A wide sky survey for steady *or* flare type TeV gamma-ray sources using the Tibet-HD and Tibet III data

The Tibet-ASG group

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The Tibet-ASG collaboration

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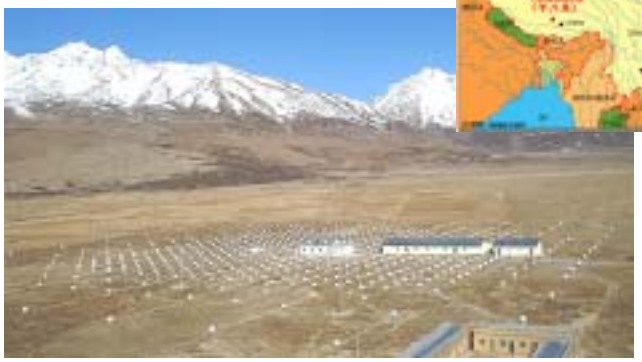
The Tibet Air Shower Array

Yangbajing Station

4,300 m a.s.l. ; 606 g/cm²

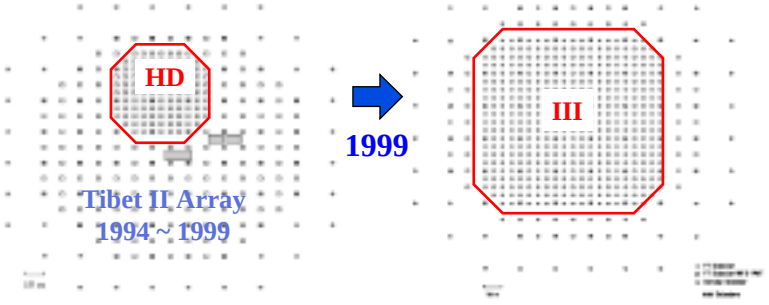
Long. 90.52°E , Lat. 30.11° N



The Tibet HD and Tibet III Array

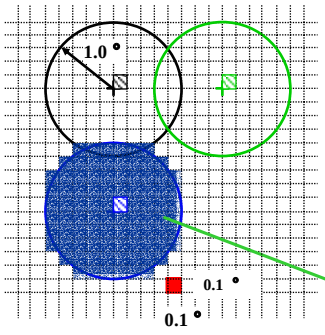
Tibet HD, 1997.2/15 ~ 1999.9/15

Tibet III, Phase1; 1999.11/17. ~2000.6/29



5,175 m^2	Array area	22,000 m²
7.5 m	Grid span	7.5 m
~ 110 Hz	Trigger rate	~ 680 Hz
3 TeV	Mode energy	3 TeV
~ 0.90° ± 0.1°	Angular resolution	~ 0.90° ± 0.1°
780 days	Observation period	173 days (Phase 1)
~ 6.9 ×10^9	No. of triggered events	~ 10.2 ×10^9

A fast method to get event No. included in ~ 1°f window



α= 0°~ 360°,

δ = +10° ~ +50°

Event numbers in small cells

$(\Delta\delta, \Delta\alpha) = (0.1° \times 0.1°)$

1,440,000 cells

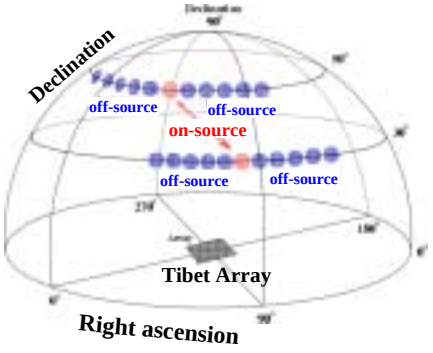
Obtain No. of events in Mosaic-like 1.0°ϕ circle window

Estimation of background event No. included in on-source window

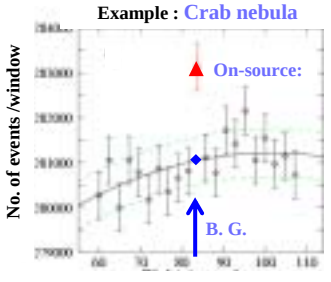
20 off-source windows, same R.A. as on-source

Root mean square fitting for off-source windows

Background level



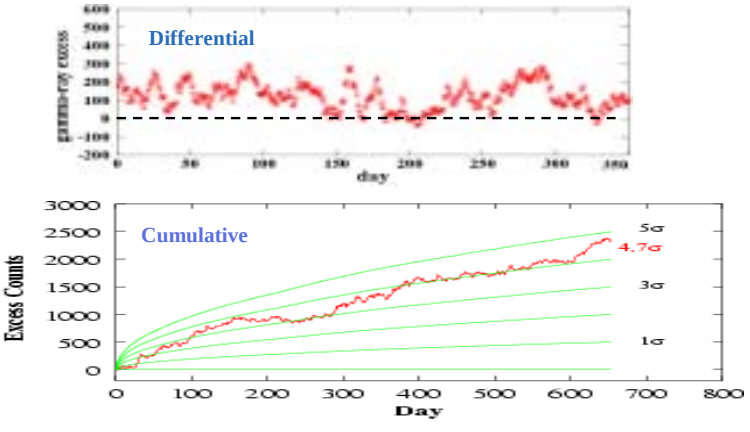
Example : Crab nebula



Search for steadily emitting sources

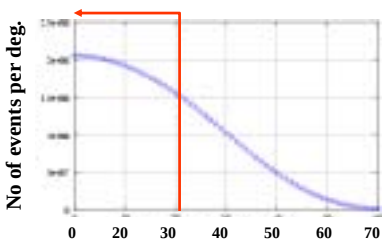
A template for time profile of steady emissions of TeV γ - ray

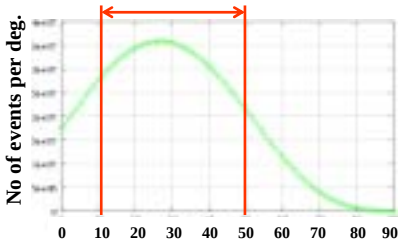
An example : Crab nebula observed by the Tibet HD array



Event selection

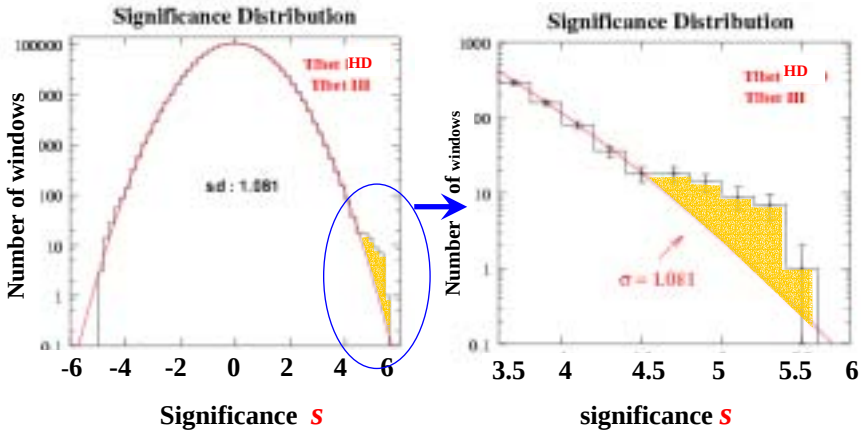
- 953 days (in 1997 2/15 ~ 2000 6/29) Tibet HD + Tibet III
- $\Sigma \rho_{FT}$ > 15 particles /event
- Zenith angle < 30 °
- Declination +10 ° ≦ δ < +50 °
- Right ascension 0 ° ≦ α < 360 °



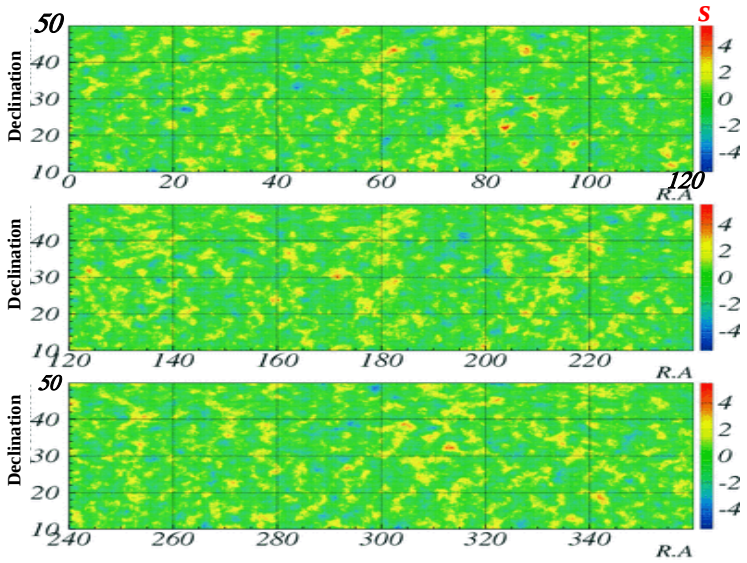


Results 1: Search for steadily emitting sources

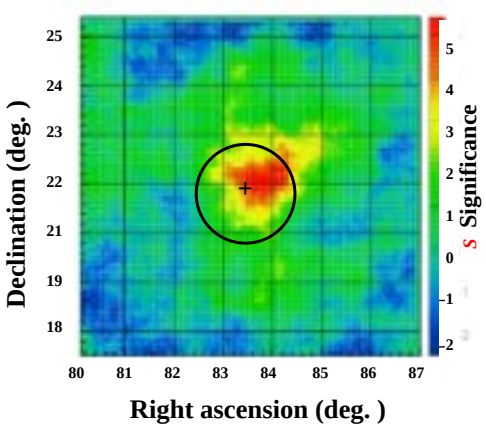
Significance distribution for14,400,000 directions



Significance map by the data Tibet HD and Tibet III(Phase1)



Significance map around Crab nebula

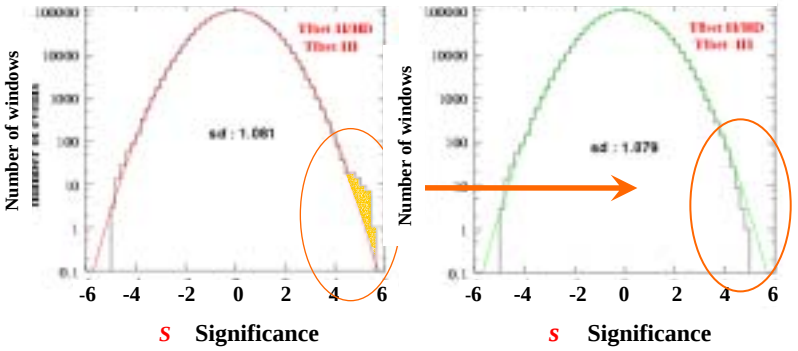


If we omit *s* values of inside directions included in the 1 degree circle centered at Crab nebula

Contribution of Crab nebula to the upper end of …. s – distribution

Directions inside 1 deg. ϕ centered at Crab are

------- Included ---------- ---------- Omitted ----------



s at other than Crab-region are consistent with statistical fluctuation.

Tibet HD + III$_{phase1}$ $S > 4.0\ \sigma$

	#	R.A	+Decli	signif.
	T1	53.2	49.0	4.30
	T2	62.7	43.3	4.66
	T3	77.7	21.2	4.03
Crab	T4	83.6	22.0	5.43
	T5	88.0	43.7	4.34
	T6	88.7	+30.1	4.81
	T7	89.6	25.3	4.05
	T8	96.9	17.6	4.06
	T9	115.4	12.0	4.31
	T10	160.2	23.8	4.07

#	R.A	Decli	signif.
T11	171.5	30.0	4.11
T12	199.4	11.2	4.10
T13	216.0	31.7	4.12
T14	276.6	13.3	4.09
T15	254.3	40.8	4.16
T16	304.3	38.8	4.51
T17	313.5	32.4	4.62
T18	322.4	45.3	4.29
T19	342.7	18.3	4.09

Summary 1: Search for steady emission

1 ■ 19 Prominent direction with $s > 4.0\,\sigma$

2 ■ Crab ($s = 5.4\,\sigma$) is the only one which gave a statistically significant excess. ➡ Crab is the strongest source in the sky we surveyed.

3 ■ Interesting directions are as follows;

➡ T6 (α:305.°58, δ:+38.°43) gave a high s (4.8 σ) : This direction gave similar growth of s both in HD (3.48σ) and III (Phase 1) (3.39σ) .

➡ 3 directions are near to an EGERT source and SNRs with angular distance $d \sim < 1.0°$.

T16 G 76.9+1.0 SNR (305. 58, +38.43) $d = 1.06°$

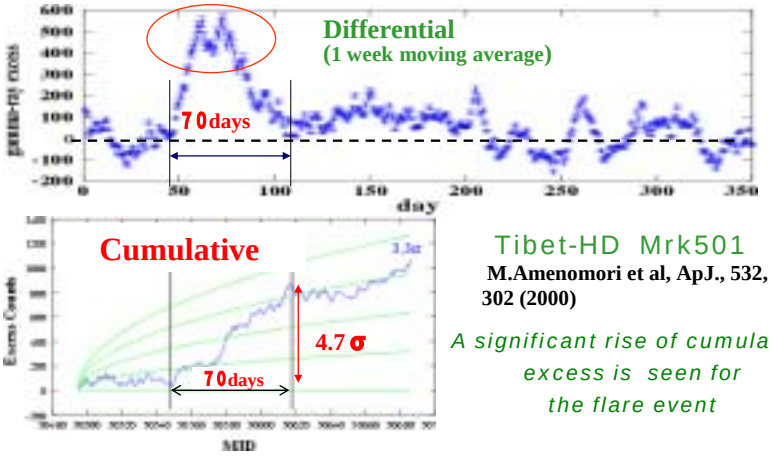
T17 Cygnus Loop SNR (312.53, +32.40 : brightest by x-ray) $d = 1.01°$

T19 3EG J2248+1745 unknown (342.24, +17.77) $d = 0.68°$

2: Survey for flare type TeV gamma-ray sources using the Tibet-HD data

A template for time profiles of Flare type Emissions of TeV γ-rays

An example : 1997 flare of **Mrk501** observed by the **Tibet HD** array



Tibet-HD Mrk501

M.Amenomori et al, ApJ., 532, 302 (2000)

A significant rise of cumulative excess is seen for the flare event

Selection of directions to be examined

Tibet HD : 19 directions with S(780days) > 4.0 σ are examined.

#	R.A	Decli	S
HD1	56.8	34.2	4.91
HD2	57.4	37.7	4.10
HD3	70.3	11.3	4.24
HD4	74.7	37.8	4.23
Crab HD5	83.3	22.2	4.78
HD6	94.6	15.6	4.02
HD7	125.8	13.1	4.41
HD8	141.6	20.4	4.39
HD9	204.6	24.2	4.16
HD10	204.8	36.6	4.02

#	R.A	Decli	S
HD11	213.2	45.0	4.05
HD12	284.8	12.8	4.48
HD13	295.5	20.2	4.11
HD14	305.4	37.9	4.16
HD15	313.5	32.4	4.28
HD16	322.4	45.3	4.78
HD17	328.4	49.1	4.24
HD18	334.5	34.5	4.01
HD19	358.0	30.1	4.10

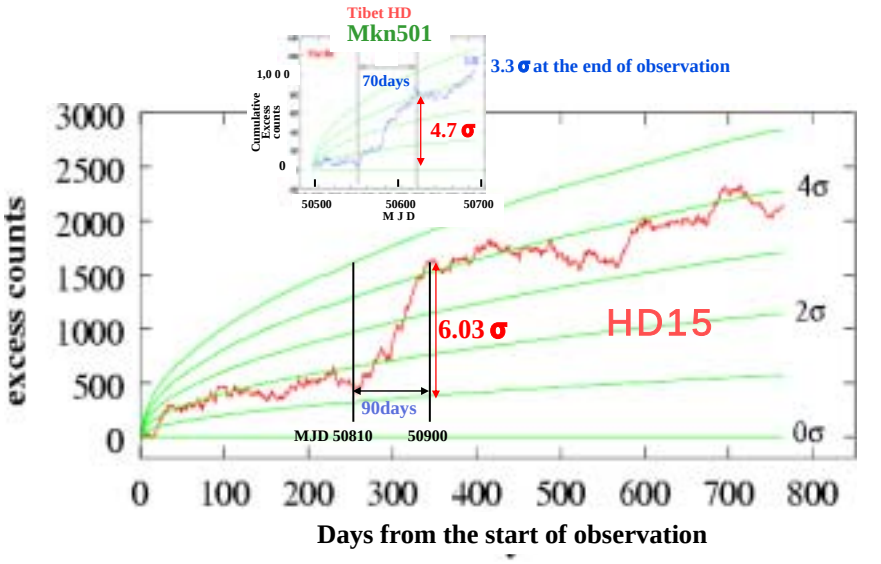
Result 2 Survey for flare type sources using the Tibet-HD data

- A very prominent flare-like rising in cumulative excess curves was found for a direction :

  HD15 : R.A=313.5 ° , Dec=32.4 °

Time profile of HD15

Compared with the 1997 flare of Mkn 501



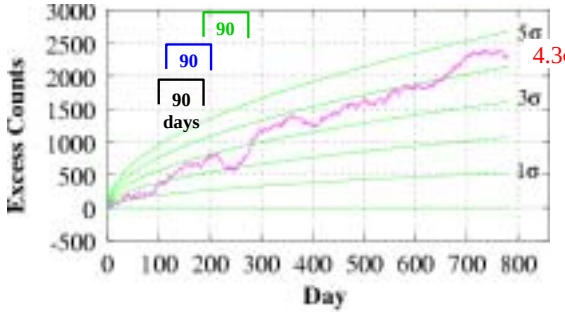
Is 6σ rising in 90 days appeared in HD15 understood by the statistical fluctuation ?

Estimation of expected number by simulation

Estimation of expected number (simulation)

- **Generate one-day event numbers for each on-source direction and for corresponding 20 off-source directions using Poisonian distribution.**
- **By 1,440,000 of on and off data one day map of significance distribution is made.**
- **At every 780 days, we find direction which gives $S(780) > 4\sigma$.**
- **Selected directions are examined if any continued 90 days in each set of 780 days have rise of S greater than 6.0 σ.**

A time profile of cumulative excess : simulated example

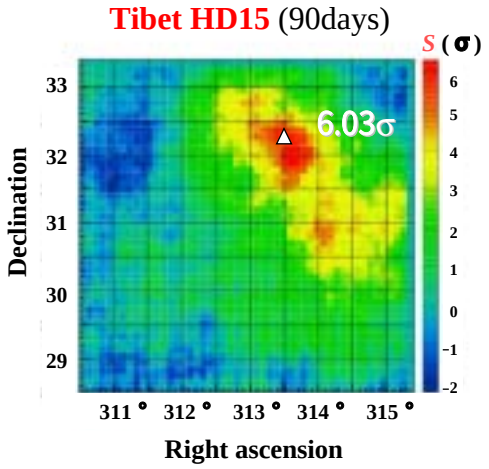


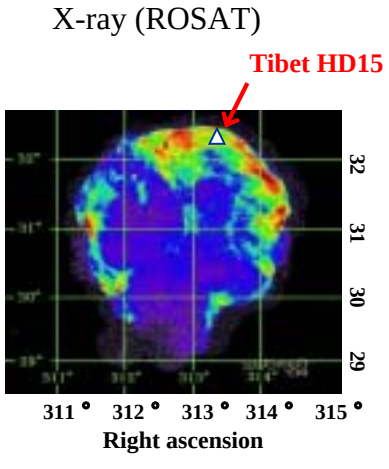
Estimation for statistically expected number of HD15 type 6 σ rising.

	Total No. of tested directions	No. of directions with *S* (780days) > 4σ	Expected No. of directions for s rising greater than 6σ in 90 days.
Tibet HD (Experiment)	1,440,000	19	1
Simulation	80,000,000	3,849 (19)	2 (0.0098)

Expected No. of directions $= \frac{2}{3{,}849} \times 19 = 0.0098$

HD15 and Cygnus Loop





Summery 2: Search for flare emission

Using Tibet HD we examined 19 directions which gave significance > 4.0 σ at the end of 780 observation days

- **HD15 (RA. 313.5 ° , Dec. 32.4 °) have shown a steep rise of significance Δ *S* = 6.03σ in 90 days.**
- Statistically expected number of HD15 type 6 σ rising is
  0.0098 ±0.006 .
- **Corresponding source**
  : Near to the X-ray ridges of Cygnus Loop.
  : No AGN or EGRET sources.
  : AGASA BC1 cluster of EAS with energies above 10^{19} eV.
- **Preliminary: Estimation of g-ray flux *F*(>3TeV) /cm2･sec**
  HD15: ~ 11 ×10-12
  Mrk501: 9.1 ×10-12
  Crab: 5.5 ×10-12