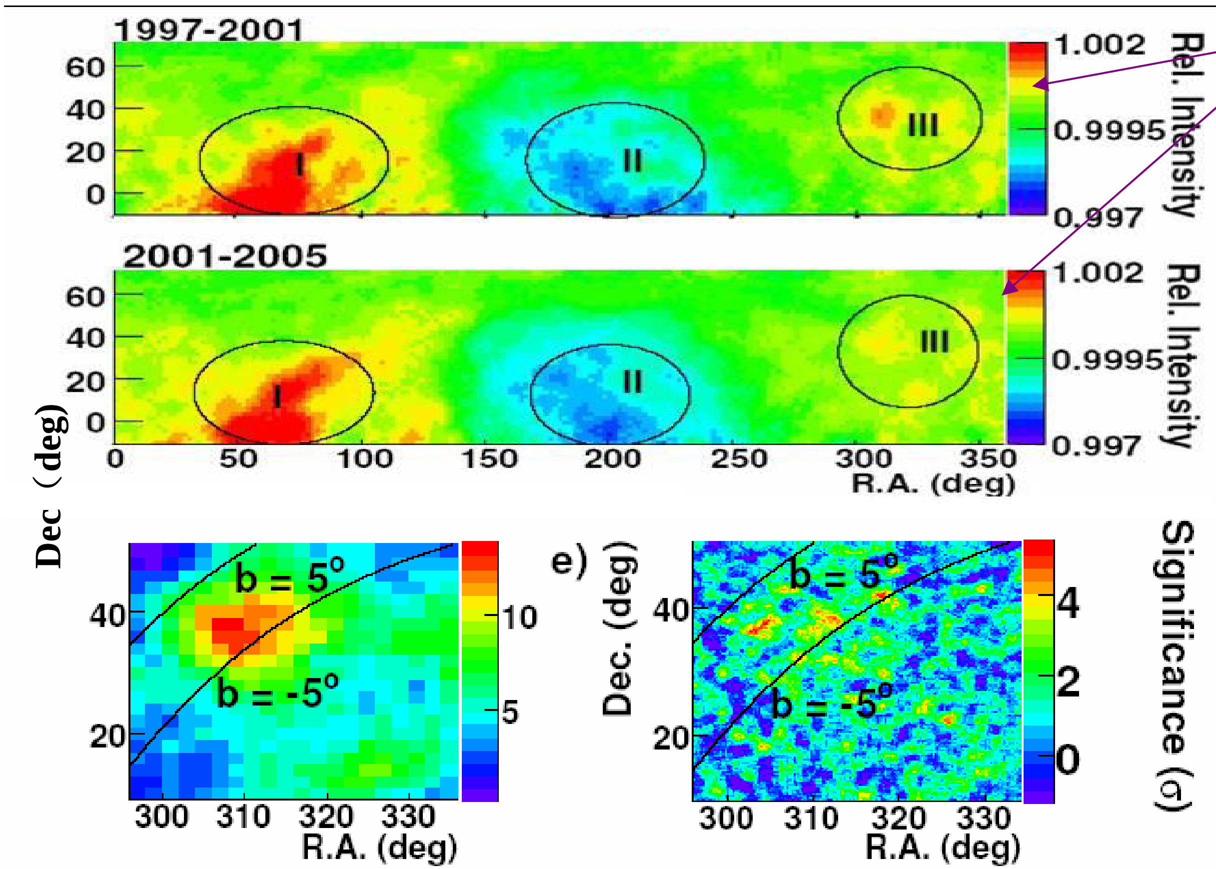
- Whipple (excess close to J2032+4130)
  A&A ,423,L415,(2004) ApJ,658:1062(2007)
- **HEGRA**(TeV J2032+4130)
  A&A 393,L37(2002) A&A, 431 ,197(2005)
- MAGIC (*compatible with HEGRA reported*)
  arXiv:0801.2391v1

EAS

- **Milagro** (MGRO J2019+37 and other candidates)
  ApJ, 658,L33(2007)
- **As γ** (the highest significance ~5.8 σ ; Cygnus hot spot)
  30th ICRC (2007) **2006,Science,314,439**

The previous AS γ observation result about Cygnus

Cygnus region



2006,Science, 314,439

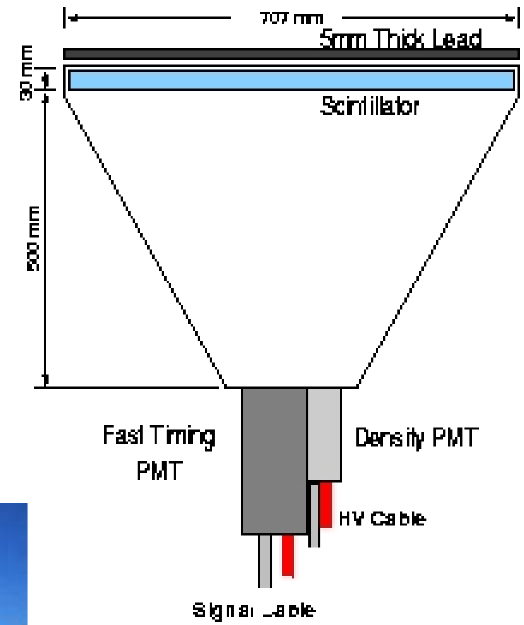
Smooth radius 2°

Smooth radius 0.9°

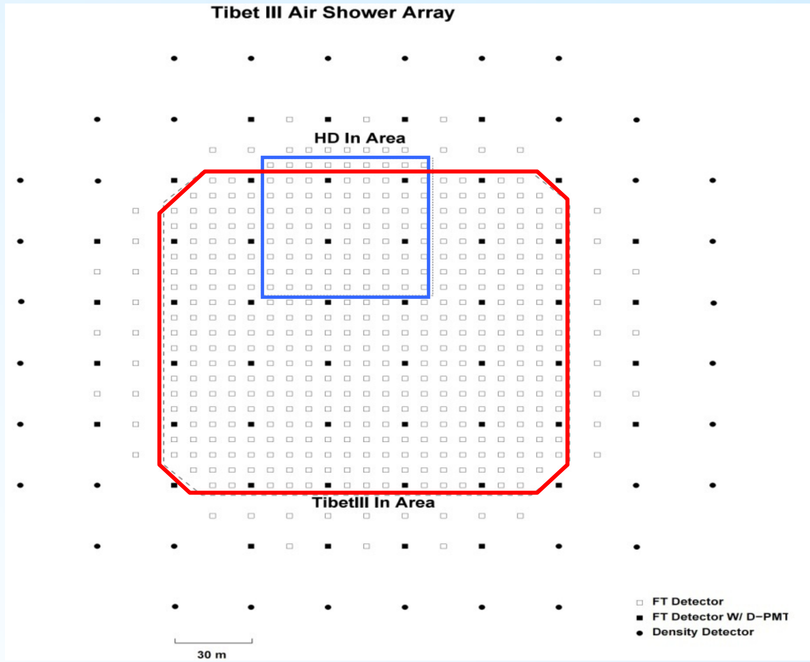
Performed the highest precise measurement on large scale cosmic ray anisotropy and first pointed out the Cygnus hot spots

Tibet Air Shower Array

- Located at an elevation of 4300 m (Yangbajing , China)
- Atmospheric depth 606g/cm^2
- Wide field of view
- High duty cycle (>90%)



Tibet HD and III air shower arrays



Run time	Live time	Mode energy	Angular resolution (@3TeV)	Area
TibetII (HD) 1997.2~1999.9	555.9day	~3TeV	0.9°	5175m^2
TibetIII (P1~6) 1999.11~2005.11	1318.4day			22050m^2

Event Selection

- Analysis Data:

Tibet II-HD data obtained from 1997 February to 1999 September (Live time:555.9 days) and Tibet III data obtained from 1999 November to 2005 November (Phase1~6 VersionB4 , Live time:1318.9 days)

- Data cut condition:

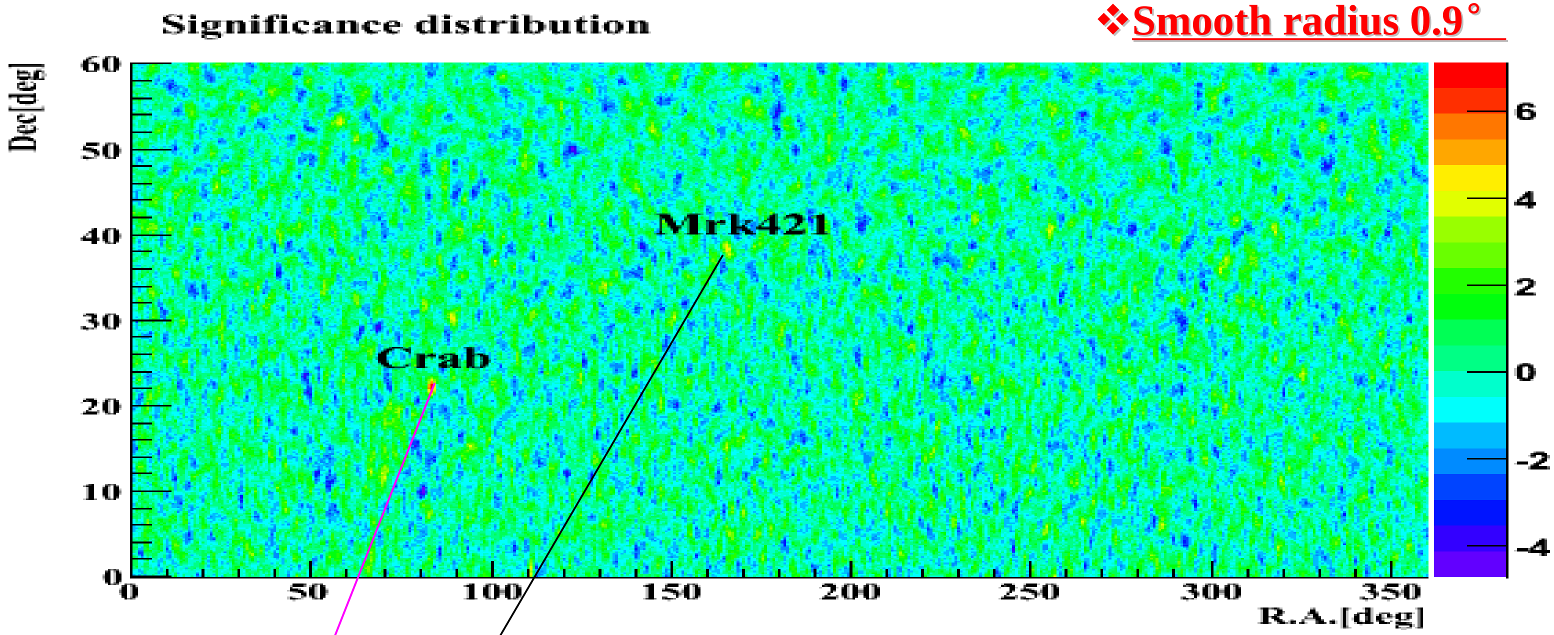
1.25 particle any4, $\Sigma\rho FT>15$ && $\Sigma\rho FT<1000$,

Zenith angle $< 40°$, **internal event**, Residual error < 1.0 m

- About **2.0×10^{10}** shower events were available for analysis.

2D All Sky Significance map(1)

*—All sky **point sources** surveying*



❖**Smooth radius 0.9°**

List of sky cells with clustered directions (5) having statistic significance larger than 4.5 σ

No.	R.A.	Dec	N_{ON}	N_{OFF}	N_S	$\triangle N_S$	$S_{pretrials}$
1	57.95	53.25	2405072.8	2397926.7	7146.1	1548.5	4.6
2	70.55	11.35	2306840.6	2299785.4	7055.2	1516.5	4.7
3[a]	83.75	21.95	3078848.1	3066434.9	12413.3	1751.1	7.1
4	89.45	30.05	3359526.5	3350799.7	8726.8	1830.5	4.8
5[b]	166.25	38.25	3301780.3	3292945.8	8834.4	1814.6	4.9

Extended source MGRO J2019+37 observing

- According to:
  Milagro adopted $3^\circ \times 3^\circ$ windows to perform the Cygnus region and found MGRO J2019+37's extension 0.32°

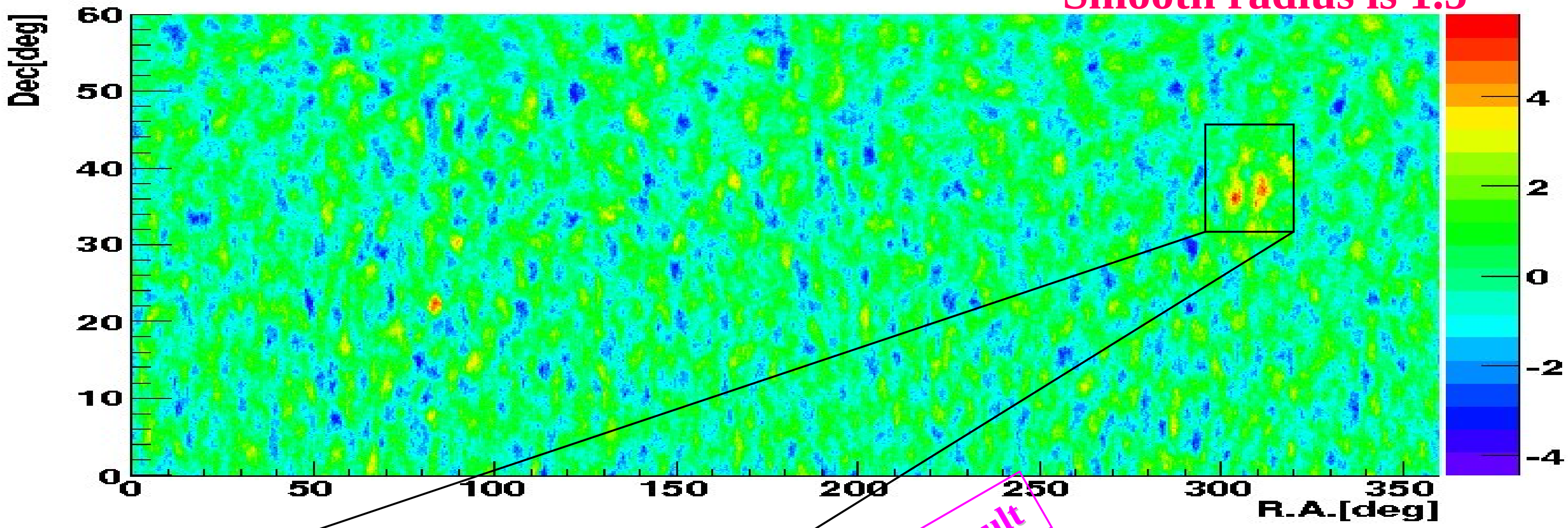
- Smooth radius is 1.5°

- Smooth radius is optimal radius(0.99°) observing 0.32° extension source

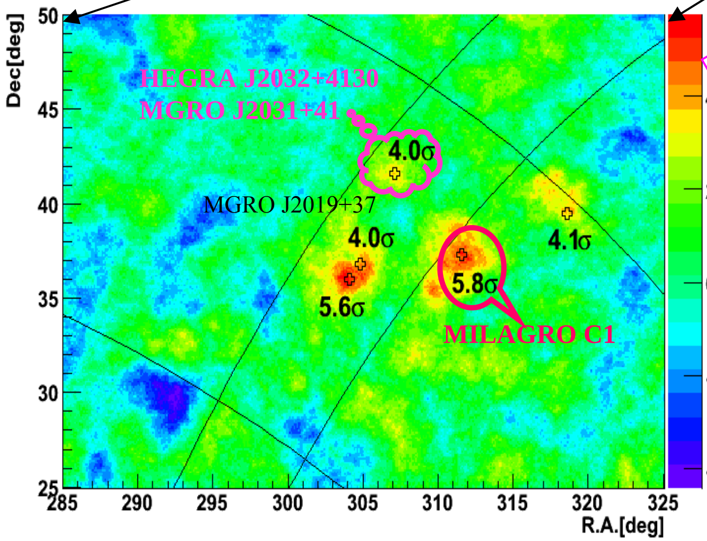
All Sky Significance map(2)

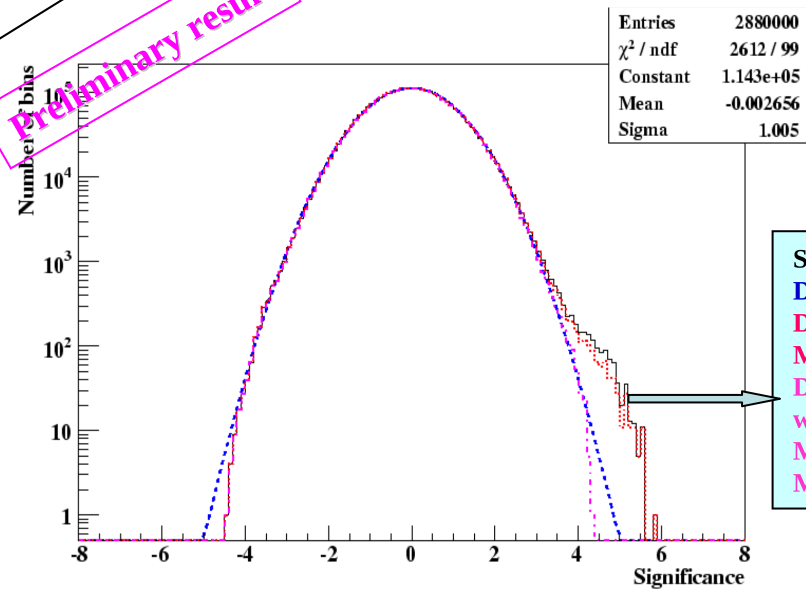
—*Extended source MGRO J2019+37 observing*

——Smooth radius is 1.5°



Preliminary result



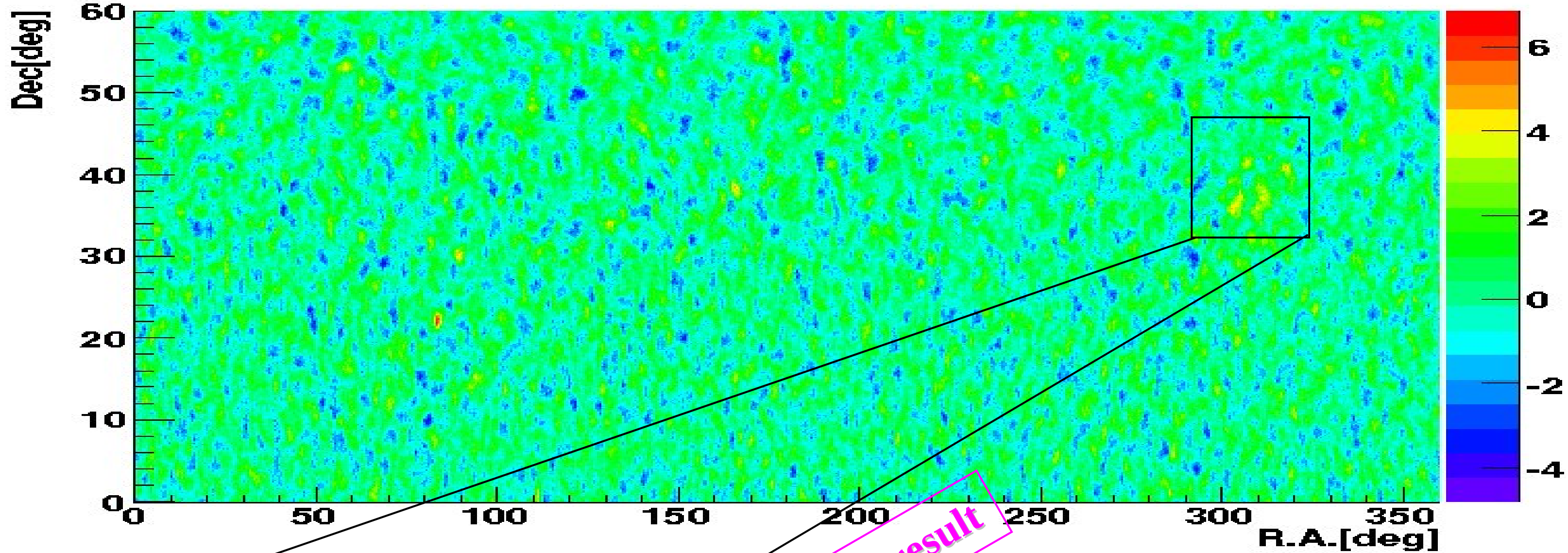


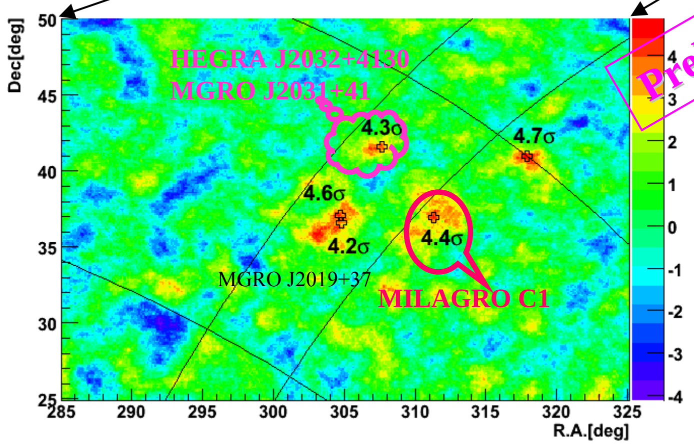
Solid line--all sky;
Dashed line-gaus fit;
Dotted line-without Mrk421 and Crab;
Dot-dashed line-without Mrk421,Crab and MGRO J2019+37;

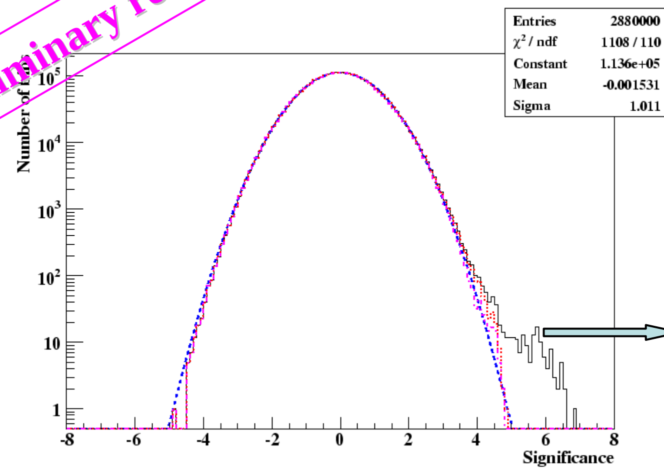
All Sky Significance map(3)

—Extended source MGRO J2019+37 observing

—Smooth radius is optimal angular resolution(0.99 °) thinking about the extension 0.32 ° of MGRO J2019+37







Solid line--all sky;
Dashed line-gaus fit;
Dotted line-without Mrk421 and Crab;
Dot-dashed line-without Mrk421,Crab and MGRO J2019+37;

Four other candidates with significance > 4 σ were found

Smooth radius is 1.5°

No.	$R.A.$	Dec	$S_{pretrials}$
1^a	$304.1°$	$36.0°$	5.6σ
2	$307.1°$	$41.6°$	4.0σ
3	$311.6°$	$37.4°$	5.8σ
4	$318.6°$	$39.5°$	4.1σ
5^b	$304.8°$	$36.8°$	4.0σ

Smooth radius is optimal radius 0.99°

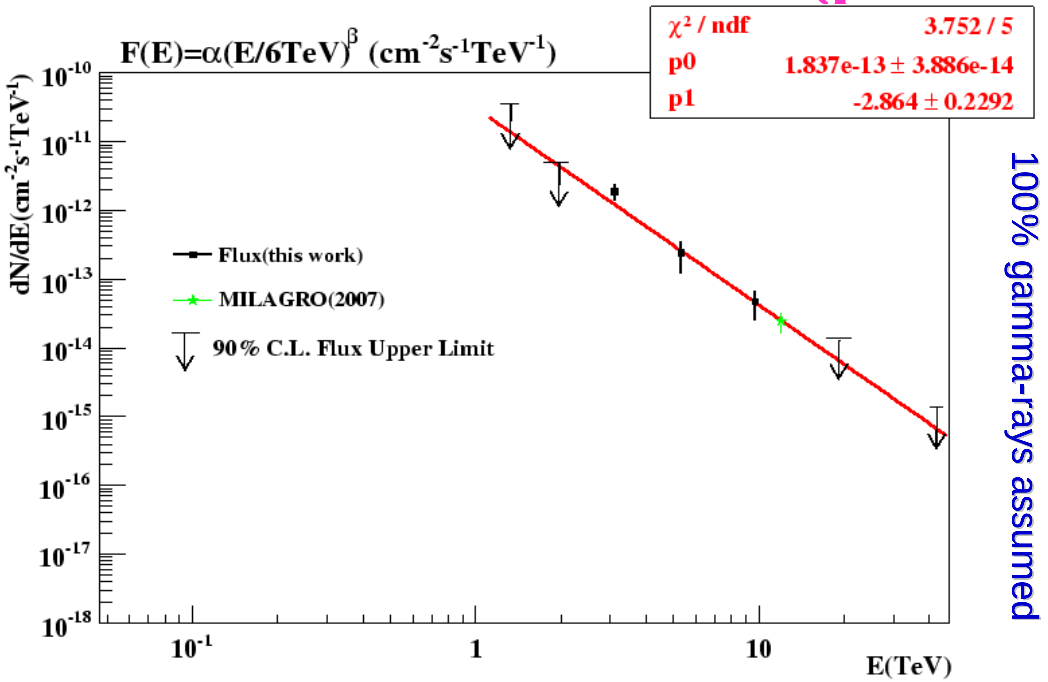
No.	$R.A.$	Dec	$S_{pretrials}$
1^a	$304.6°$	$37.2°$	4.6σ
2	$307.8°$	$41.6°$	4.3σ
3	$311.4°$	$37.1°$	4.4σ
4	$317.9°$	$41.0°$	4.7σ
5^b	$304.8°$	$36.8°$	4.2σ

- **a---Stands for As γ highest significant position nearest to MGRO J2019+37 in the Cygnus region**
- **b---Stands for the position of MGRO J2019+37**

➢ **As for MGRO J2019+37, the significance is consistent at two different smooth radius ⟺ Milagro adopted 3° × 3° windows to study MGRO J2019+37 and got its extension is 0.32° .**

➢ **As for the other four candidates, we need to go on studying with the data accumulating.**

MGRO J2019+37 Energy Spectrum Measurement (preliminarily)

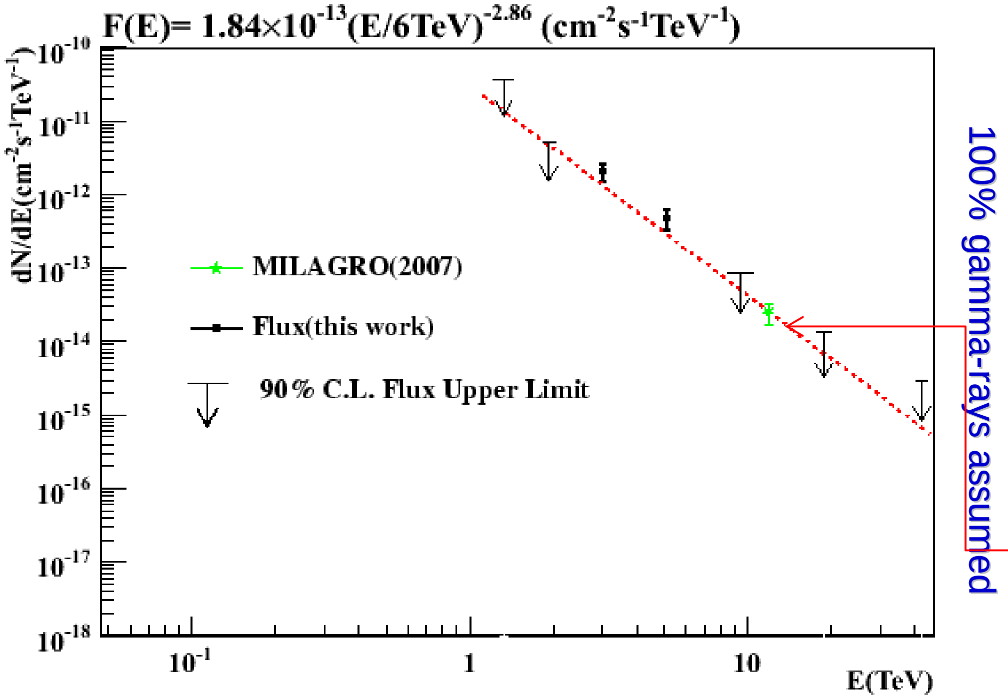


- Using optimal angular resolution as smooth radius in every energy interval

$\sum \rho_{FT}$	$R_{optimal}/(^\circ)$	N_{on}	N_{off}	N_s	$\triangle N_s$	$S_{pretrials}$
[10,17.8)	1.76	391014.0	390887.0	127.0	625.3	0.20
[17.8,31.6)	1.52	2701684.0	2699763.1	1920.9	1643.7	1.17
[31.6,56.2)	1.22	2099870.0	2094503.1	5366.9	1449.1	3.70
[56.2,100)	0.94	696374.0	694662.4	1711.6	834.5	2.05
[100,215.4)	0.75	250158.0	249064.4	1093.6	500.2	2.19
[215.4,464.2)	0.63	58818.0	58409.3	408.7	242.5	1.69
[464.2,1000)	0.58	16267.0	16285.7	-18.7	127.5	-0.15

Note: when the significance <2 σ , we set 90% C.L upper limits

MGRO J2019+37 Energy Spectrum Measurement (preliminarily)



➢Using smooth radius 1.5°
in every energy interval

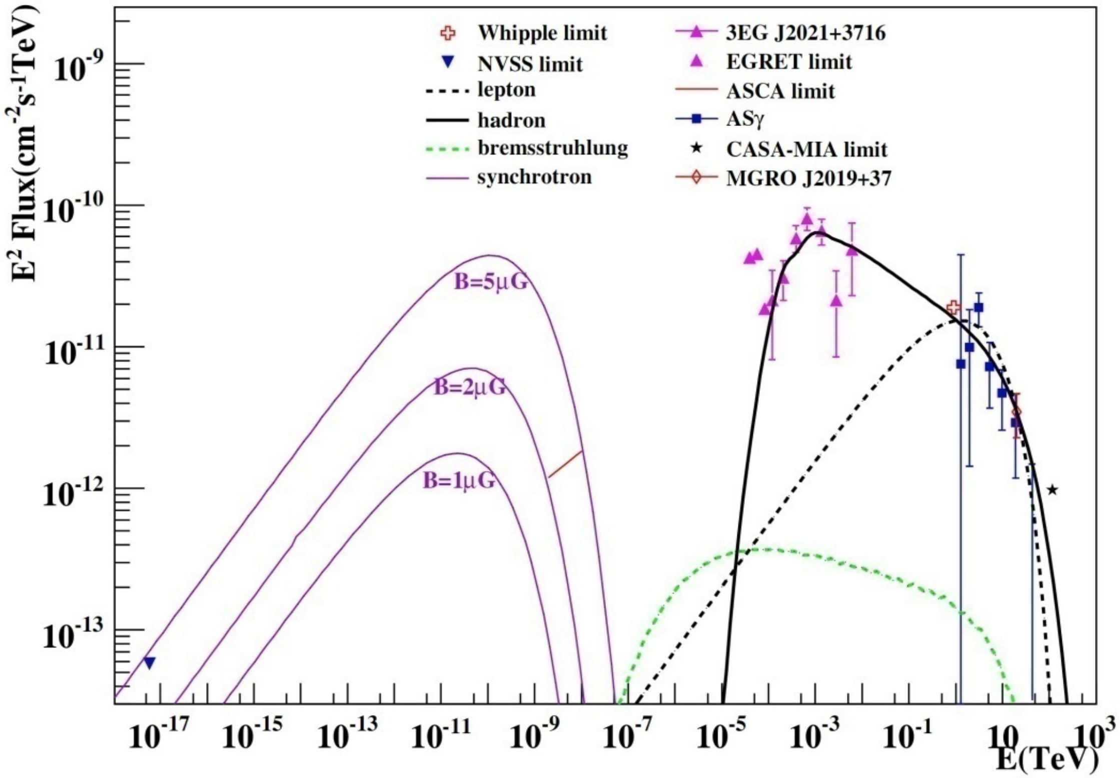
The line is the fit line at the condition of optimal angular resolution

It can be seen that the line is also consistent with the measurement results of smooth radius 1.5 °

Note: when the significance<2 σ , we set 90% C.L upper limits.

※At two different smooth radius conditions, the observed energy spectrum is consistent with what measured by Milagro at 12TeV within statistical and systematic errors.

Gamma rays and cosmic rays



–Assuming a simple power-law:

$$\phi \propto E^{-\alpha} \exp(-E / E_c)$$

➢hadronic model: (index=-2.25)

Protons Ec =198 TeV

➢ leptonic model: (index=-2.1)

Electrons Ec = 25 TeV

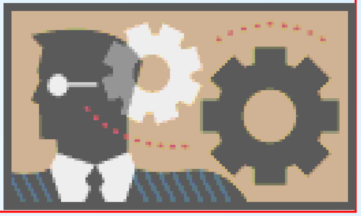
We find that both the hadronic and leptonic models can account for the current observational data.

Conclusion (very preliminarily)

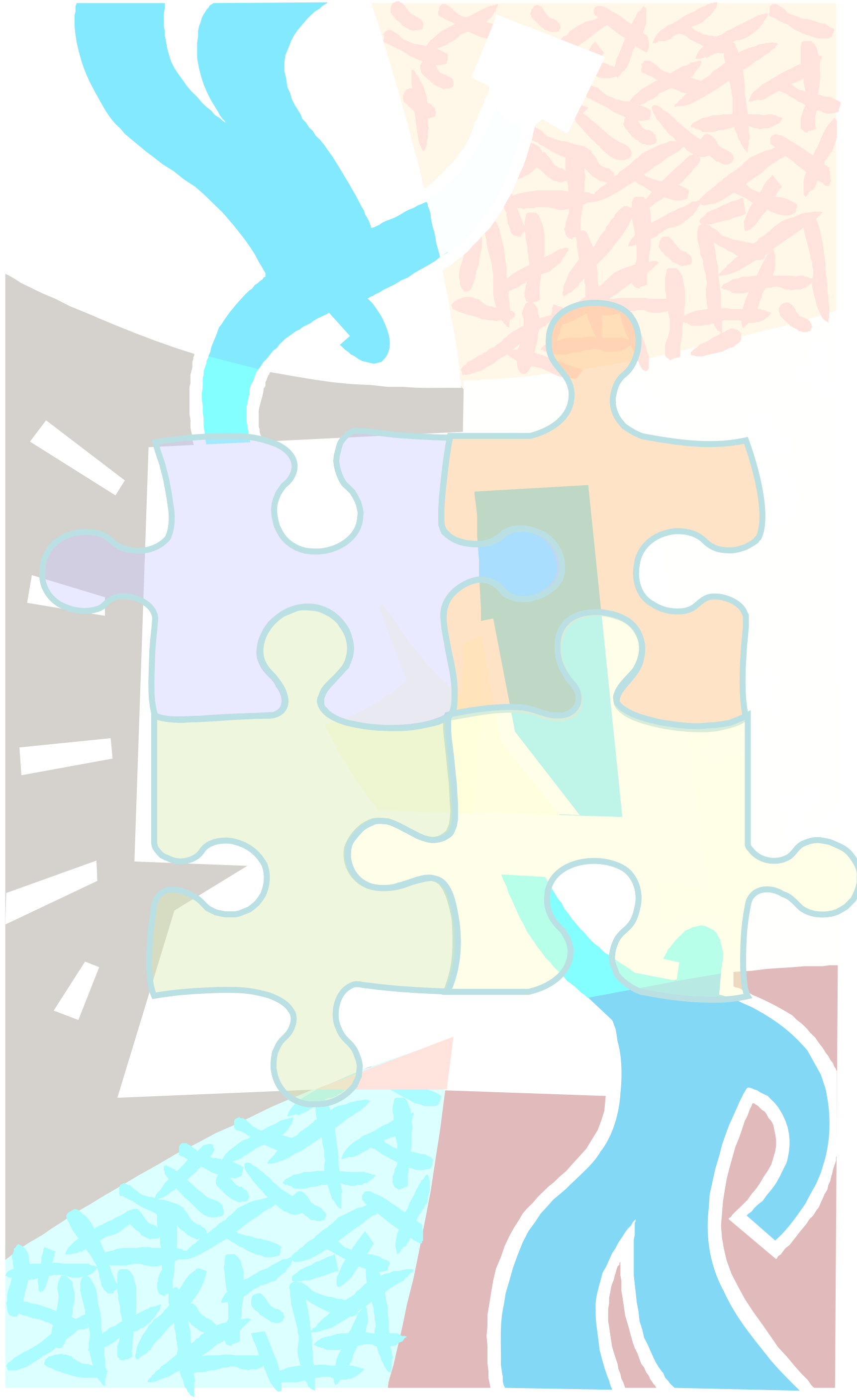
- We surveyed the known source MGRO J2019+39 and found ~4.0 σ significance due to our lower sensitivity which mainly because AS γ has no γ/p separation power.
- Four other candidates with significance > 4 σ were found and the nearest candidate to the MGRO J2019+37 is 4.6 σ when using optimal angular resolution as smooth radius. But they are not significant enough to be claimed as diffuse gamma emissions.
- Very Preliminary energy spectrum of the MILAGRO source J2019+37 measured to be (when smooth radius is optimal angular resolution):

$$dN/dE = (1.84 \pm 0.39_{stat}) \times 10^{-13}\ (E/6TeV\ )^{(-2.86 \pm 0.23stat)}\ TeV^{-1}cm^{-2}s^{-1}$$

- At present both the hadronic and leptonic models are consistent with the measured spectrum of the source.
- More studies on systematic uncertainty are undergoing.



Thank you!



Bake up

Sumft interval：

(10,17.8], (17.8,31.6], (31.6,56.2], (56.2,100],

(100,215.4], (215.4,464.2], (464.2,1000]

Just as before!!

The γ -ray emission mechanism

- The Galactic diffuse γ -ray emission provides important information to understand the origin and propagation of Galactic cosmic rays
- In general the emission mechanisms of the high energy γ -rays are thought to be of three types:

CR protons + ISM nuclei → π^0 → γ rays

$$p + p \rightarrow \cdots + \pi^0 \rightarrow \gamma\gamma$$

CR electrons + ISM nuclei → γ rays

$$e + p \rightarrow \cdots + \gamma$$

IC: CR electrons + ISRF photons → γ rays

$$e + \gamma \rightarrow e + \gamma$$

暗物质
自湮灭?

$$\chi\chi \rightarrow \cdots \rightarrow \gamma$$

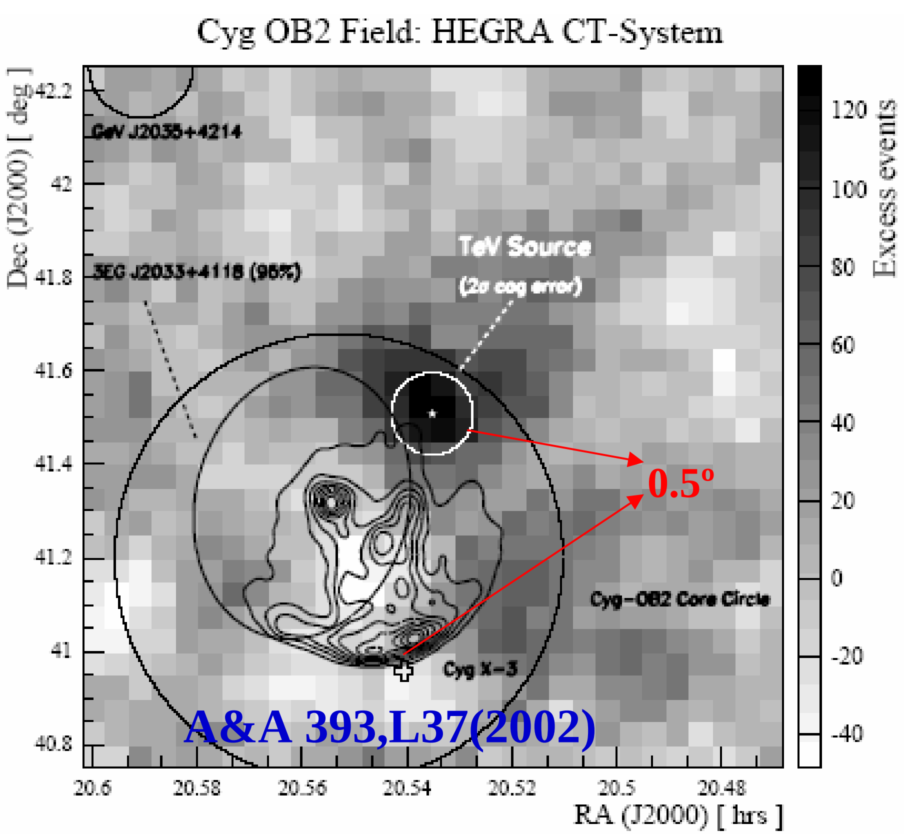
Some observations of Cygnus region from ground-based experiments

- IACTs
  - Whipple **(A&A ,423,L415,2004)** **ApJ ,658:1062(2007 Apr 1)**
  - HEGRA(unidentified TeV γ ray source J2032+4130)
    A&A 393,L37(2002) **A&A, 431 ,197(2005)**
  - MAGIC **arXiv:0801.2391v1**

- EAS
  - Milagro(MGRO J2019+37 and some other candidates)
    ApJ, 658,L33(2007)
  - **As γ** (the highest significace ~5.8 σ) **(30th ICRC 2007)**

  → **the wide of view and high duty cycle**

HEGRA serendipitously observation about the unidentified source



Skymap 1.5°×1.5° of excess

Original objects: Cygnus X-3 region *(1999-2001) (~113hrs)*
serendipitously discovery a signal,
---- The position :
Ra=$20^h32^m07^s$
Dec=41°30‘30“(J2000)
(consistent with Crimean reported)
---- significance:4.6 σ
----nature: steady
----extended radius: ~5.6‘
---- γ =-1.9±0.3stat±0.3sys
----Flux(>1 TeV): ~3% that of the Crab
----disfavor an exclusive pulsar or AGN origin (acceleration :1)not co-located TeV source, may be from the winds of the young/massive stars of cyOB2—no strong indication; 2)Alternative source involves a jet-driven termination shock(e.g. Cy-X3…..bi-lobal jet)

Whipple observation about the unidentified TeV source

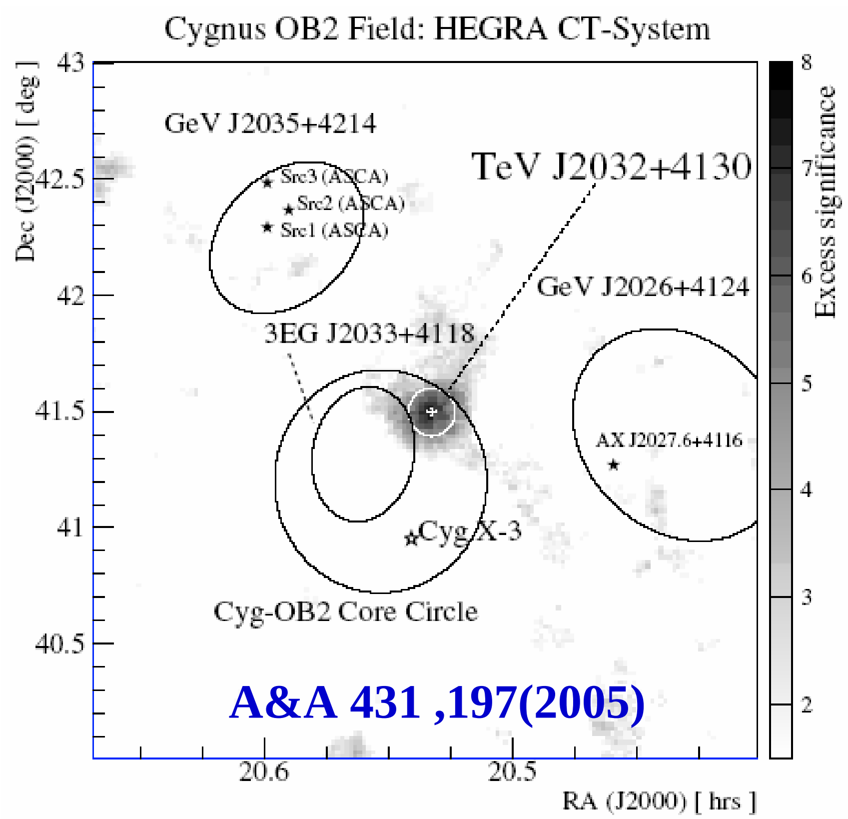
- Focus Cygnus X-3 and found no evidence of a signal
  (1989-1990 (50.4hrs))
- Later analysis by Lang(2004) for TeV J2032+4130

— Analysis result: ~3.6' to the northwest of TeV J2032+4130
— Significance: 3.3 σ
— Position: ~0.6º to the north of Cygnus X-3
— Flux: ~12% of the Crab(> 400GeV)

The flux variability seen with Crimean and HEGRA is easier to explain in terms of a point source such as the proton blazer or the microquasar explanations.
(A&A ,423,L415,2004).

- The correlation of time variations with observations at longer wavelengths will be particularly important.

HEGRA updated observation confirmed the unidentified source J2032+4130



Confirmed the TeV source:

(1999 to 2002 (~158hrs)

— significance: ~7 σ

— position: Ra=$20^h31^m57^s$

Dec=41º29'56.8"(J2000)

—extended radius:

6.2' ± 1.2'stat ± 0.9'sys

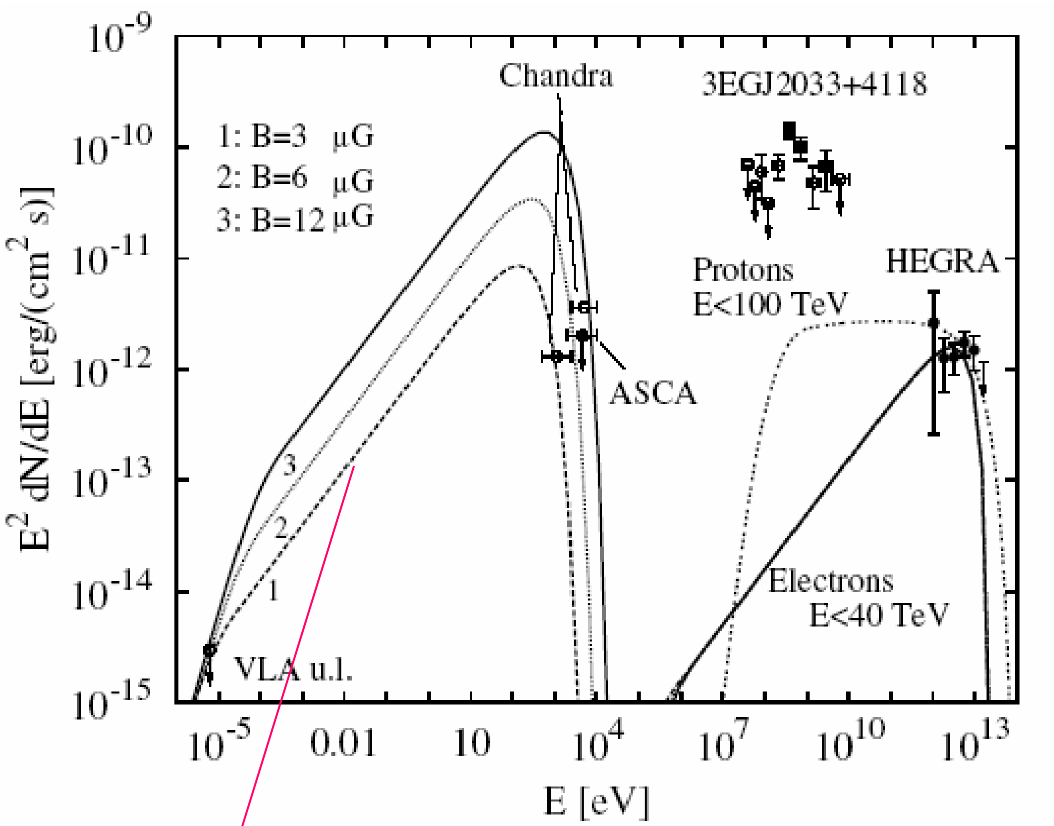
— γ =-1.9 ± 0.1stat ± 0.3sys

— Flux(>1 TeV): (6.89 ± 1.83) × 10^{-13} $cm^{-2}s^{-1}$ (~5% that of the Crab)

—nature: steady

Skymap of correlated event excess significance from all HEGRA data (3º × 3º FOV) centered on TeV J2032+4130

Spectrum of TeV J2032+4130



A&A 431 ,197(2005)

Expected in the Galactic disk

- hadronic model: (index=-2.0)

  Protons E < 100 TeV

- leptonic model: (index=-2.0)

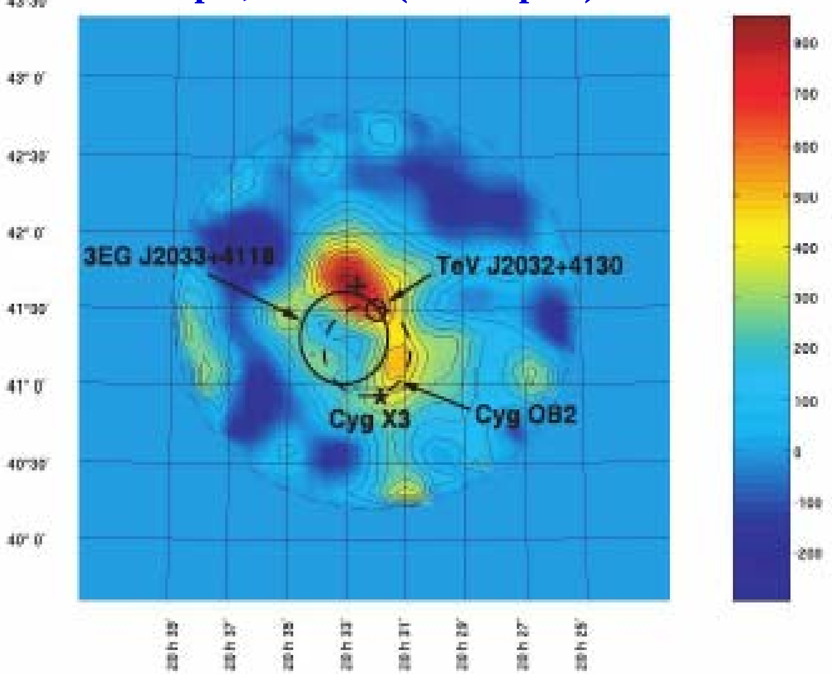
  Electrons E < 40 TeV

—likely the galactic TeV source

Whipple observation of J2032+4130

- **2003-2005 (65.5hrs of good on-source data**)--observations of the sky region around the unidentified TeV γ - ray source (TeV J2032+4130)

ApJ ,658:1062(2007 Apr 1)

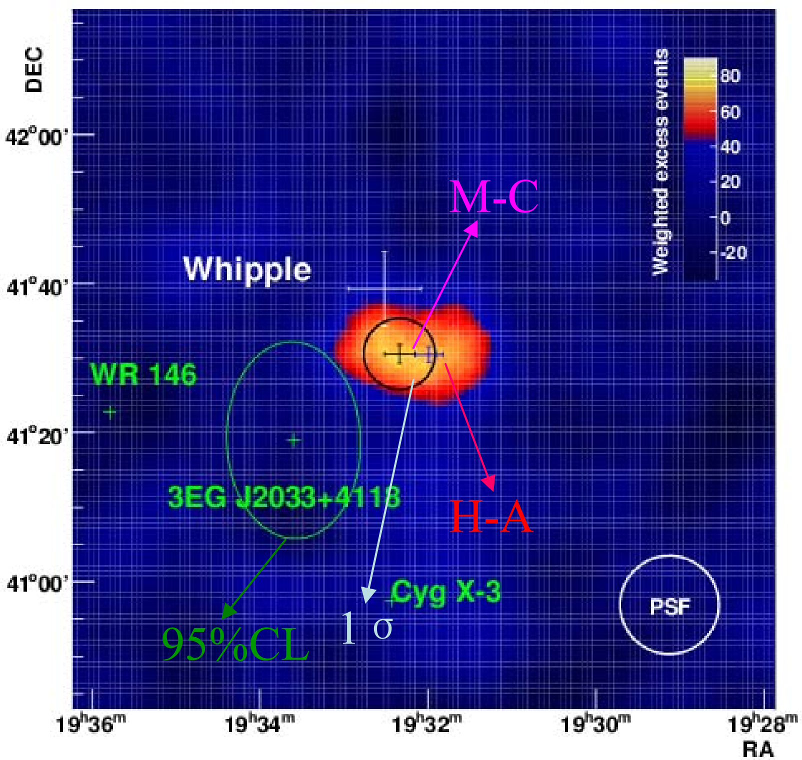


Dec vs. R.A. map of the excess counts from the TeV J2032+4130 region

—Significance : 6.1 σ
— Location:
RA=20^h 32^m 27^s, Dec= 41 º39‘ 17“
(9‘ from J2032+4130)
—Flux: ~8% Crab
(assuming a Crab like spectrum).
—Extended radius: no more than 6'.
—Accumulated mechanical power in the Cygnus OB2 accelerate TeV source.
—X-ray counterpart need to be detected and now may be favor hadronic origin

It is note that a second excess located to the southwest of the HEGRA source less 3 σ need to be confirmed

MAGIC observation about J2032+4130



Observation result:

- Significance: 5.6 σ
- Flux(>1TeV) : $(4.5 \pm 0.3_{stat} \pm 0.35_{sys}) \times 10^{-13}$ ph cm^{-2}s^{-1}
- $\gamma = -2.0 \pm 0.3_{stat} \pm 0.2_{sys}$

(The flux, position, and angular extension are compatible with HEGRA reported five years ago)

(arXiv:0801.2391v1)

Part results from different observations

实验名称	谱指数	与Crab流强比(倍数)	积分流强值 (E>1TeV) (ph $cm^{-2}s^{-1}$)
Crimean Observatory	Assuming -1.5	~1.7	3×10^{-11}
HEGRA	$\gamma=-1.9\pm0.1_{stat}\pm0.3_{sys}$	~5%	$(6.89\pm1.83_{stat})\times10^{-13}$
Whipple (1989-1990)		~12%	
Whipple (2003-2005)	Assuming Crab-like	~8%	
MAGIC	$\gamma=-2.0\pm0.3_{stat}\pm0.2_{sys}$		$(4.5\pm0.3_{stat}\pm0.35_{sys})\times10^{-13}$

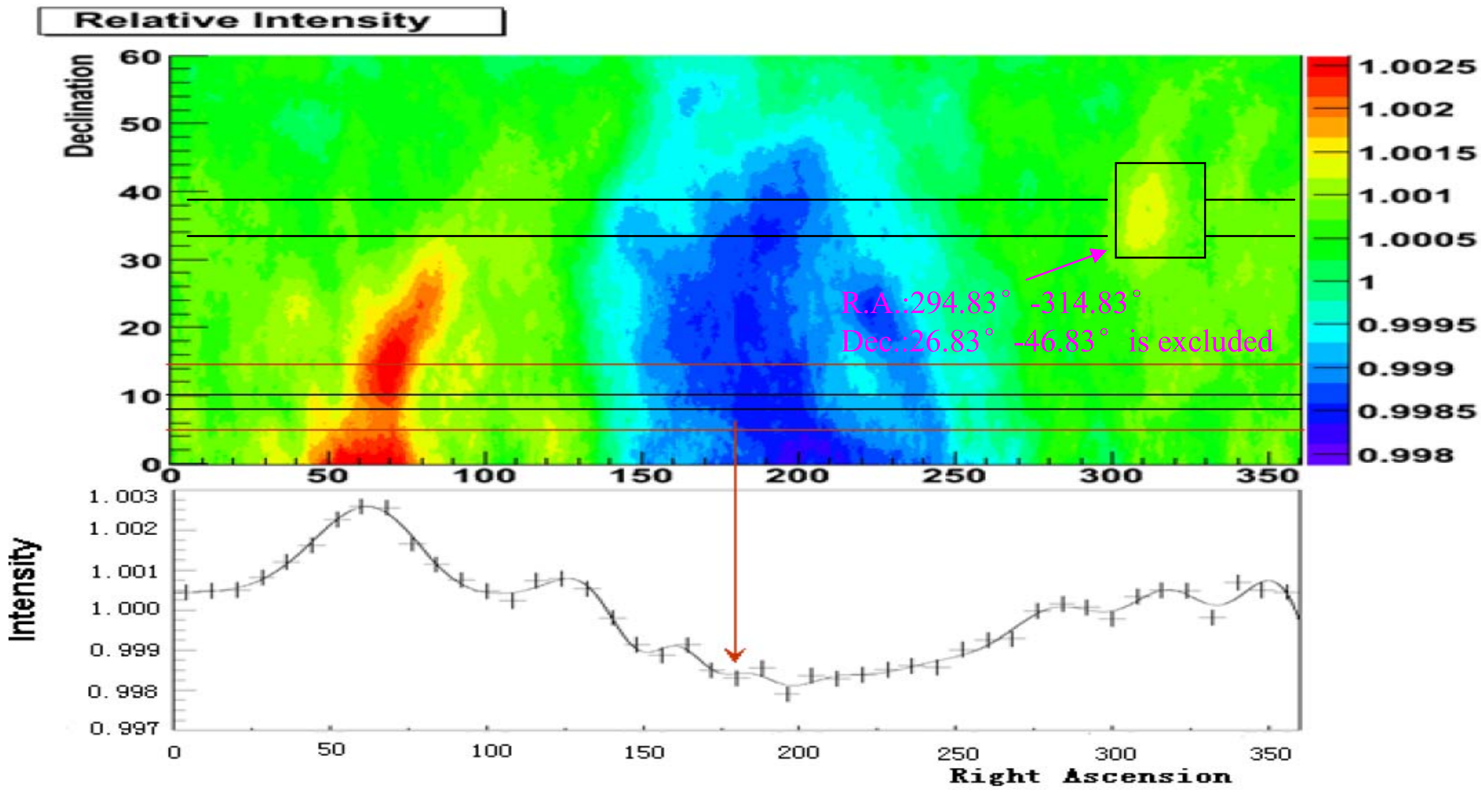
Conclusion2 about TeV J2032+4130

- No evidence for variability within any individual databases (**steady?)**
- Extended radius no more than 6‘
- No established counterparts at other wavelengths.
- Cygnus OB2 association may be a tremendous mechanical power density accumulated to accelerate the TeV sources.
- The ***Chandra*** satellite revealed no obvious X-ray counterpart, evidently favoring a hadronic origin for the γ -rays from the Cygnus region.

Conclusion1 about MGRO J2019+37

- May be a diffuse source
- No established counterparts at other wavelengths.
- The origin is still mystery
- The later observations from GLAST , VERITAS et.al will be helpful

Large scale anisotropy subtraction



MGRO J2019+37 Expected significance calculation（using HD+TibetIII data)

According to the MGRO J2019+37's flux value at 12TeV from MILAGRO, We can know the differential flux is:

$$dN/dE = (1.55 \pm 0.21_{stat} \pm 0.47_{sys}) \times 10^{-11}\ \mathrm{TeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

The effective area: $A_{eff} = \varepsilon S_0$

$$\varepsilon_{smr1.5^\circ} = \frac{N_{sim}^{cut1.5}}{N_{sim}^{all}} = \frac{18970}{20000 \times 97 \times 10} = 9.78 \times 10^{-4}$$

$$\varepsilon_{smr0.99^\circ} = \frac{N_{sim}^{cut0.99}}{N_{sim}^{all}} = \frac{13489.3}{20000 \times 97 \times 10} = 6.95 \times 10^{-4}$$

$$N_{expt}^{smr1.5^\circ} = \int_{0.3}^{1000} A_{eff} T_{obs} \frac{dN}{dE} dE = 9.06 \times 10^3$$

$$N_{expt}^{smr0.99^\circ} = \int_{0.3}^{1000} A_{eff} T_{obs} \frac{dN}{dE} dE = 6.44 \times 10^3$$

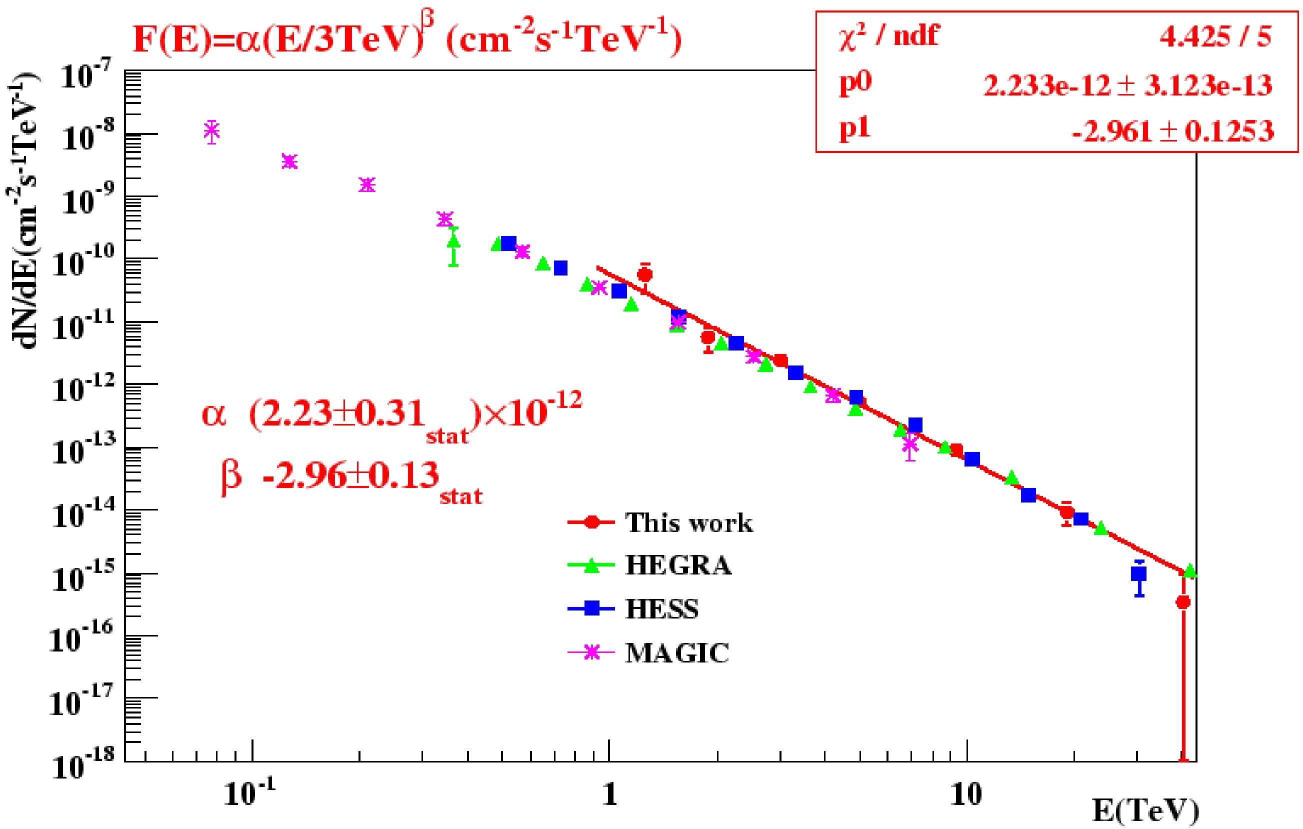
$$N_{bkg}^{smr1.5^\circ} = 9182654.8 \quad , \quad N_{bkg}^{smr0.99^\circ} = 4000614.6$$

Then we can know the significance is：

$$S_{smr1.5^\circ} = \frac{N_{expt}^{smr1.5^\circ}}{\sqrt{N_{bkg}^{smr1.5^\circ}}} = 3.0\sigma$$

$$S_{smr0.99^\circ} = \frac{N_{expt}^{smr0.99^\circ}}{\sqrt{N_{bkg}^{smr0.99^\circ}}} = 3.2\sigma$$

Crab energy spectrum measurement



Consistent with other results ⟹ measurement method is reliable

Energy spectrum measurement method

$$\begin{pmatrix} s_1 \pm \sigma_1 \\ s_2 \pm \sigma_2 \\ \vdots \\ s_n \pm \sigma_n \end{pmatrix} = \begin{pmatrix} M_{1,1} & M_{1,2} & \cdots & M_{1,m} \\ M_{2,1} & M_{2,2} & \cdots & M_{2,m} \\ \vdots & \vdots & \vdots & \vdots \\ M_{n,1} & M_{n,2} & \cdots & M_{n,m} \end{pmatrix} \begin{pmatrix} T_1 \\ T_2 \\ \vdots \\ T_m \end{pmatrix}$$

----用地面宇宙线阵列推算原初γ射线能谱时，需要将观测到的总粒子数转换成原初γ光子的初能（E_0），而由于探测器的能量分辨率差，实际上观测的每组信号数是各能段原初γ光子贡献的总和。

$$\chi^2 = \left(s_1 - \sum_{j=1}^{m} M_{1,j} \cdot T_j \right)^2 / \sigma_1^2 + \left(s_2 - \sum_{j=1}^{m} M_{2,j} \cdot T_j \right)^2 / \sigma_2^2$$

$$+ \ldots\ldots\ldots + \left(s_n - \sum_{j=1}^{m} M_{n,j} \cdot T_j \right)^2 / \sigma_n^2$$

TMINUIT Fit χ^2 we can get α and β

$$\text{Integral } Flux(> E_{\min}) = \frac{a}{\Omega S_{sim} T_{obs}} \int_{E_{\min}}^{\infty} E^b dE$$

$$S_{sim} = \pi r^2, \quad r = 300m$$

$$d\Omega = \sin\theta \, d\theta \, d\varphi, \quad (\theta, \varphi) = (\pi/2 - dec, ra)$$

$$T_{obs} = T(1 - P_{dr})$$

P_{dr} – is the mean dead time rate

where： s_i (i=1,2,….n) : the real excess in Σρ FT bin i
$M_{i,j}$(i=1,2…n;j=1,2…m) : efficiency of detector at energy band j and Σρ FT bin i (obtained by MC)
T_j(j=1,2,….n) : the integral value at the energy band (E_{lj}, E_{uj})

$$T_j(E_{l_j}, E_{u_j}, \alpha) = \int_{E_{l_j}}^{E_{u_j}} \alpha E^{\beta} dE$$

Flux Estimation (Kawata) method so as to check each other

$$N_{obs} = T_{obs} \int_0^{1day} \int_0^{2\pi} \int_0^{\infty} \int_0^{\infty} \alpha_{obs} E^{-\beta} \varepsilon_{obs}(E, r, \omega, O) dE dr d\omega dO$$

$$N_{sim} = T_{sim} \int_0^{1day} \int_0^{2\pi} \int_0^{R_{sim}} \int_{E_{sim}^{min}}^{\infty} \alpha_{sim} E^{-\beta} \varepsilon_{sim}(E, r, \omega, O) dE dr d\omega dO$$

$$\frac{N_{obs}}{N_{sim}} = \frac{\alpha_{obs} T_{obs}}{\alpha_{sim} T_{sim}}$$

$$N_{sim}^{all} = S_{sim} T_{sim} \int_{E_{sim}^{min}}^{\infty} \alpha_{sim} E^{-\beta} dE$$

$$\alpha_{obs} = \frac{N_{obs}}{N_{sim}} \frac{N_{sim}^{all}}{\int_{E_{min}^{sim}}^{\infty} E^{-\beta} dE \, S_{sim} T_{obs}}$$

$$f(E_{dif}) = \alpha_{obs} E^{-\beta}$$

$$f_i(E_{\log m\_i}) = \frac{N_{obs\_i}}{N_{sim\_i}} \frac{N_{sim}^{all}}{\int_{E_{min}^{sim}}^{\infty} E^{\beta} dE \, S_{sim} T_{obs}} (E_{\log m\_i})^{\beta}$$

$f_i (E_{log\_i})$: Differential flux at E_{logm_i}

E_{logm_i}: Representative energy in each Σρ FT bin i

(logarithm mean[10 $^{<\log10(E)>}$] in each Σρ FT bin i)

N_{obs_i}: Experimental excess in each Σρ FT bin i

N_{sim_i}: Simulated excess in each Σρ FT bin I

N_{sim}^{all}: All simulated event number at the top of atmosphere for a diurnal motion

S_{sim}: Simulated core location area(300m*300m*π)

T_{obs}: Live time(1319*86400s)

β : Simulated spectrum index

Energy spectrum index convert: Weighted event ω at different spectral index β is used for counting N_{sim_i} ,To change spectral index -2.6 to β , ω is expressed by:

$$N_{sim}^{all} = a_1 \int_{E_{sim}^{min}}^{\infty} E^{-2.6} dE = a_2 \int_{E_{sim}^{min}}^{\infty} E^{\beta} dE \Rightarrow \omega = \frac{a_2 E^{\beta}}{a_1 E^{-2.6}} = \frac{-(\beta + 1.0)}{1.6} E_{sim}^{\min -2.6-\beta} E^{\beta+2.6}$$

The information at different energy interval

—Smooth radius is optimal angular resolution(0.99°)

$\sum \rho_{FT}$	$R_{optimal}/(^\circ)$	N_{on}	N_{off}	N_s	$\triangle N_s$	$S_{pretrials}$
[10,17.8)	1.76	391014.0	390887.0	127.0	625.3	0.20
[17.8,31.6)	1.52	2701684.0	2699763.1	1920.9	1643.7	1.17
[31.6,56.2)	1.22	2099870.0	2094503.1	5366.9	1449.1	3.70
[56.2,100)	0.94	696374.0	694662.4	1711.6	834.5	2.05
[100,215.4)	0.75	250158.0	249064.4	1093.6	500.2	2.19
[215.4,464.2)	0.63	58818.0	58409.3	408.7	242.5	1.69
[464.2,1000)	0.58	16267.0	16285.7	-18.7	127.5	-0.15

$\sum \rho_{FT}$	N_{sim_i}	$E_{logm_i}/(\mathrm{TeV})$	$flux_i$	$\triangle flux_i$	$\mathrm{uplimit}_{90\%\mathrm{C.L.}}$
[10,17.8)	391.79	1.33	4.00e-12	1.97e-11	3.50e-11
[17.8,31.6)	3248.15	1.98	2.38e-12	2.04e-12	5.15e-12
[31.6,56.2)	3229.65	3.12	1.83e-12	4.93e-13	
[56.2,100)	1728.38	5.33	2.39e-13	1.16e-13	
[100,215.4)	1016.80	9.73	4.69e-14	2.14e-14	
[215.4,464.2)	348.65	19.23	7.39e-15	4.37e-15	1.32e-14
[464.2,1000)	92.88	42.90	-1.30e-16	8.87e-16	1.38e-15

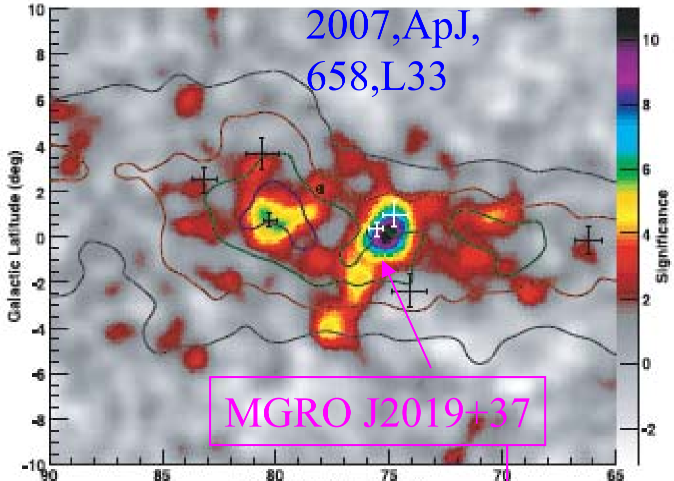
The information at different energy interval

—Smooth radius is 1.5°

$\sum \rho_{FT}$	N_{on}	N_{off}	N_s	$\triangle N_s$	$S_{pretrials}$
[10,17.8)	283061.0	282884.0	177.0	532.0	0.33
[17.8,31.6)	2617672.0	2616030.5	1641.5	1617.9	1.01
[31.6,56.2)	3141260.0	3135010.5	6249.5	1772.4	3.53
[56.2,100)	1753489.0	1749489.5	3999.5	1324.2	3.02
[100,215.4)	982212.0	981107.3	1104.7	991.1	1.11
[215.4,464.2)	331293.0	331473.4	-180.4	575.6	-0.31
[464.2,1000)	107589.0	107668.9	-79.9	328.0	-0.24

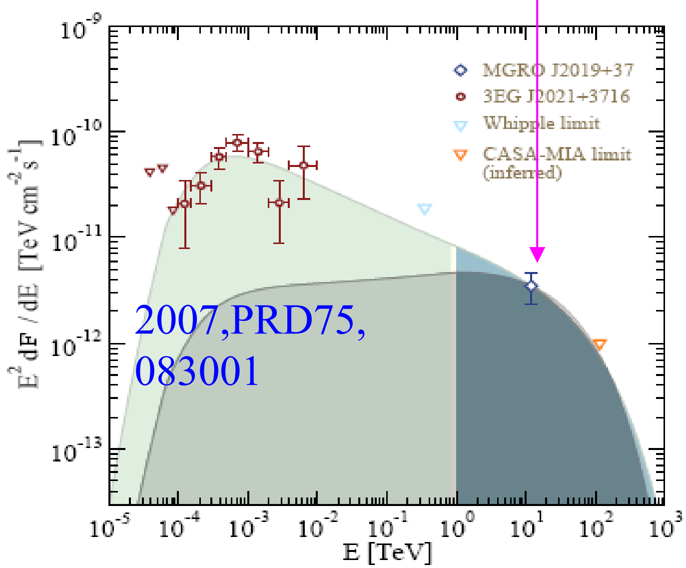
$\sum \rho_{FT}$	N_{sim_i}	$E_{logm_i}/(\mathrm{TeV})$	$flux_i$	$\triangle flux_i$	$\mathrm{uplimit}_{90\%\mathrm{C.L.}}$
[10,17.8)	326.55	1.33	6.54e-12	1.96e-11	3.67e-11
[17.8,31.6)	3111.27	1.93	2.15e-12	2.12e-12	5.09e-12
[31.6,56.2)	3605.27	3.05	1.91e-12	5.41e-13	
[56.2,100)	2116.51	5.13	4.64e-13	1.54e-13	
[100,215.4)	1172.23	9.46	3.96e-14	3.55e-14	8.83e-14
[215.4,464.2)	361.09	18.91	-2.86e-15	9.14e-15	1.34e-14
[464.2,1000)	94.50	42.52	-4.69e-16	1.93e-15	2.90e-15

Cygnus region—MILAGRO research status



Contours- matter density

Crosses- EGRET source location



Galactic Sources and Source Candidates

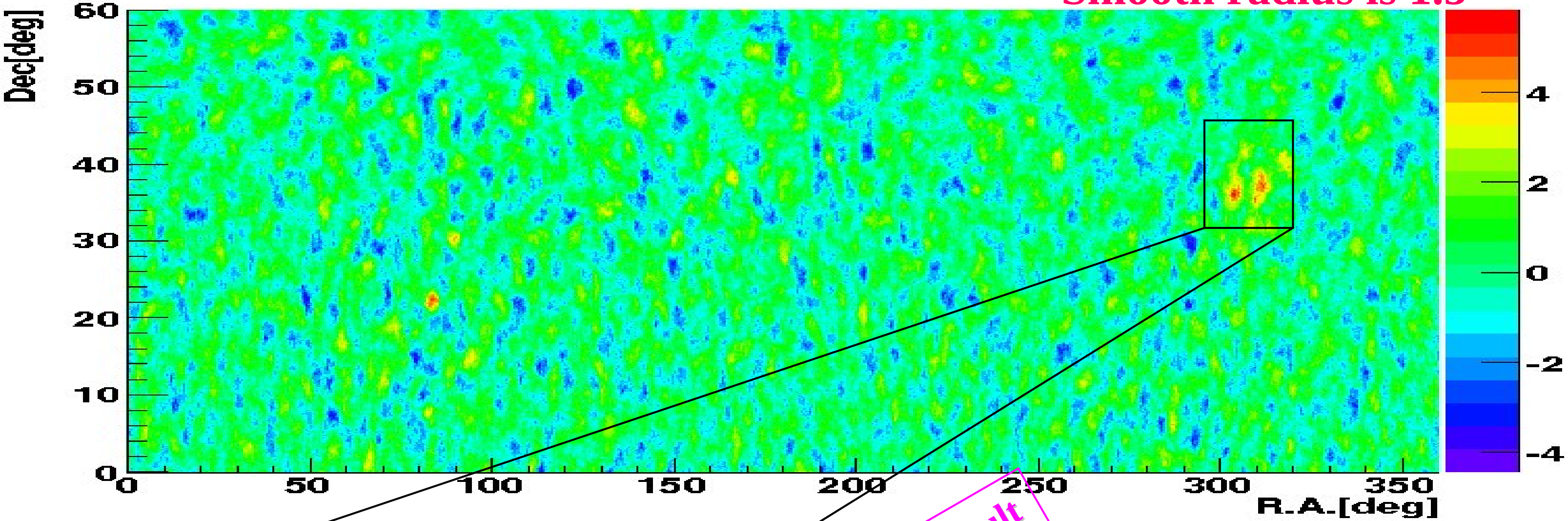
Object	Location (l, b) (deg)	Error Radius[a] (deg)	Significance (σ)[b] Pretrials	Posttrials	3° × 3°	Flux[c] at 20 TeV (10^{-15} TeV^{-1} cm^{-2} s^{-1})
Crab	184.5, −5.7	0.11	15.0	14.3	11.5	10.9 ± 1.2
MGRO J2019+37	75.0, 0.2	0.19	10.4	9.3	8.5	8.7 ± 1.4
MGRO J1908+06	40.4, −1.0	0.24	8.3	7.0	6.3	8.8 ± 2.4
MGRO J2031+41	80.3, 1.1	0.47	6.6	4.9	6.4	9.8 ± 2.9
C1	77.5, −3.9	0.24	5.8	3.8	3.4	3.1 ± 0.6
C2	76.1, −1.7	...[e]	5.1	2.8	4.5	3.4 ± 0.8
C3	195.7, 4.1	0.40	5.1	2.8	5.9	6.9 ± 1.6
C4	105.8, 2.0	0.52	5.0	2.6	6.3	4.0 ± 1.3

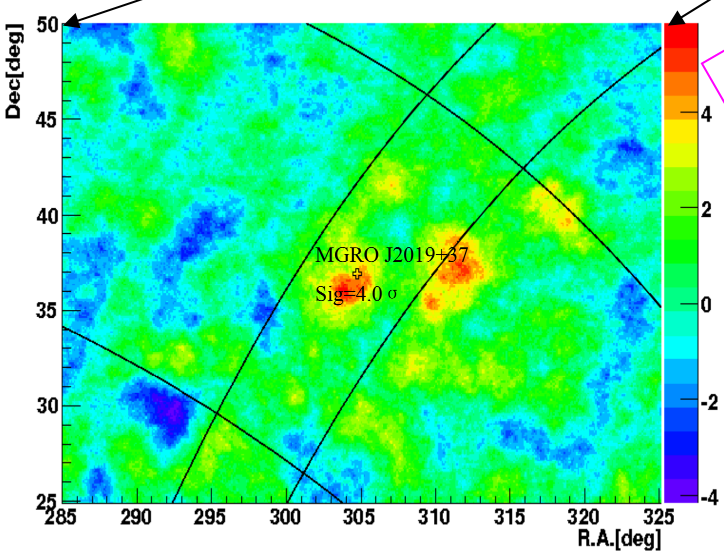
2007,ApJ,
664,L91

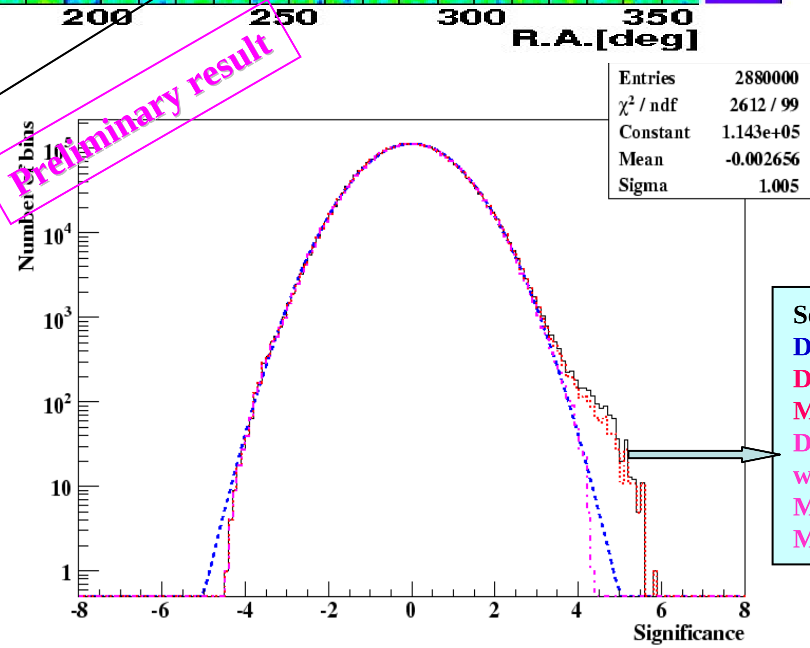
All Sky Significance map(2)

—Extended source MGRO J2019+37 observing

——Smooth radius is 1.5°





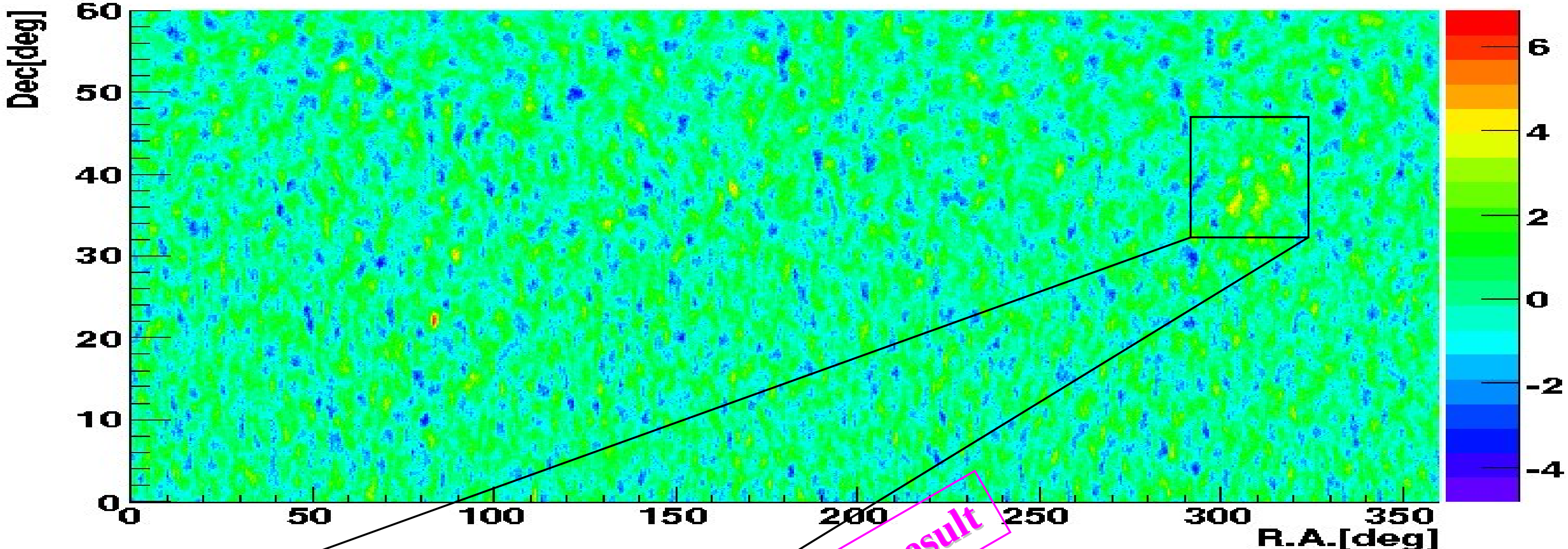


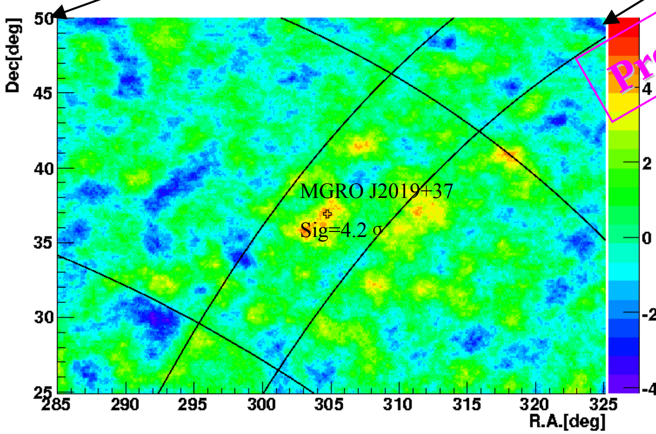
Solid line--all sky;
Dashed line-gaus fit;
Dotted line-without Mrk421 and Crab;
Dot-dashed line-without Mrk421,Crab and MGRO J2019+37;

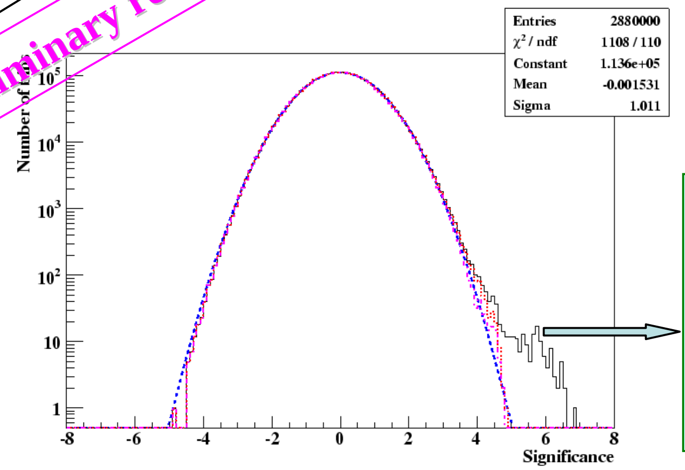
All Sky Significance map(3)

—Extended source MGRO J2019+37 observing

—Smooth radius is optimal angular resolution(0.99 °) thinking about the extension 0.32 ° of MGRO J2019+37







Solid line--all sky;
Dashed line-gaus fit;
Dotted line-without Mrk421 and Crab;
Dot-dashed line-without Mrk421,Crab and MGRO J2019+37;