Ashra Potentials

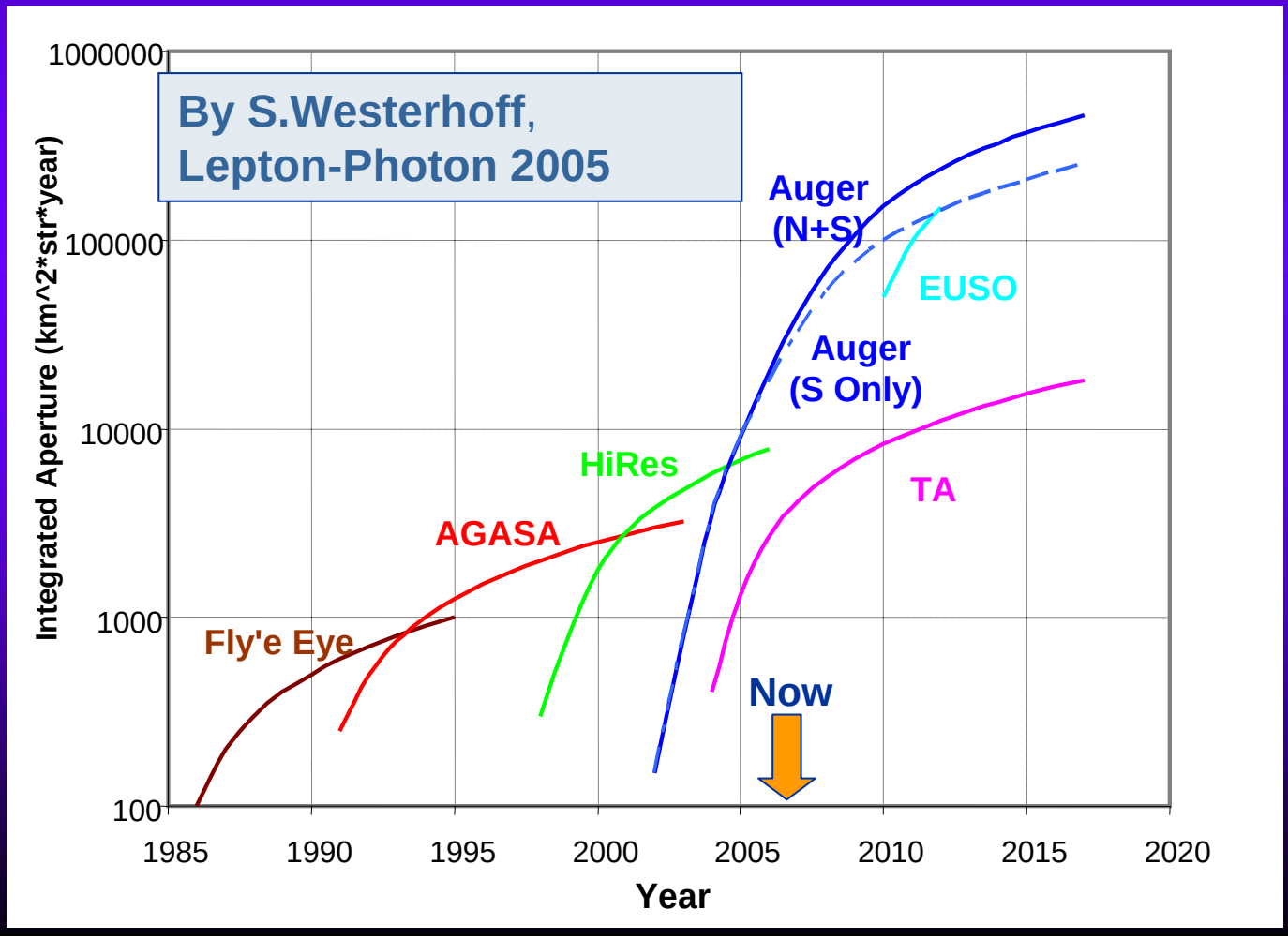
optical-CR connection

VHEPA-6

Makoto Sasaki
ICRR, Univ.Tokyo
for Ashra Collaboration

Cosmic Ray Renaissance

- **Discovery of Ultra High Energy Cosmic Ray?**
  - AGASA discovery vs HiRes denial => Auger resolution



Overview:
Toward More Astronomical Approach

- Ashra: 1.2 arcmin/pix ✕ 80% all-sky
  - Continuous exposure for stars
  - Triggered exposure for air-showers

- Ojectives: the HE Universe
  - Probing transients
    - Gamma Ray Bursts (GRBs)
    - Core-collapse Supernovae (CC-SNs)
  - Evidence of Cosmic Accelerators with
    - VHE neutrinos (Test for charged pions)
    - VHE gamma rays (Test for neutral pions)

Talk Relay

- This talk
- Tsutomu Chonan (ICRR-UT): 10min.
  Main Features of Ashra Image Pipeline
- John Hamilton (UHH): 15min.
  Construction Status of Mauna Loa Site

Optical Air-shower Detector

Progress of Resolution×FOV

Fly's Eye (1981-1993)

4deg/pix × All-sky

PMT

HiRes (1994-2006)

1deg/pix × 28deg

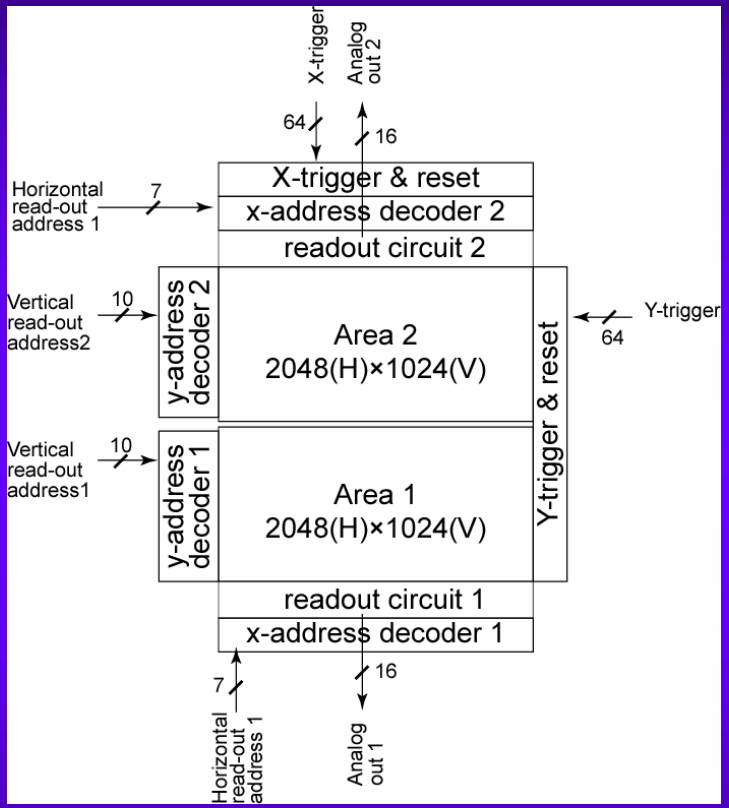
PMT

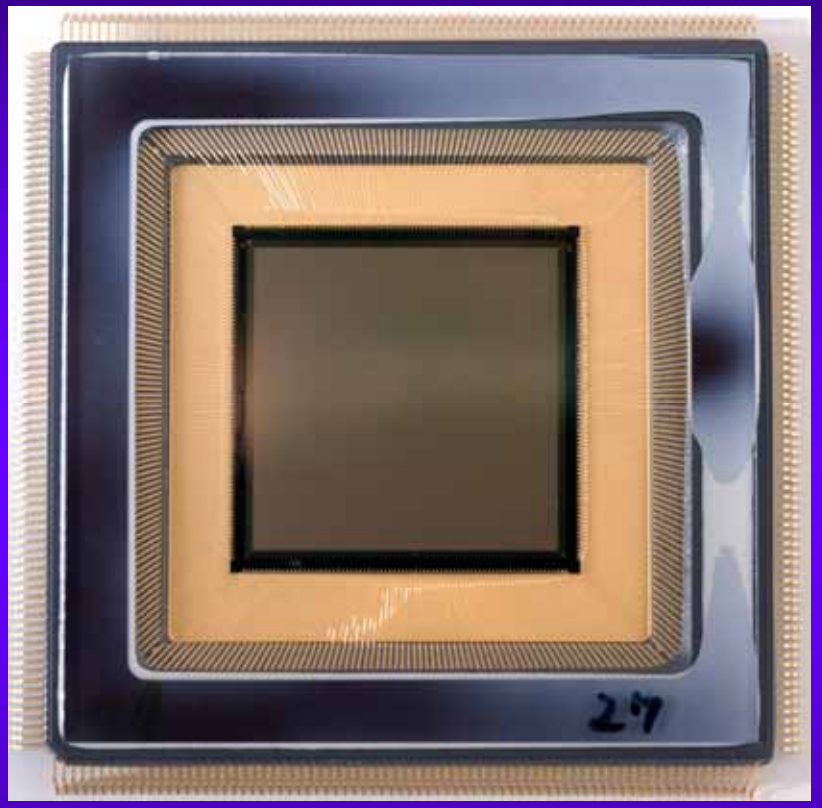
Ashra

1.2min/pix×All-sky

Image Tube＋CMOS

Ashra CMOS Fine Sensor





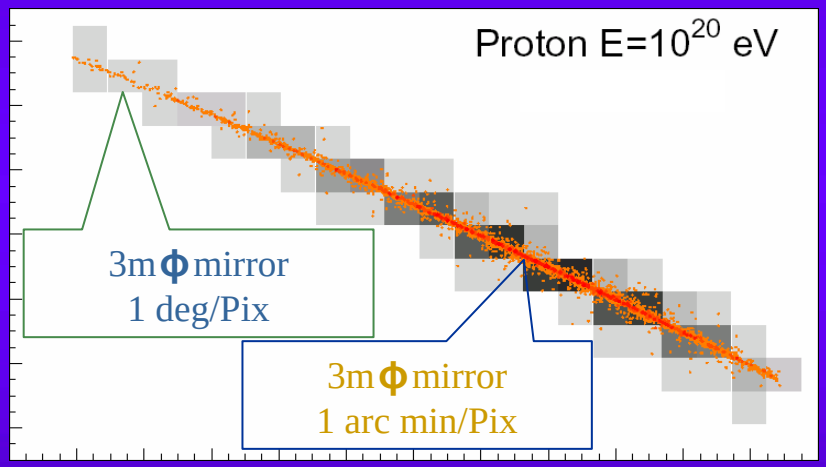
- Readout 2 directions independently
  - ⇒ Low parasitic capacitance
  - ⇒ Speed-up of readout
- Areas are subdivided => 16✕16 cells

- 2-poly 3-metal 0.35μm Standard CMOS process
- 2048✕2048 pixels (4.2Mpix)
- Chip size: 19 mm□

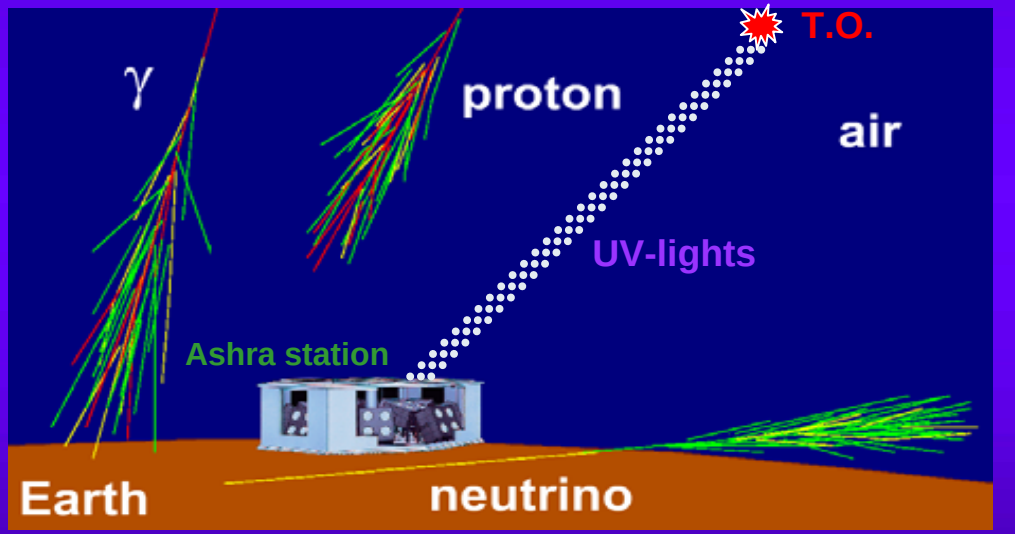
Ashra Station

Advantage of High Resolution & Wide FOV

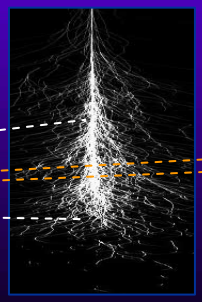
Main Station = “compound eye” with a few arcmin resolution
covers 5 sr (80% of full sky) with 12 “eye segments”



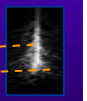
Precise Direction => Mag. Field Charges



Require
5pix=5deg track length



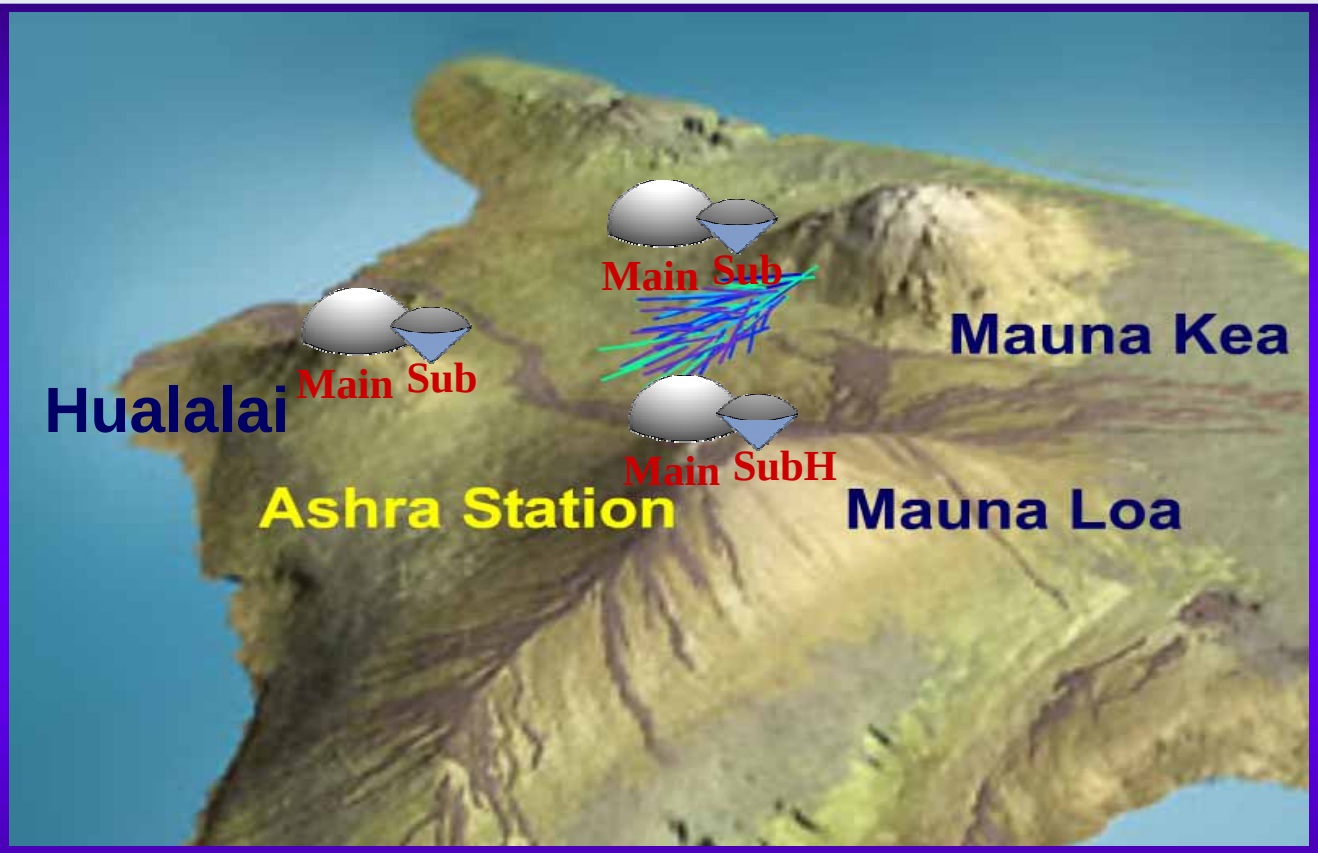
Require
5pix=6 min track length



=> Large effective aperture

Full-configuration of Ashra

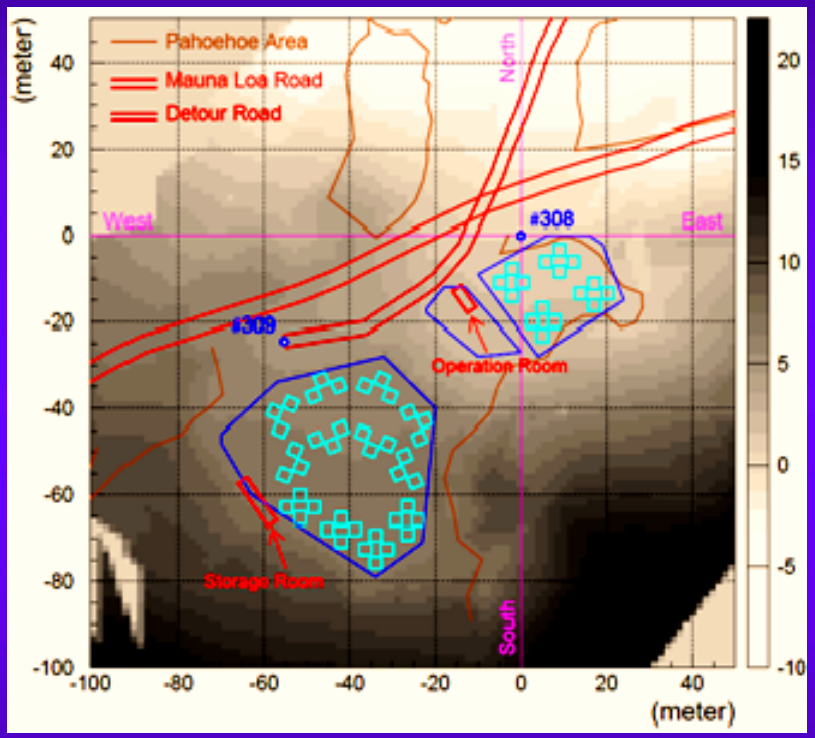
Phase-2 Layout



Hawaii Island

- 3 sets of (Main+Sub) stations will be installed on the 30km triangular points
- VHE **γ** , **ν** ,EHECR: statistically competitive in the world
- Optical flash: local BGs can be eliminated with parallax method

Phase-1 Layout



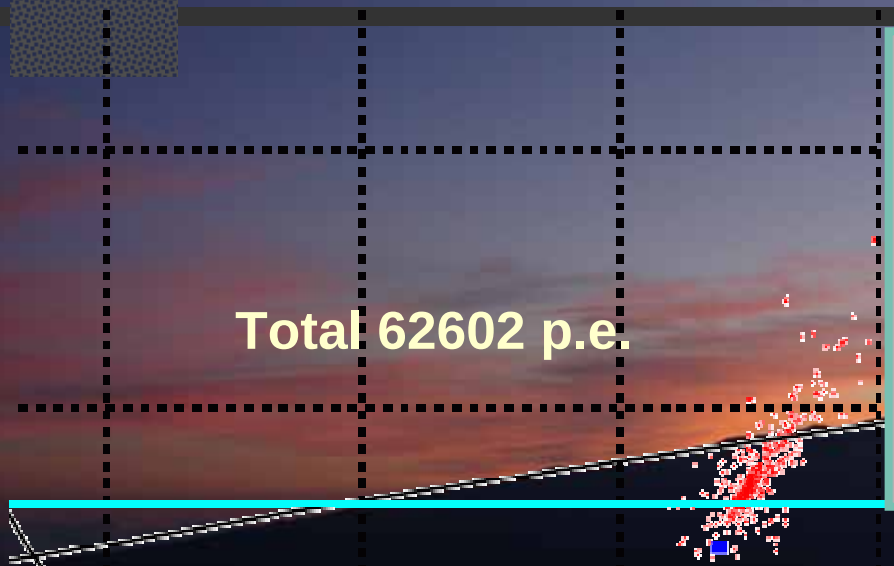
- Main station (12 pc) under construction on Mauna Loa at 3300m asl.
- 2 subs. = high ele.(4pc@80m) + low ele. (8pc@32km)
- Demonstration of hybrid stereo obs. for both Cerenkov and fluorescence

Light Collector with Lower Elevation FOV

Covering 70% of the View of Mauna Kea

Expected Tau Neutrino Signal

Simulated Cherenkov Air-shower Image @ Ee=10^{16}eV for tau decay into electron



Statistics：Natarajan2005, Dermer2006

- Diffuse AGNν Cherenkov: 0.2/yr
- GRB behind Mauna Kea： 0.4/yr
- GRB(Z<0.1) with fluo. : 1~2/yr
- Detectable taus with fluo.: ~10/GRB

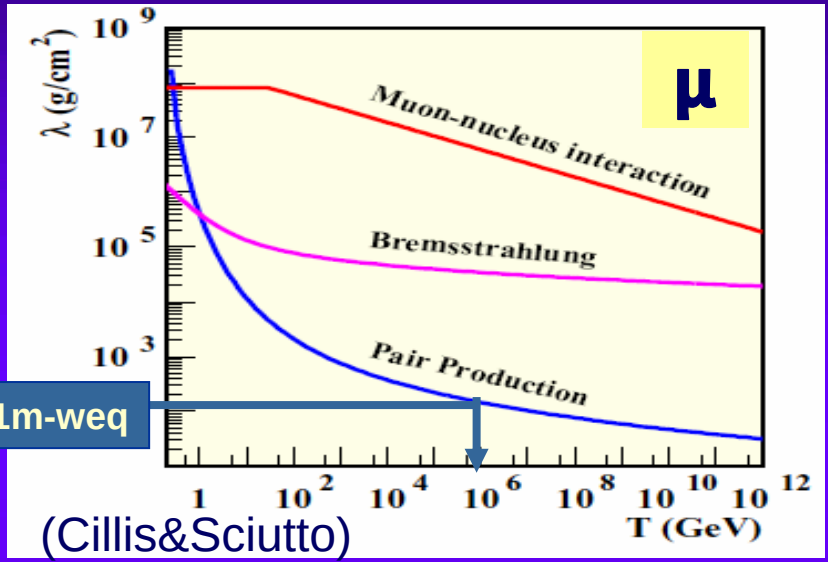
Mauna Kea view

from Mauna Loa Site

Precisely Reconstructed Generation Point
=> Clear Evidence of VHE Neutrino with No BG

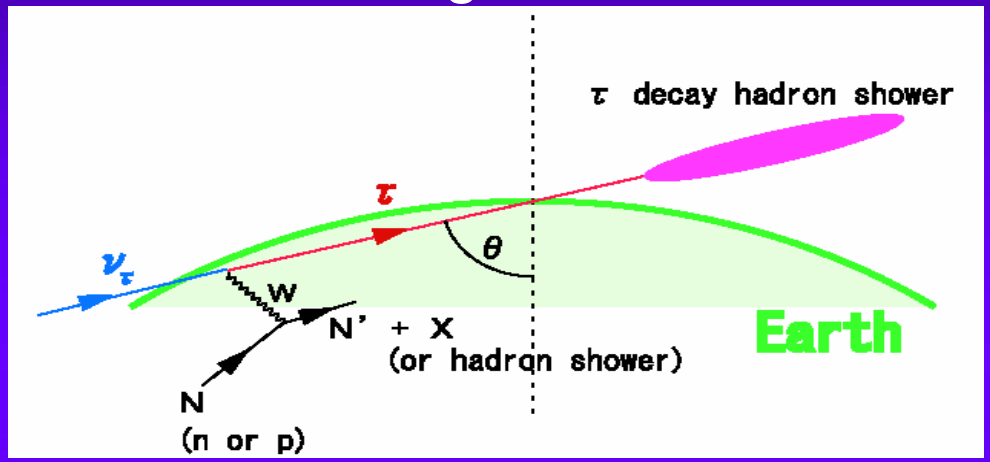
Tau Neutrino Detection

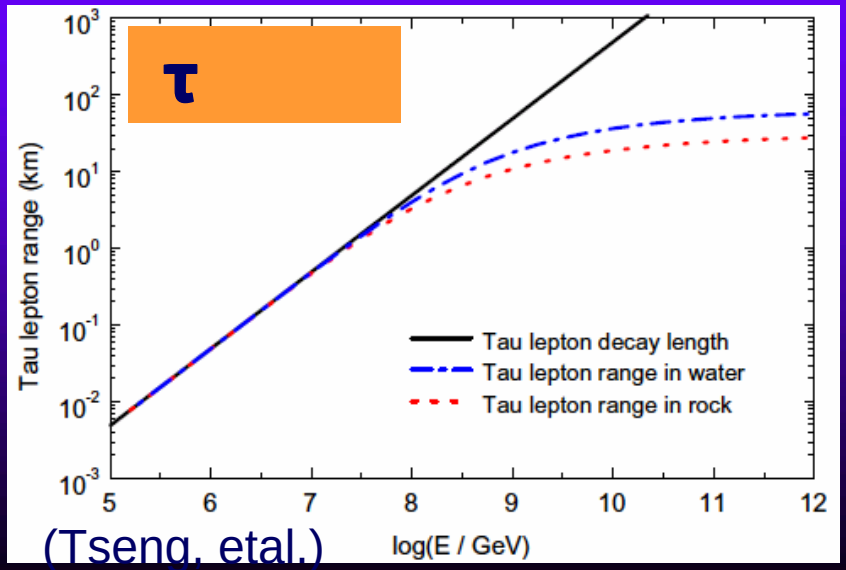
with Earth and Mountain



(Cillis&Sciutto)

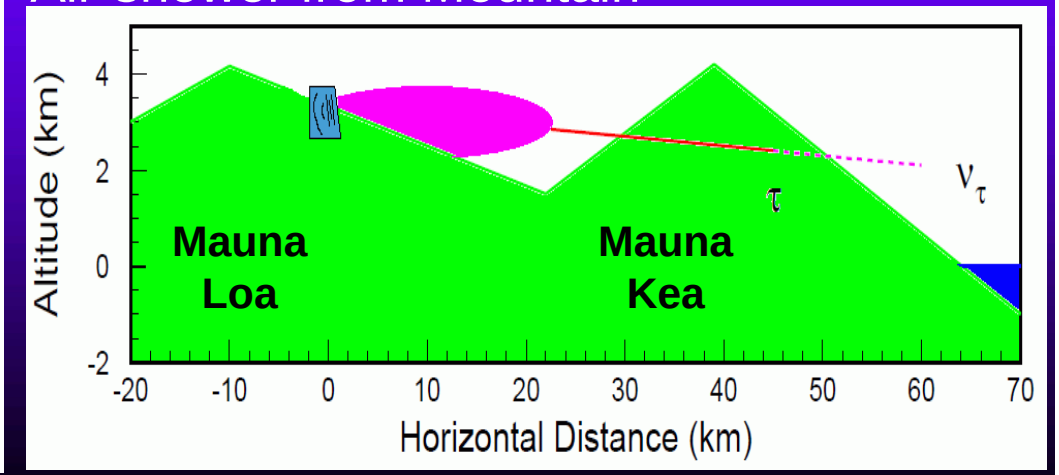
Earth Skimming Tau Neutrino





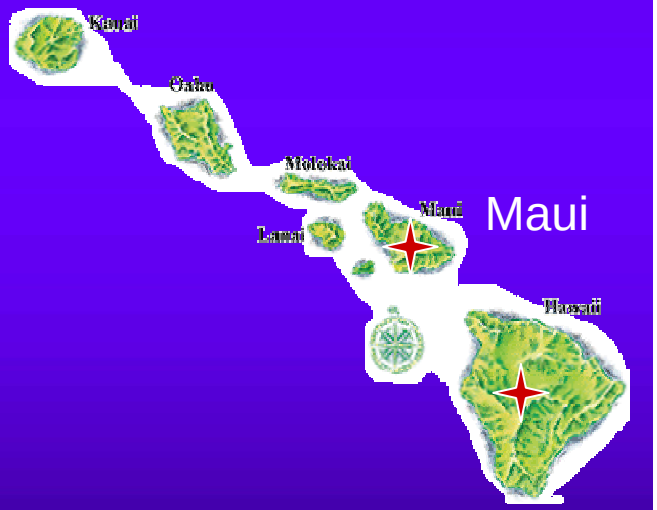
(Tseng, etal.)

Air-shower from Mountain



Brief History

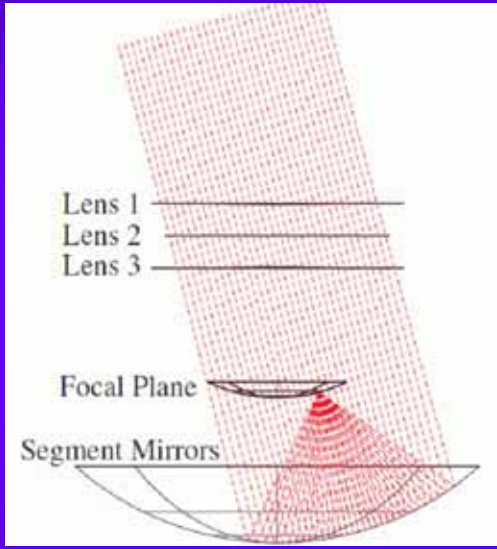
- FY2002 Started the Collaboration and R&D
- FY2003~ Main part of Ashra-1 was funded
  $5M for 3 years
  - FY2003 Developments
  - FY2004 Test Observation @ Haleakala
  - FY2005 Construction @ Mauna Loa
    (Land usage permitted in July)
- FY2006 Under construction
  Failed in grants for maintenance money
  Delayed Progress

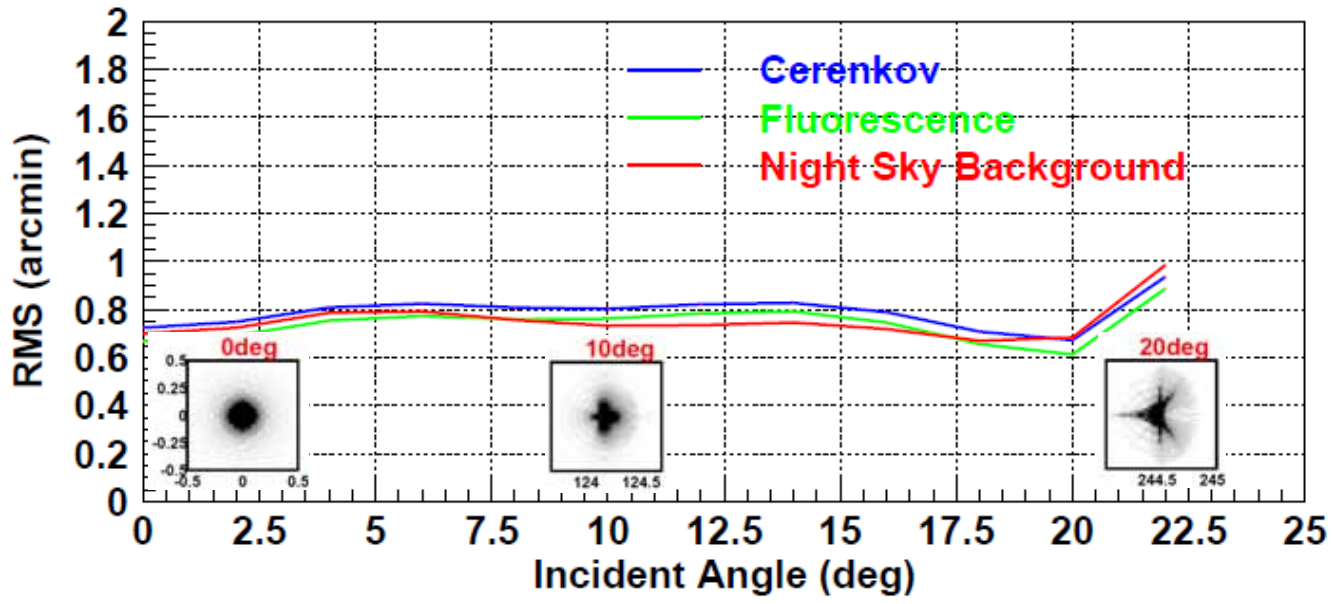


Maui

Hawaii

Modified Baker-Nunn Optics

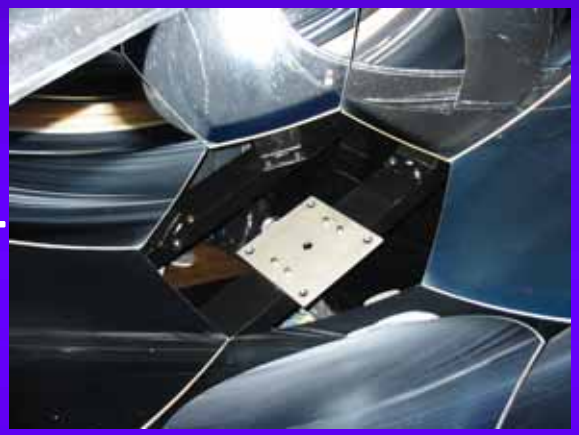




- 0.8 arcmin. RMS (theoretical) resolution is stable over all FOV
- Dependence of spectrum due to chromatic aberration is negligible
- Point spread σ=0.2mm on the focal sphere corresponds to 1 arcmin.

Resolution after all adjustments

+



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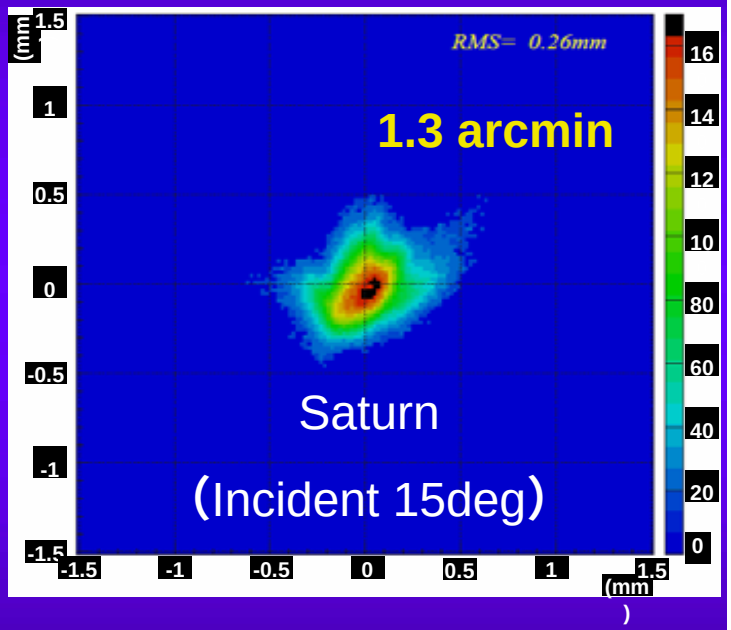


Assembly and install

- Shelter
- Mount
- Correcting lens

Assembly and install

- Mirror
- Stewart platform

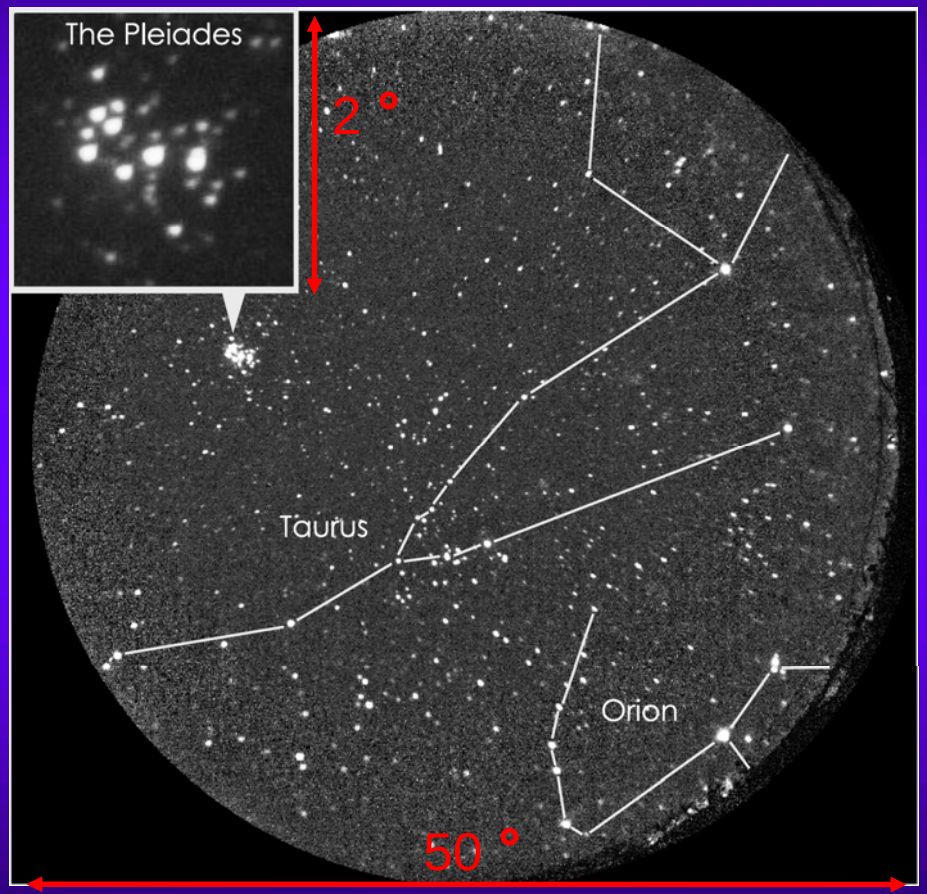
Adjusting all

- CCD image on focal sphere
- Total resolution:
  1.3 arcmin
- Satisfies our requirement

2/3-scale Prototype on Haleakala

Constellations Taurus and Orion & close-up view of the Preades

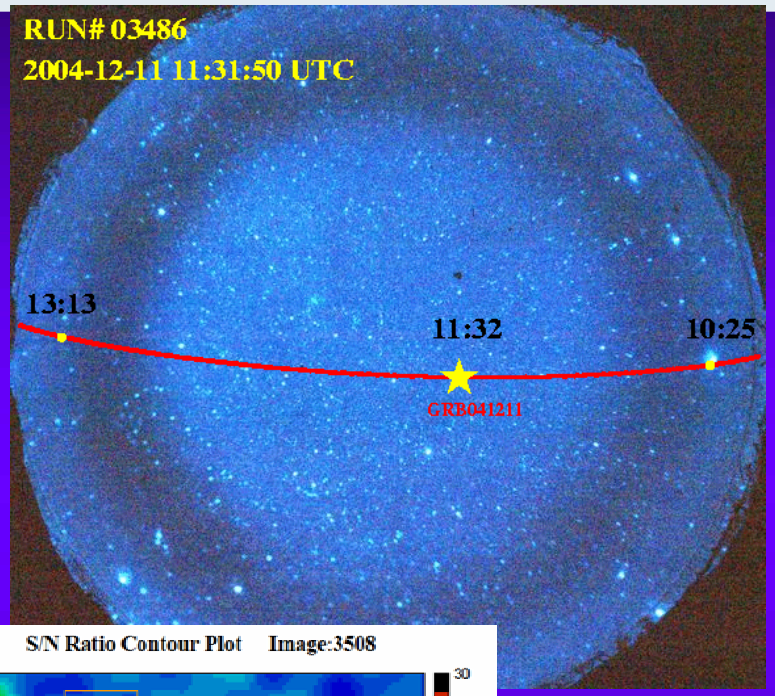
Prototype with 4 seg. mirrors and 16''-IT

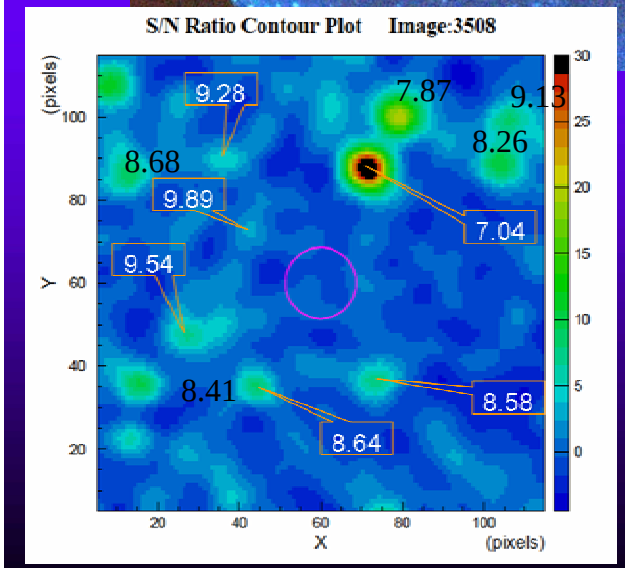


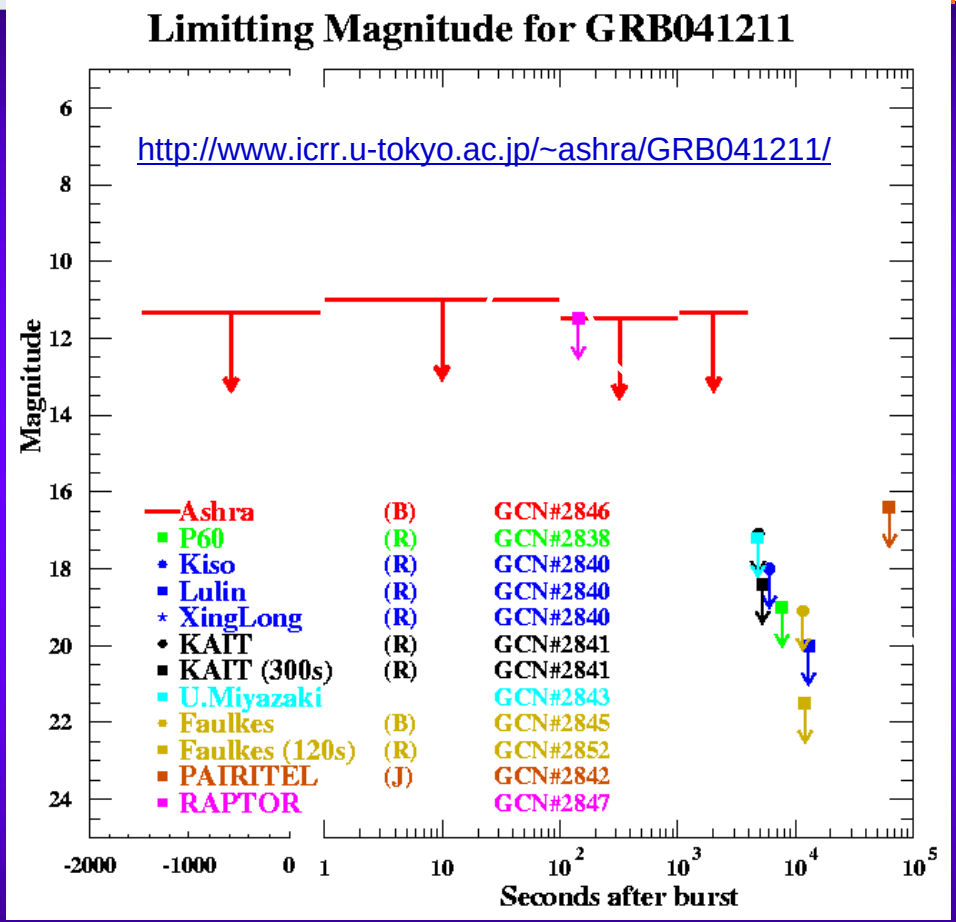
Concept of the optics = "Wide (50deg) & High resolution (arcmin)"

Demonstrated well

GRB041211 Cross Observation

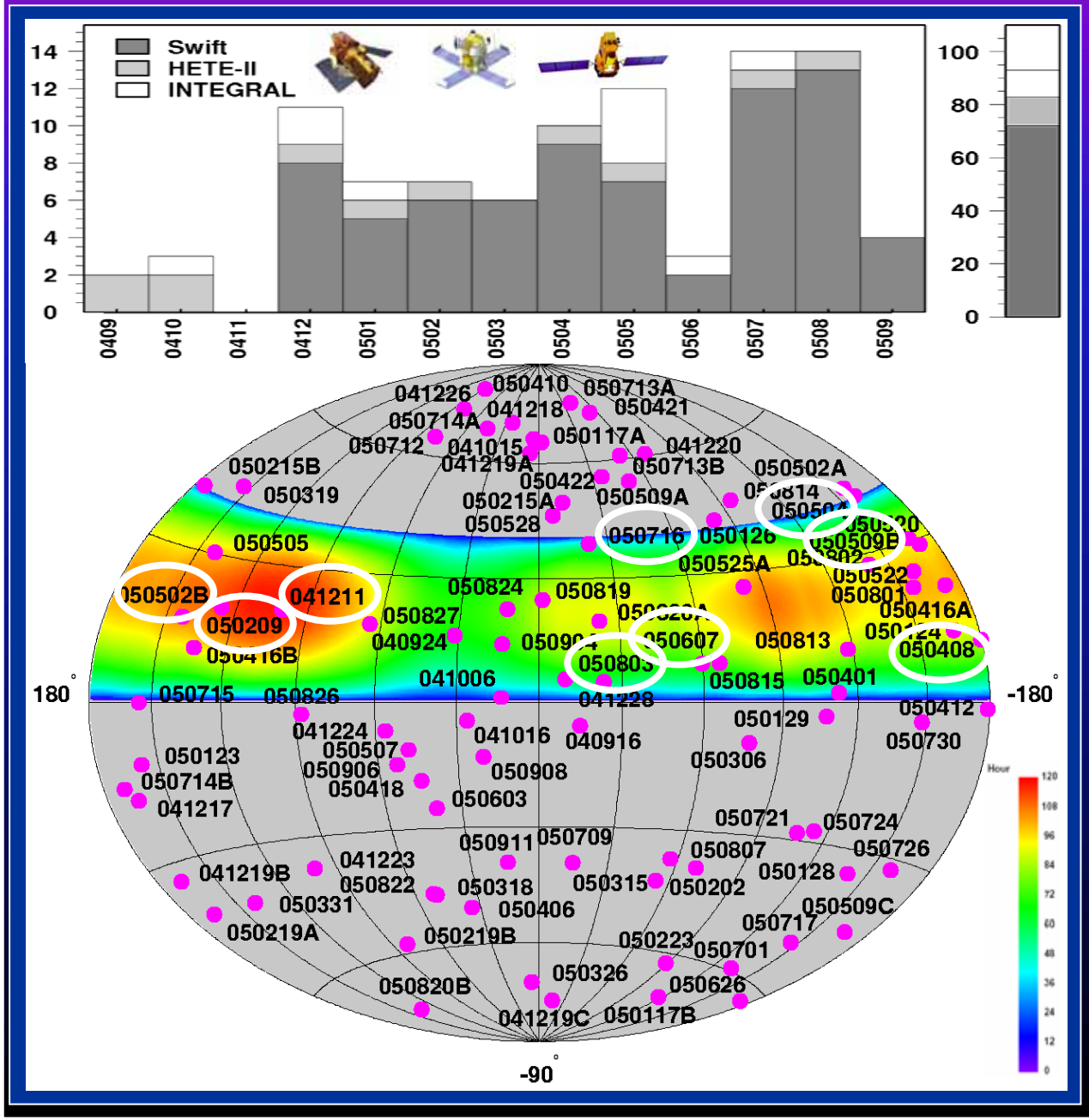






- HETE-II detected the GRB near the center of FOV
- Received the alert & searched for optical couterpart.
- Set limit on the magnitude of new optical counterpart.
- Unique observation starting before the GRB.

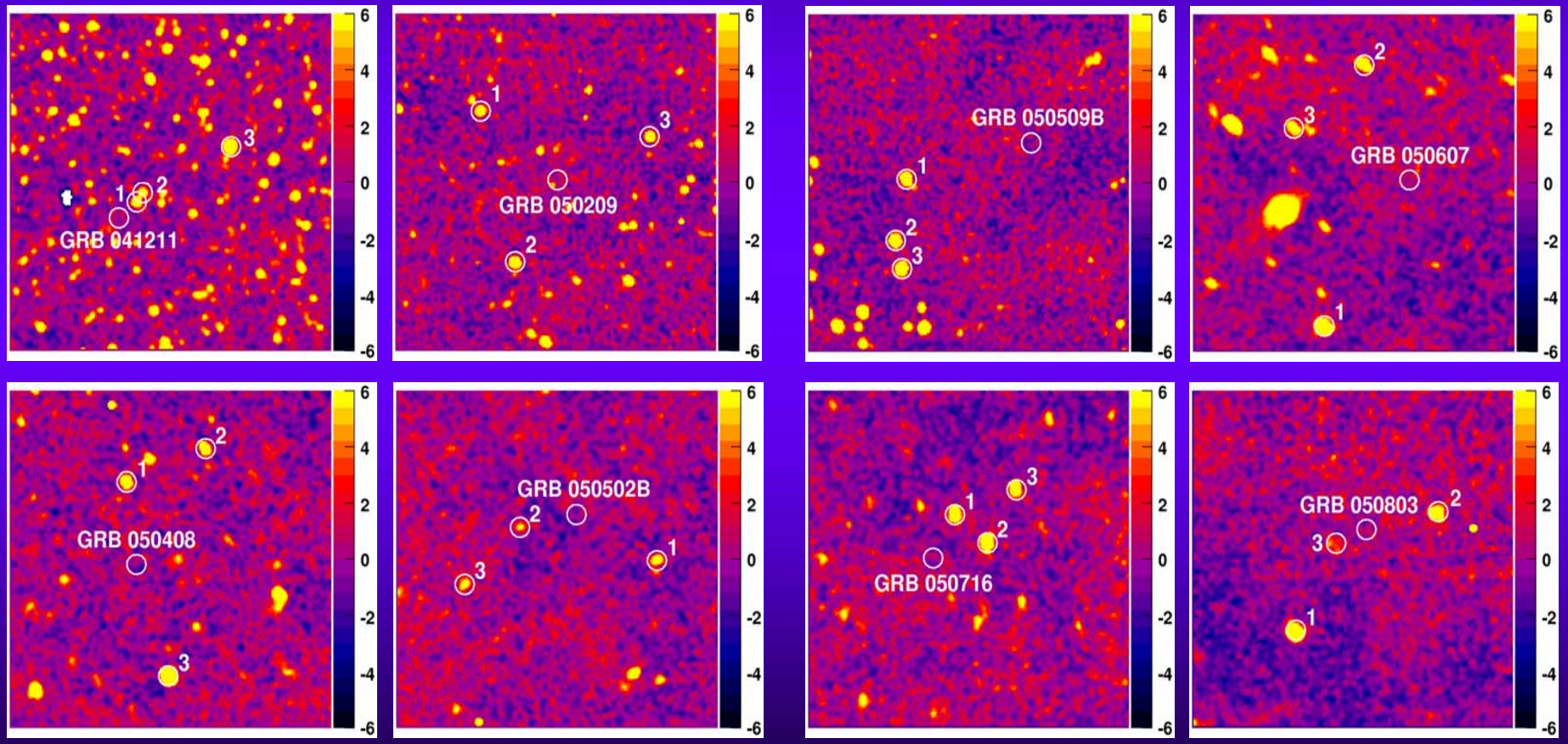
First Optical Precursor Search



- 9 possible GRB counterparts passed through the FOV within 24 hours before GRB
- First systematic search for GRB optical precursors
  - GRB 041211
  - GRB 050209
  - GRB 050408
  - GRB 050502B
  - GRB 050504
  - GRB 050509B
  - GRB 050607
  - GRB 050716
  - GRB 050803

First Optical Precursor Search

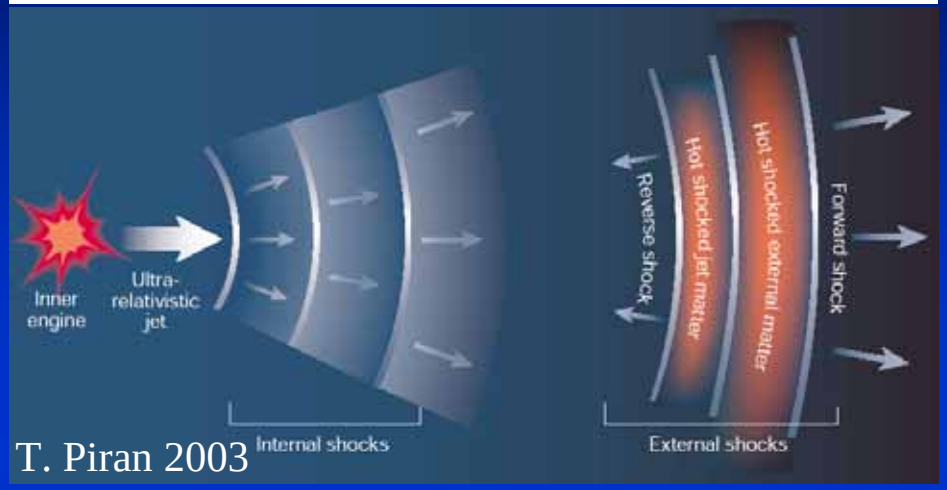
Publish the limits soon.



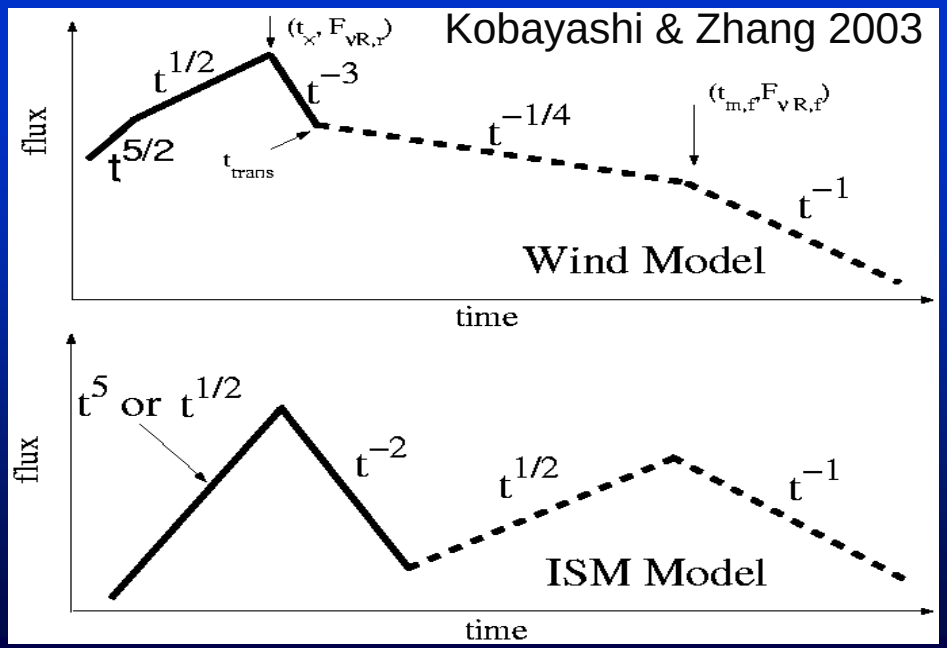
Introduction / Prompt Optical Afterglow

- **Reverse Shock into ISM**
  - Sari & Piran 1999
  - Nakar & Piran 2004
- **Reverse Shock in wind environment**
  - Kobayashi & Zhang 2003
- **Others**
  - Internal Shock
  - Neutron-Fed GRB
  - Pair Avalanche
- **Lightcurve ⇨ Model test**
- **Farther constraints can be obtained by cooperating with radio/IR observations**

Fireball model



T. Piran 2003



Ashra Potential for Opt. Tran.

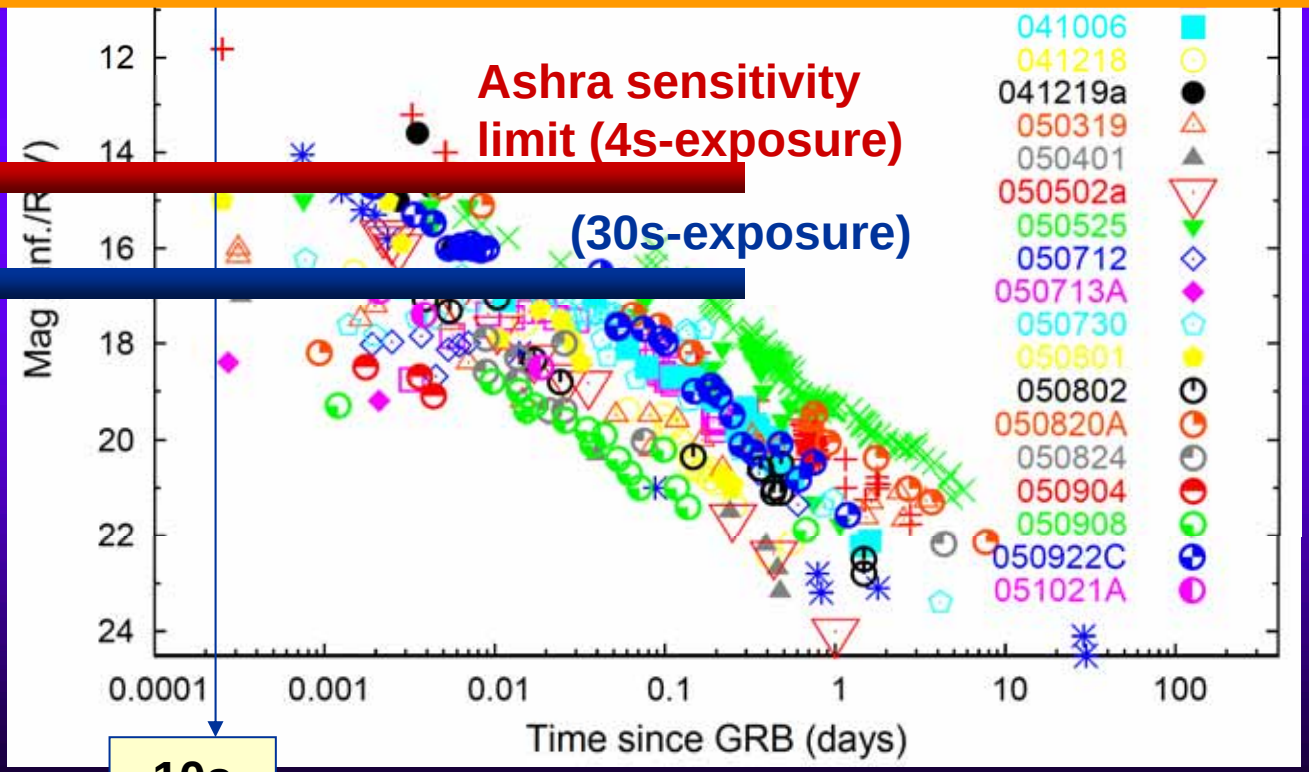
Ashra Unique Point:

Possible Detection of Opt. Flash <10s after/before GRB

=> Autonomous Trigger for Multi-wavelength Campaign

Precurser?

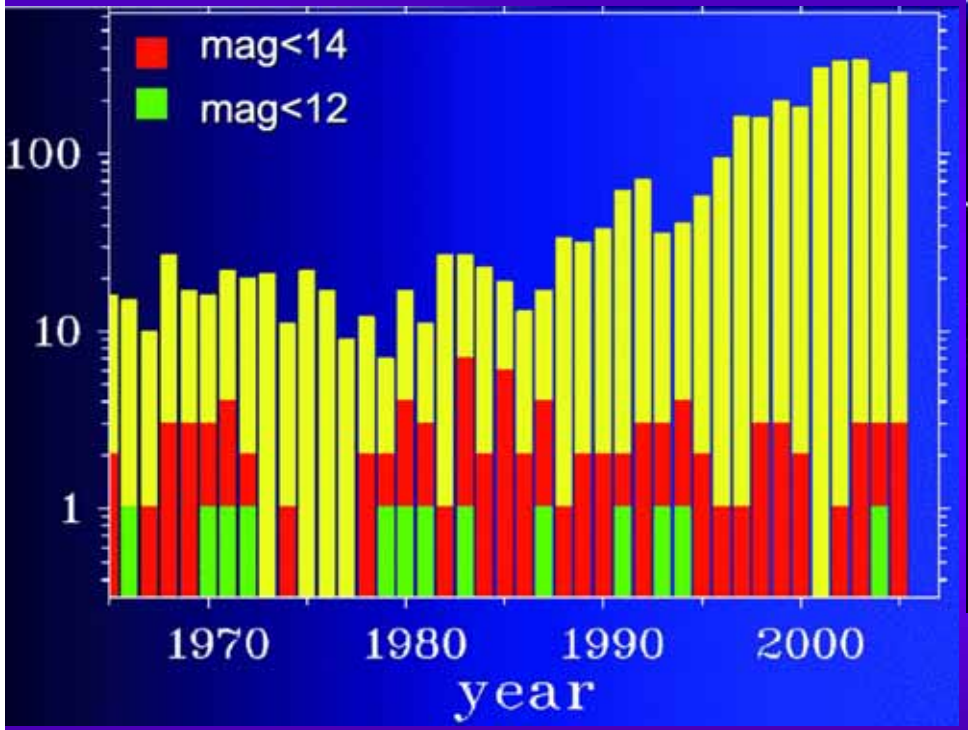
Orphan?



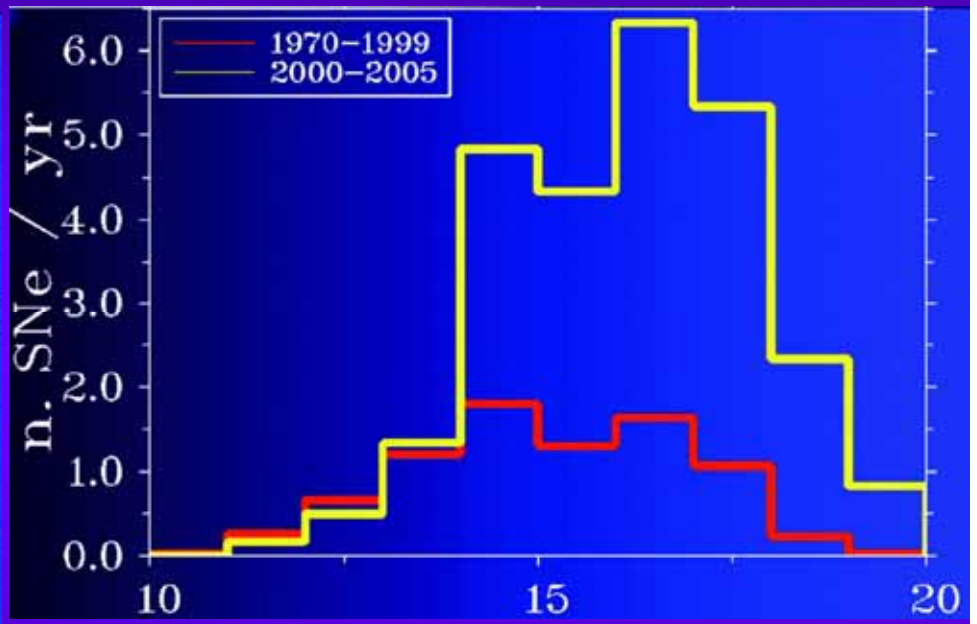
Guidorzi et al. 2005

Supernova

SNe Discovery Record



Mag. distribution of SNe (z<0.01)



By E.Cappellaro, KITP SN-GRB 1-18-06

Good exercise for probing progenitor of long GRB

Check coincidence between optical ⇔ VHEν.

Nearby CC-SNe Search?

CC-SN rate reflects on-going SFR

Can the Ashra OT search contribute to SFR estimates with nearby CC-SNe?

For example, monitor & alert by Ashra and type-ID & z estimate by SUBARU?

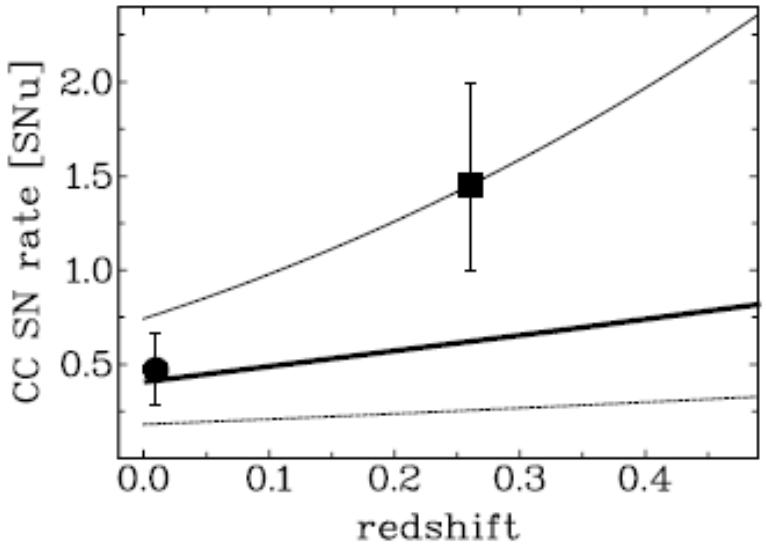


Fig. 8. CC SN rate with redshift. The dot is the estimate of the local CC SN rate from Cappellaro et al. (1999) whereas the square is the new measurement derived in this paper. The solid line shows the deduced evolution with redshift. The dashed line shows the deduced type Ia rate evolution (see the text for details). The thick solid line is the CC SN rate evolution predicted by model M2 of Sadat et al. (1998).

Cappellaro et al. A&A 430, 83-93 (2005)

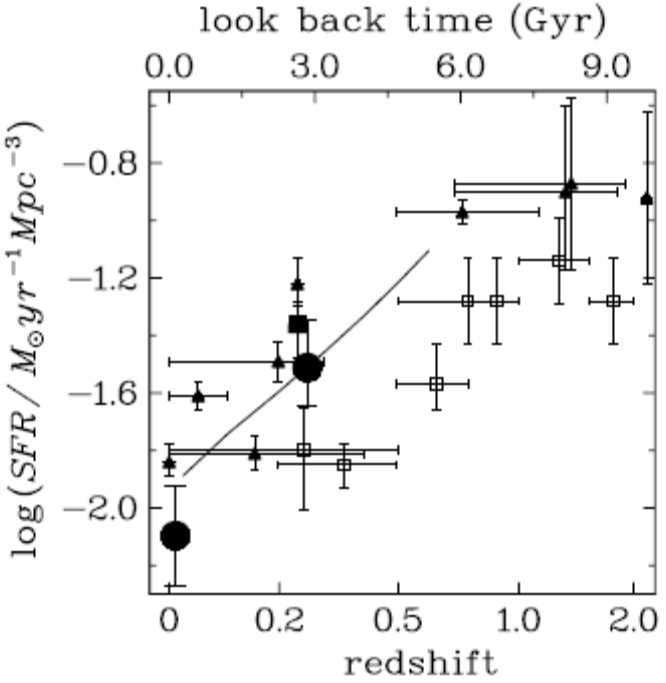


Fig. 9. We compare our estimate of the SFR at redshift $z = 0.26$ (big filled dot) with the recent estimate of Fujita et al. (2003) based on the Hα luminosity density at $z = 0.24$ (filled square). Also shown are estimates of the SFR at other redshifts based either on measurements of the Hα (filled symbols) or of the UV luminosity density (adapted from Fujita et al. (2003) and reference therein). Also plotted is the value derived from the local CC rate (also big filled dot).

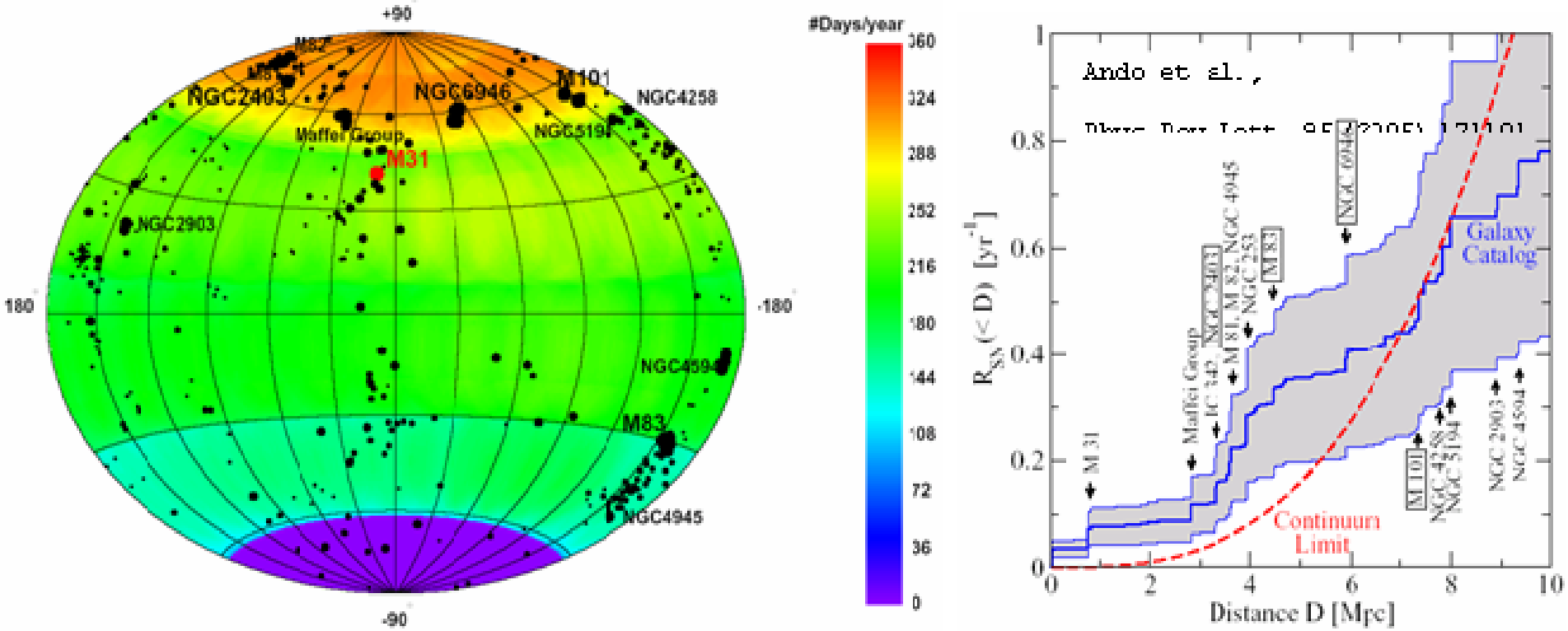


図 1: (左)Ashra による近傍銀河の観測効率。1 年のうちで、1 日あたり 15 分以上の観測時間がある日数を数えている。月のない闇夜を観測条件とし、悪天候等によるロスは考慮しいていない。カタログは 10Mpc 以内の銀河を網羅した、Karachentsev et al., AJ 127 (2004) 2031 による。特に近傍の銀河及び超新星頻度の高い銀河の位置を明示した。(右)青線：各銀河での星生成率より計算した CC SNe の

Optical Transient Observation Network

Ashra @ Mauna Loa

MAGNUM @Haleakala

Alert

Alert

Big Telescopes @Mauna Kea

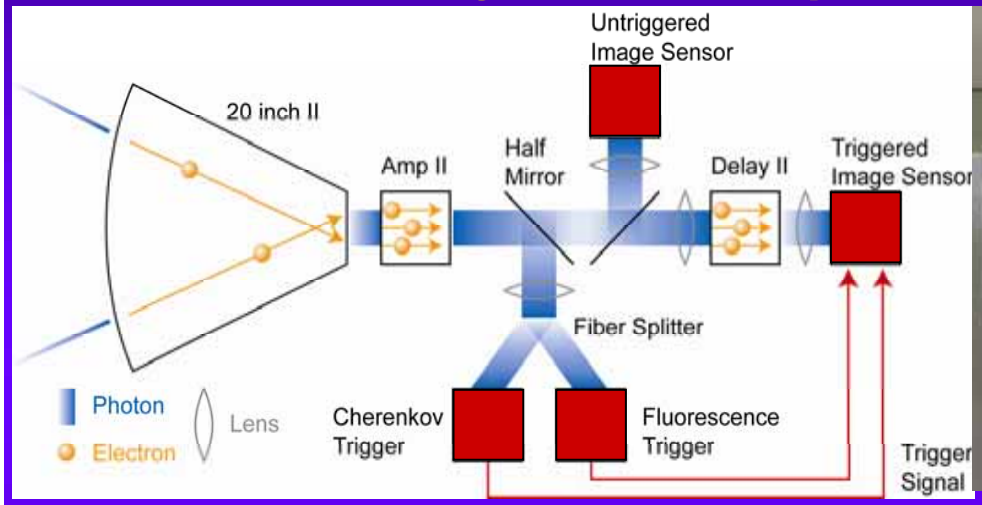
Ashra: 1mϕ pupil
All-sky Monitor
⇒ **Optical&Particle Alert**
⇒ **Test Particle Emission**

Middle-class Telescope: ～2mϕ
Rapid follow-up
⇒ **Precise pointing to the afterglow**

Big Telescopes：～8mϕ
⇒ **Spectroscopy, z estimate**

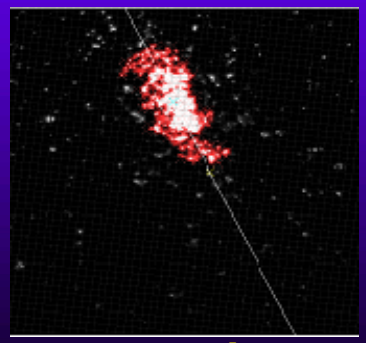
Trigger & Readout

Distributes same image to 4 sensors keeping good resolution and brightness with proc. IIs, splitters, and relay lenses



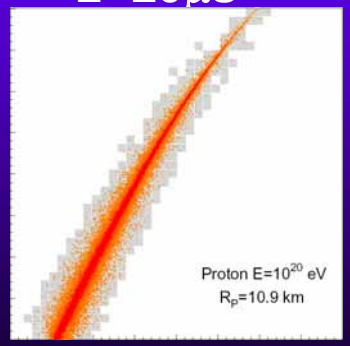
- **3 types of images with different exposure times:**

<100ns



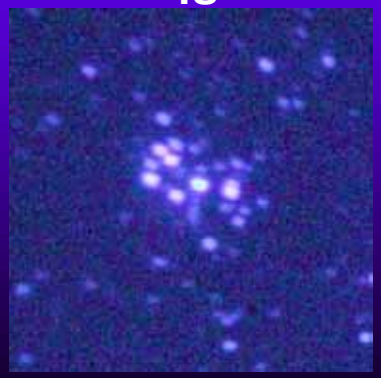
Cerenkov triggered Image

1~10μs



Fluorescence MC triggered Image

4s



Untriggered Image

TeVγ Prototype Test on Haleakala

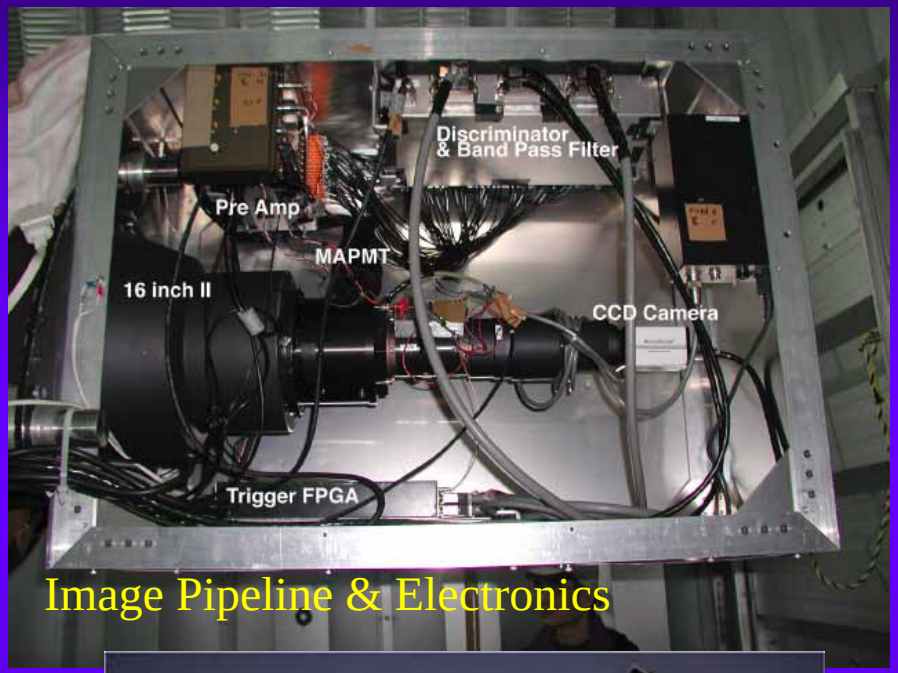


Image Pipeline & Electronics

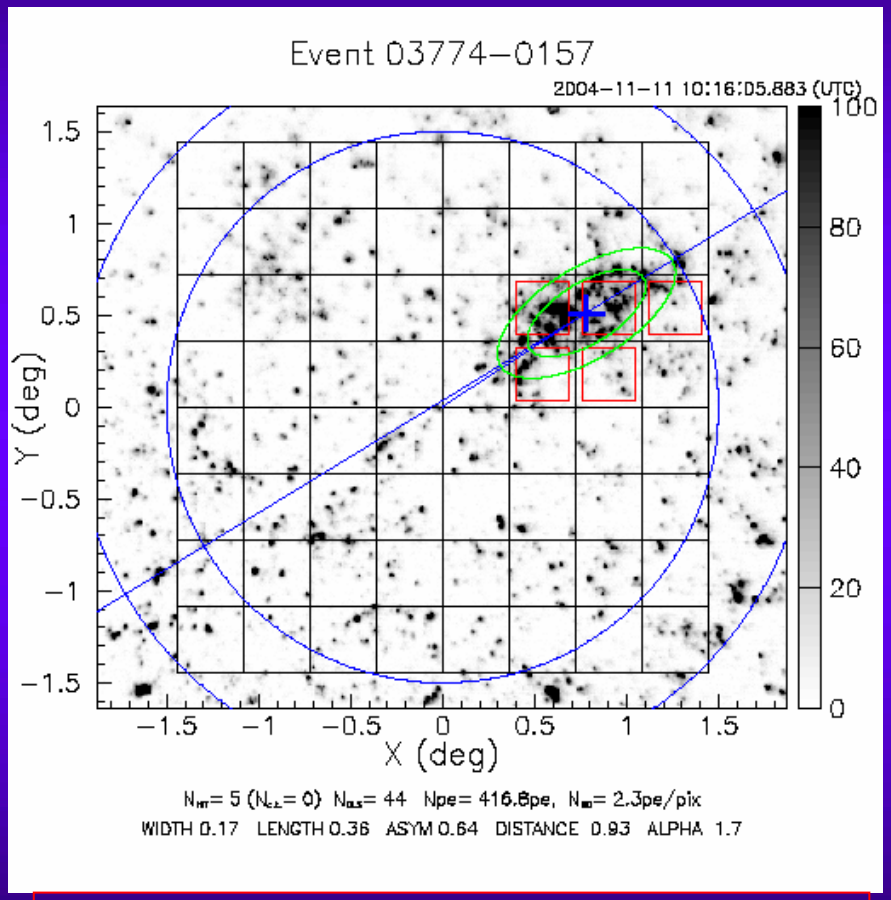

Alt-azimuth mounting telescope

Target: To demonstrate Ashra capability to detect air showers with self-trigger

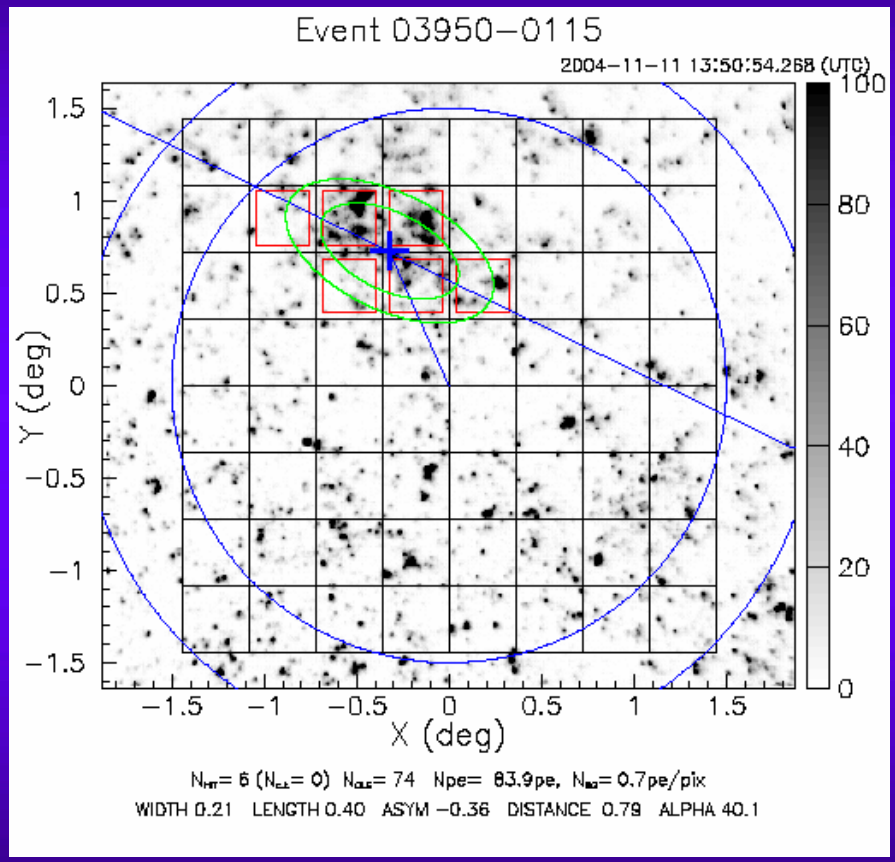
- Tracking observation
- We've observed Crab nebula.
- Study on the fine image analysis

Examples of Cerenkov AS Images

in tracking Crab nebula



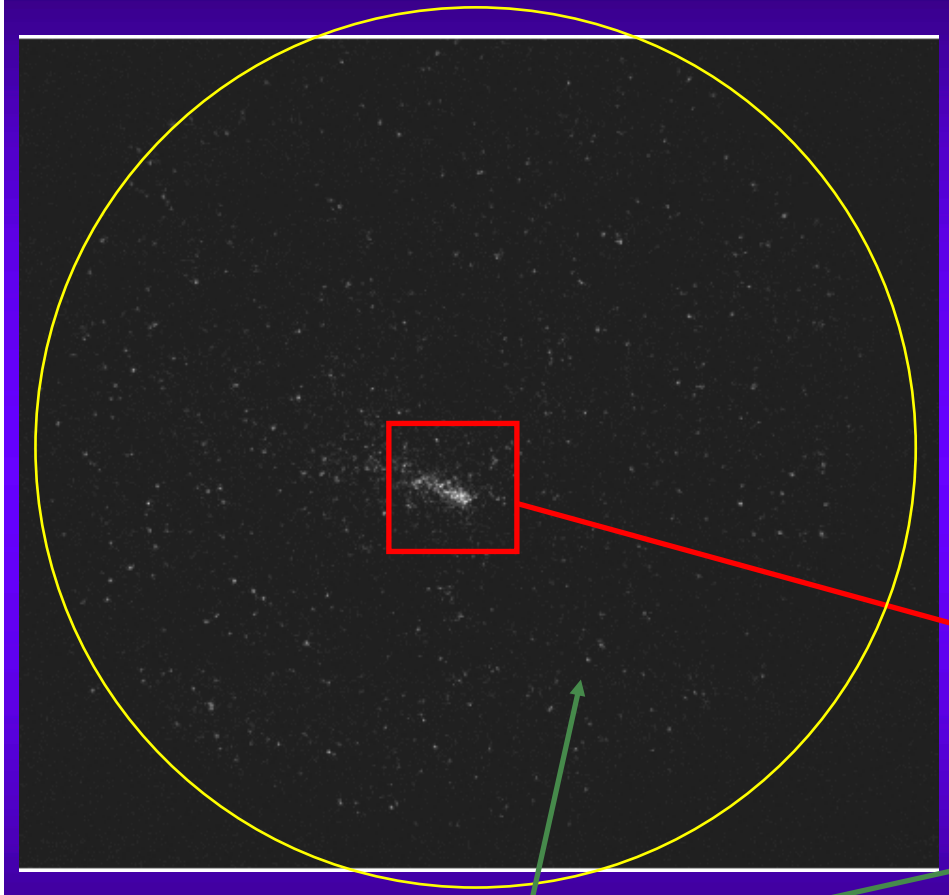
gamma ray shower candidate



proton shower candidate

Self-triggered air Cerenkov images using IT and CCD.

Pilot Observation of Cherenkov Showers

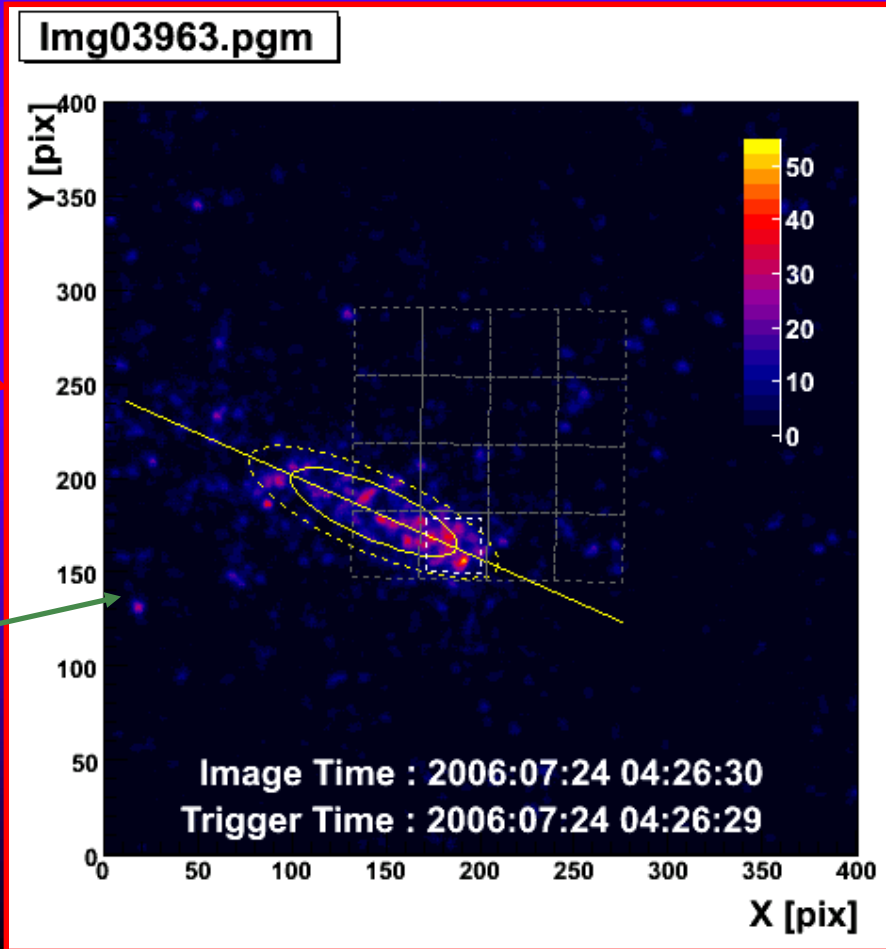


Exposure: 200ns

Each spot corresponds to individual incoming photon.

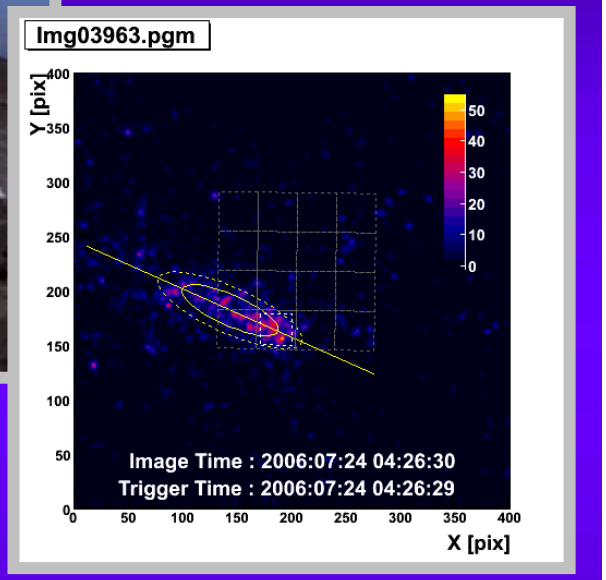
Succeeded in self-triggering with almost final setup

Proton Shower Candidate



Conclusion

Status and Strategy



Optics 6LCs Ready

- Start Official Run on September 1st 2007 ⟶ ***Opt.Transient Search&Alert***
- Developing Quick Search Algorithm

Trigger Test Observation

- Installation in Day Time
- without Sacrificing the Run Efficiency ⟶ ***Start in 2008***


Ashra