Observation of Crab Nebula by Nuclear Compton Telescope (NCT)

32nd ICRC, Aug.15, 2011 at Beijing, China

Ming-Huey A. Huang for NCT Collaboration

National United University & LeCosPA, NTU

NCT Collaboration: Berkeley, NTHU, NCU, NSPO, NUU, LBNL, CESR
The NCT’09 Team

Goals of 2009 balloon flight:

• Qualify for LDBF from Australia
• Image Crab, if possible verify its polarization

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NCT Science Goals

- Positron astrophysics (0.511 MeV)
- SNe gamma-ray lines
  - $^{26}\text{Al}$ (1.809 MeV)
  - $^{60}\text{Fe}$ (1.173, 1.333 MeV)
  - $^{44}\text{Ti}$ (1.157 MeV)
- Compact objects
  - AGN
  - Black holes
  - Neutron stars
  - GRBs
- Gamma-ray polarization
NCT Instrument

Electronics Bay

Instrument cradle

- Dewar
- Cryostat
- Preamps
- BGO PMTs
- Signal cables
- BGO shields
- Ge detectors

10x Cross Strip
3-D GeDs
- 37x37 strips
- 81 cm$^3$ volume
Record breaking flight

- May 17~19, 2009, launch from Fort Sumner, NM, USA.
  - 38 hours at float altitude

- Qualify for long duration flight!
- Detect the first image of Crab by the new generation Compton telescopes!
Collection Time Difference (CTD)

CTD histogram of a single pixel (AC 9, DC 2), showing events that are energy-selected to be photo-absorptions of 59.5 keV photons.

Charge transport simulation: to convert CTD to depth (Z).

Calibration

Two $^{137}$Cs sources that are $\sim 10^\circ$ away

Field of View Calibration

FOV is $-20^\circ \sim +40^\circ$ in backward-forward direction ($\sim$ zenith angle $\theta$) and $\pm 40^\circ$ in sideway ($\sim$ azimuth angle $\phi$).

Calibration

Field of view test: radioactive source at 20° from zenith.

### Targets for May 2009 flight

<table>
<thead>
<tr>
<th>Source</th>
<th>Exposure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crab</td>
<td>11 hr</td>
</tr>
<tr>
<td>3C273, 3C279, NGC4151</td>
<td>5.6 hr</td>
</tr>
<tr>
<td>Cas A</td>
<td>0.9 hr</td>
</tr>
<tr>
<td>Cyg X1</td>
<td>0.9 hr</td>
</tr>
</tbody>
</table>

**FOV display**

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NCT’09 flight data analysis

Raw spectra during the flight while observing the Crab nebula on May 17, 2009.

- 2-7 site events
- 0.511 MeV e+ line
- 3-7 site events
- Background from Al in solar shield

Jeng-Lun Chiu, PhD thesis, NTHU, 2010

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Image of Crab

- The Crab was detected at a significance of at least $4\sigma$ by NCT during the 2009 balloon flight.
- First image of crab by the New Generation Compton telescopes!

Different approach

- Veto the most noisy detectors D0, D1, D8, and D9.

Jau-Shiang Liang, PhD thesis, NTHU, 2010

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Polarization

• Scattered electron from 100% Polarized $\gamma$ of 0.5 MeV.

• (Zenith angle $\theta$ are plotted in radial distance in this polar plot. The center $\theta=0$ is the forward direction of photon. The azimuth angle is electric field direction. Color code is $d\sigma/d\Omega$)

• Klein Nishina differential cross-section for a polarized photon beam

$$\frac{d\sigma}{d\Omega} = \frac{r_0}{2} \left( \frac{E'_\gamma}{E_\gamma} \right)^2 \left( \frac{E'_\gamma}{E_\gamma} + \frac{E_\gamma}{E'_\gamma} - 2\sin^2 \theta \cos^2 \varphi \right)$$

Jau-Shiang Liang, PhD thesis, NTHU, 2010
Polarization Measurement

- Preliminary result:
  \[ \text{Polarization} = 41.2 \pm 3.6 \% \]

- Measured polarization angle

- Simulated angle from unpolarized beam


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NCT’09 Flight Spectrum

Preliminary!

Jeng-Lun Chiu, PhD thesis, NTHU, 2010
Summary

• NCT performed two balloon flights in 2005 and 2009 and qualify for future long duration flight.

• NCT’09 flight observed image of the Crab nebula and possible polarization.
  – Data analysis are still on-going.

• Due to launch failure in 2010, NCT will be rebuilt and may fly again in 2012-2013.
Some publications


NCT 2010 flight at Alice Spring, Australia

Launch attempt in Apr. 29, 2010. Payload fail to launch, crash to ground, NCT gondola destroyed.
Launch failure

Launch attempt in Apr. 29, 2010 at Alice Spring, Northern Territory, Australia,

Payload fail to launch, crash to ground, NCT gondola destroyed.