CANGAROO III

CANGAROO MWL strategies, policies and outcomes

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CANGAROO team

- University of Adelaide
- Australian National University
- Ibaraki University
- Ibaraki Prefectural University
- Konan University
- Kyoto University
- STE Lab, Nagoya University
- National Astronomical Observatory of Japan
- Kitasato University
- Australia Telescope National Facility
- Tokai University
- ICRR, University of Tokyo
- Yamagata University
- Yamanashi Gakuin University
- Hiroshima University

Brief history of CANGAROO

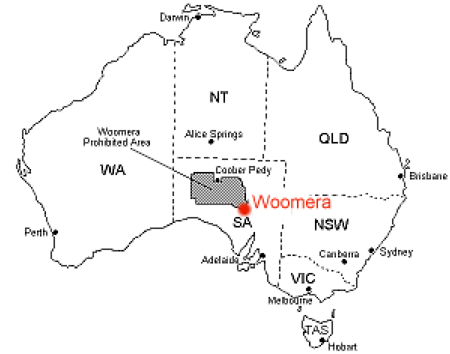
- 1987: SN1987A (JANZOS collaboration in New Zealand)
- 1990: 3.8m telescope (CANGAROO-I)
- 1990: ICRR-Adelaide Physics agreement
- 1992: Start obs. of 3.8m tel.
- 1999: 7m telescope
- 2000: Upgrade to 10m (CANGAROO-II)
- 2001: U.Tokyo-U.Adelaide agreement
- 2002: Second and third 10m tel.
- 2004: Four telescope system (CANGAROO-III)

CANGAROO-I (3.8mϕ)

CANGAROO-II (10mϕ)

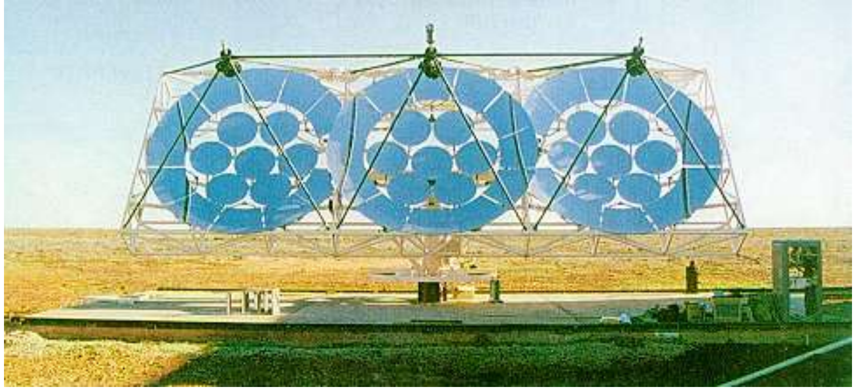
CANGAROO-III (4 x 10mϕ)

CANGAROO site: Woomera



- 136°47’E, 31°06’S, 160m a.s.l.
- Desert area…good weather (72% clear nights)
- Far from large cities…dark sky
- Former rocket range and prohibited area…infra-structure, support and safety
- Adelaide group was operating *BIGRAT*…experience

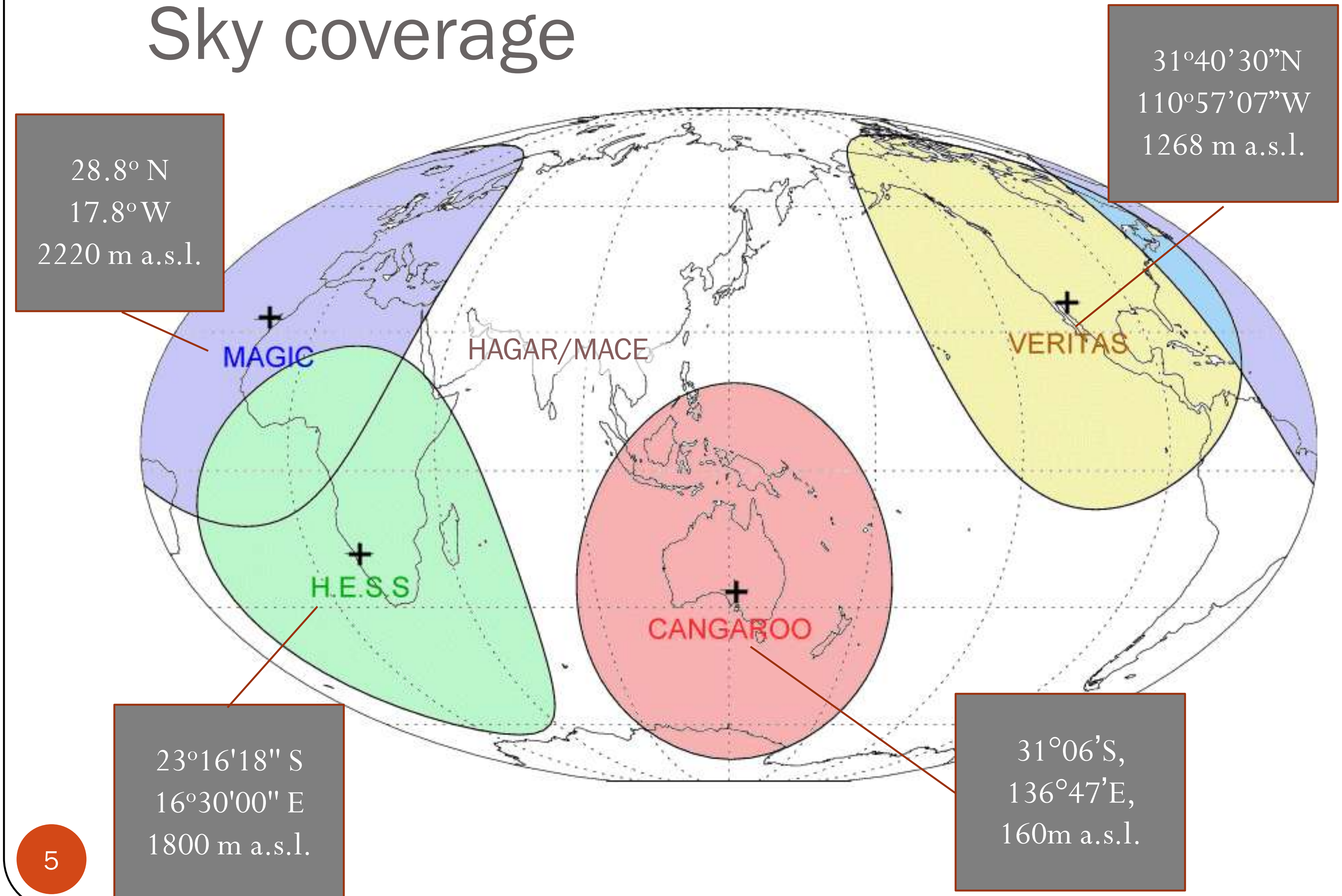
ELDO rocket Launch site in ’60s



BIGRAT

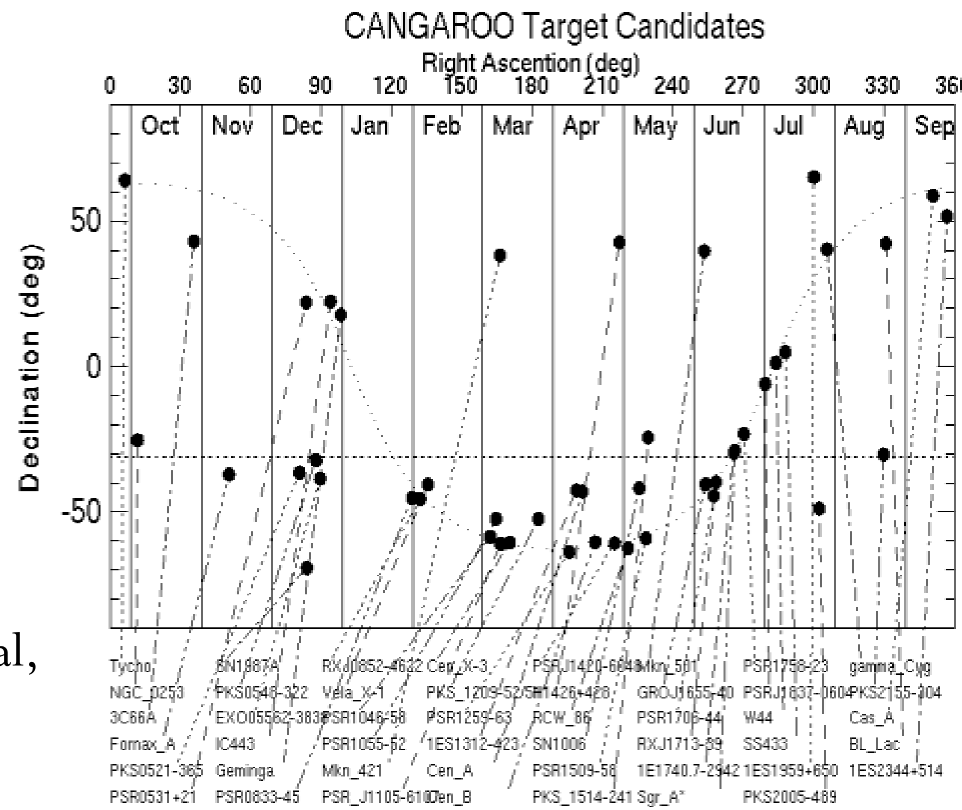
(BIcentennial Gamma RAy Telescope)

Sky coverage



Target selection

- Target meeting
  - Proposal and selection of targets
  - Every a few months, TV conference
  - 1-3 targets/month, matching in right ascension
- Target-of-Opportunity (ToO) observations
  - AGNs etc.
  - Trigger: ASM etc.
- Extended target meeting
  - Discussion of possible TeV objects with researchers in wide fields (X-ray, optical, IR, radio, theorists)
- Observation
  - Moonless, clear nights
  - ~ 700 hours/year (past record)

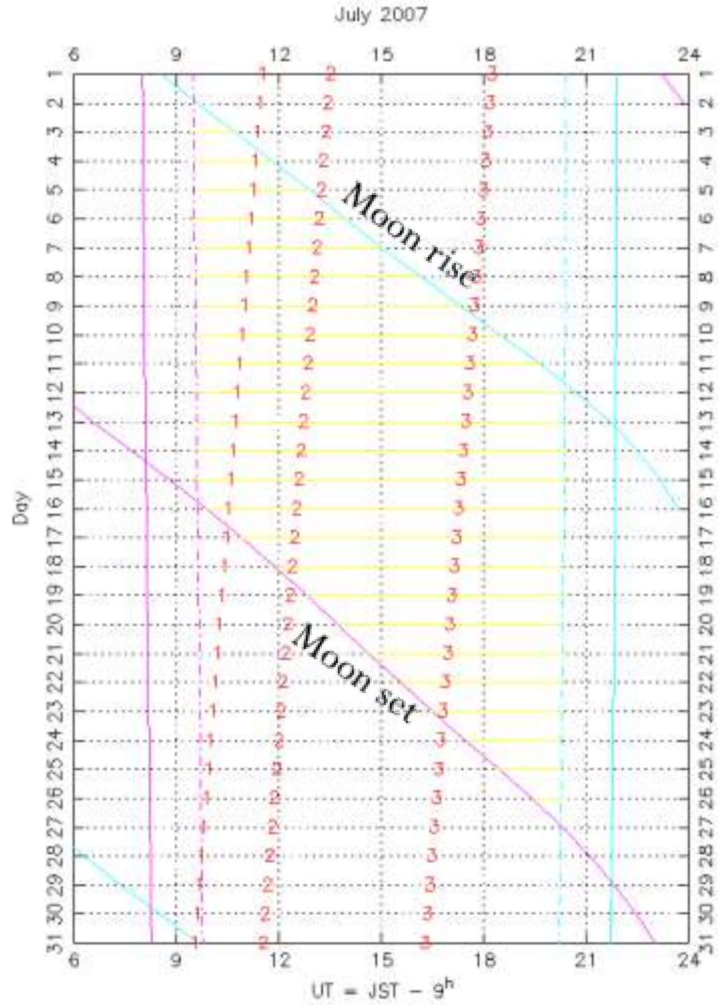


Illustrative example

Observation schedule

- **Observation Schedule for July 2007**
- Cyan lines: rising times of Sun and Moon
- Magenta lines: setting times of Sun and Moon
- Dot-dashed lines: astronomical twilight (sunrise - 1.5 hr and sunset + 1.5 hr)
- Yellow lines: observable periods
- Red numbers: culmination times of the selected objects

    1. PSR 1509-58
    2. RX J1713.7-3946
    3. PKS 2155-304



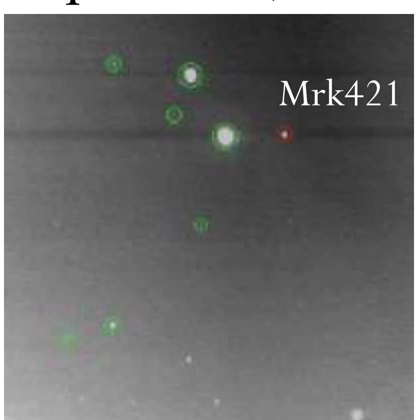
Data handling and analysis

- Data are stored on local HDD and copied to mobile HDD, then carried to Japan monthly (~70GB/month).
  - Online-analysis system is still underway…
  - Woomera site – only dial-up connection is available (64 kbps)
  - Recently 512 kbps ADSL line is connected to observer's flat (at last).
- Data are archived on ICRR storage (79TB HDD+225TB tape) and accessed by each institution.
- Analysis (and MC simulation) is carried out by mainly ICRR computer farm (700 CPUs).
- ICRR computer system will be upgraded in January 2008 (1 PB, 1000 CPUs).

Small optical monitor telescope

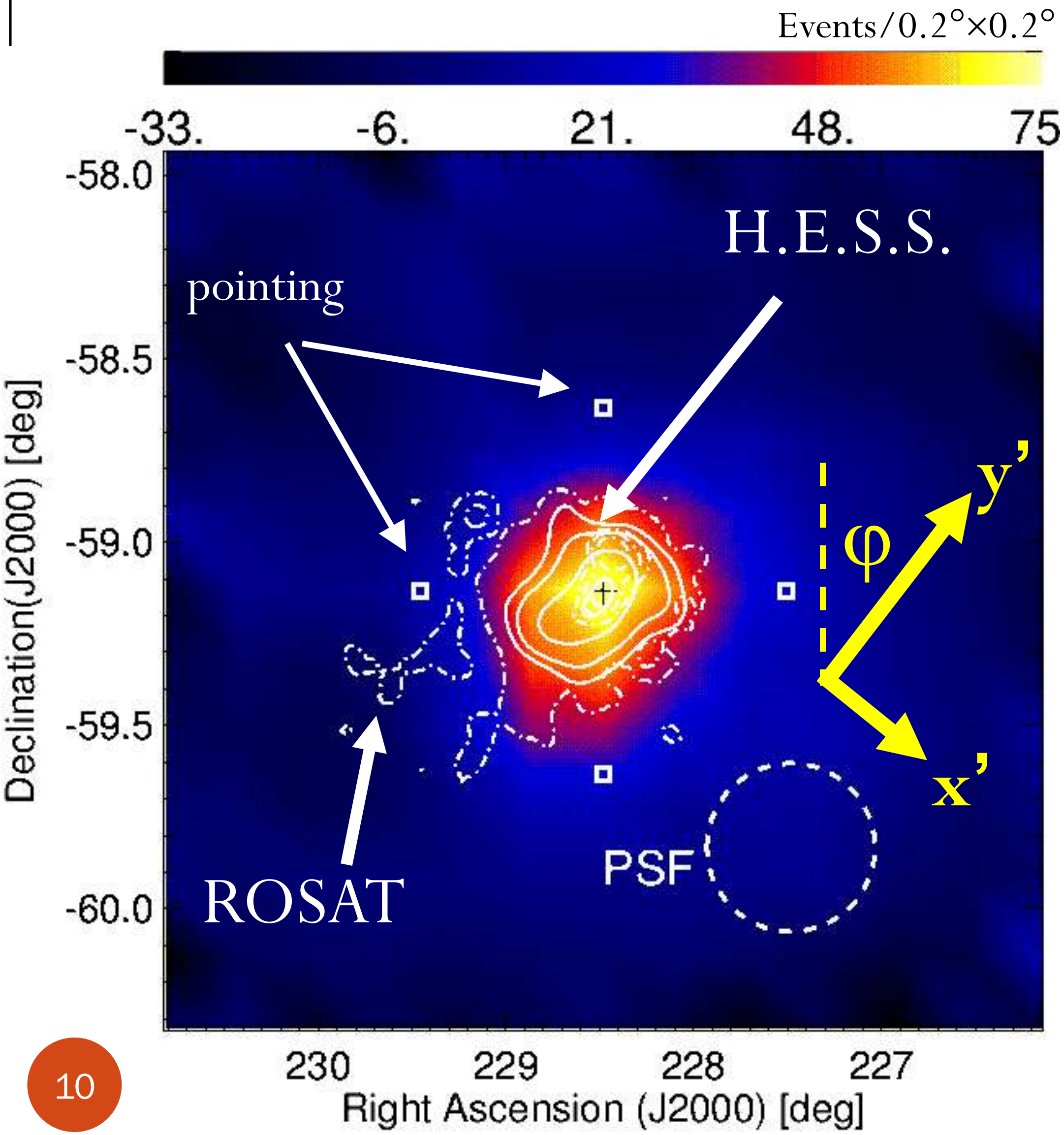
- Mead LX200-30 telescope
- CCD: Apogee Ap-7p
- Linux controlled
- Automated operation upon GCN alert (in preparation)

Opens automatically



T. Nakamori et al., Proc. ICRC 2007

Case study I – MSH15-52



MSH15-52 / RCW89
PSR 1509-58 ($\dot{E}$=2×10^{37}erg/s)
Pulsar wind nebula

CANGAROO-III: Extended emission (total excess 582±77)

2D Gaussian fit results (before smoothing)

rotation angle

φ = 29.8 ± 1.9deg

intrinsic standard deviations

$\sigma_{x'}$ = 0.07 ±0.07 deg

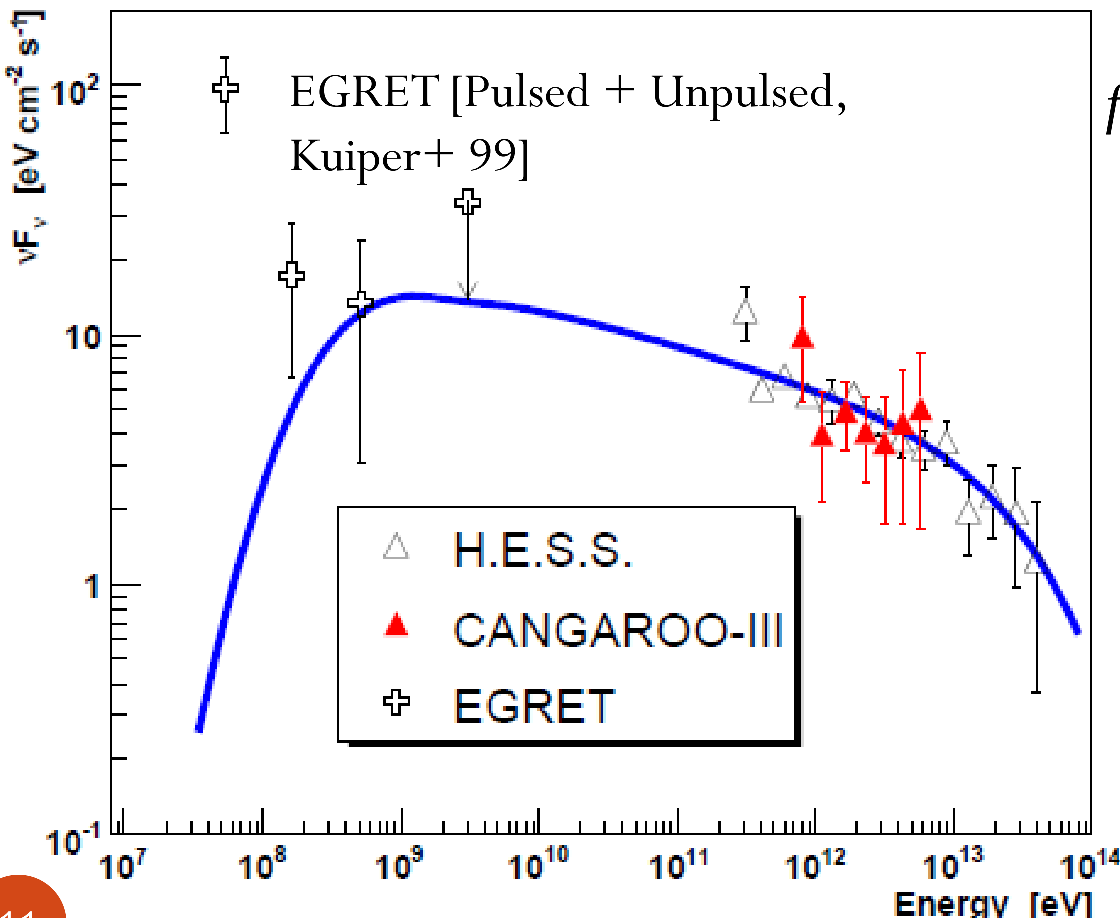
$\sigma_{y'}$ = 0.21 ±0.08 deg

consistent with H.E.S.S.

(preliminary)

T. Nakamori et al., Proc. ICRC 2007

MSH15-52 – hadronic model



Proton spectrum:

$$f_p(p) = f_0 \frac{V}{4\pi d^2} p^{-\alpha} \exp(-\frac{p}{p_{\max}})$$

Fit with TeV data:

$\alpha = 2.16 \pm 0.05$

$p_{\max} = 530 \pm 399\,\mathrm{TeV/c}$

$E_{tot} = 3.2\times10^{51}$ erg

@5.2kpc, 1.0 H/cc

c.f.

$$\int_0^{\tau} \dot{E}_{rot} dt \sim 10^{48} \mathrm{erg}$$

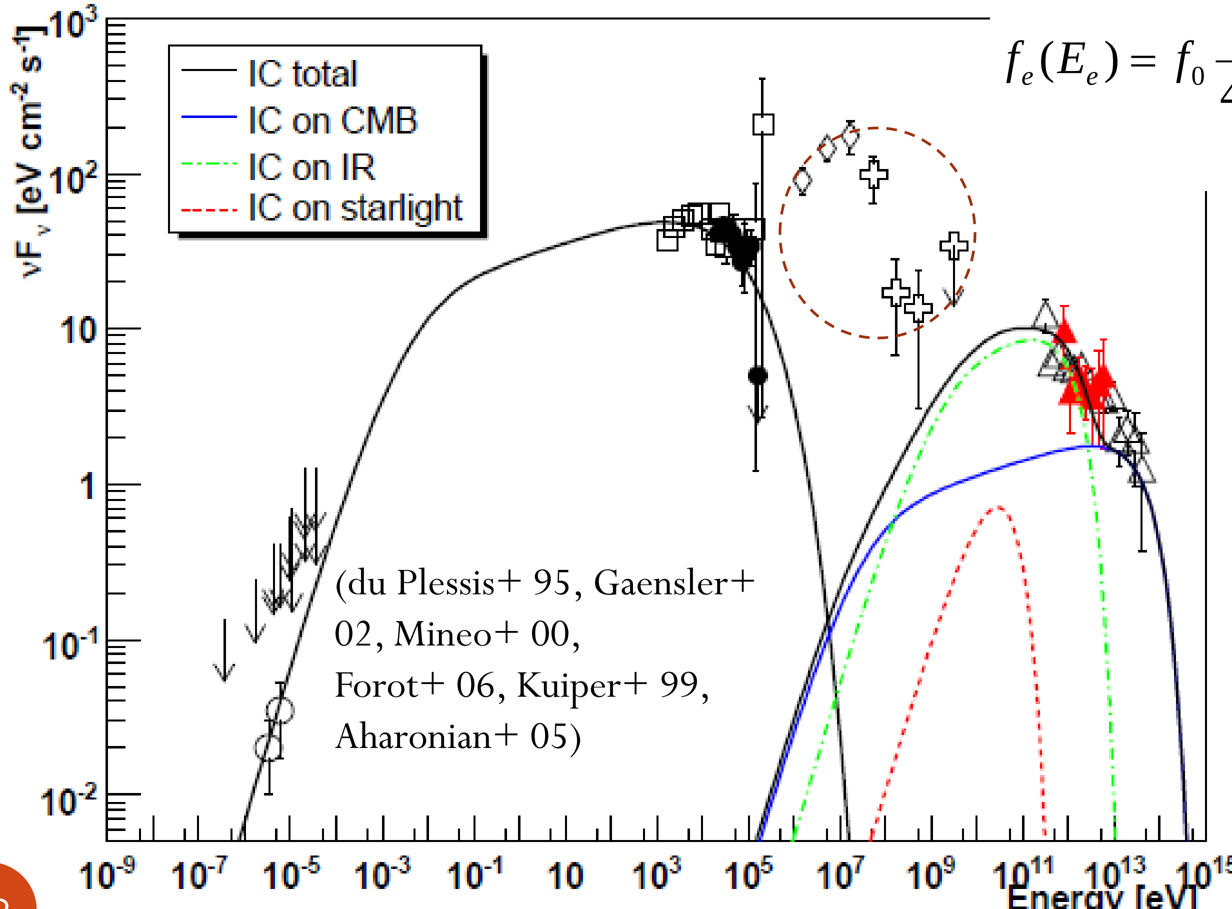
(preliminary)

MSH15-52 – leptonic model (1)

- BeppoSAX/MECS data for soft X-ray
- INTEGRAL/IBIS data for hard X-ray

Electron spectrum:

$$f_e(E_e) = f_0 \frac{V}{4\pi d^2} \frac{\left(\frac{E_e}{E_{br}}\right)^{-\gamma_1}}{1+\left(\frac{E_e}{E_{br}}\right)^{\gamma_2-\gamma_1}} \exp\left(-\frac{E_e}{E_{max}}\right)$$



- *Broken power law*
- "Eye-fit"
- B=17μG (Aharonian+ '05)
- Starlight 1.4 eV cm^{-3}
- IR necessary (parameter)
- E_{tot}=7×10^{48} erg
- E_{br} does not match the characteristic age (if τ = 1700yr, sync. break @ 0.2keV)

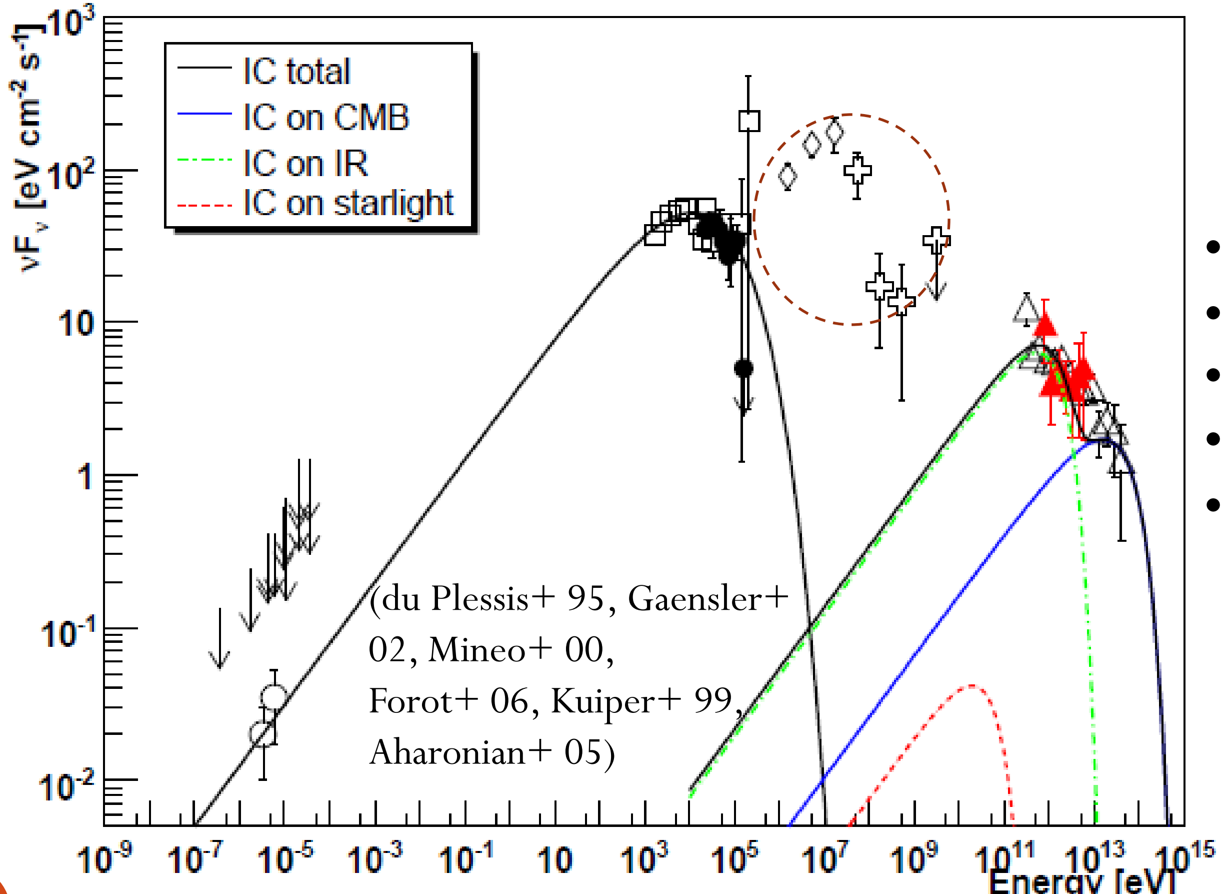
(preliminary)

T. Nakamori et al., Proc. ICRC 2007

MSH15-52 – leptonic model (2)

- BeppoSAX/MECS data for soft X-ray
- INTEGRAL/IBIS data for hard X-ray

Electron spectrum:
Single power law

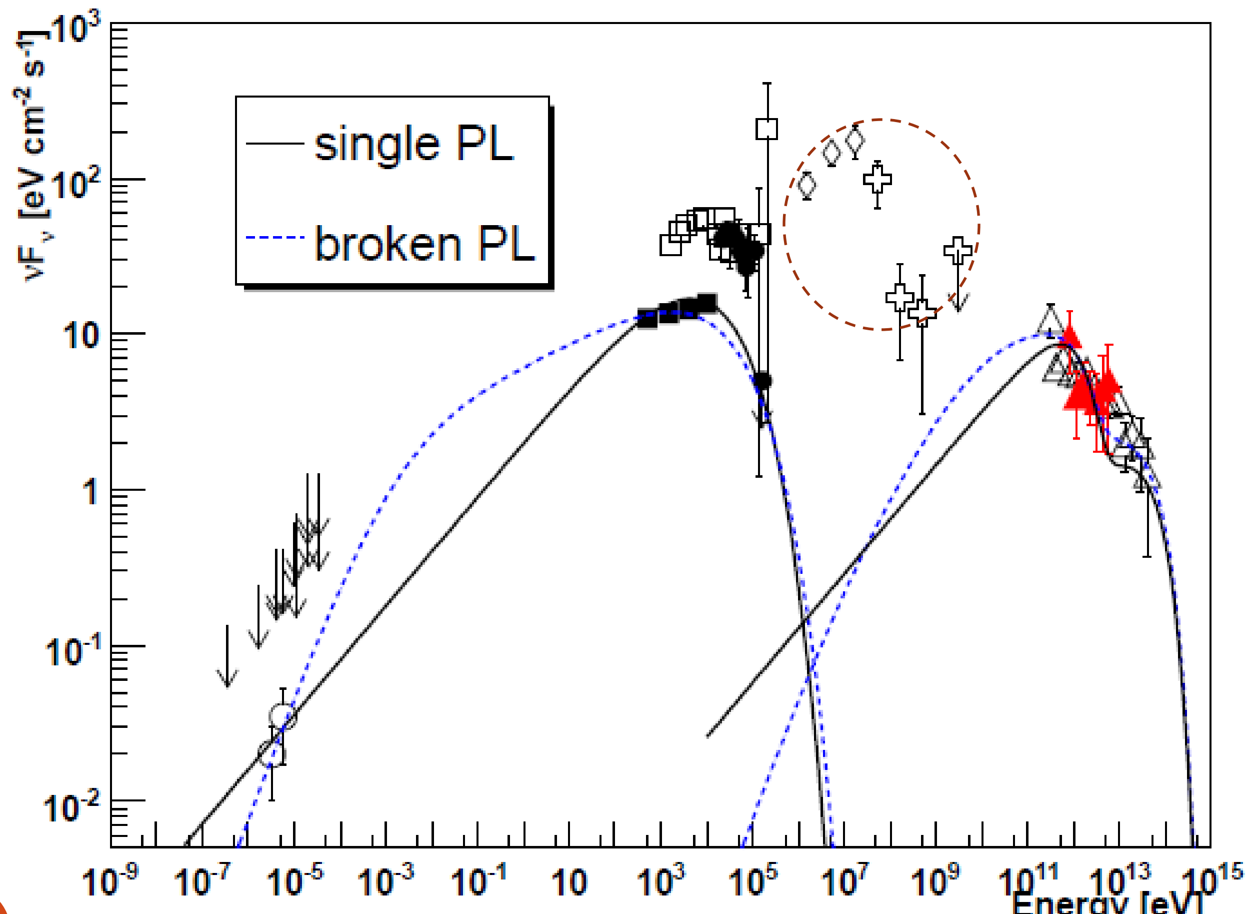


- "Eye-fit"
- B=12μG
- Starlight 1.4 eV cm^{-3}
- IR necessary (parameter)
- E_{tot}=1.4×10^{48} erg

(preliminary)

MSH15-52 – leptonic model (3)

- Chandra ACIS (excluding PSR1509-58 region)



- "Eye-fit"
- B=8μG
- Starlight 1.4 eV cm^{-3}
- IR necessary (parameter)

- *Broken power law:*
  - E_{tot}=6×10^{48} erg
- *Single power law:*
  - E_{tot}=1.3×10^{48} erg

(preliminary)

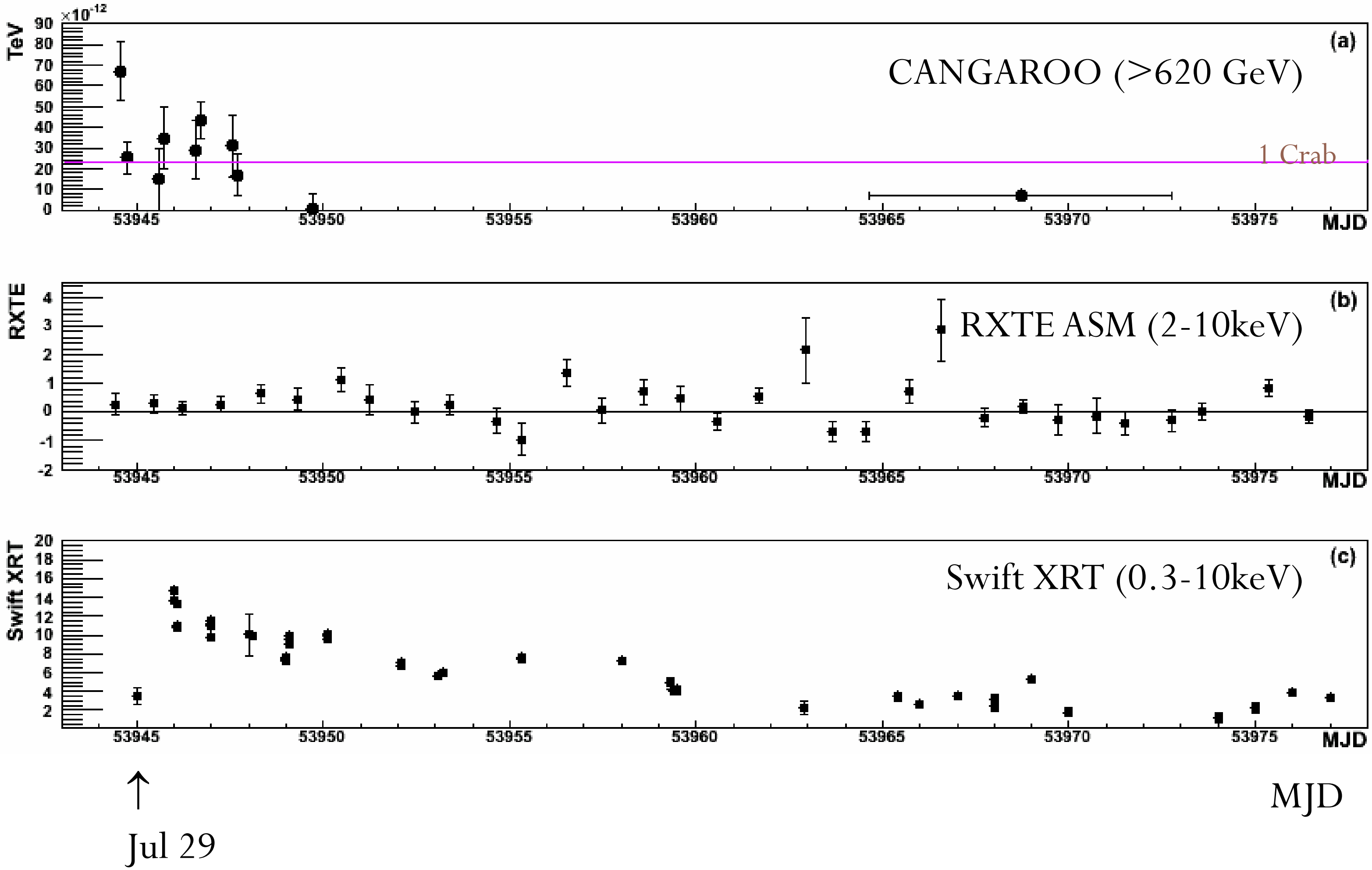
Case study II – PKS 2155-304

- Nearby HBL in the southern sky (z=0.116)
- TeV detection (Durham 1999; H.E.S.S. 2005)
- Large flare in 2006 (H.E.S.S., ATEL#867/ arXiv:0706.0797)
- CANGAROO-III ToO observations

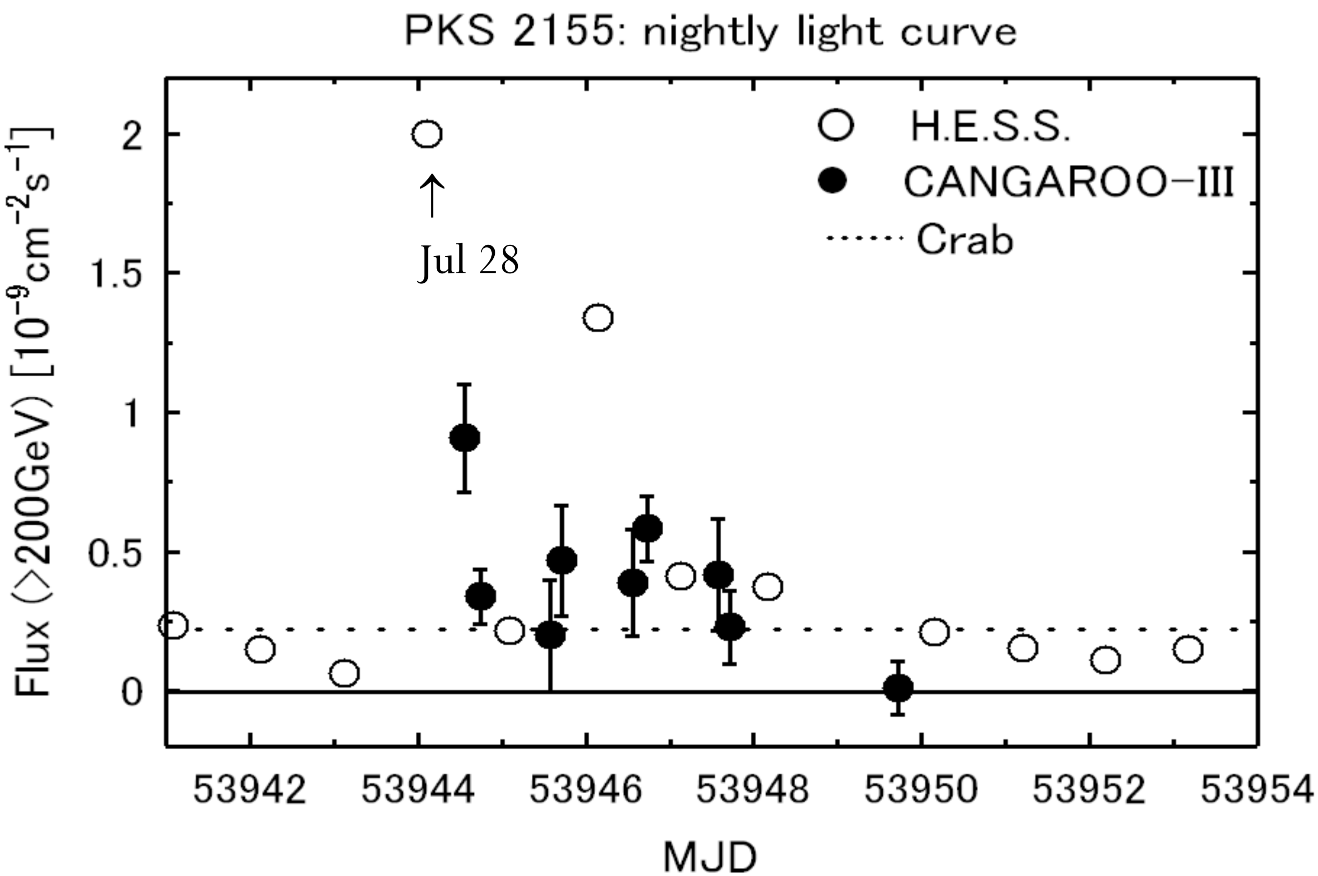
	t_{obs}[hrs]	z [deg]	r_{tr}[Hz]	r_{sh}[Hz]	t_{liv}[hrs]	N [events]	s [σ]
July 28	3.9	20.4	12.1	8.0	2.5	54±16	3.4
July 29	2.0	12.1	6.2	4.1	0.9	28±12	2.4
July 30	4.0	22.2	12.5	8.1	2.3	86±17	5.0
July 31	3.9	21.7	11.6	7.6	2.4	35±21	1.7
Aug 2	3.9	21.5	11.9	7.7	2.3	1.6±15	0.11
Sub total	17.6	20.4	11.4	7.3	10.5	189±33	5.7
Aug. 17-25	19.1	20.9	10.9	7.4	11.6	75±29	2.6

K. Nishijima et al., Proc. ICRC 2007

PKS 2155-304 – TeV vs X-ray



PKS 2155-304: nightly light curve



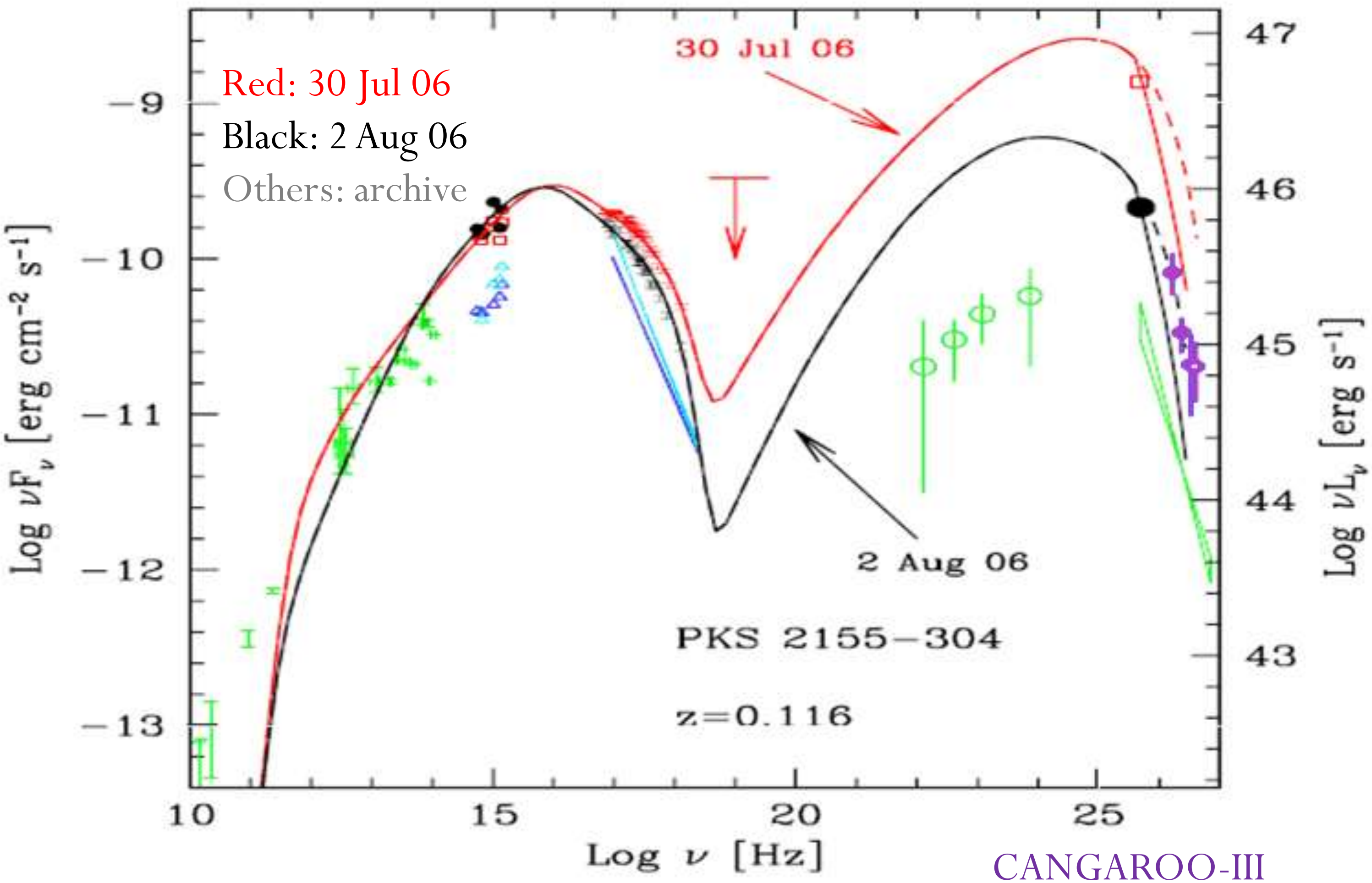
φ(CANGAROO) - φ(H.E.S.S.) = 120° = 8hr

Note 1: CANGAROO points were scaled from those above 620 GeV by $E^{-3.3}$ spectrum.

Note 2: X-axis of HESS data are NOT official [from M. Raue, INTEGRAL Workshop, Rome, Oct. 2006]

Foschini et al., arXiv:0701868 [astro-ph]

PKS 2155-304 SED



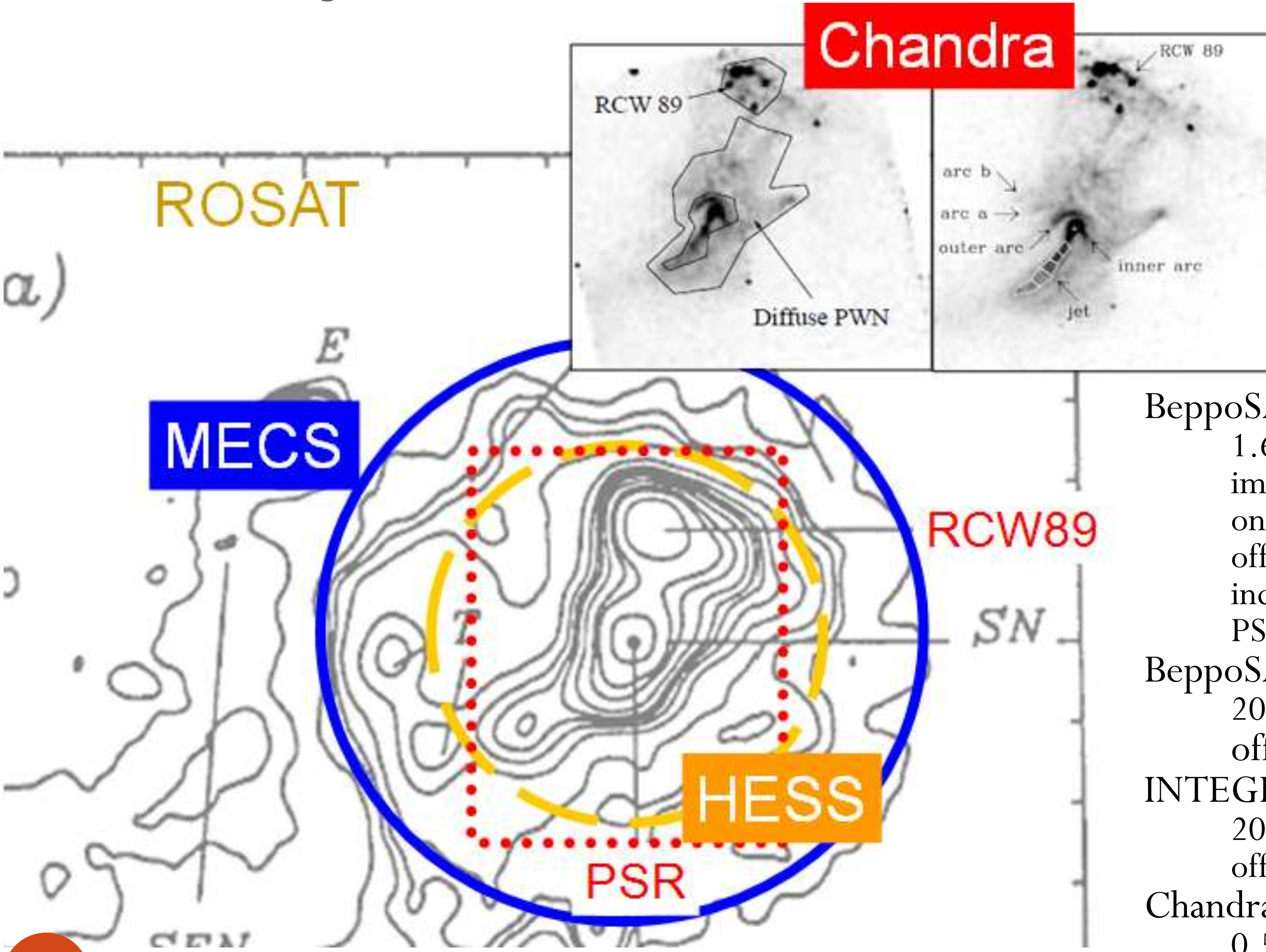
CANGAROO-III
Jul/Aug 2006

Curves: SSC model (Ghisellini et al. 2002)

Summary

- CANGAROO-III covers a part of the southern sky that does not overlap with H.E.S.S. at the same time in the TeV region.
- Needless to say, multiwavelength coverage of objects is essential in exploring the emission mechanism of non-thermal radiation.
  - Discrimination of emission models is only possible with complete coverage on spectrum.
  - Campaign observations for variable sources are important.
- Still the coverage in the TeV sky is far from complete – both in space domain and time domain – since FOV and operation time of Cherenkov telescopes is limited ($\sim 10^{-2}$sr ; dark, clear nights).
  - Observatories should be spread over the world!

X-ray observations of MSH15-52



BeppoSAX / MECS
- 1.6 -10 keV
- imaging (17' circle centered on the PSR1509)
- off-pulse
- including RCW89 and PSR1509

BeppoSAX / PDS
- 20 – 200keV
- off-pulse

INTEGRAL / IBIS
- 20 – 200keV
- off-pulse

Chandra / ASIS
- 0.5-10 keV
- fine imaging (excluding PSR1509-58)