Ashra

- Project and Achievements -

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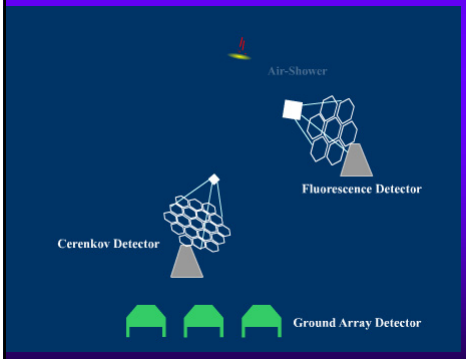
Pioneering Air-light Imaging Detector *Ashra*

All-sky Survey High Resolution Air-shower detector

High Resolution "Simultaneous" Monitor for Cherenkov, fluorescence, and star lights

Standard AS detectors

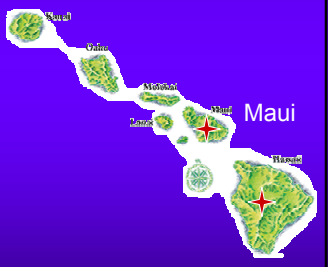


Concept of Ashra Main station

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

Brief History

- FY2002 Started the Collaboration and R&D
- FY2003~ Main part of Ashra-1 funded
  $5M for 3 years
  - FY2003 Developments
  - FY2004 Test Observation @ Haleakala
  - FY2005 Construction @ Mauna Loa
    (Land usage permitted in July)
- FY2006 Under construction
  Started Pilot Observation for opt. transients and VHEγ.



Objectives

Cosmic Ray Astronomy
Optical / TeVγ Transients
TeVγ sky map
Earth / Mountain Tau Neutrino

Cosmic Ray Renaissance

- **Discovery of Ultra High Energy Cosmic Ray?**
  - AGASA discovery vs HiRes denial => Auger resolution
- **New Step of Gamma Ray Astronomy**
  - Fascinating Gamma Ray Bursts
  - H.E.S.S. IACT Activity (Morphology, Survey, …)
- **Approach to High Energy Neutrino Detection**
  - IceCube in the South Pole

Ashra Unique Point:
What is our choice?
⇒ What is the expected fruit?

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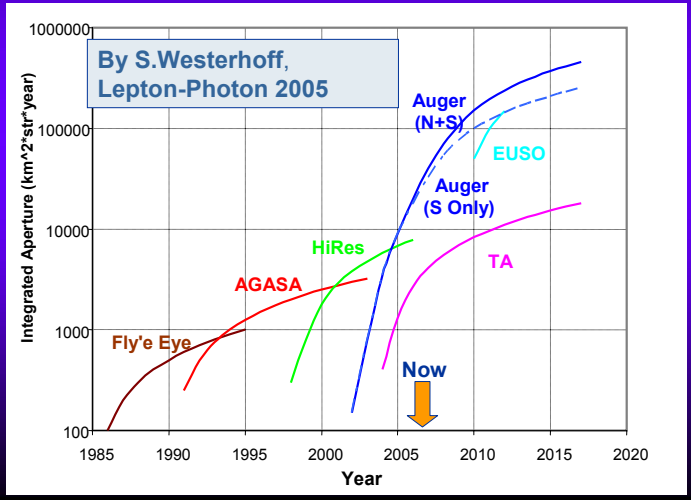

Cosmic Ray Renaissance

- **Discovery of Ultra High Energy Cosmic Ray?**
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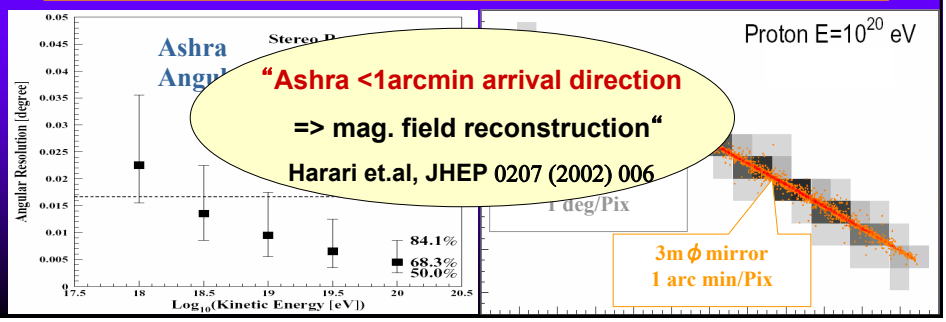
Ashra Unique Point:
Precise Determination of Arrival Direction ~ 1 arcmin
⇒ Cosmic ray source ID
⇒ Cosmic ray astronomy



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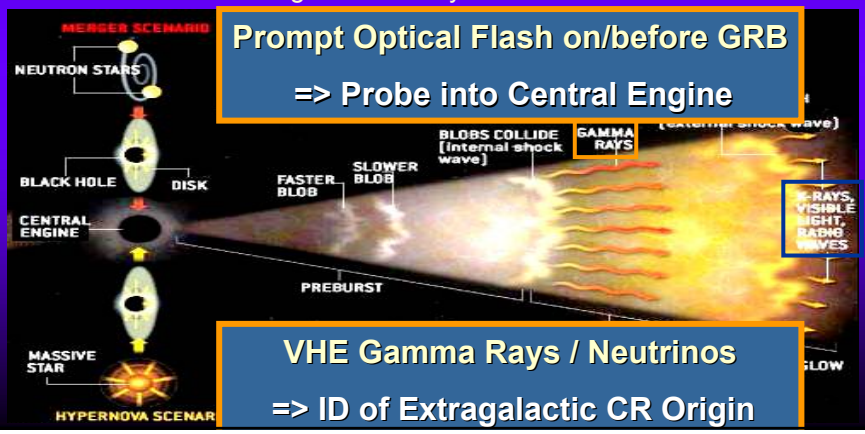


Ashra Potential for Opt. Tran.

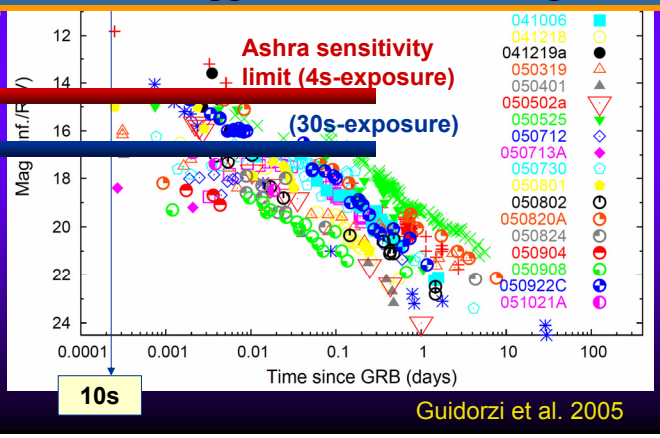
Ashra Unique Point:

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

=> Autonomous Trigger for Multi-wavelength Campaign

Precurser?

Orphan?



Guidorzi et al. 2005

Cosmic Ray Renaissance

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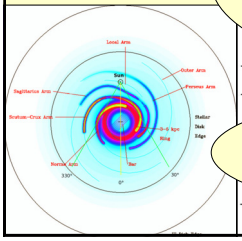
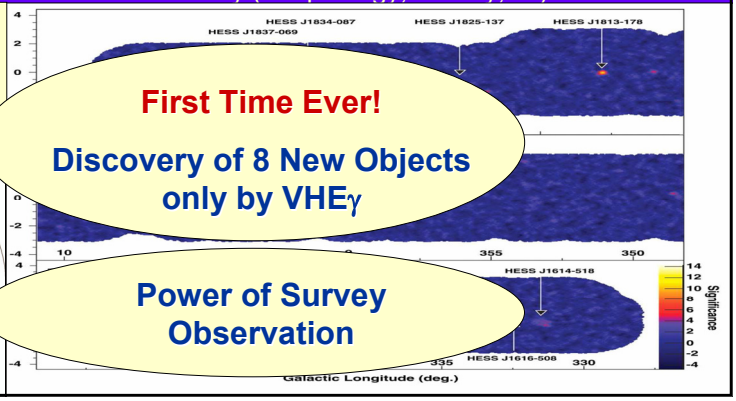
- Galactic plane ±30° × ±3°
- 0.7° × 1° step / 28min, 112h total





First Time Ever!

Discovery of 8 New Objects only by VHEγ

Power of Survey Observation

Cosmic Ray Renaissance

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Ashra Unique Point:
All-sky Simultaneous Observation
⇒ Optical & VHEγ Transients (GRB, SGR, SN, …)
⇒ VHEγ Sky Map

Cosmic Ray Renaissance

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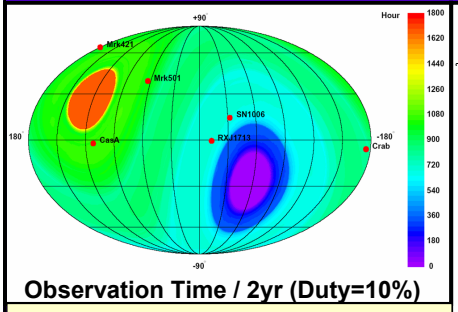
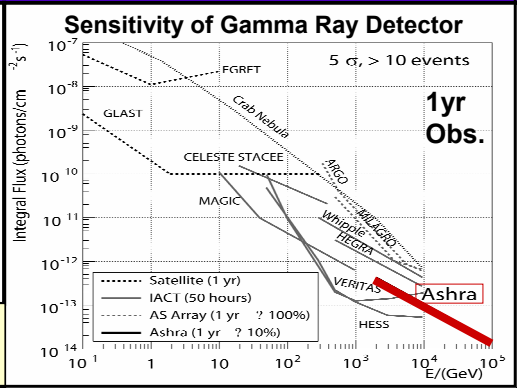


Observation Time / 2yr (Duty=10%)

Low Ene. => Poor Light =>Big Mirror

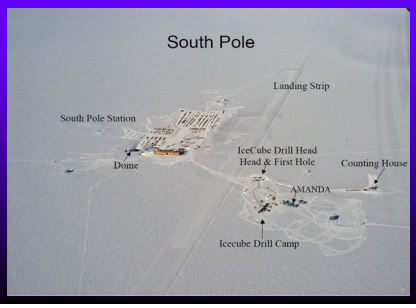
High Ene.=> Poor Flux =>Long Obs.

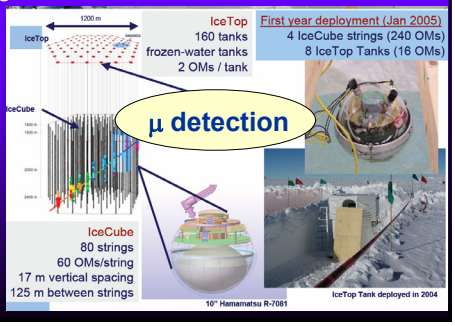


Cosmic Ray Renaissance

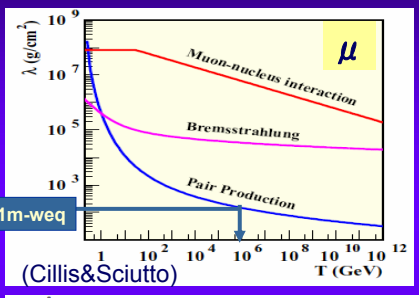
Ashra Unique Point:
PeV-EeV Tau Shower
⇒ Acceptance >100km³-weq. sr
⇒First Tau Neutrino Detection

- **Approach to High Energy Neutrino Detection**
  - IceCube in the South Pole

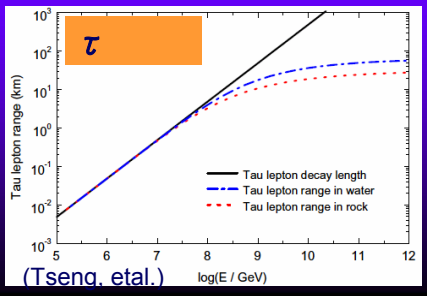




Tau Neutrino Detection using Earth and Mountain

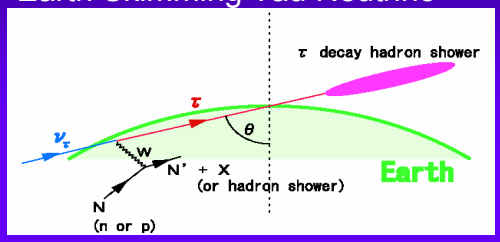


(Cillis&Sciutto)

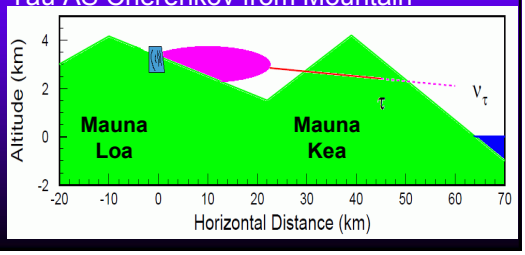


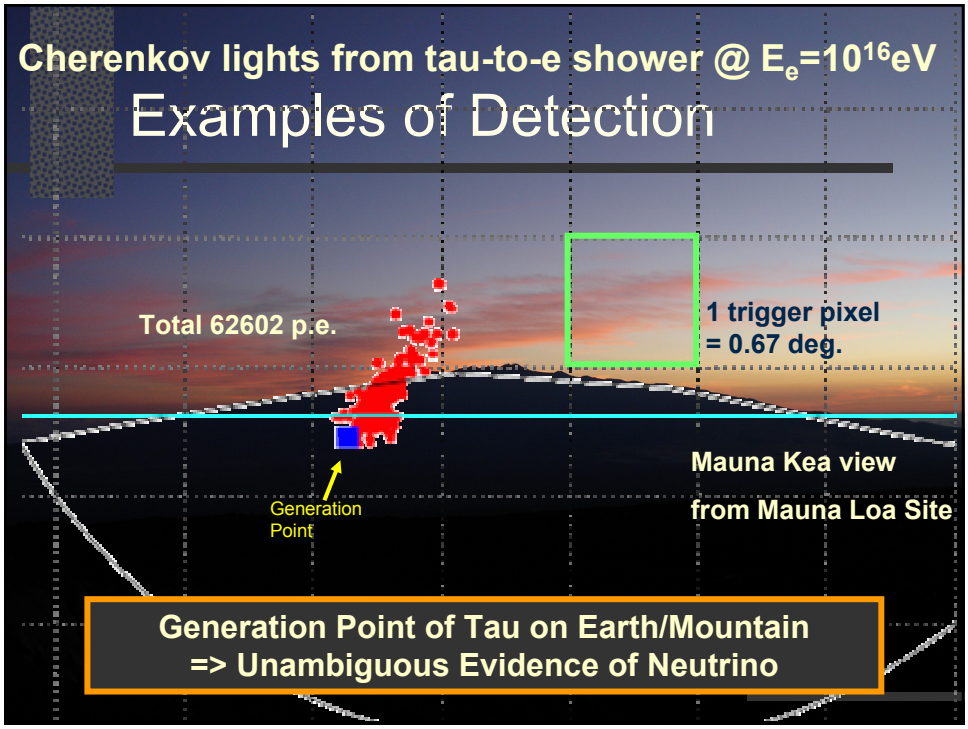
(Tseng, etal.)

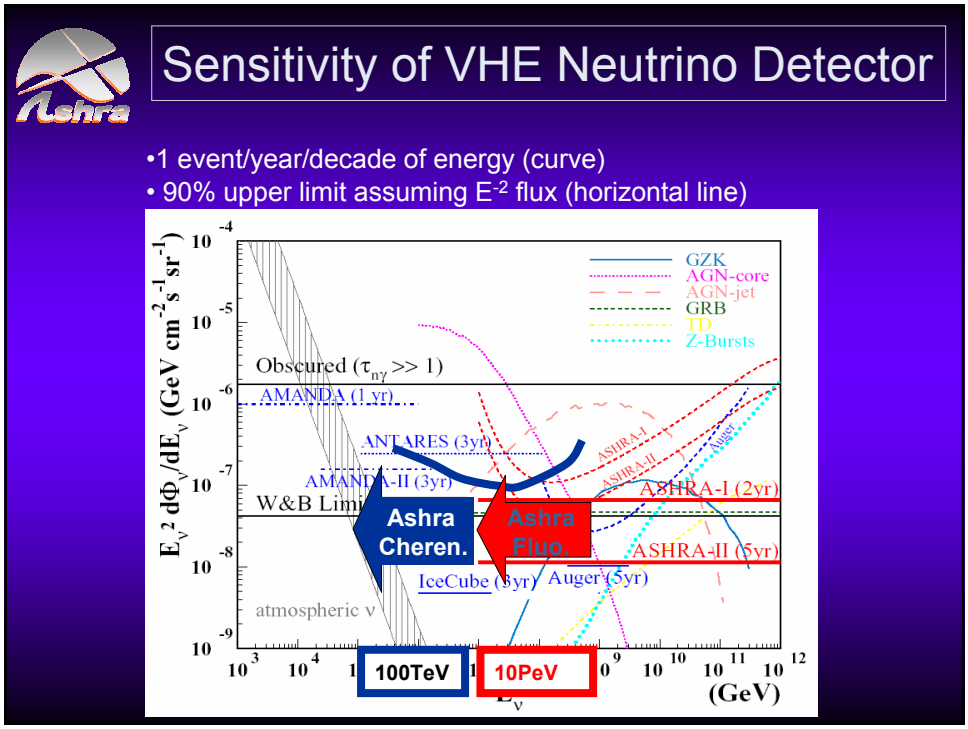
Earth Skimming Tau Neutrino



Tau AS Cherenkov from Mountain




Cherenkov lights from tau-to-e shower @ E_e=10^{16}eV
Examples of Detection
Total 62602 p.e.
1 trigger pixel
= 0.67 deg.
Mauna Kea view
from Mauna Loa Site
Generation
Point
Generation Point of Tau on Earth/Mountain
=> Unambiguous Evidence of Neutrino


Sensitivity of VHE Neutrino Detector
•1 event/year/decade of energy (curve)
• 90% upper limit assuming E^{-2} flux (horizontal line)
GZK
AGN-core
AGN-jet
GRB
TD
Z-Bursts
Obscured ($\tau_{n\gamma}$ >> 1)
AMANDA (1 yr)
ANTARES (3yr)
AMANDA-II (3yr)
W&B Limit
ASHRA-I
ASHRA-II
ASHRA-I (2yr)
ASHRA-II (5yr)
Ashra
Cheren.
Ashra
Flux
IceCube (3yr)
Auger (5yr)
atmospheric ν
100TeV
10PeV
(GeV)

Tau Effective aperture $(A\Omega)_{eff}$

required for 1 event/yr, assuming a 10% duty cycle.

Steady ν source

Energy & Aperture (km^2 sr)	AGN	GRB	GZK
10^{15}-10^{16} eV	4.5	1000	
10^{16}-10^{17} eV	2.0	1400	910
10^{17}-10^{18} eV	50	19000	120
10^{18}-10^{19} eV			290

(Tsen, et al., 2003)

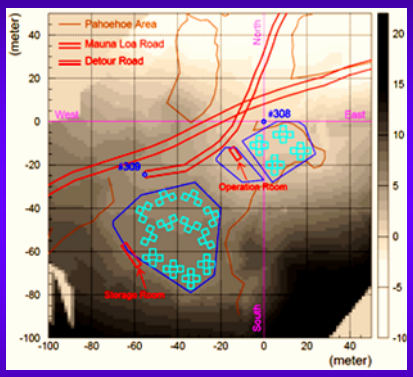
Enough Sensitivity with Ashra

Developments

To reach the objectives, we need

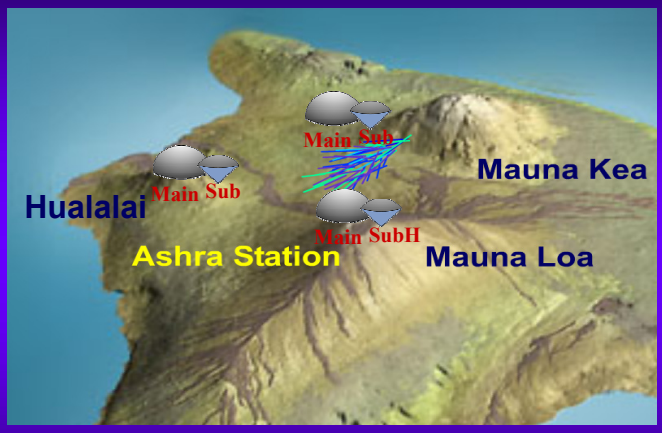
1) **Optical System**
   with Super Wide Angle & High Resolution
2) **Trigger & Readout System**
   for Simultaneous Observation of Cherenkov, Fluorescence, and Optical Flash lights

Phase-1 Layout



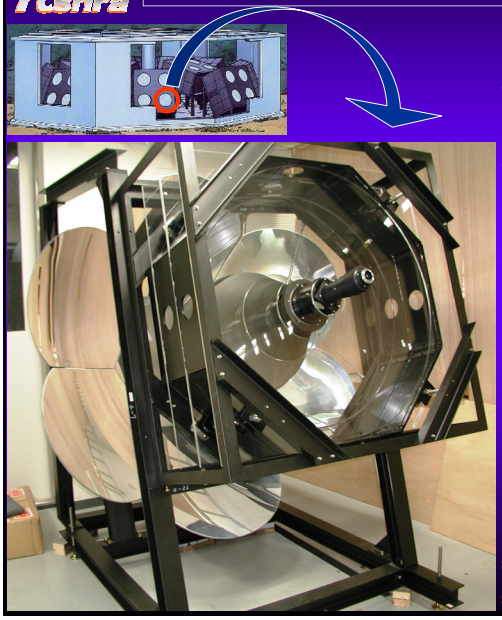
- Main station (12 pc) under construction on Mauna Loa at 3300m asl.
- 2 subs. = high ele.(4pc@80m) + low ele. (8pc@32km)
- Demonstration of hybrid stereo obs. for both Cerenkov and fluorescence

Phase-2 Layout



- 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

Light Collector



- Optics:
  - **Modified Baker-Nunn**
- Components:
  - **Correcting lens** (1.0~1.2mϕ) with 3 acrylic cut plates
  - **Spherical mirror** (2.2mϕ) with 7 curved glass plates on adjustable tables.
  - **Photoelectric lens IT** (0.5mϕ) on focal sphere suspended with Stewart platform mechanism
  - **Mount structure** with steel channels for easy assembly

=> arcmin. resolution over 42deg FOV
=> Affordably cost-effective

Resolution after all adjustments

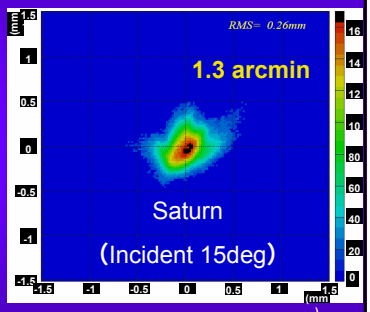
Assembly and install
- Shelter
- Mount
- Correcting lens

+

Assembly and install
- Mirror
- Stewart platform

Adjusting all

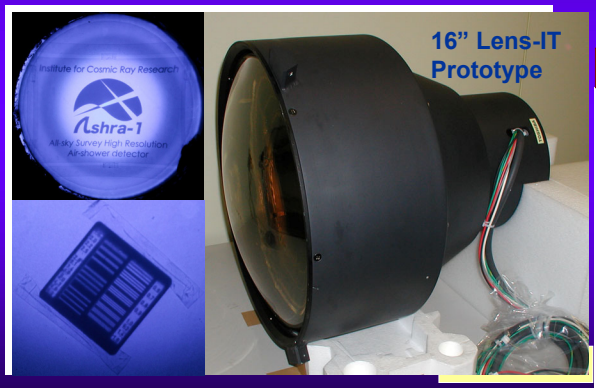
=



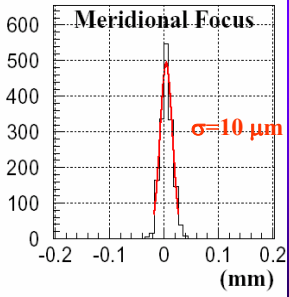
- CCD image on focal sphere
- Total resolution: 1.3 arcmin
- Satisfies our requirement

Photoelectric Lens Image Tube

- Final image focusing by electrostatic lens (x20)
- Good sphericity of cathode surface is required.
- Brightness amplification (100 ph/pe)



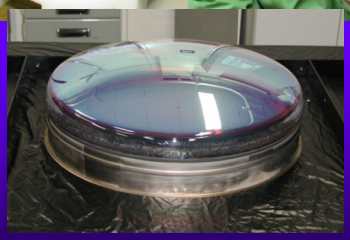
Point Spread

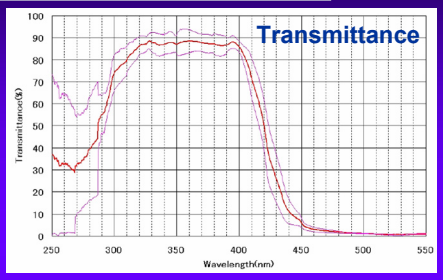


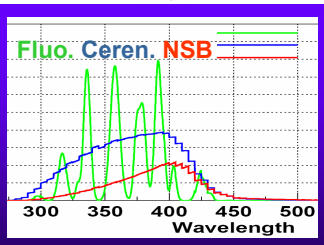
Key technology for the uniqueness of the Ashra optics

20" Lens-IT & Filter

20"ϕ Prod.ver.



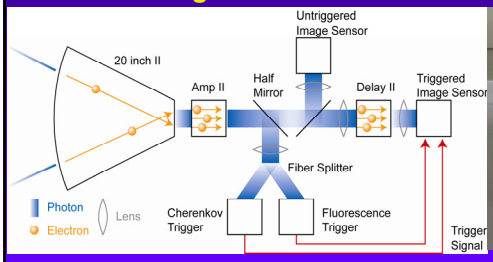




- Input window is coated with multi(40-)layer thin film filter to cut λ>450nm
- Keep good S/N of fluorescence and Cerenkov lights against NSB

Trigger & Readout

Light Distribution => Multipurpose Image Pipeline

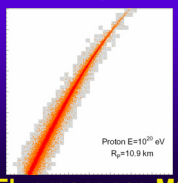


- 3 typical exposure times:

<100ns

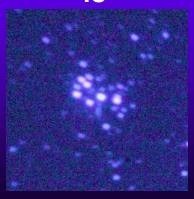
Cerenkov triggered Image

1~10μs



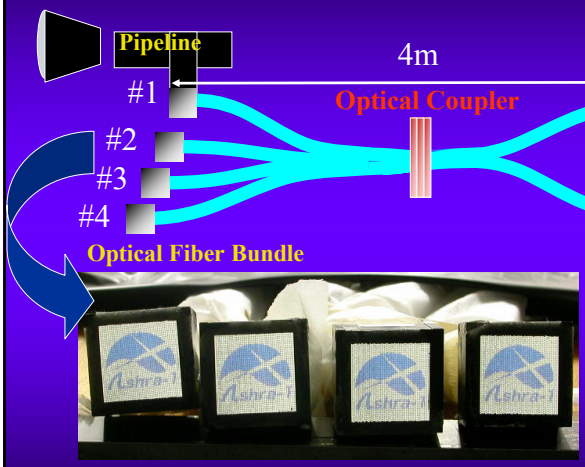
Fluorescence MC triggered Image

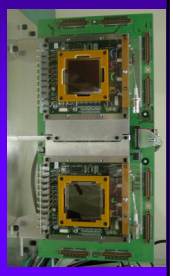
4s



Untriggered Image

Optical Fiber Transmission System



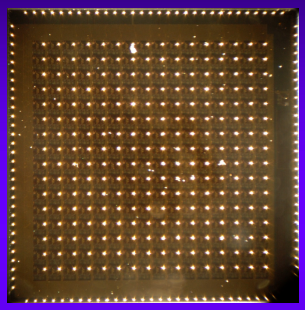


- 64x64 fibers(0.5mmϕ)
- 0.67deg-FOV / fiber

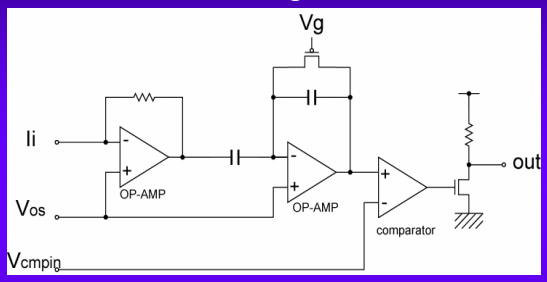
Light collectors can be easily appended to the trigger.

Sensitivity can be reinforced when more budget is available.

Trigger Sensor LSI

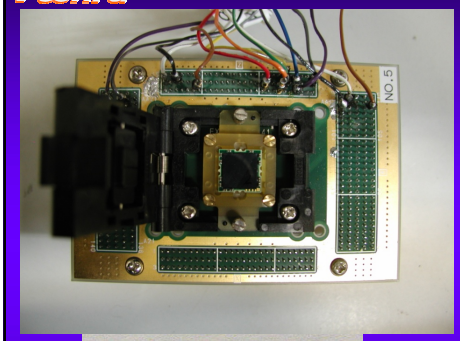


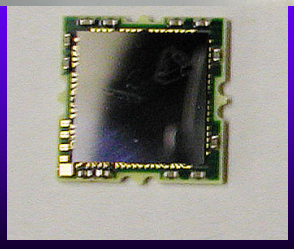
Pixel Circuit Diagram

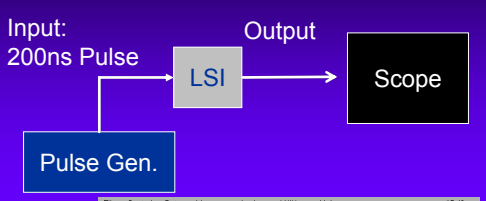


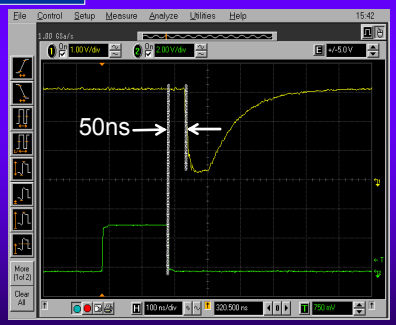
- Pixel includes I/V transformer、filter、and comparator in the size of 500μm□
- 16×16 pixel array / LSI chip ⇒ 64×64 trigger generated with 4×4 LSI chips
- LSI size: 9.8mm□

Timing Test of Trigger LSI



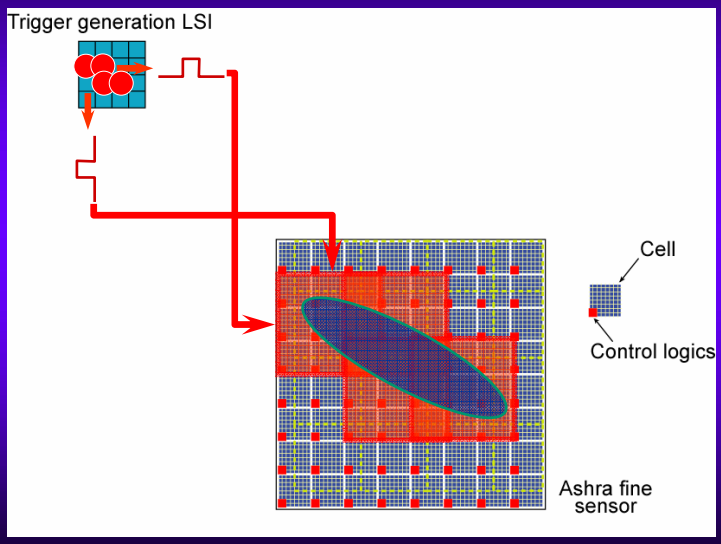




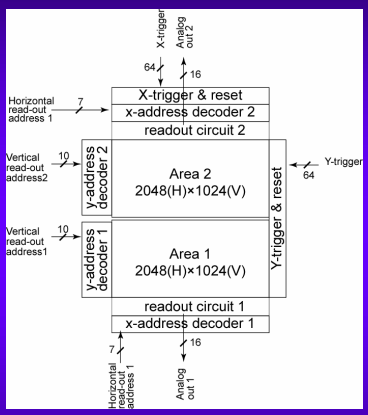


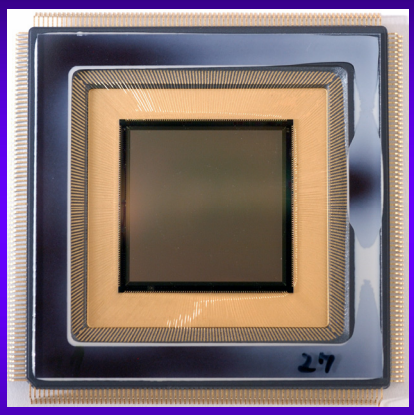
- Delay in LSI = 50ns
  < Delay II afterglow sustains for ~100ns

Coordinated Local Control with Trigger & CMOS Fine Sensor



CMOS Fine Sensor

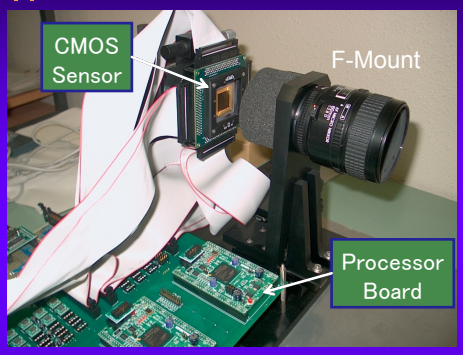


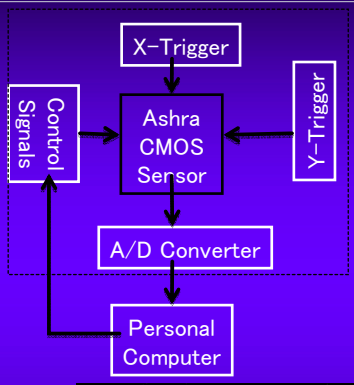


- Readout 2 directions independently
  - ⇒ Low parasitic capacitance
  - ⇒ Speed-up of readout
- Areas are subdivided => 16 × 16 cells

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

Imaging with CMOS Fine Sensor

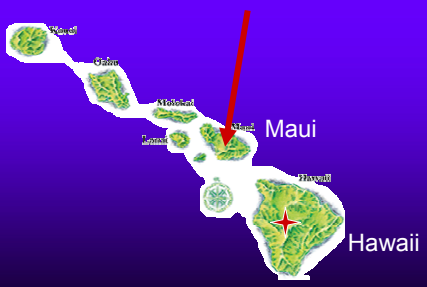




- Image is focused on the CMOS fine sensor through Nikon F-mount lens
- Processing board:
  - Generation of trigger control
  - Readout of images

100ns Exposure

Test Observation @ Haleakala



Collaboration with Univ. Hawaii

8 January 2004

Memorandum of Understanding
between
the Institute for Astronomy of the University of Hawaii
and
the ASHRA Experiment Collaboration

This letter of agreement describes the terms and conditions under which the IfA and the ASHRA staff will collaborate to temporarily operate the ASHRA telescope on Haleakala. This is an informal research agreement undertaken to obtain scientifically useful demonstration data from the prototype ASHRA telescope. The intent of this letter is to describe in general terms the obligations of each

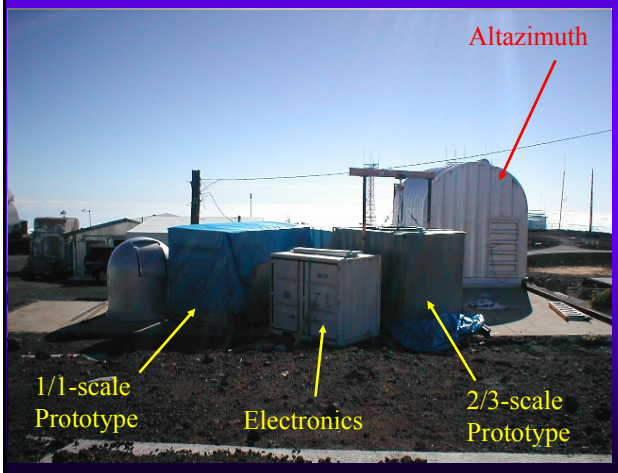
AGREEMENT ON ACADEMIC EXCHANGE
BETWEEN
THE UNIVERSITY OF TOKYO
AND
THE UNIVERSITY OF HAWAII

The President of the University of Tokyo and the President of the University of Hawaii, being convinced that cooperation between the two universities will promote the development of research and other academic activities in each university, hereby conclude this Agreement.

Article 1.
The University of Tokyo and the University of Hawaii agree to promote cooperation between both universities in academic fields of mutual interest through appropriate means as follows:
1. Exchange of faculty members and research staff members
2. Exchange of students
3. Conducting joint research projects
4. Holding lectures and symposia
5. Exchange of information and academic publications

Test Observation Site: Haleakala

Concrete Pad owned by Univ.Hawaii was used for test observation



2003.08: Clean-up

2003.12: Installation of Altazimuth Telescope

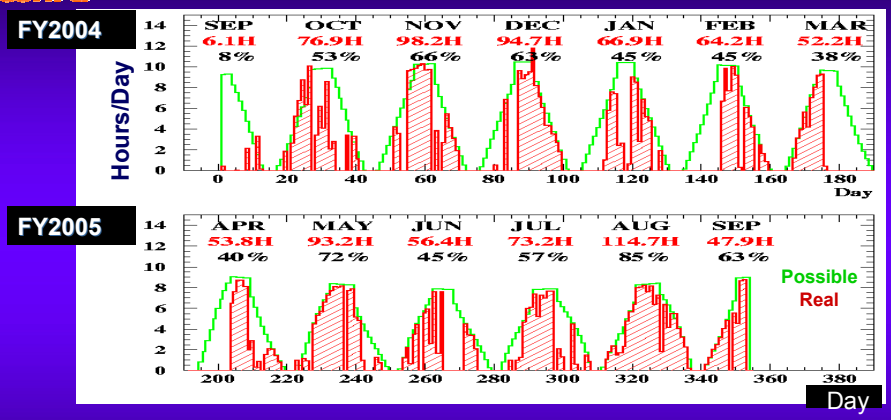
2004.03: Installation of Garage Body

2004.06: Garage ready

2004.08: Installation of Containers

2004.08: Installation of prototype optical system

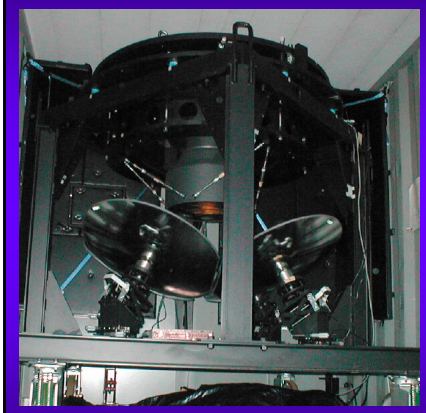
Test Observation on Haleakala

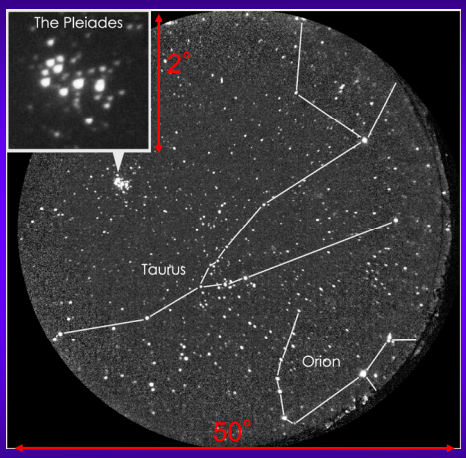


- Possible: Sun; elevation angle < -18deg. Moon; bright area < 10%
- Real: Humidity < 70%, no cloud at zenith, and detector OK.

- Observation efficiency = 55% = 844h / 1526h (2004.10~2005.08)
  Duty = 11% of all time

2/3-scale Prototype on Haleakala

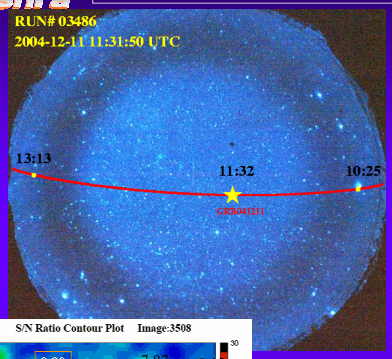


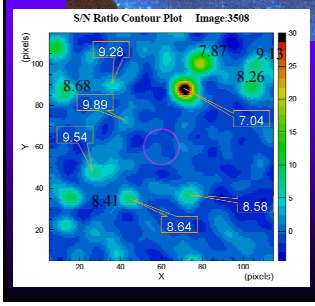


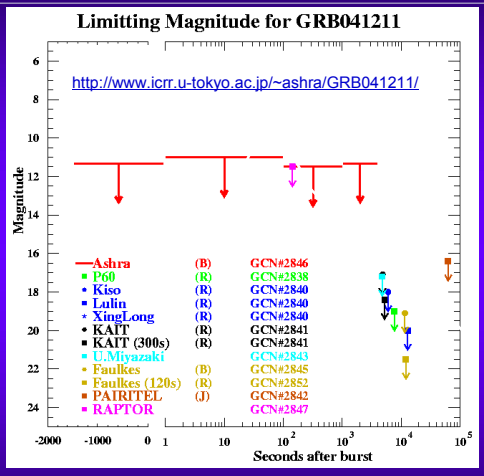
Concept of the light collector = "Wide & High resolution"

Demonstrated well

GRB041211 Cross Observation

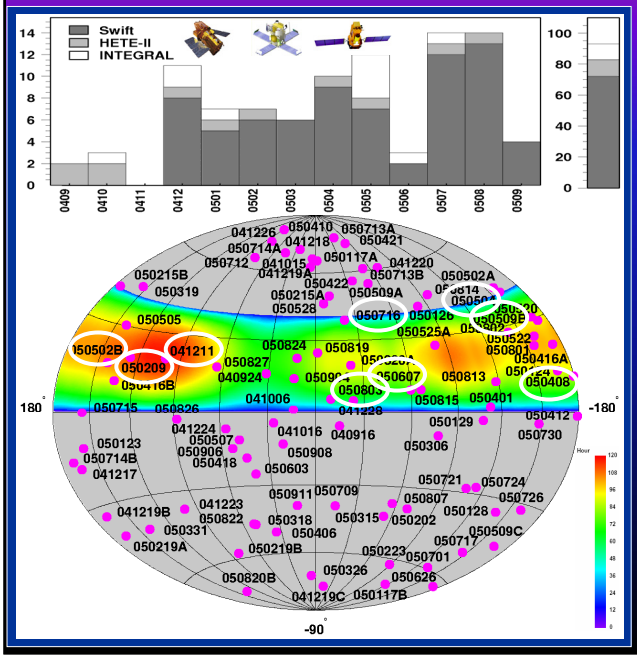




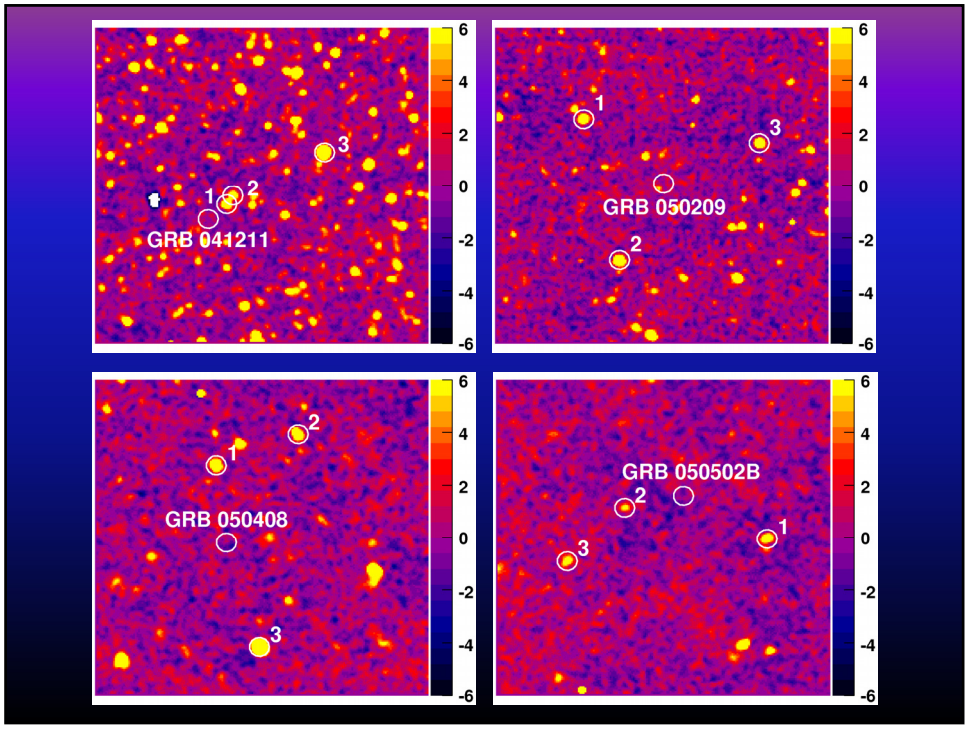


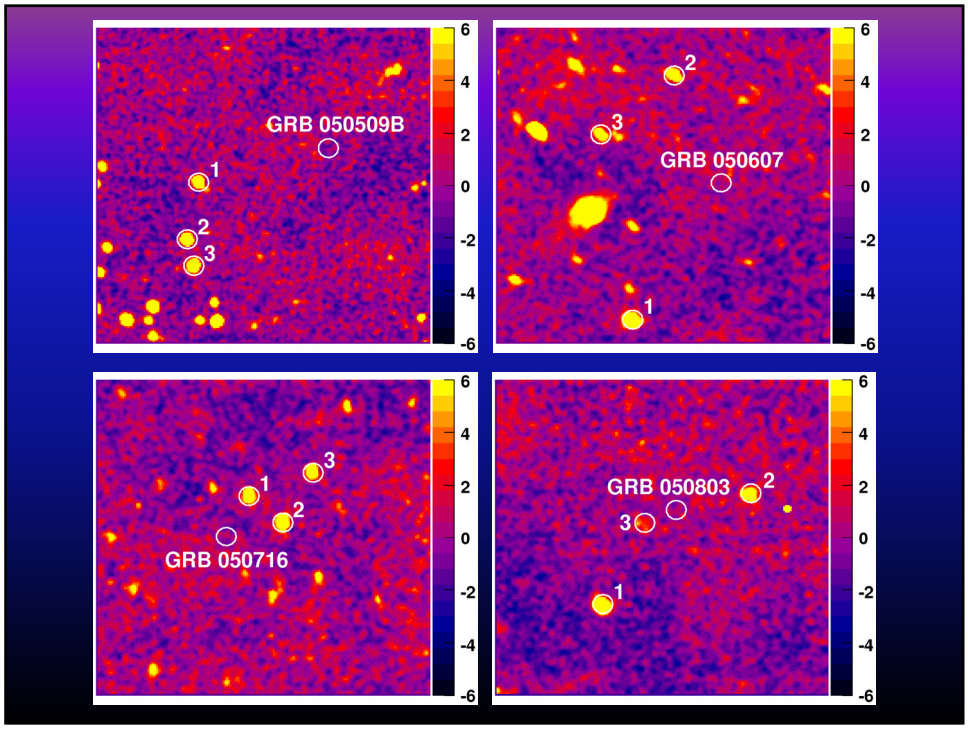
- HETE-II detected the GRB near the center of FOV
- We received the alert, and searched for new objects.
- Set limit on the magnitude of new object.
- Unique observation starting before the GRB.

First Optical Precursor Search



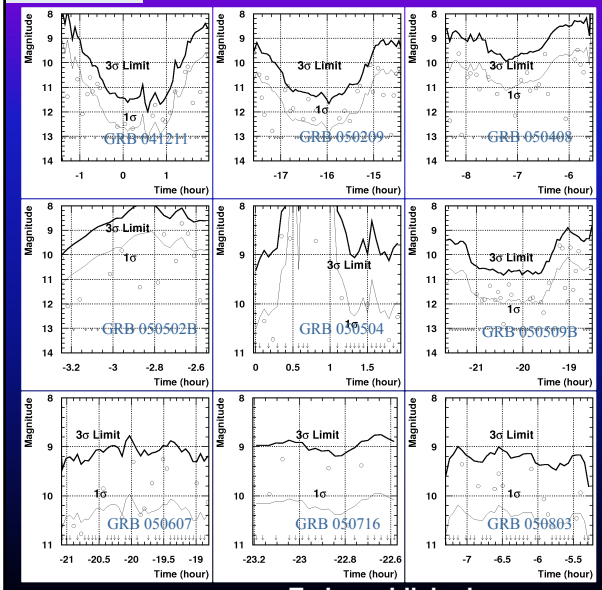
- 9 possible GRB counterparts passed through the FOV within 24 hours before GRB
- First check of GRB optical precursors
- GRB 041211
- GRB 050209
- GRB 050408
- GRB 050502B
- GRB 050504
- GRB 050509B
- GRB 050607
- GRB 050716
- GRB 050803


GRB 041211
GRB 050209
GRB 050408
GRB 050502B


GRB 050509B
GRB 050607
GRB 050716
GRB 050803

Limiting Mag. for GRB Optical Precursors

Preliminary



To be published

- GRB 041211、GRB 050504 include GRB time

Search for Optical Precursor before GRB

Observation of GRB041211 & GRB050502B using the Ashra prototype was cited and discussed in ApJ, 629, 45-51 (2005) ApJ, 638, 1, 354-368 (2006).

TeVγ Prototype Test on Haleakala

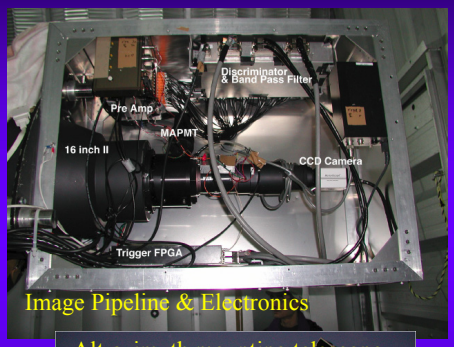
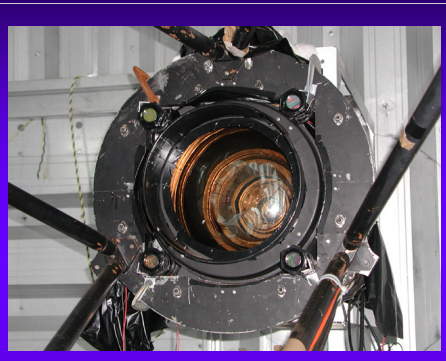


Image Pipeline & Electronics



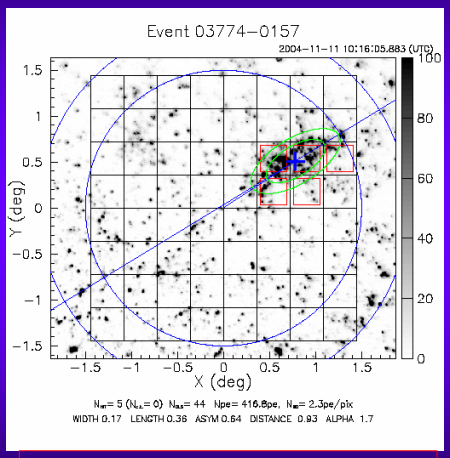
Alt-azimuth mounting telescope

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

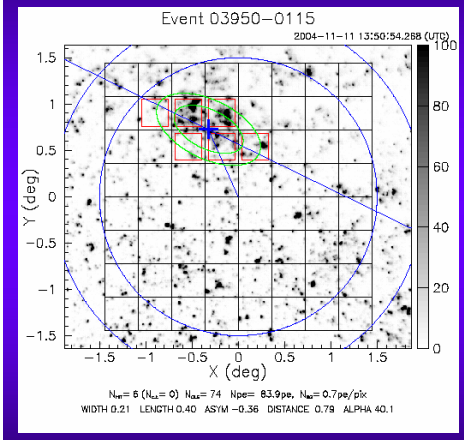
- Tracking observation
- We've observed Crab nebula.
- Study on the fine image analysis

Examples of Cerenkov AS Images

in tracking Crab nebula



gamma ray shower candidate

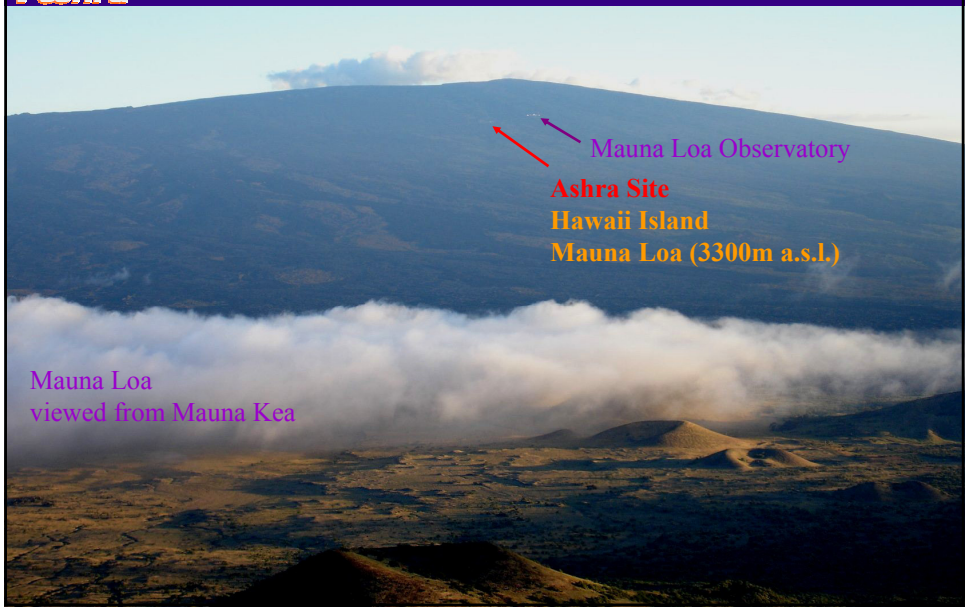


proton shower candidate

Self-triggered air Cerenkov images using IT and CCD.

Construction @ Mauna Loa Site

Ashra Mauna Loa Site



2005.05: Untrodden Lava Field

LINDA LINGLE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
OFFICE OF CONSERVATION AND COASTAL LANDS
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

PETER T. YOUNG
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

ROBERT K. MASUDA
DEPUTY DIRECTOR - LAND

DEAN NAKANO
ACTING DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

REF:OCCL:TM

FILE NO.: HA-3221

JUL - 5 2005

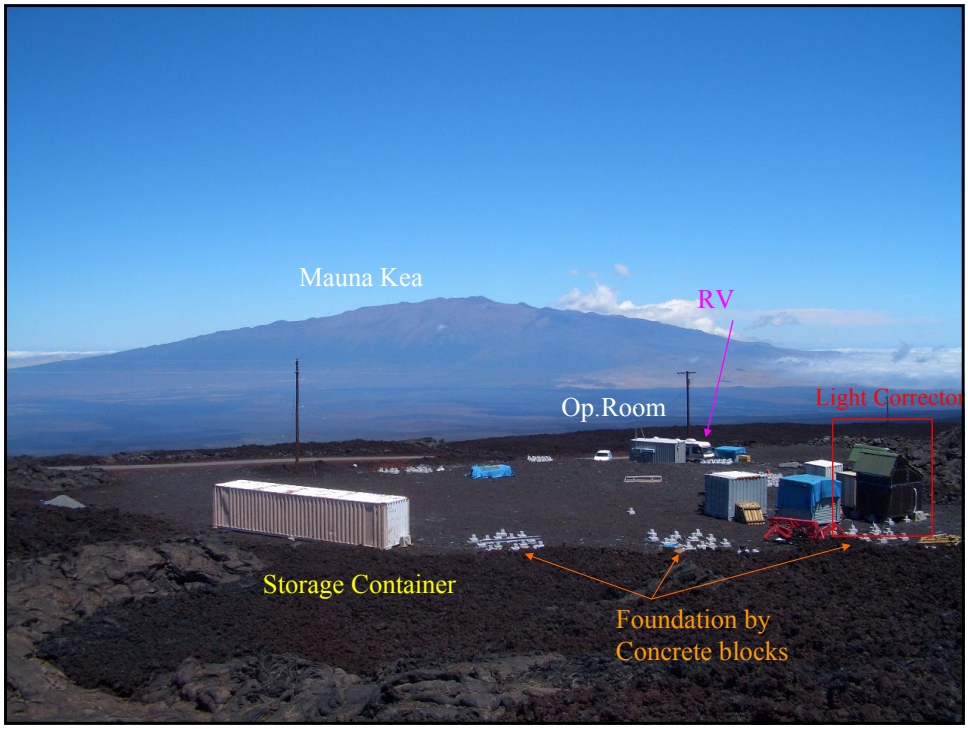
John Hamilton
Department of Physics & Astronomy
Natural Science Division
University of Hawaii-Hilo
200 West Kawili Street
Hilo, Hawaii 96720

2005.07.01:
Permission of Land Usage

Dear Mr. Hamilton;

SUBJECT: Conservation District Use Permit (CDUP) HA-3221 All-sky Survey High Resolution Air-shower Detector (Ashra) Project Located at Kaohe V, Island of Hawaii, TMK

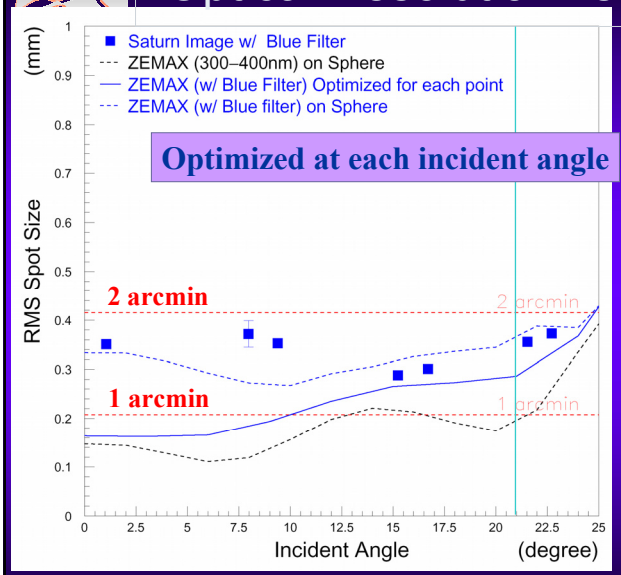

2005.07.27
Started up Grading Work

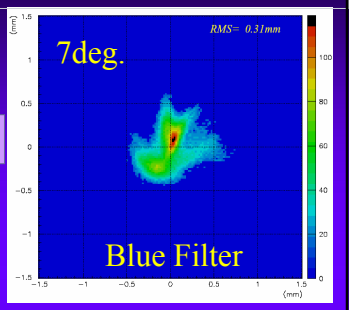

Mauna Kea
RV
Op.Room
Light Corrector
Storage Container
Foundation by
Concrete blocks

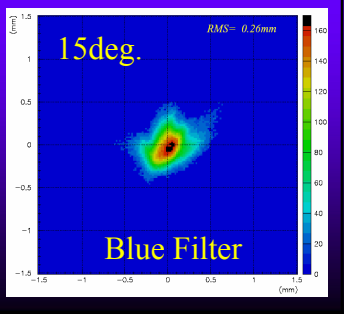
Construction of Detector and Shelter

- Improvements of structure and construction method
  ⇒ construction in shorter period of time
- Construction of the nearest detectors
  ⇒ the most difficult case
- Trigger house installation ⇒ for trigger of the same FOV detectors

Optical Resolution vs Incident Angle

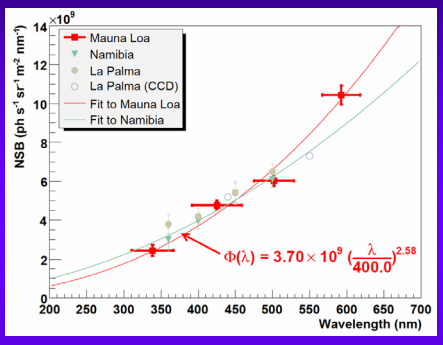






We have confirmed that optical resolution (RMS) including lens and mirrors is less than 2 arcmin.

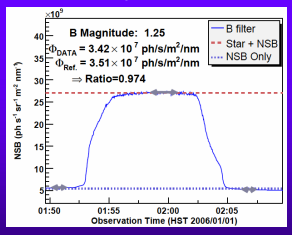
Night Sky BG on Mauna Loa

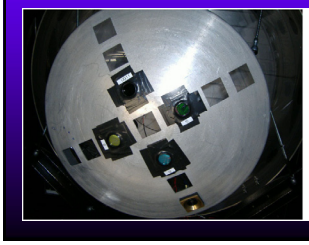


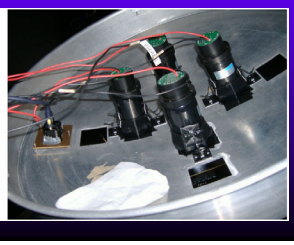
Night Sky BG Flux Spectrum

Fairly consistent with NSB measurements on Namibia and La Palma by the H.E.S.S. group (Preuβ, et al., NIM A481 (2002) 229).

Understanding of total light collection efficiency is checked well with stars crossing PMT FOVs within 5% accuracy.

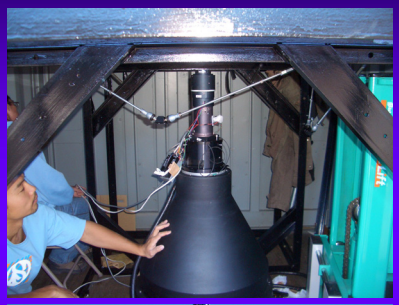




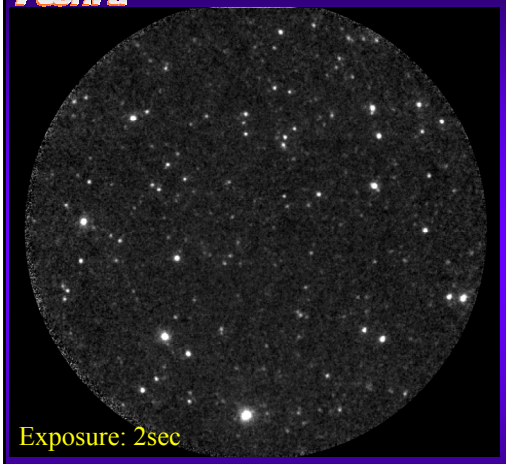


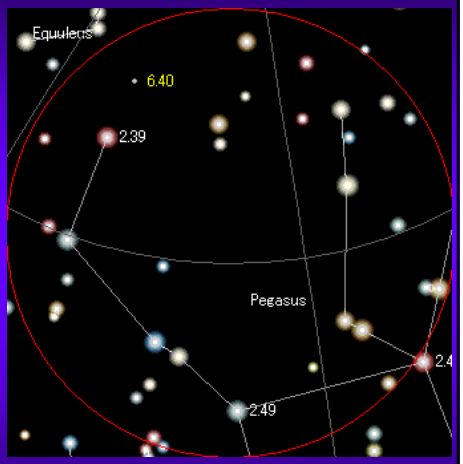
<= How to fix R, G, B, U optical filters on PMTs and CCD on the focal sphere.

Installation of Photoelectric Imaging System



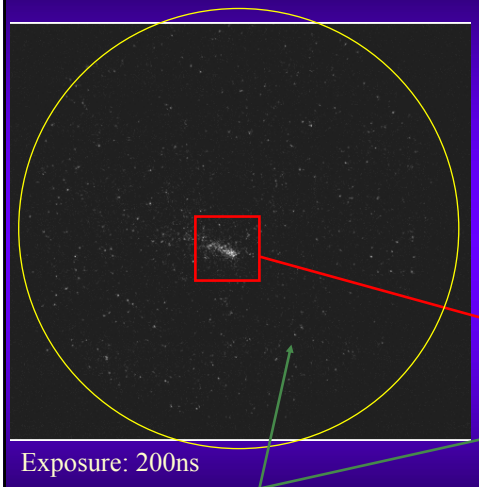
Star Images with Ashra Telescope





Star image with Ashra telescope through 20”II + Image Pipeline.
Wide FOV and high resolution have been achieved.

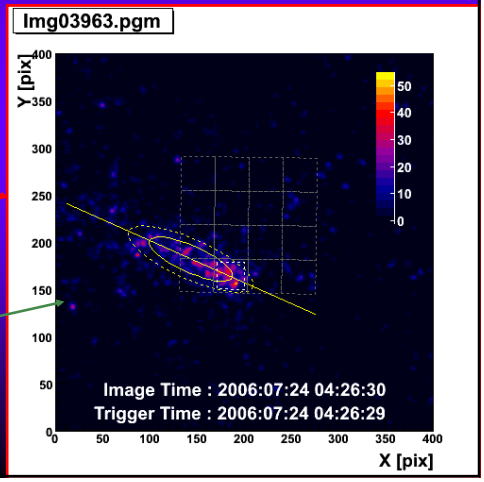
Test Observation of Cherenkov Showers



Each spot corresponds to individual incoming photon.

Succeeded in self-triggering

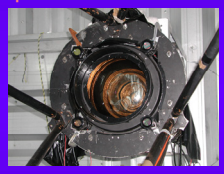
Proton Shower Candidate



Conclusion

- Advanced developments completed
  - Super Wide FOV Optical System (Low Cost)
  - Photoelectric Image Pipeline
  - Local Exposure&Readout CMOS Sensor
  - Trigger Hybrid Pixel Device
- Pioneering observations completed
  - Images with 50deg & arcmin Resolution
  - Autonomous Sensing of Air-shower Images
  - Optical Flash Searches on/before GRB
- Statistical observation on progress
  - Established Infra. and Construction Process
  - Crucial Operation Resources (money & manpower)

FY2004 Succeeded in 50deg FOV and arcmin resolution. Op. flash searches.



FY2004 Succeeded in Cherenkov AS images taken with I.I.+CCD

FY2005~ Under construction @ Mauna Loa

Near Future Plan

- FY2005 Started construction at site on Mouna Loa

- FY2006 Optical assembly & adjustment
  => Start Optical transient monitor
- FY2007 Cerenkov Trigger & Readout assembly
  => Start VHEγ monitor
  => Start VHEν Search (Mountain)
- FY2008 Fluorescence Trigger & Readout assembly
  => Start VHEν Search (Earth)