From Bottom to Top

The Particle-Astrophysics Experiments in LeCosPA

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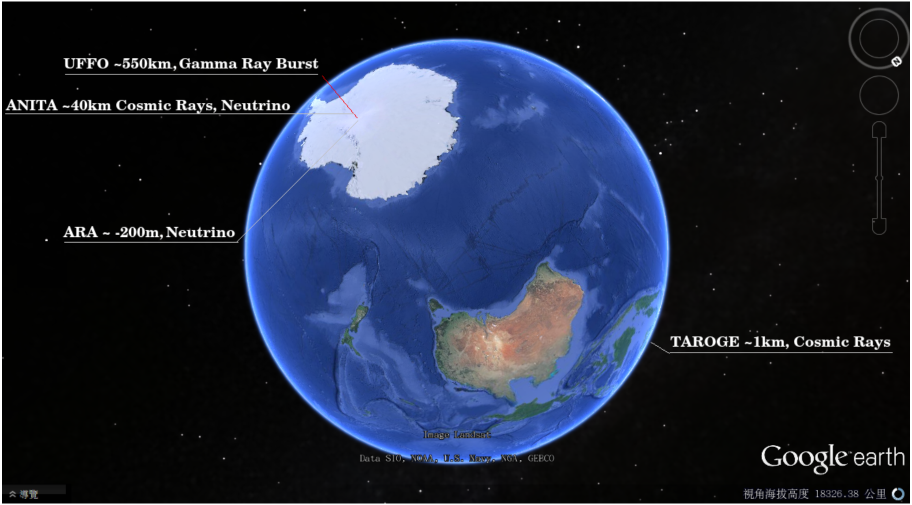
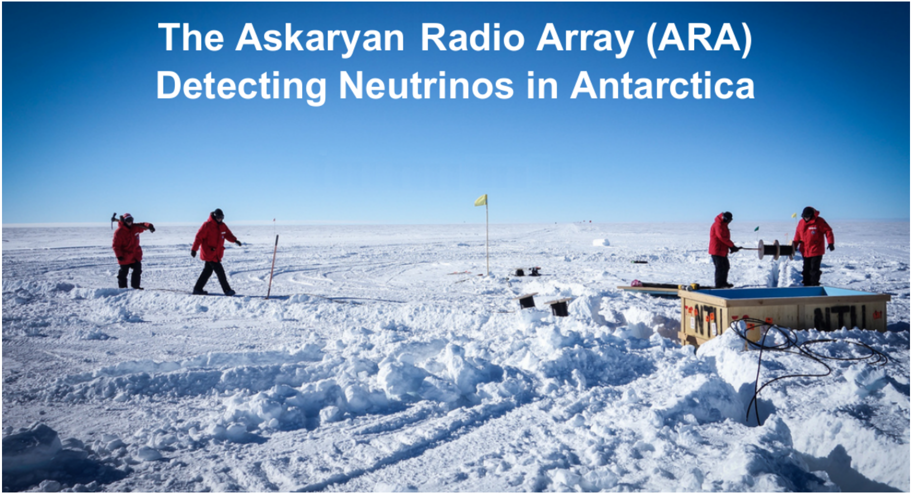
LeCosPA,
National Taiwan University

October 2, 2013

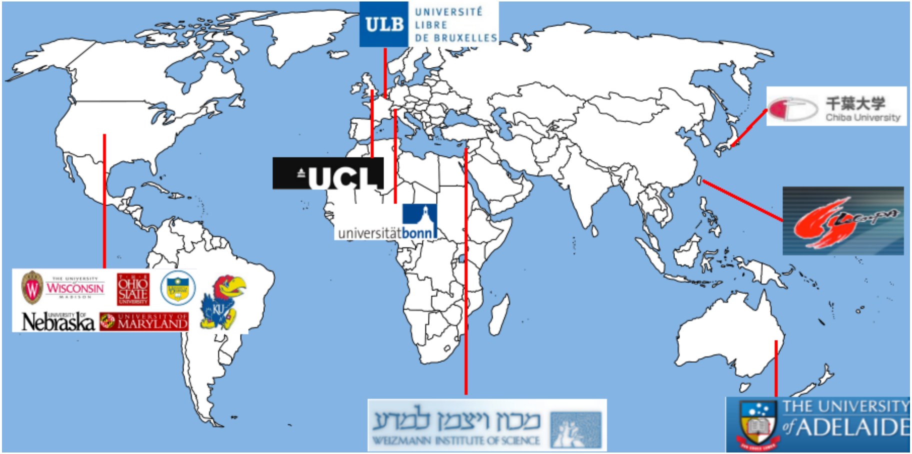
Outline: The Distribution of Experiments



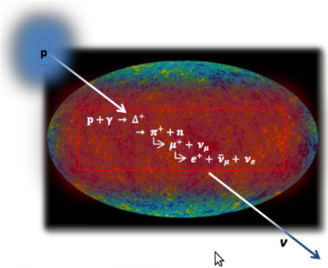
ARA at -200m


The Askaryan Radio Array (ARA)
Detecting Neutrinos in Antarctica
NTU
NTU

The ARA Collaboration



The Askaryan Radio Array (ARA) is an Ultra High Energy (UHE) Neutrino Detector at the South Pole



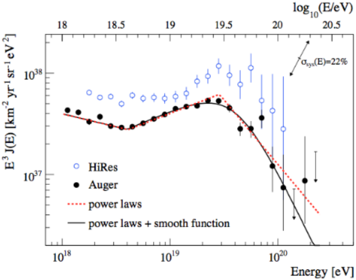
Auger and HiRes measurements of UHE cosmic rays consistent with GZK cut-off

Guaranteed GZK neutrino flux, but how large?

copy from Jonathan's slides

At energies above ~$10^{19.5}$eV cosmic rays will interact with CMB photons producing neutrinos

Process is known as the GZK effect



The Pierre Auger Collaboration (2010): Phys. Lett. B 685 (4–5): 239–246. HiRes Collaboration, Astropart. Phys. 32 (2009) 53.

Coherent Radio Emission (Askaryan Radiation)

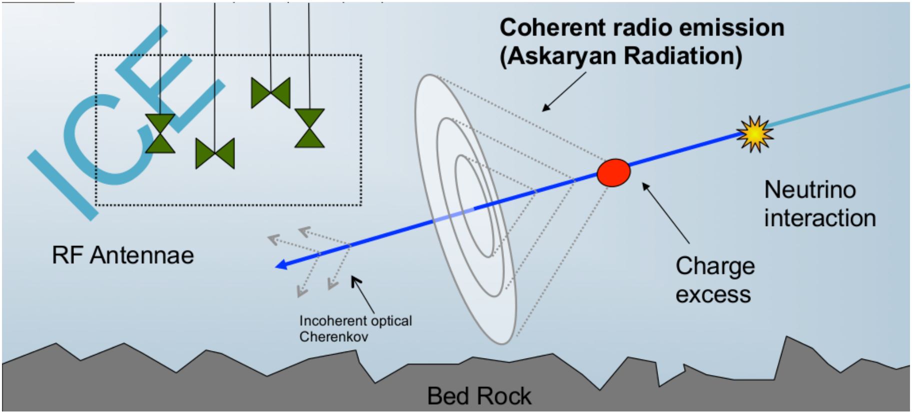
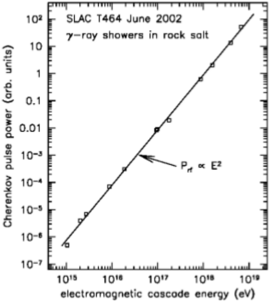
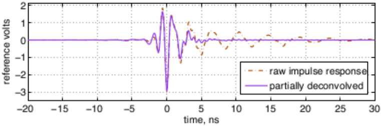


Figure: Detect radio emission from neutrino induced particle cascades in ice

Askaryan Radiation in SLAC





PRL 99, 171101 (2007)
see also:
PRE 62, 8590 (2000),
PRL 86, 2802 (2001),
PRD 72, 023002 (2005)
PRD 74, 043002 (2006)

copy from Ryan's slides

ARA-37

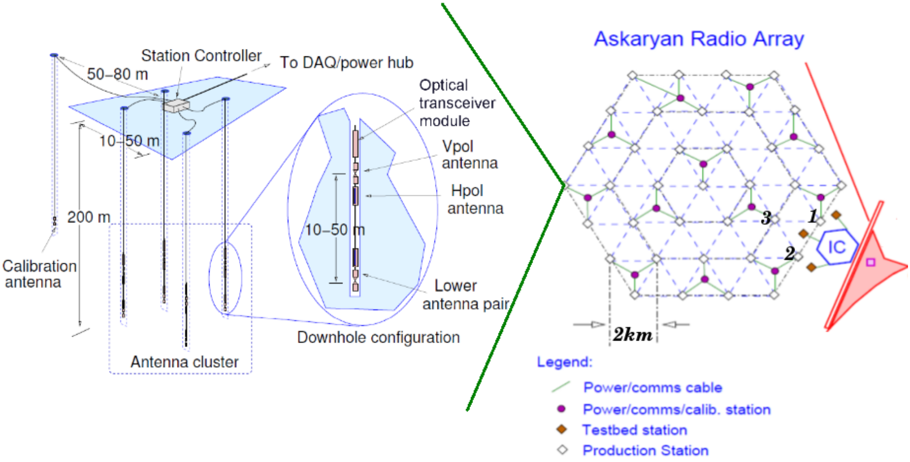


Figure: ARA 37 Layout, 37 Stations 200m below the surface∼200km^2 coverage

DAQ System and Antrnna Cluster

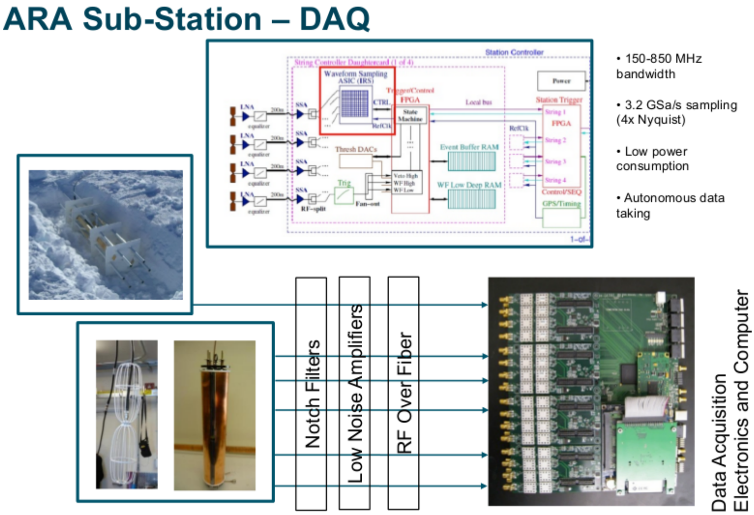


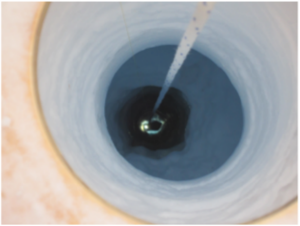
Figure: Each station has 4 string with 16 channels

Build, Test, & Delivery

Figure: Building ARA2 & ARA3 last year

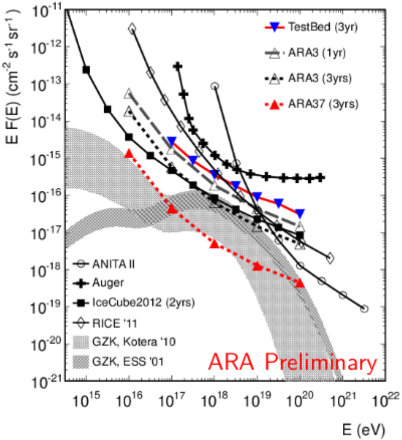
Drilling and Deployment

- Hot water drill creates 6" wide holes
- Holes are pumped dry
- Approaching $\sim 8\,\text{hr} \times \sim 1$ drill crew per 200 m hole
- Instrumentation deployed from greenhouse sled

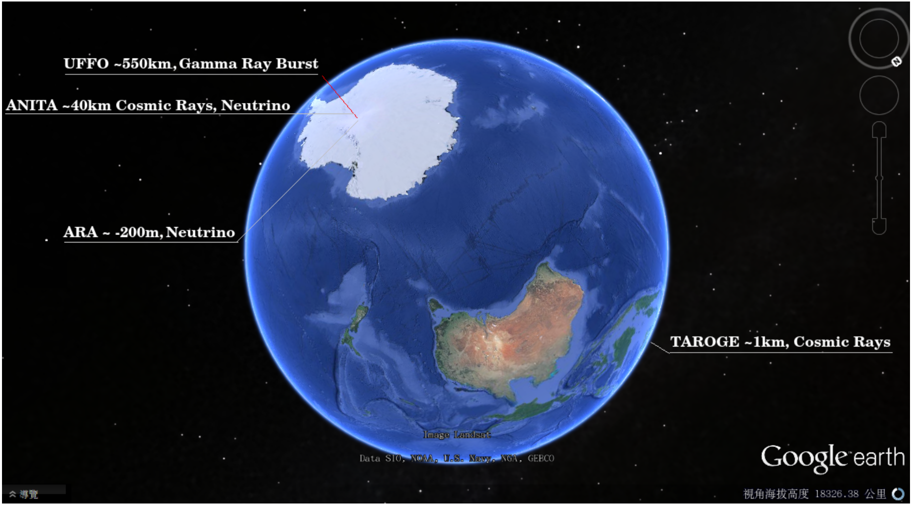


Simulation & Expected Sensitivity

- In-house tool called AraSim
- Simulates
  - → neutrino interaction
  - → radio emmission
  - → radio propagation
  - → instrument response
  - → thermal, instrument noise
  - → hardware trigger
  - → digitized waveforms
- Has been used to calculate trigger-level neutrino sensitivity

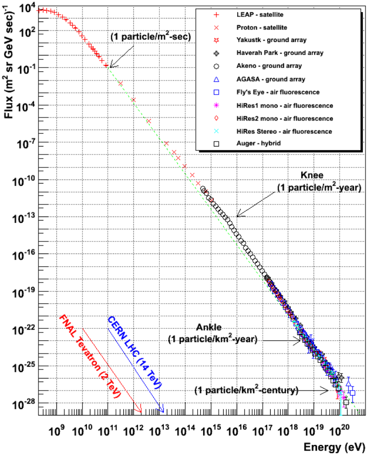


Outline: The Distribution of Experiments



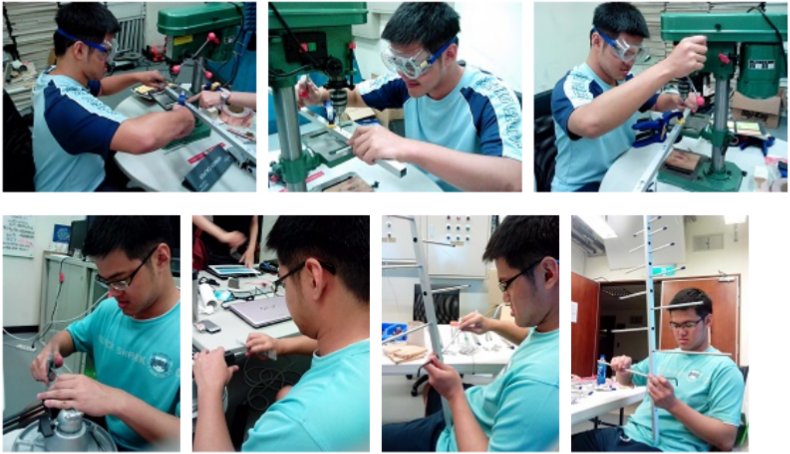
TAROGE at 1200˜2000m

Cosmic Background Flux



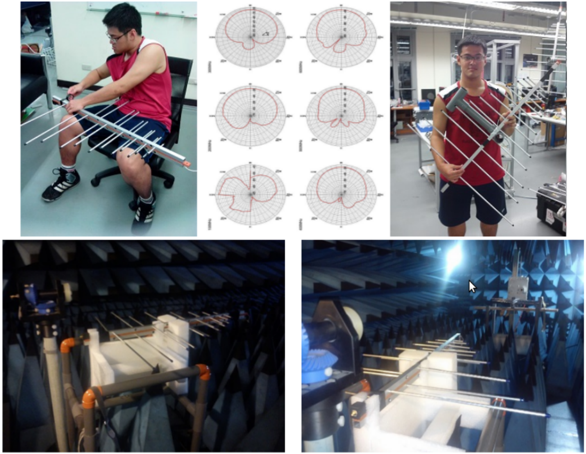
Cosmic ray spectra of various experiment

Building Antenna

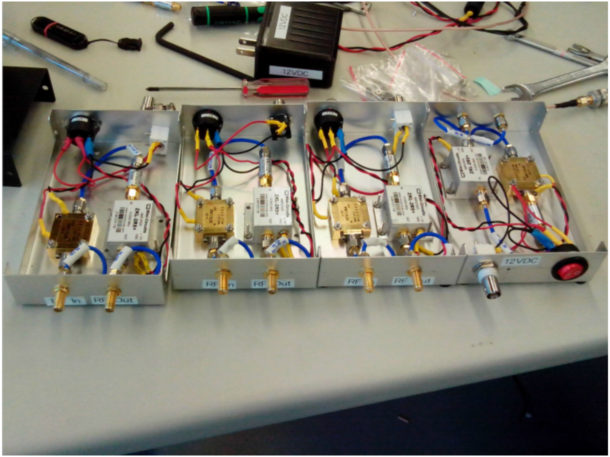


Summer intern student from FJU and NCTU makeing the antenna.

Testing Antenna



LNAs of TAROGE



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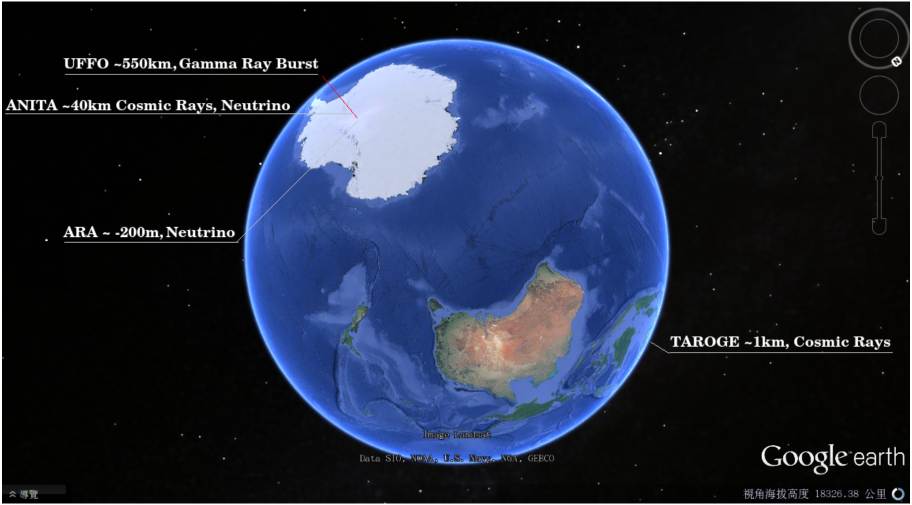
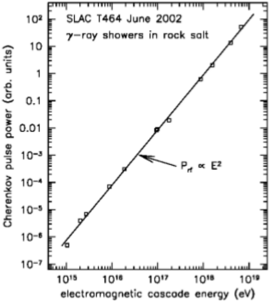
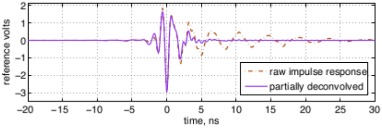


The ANtarctic Impulsive Transient Antenna

Askaryan Radiation in SLAC





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see also:
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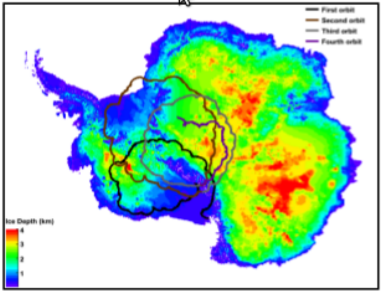
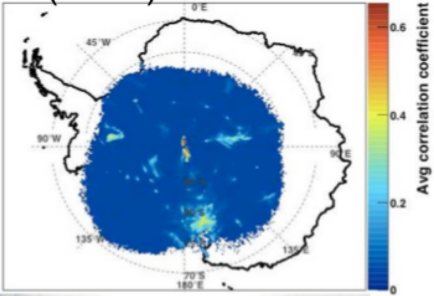
PRD 74, 043002 (2006)

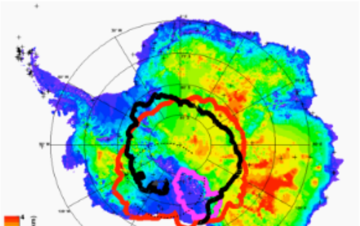
copy from Ryan's slides

Flight Path

- Over 65 days of flight over Antarctica
- Over 35 million triggered (noise) events

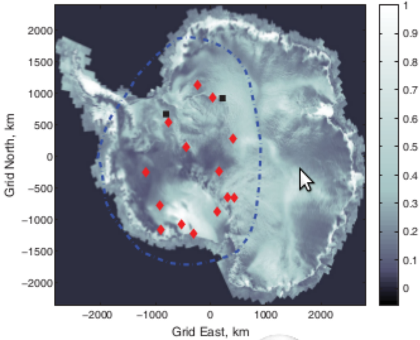


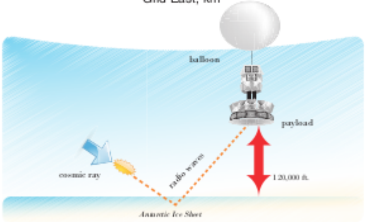




Rsults of ANITA II

PRL **105**, 151101 (2010)





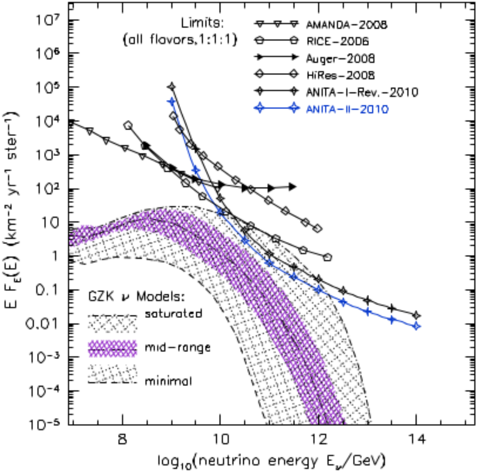
- A combination of **vxB** and Fresnel coefficients result in air shower emission being horizontally polarised at the payload
- ANITA-I detected 16 isolated H-pol candidate UHECR events
- ANITA-II did not trigger on the H-pol channels
  – Doh!!
- Still detected 5 UHECR

Rsults of ANITA II

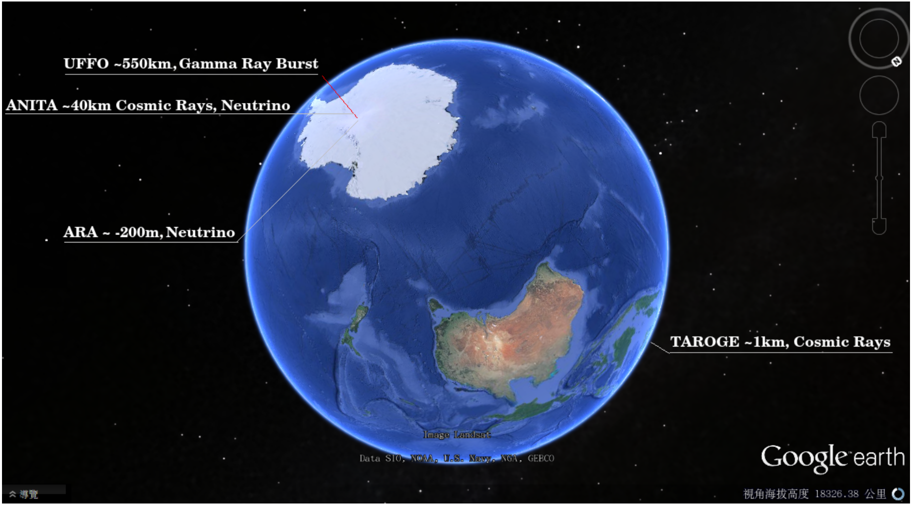
- ANITA-II Results

Isolated v-pol events	1
Expected background events	0.97 ± 0.42

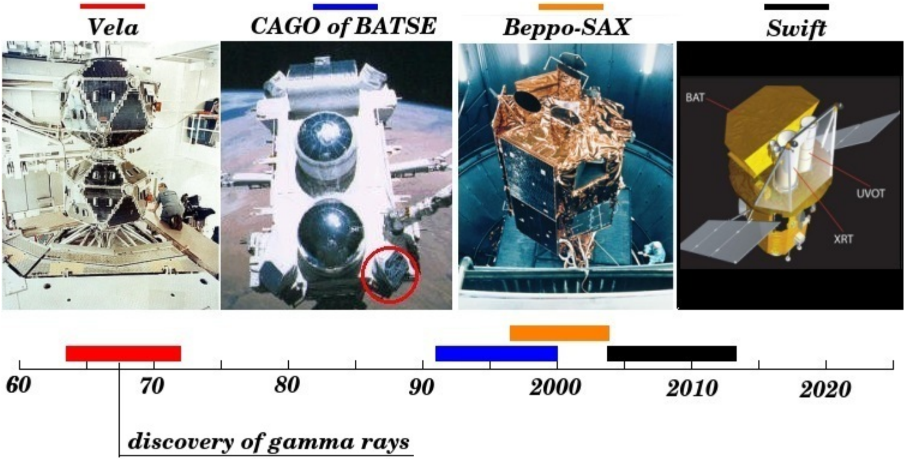
- Combine with efficiency to extract world's best limit on UHE neutrino flux above 10^{19}eV



Outline: The Distribution of Experiments

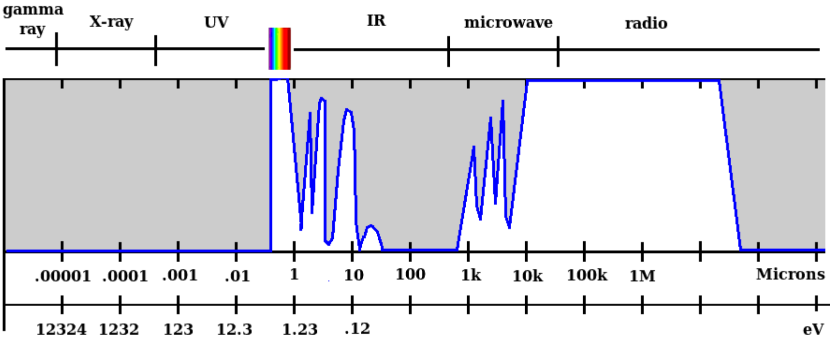


The History of GRB



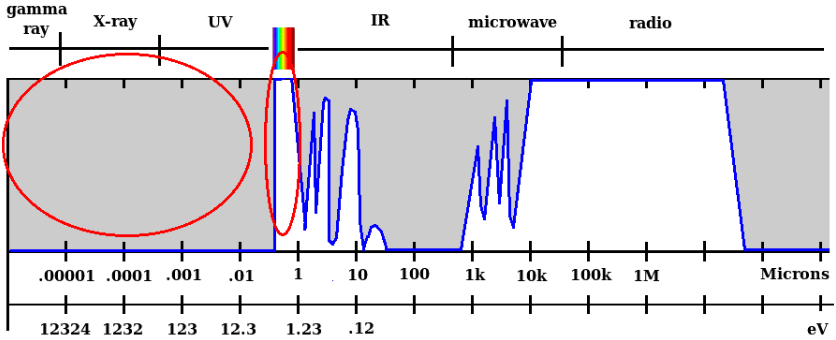
Measurement on the Earth

transmission of atmosphere

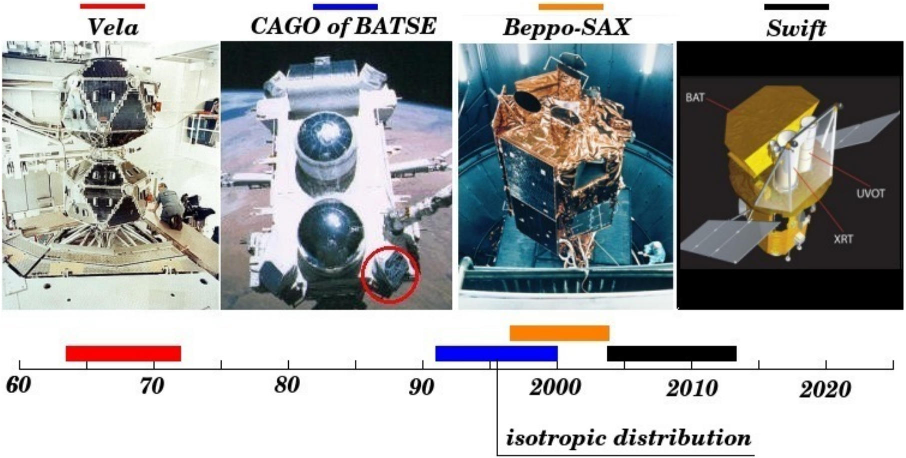


Measurement on the Earth

Absorption of atmosphere

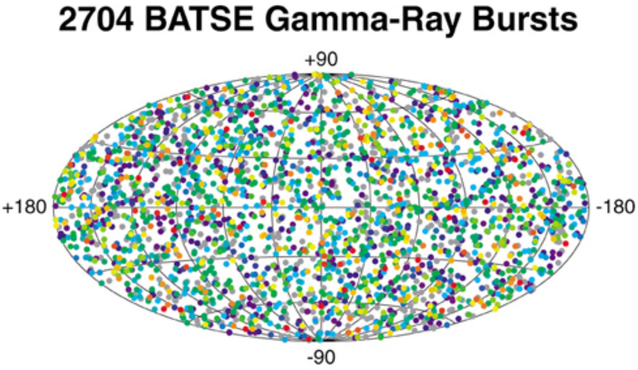


The History of GRB



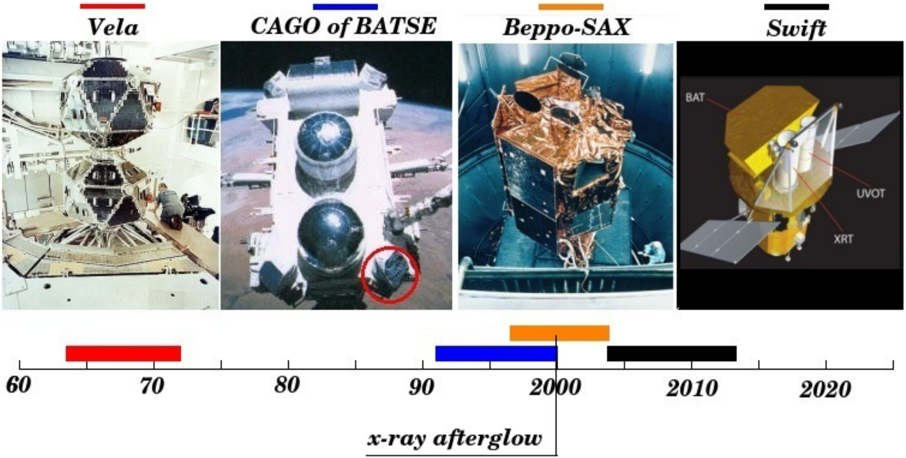
BATSE (Burst and Transient Source Experiment)

The distribution of GRBs



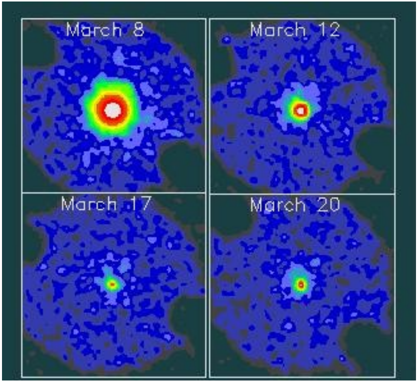
The distribution of 2704 GRBs is isotropic, with no concentration towards the plane of the Milky Way,

The History of GRB



Beppo-SAX (1997-2004)

The afterflow of GRBs

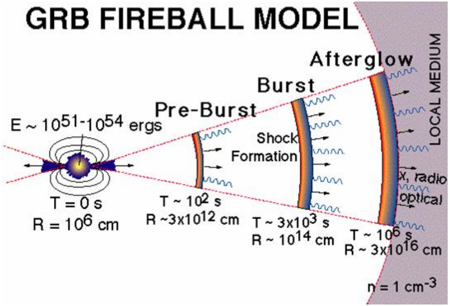


Beppo-SAX satellite succeeded in detecting them in X-ray, which after a delay of 20 hours yield sufficiently accurate positions for large ground-based telescope.(William Herschel Telescope)

Gamma Ray Burst(GRB)

Types & Basic Proprieties

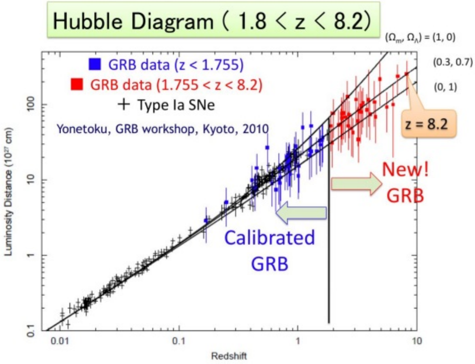
- Typical energy : $10^{51} \sim 10^{54}$ergs
- Duration : ms∼minutes

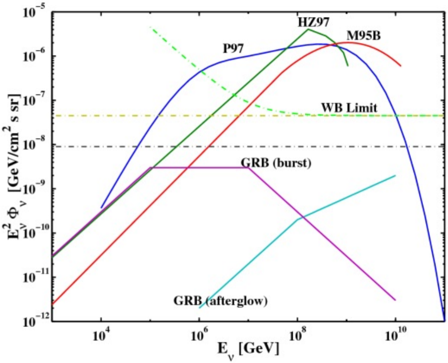


The Potential of GRB

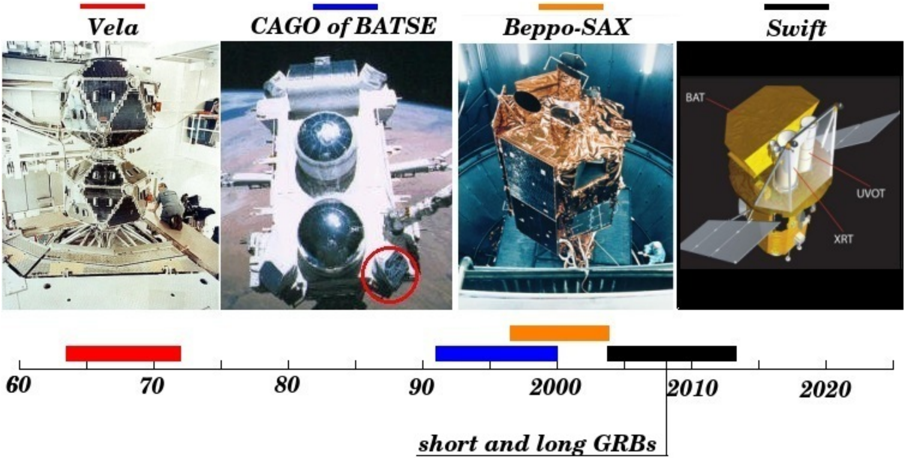
Most Distant of GRB Detected in 2009 (090423)

- The Most Luminous Events Seen in the Universe .
- The Most Distance of Objects until 2009. (Z∼8.23)
- An Origin of Ultra-High Energy Neutrino.





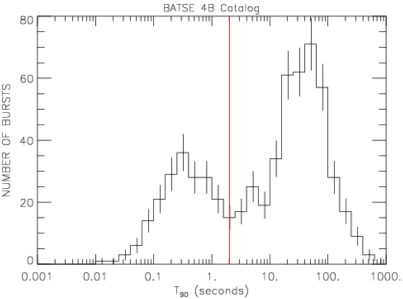
The History of GRB

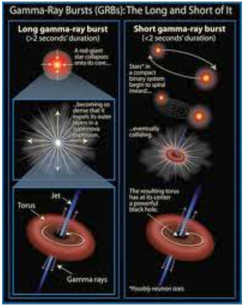


GRB

Types & Basic Proprieties

- Short-hard GRBs ($T_{peak} < 2$ secs): This type originate from the mergers of binary neutron stars (NS-NS, BH-NS). [1, 2, 3, 4, 5]
- Long-soft GRBs : This type originate from the core collapse of massive stellar proarity (hypernova). [6, 7, 8, 1, 2, 3]





New Pproject : UFFO pathfinder.

UFFO pathfinder

Ultra Fast Flash Observatory

Current Limits of Rapid Response Measurements

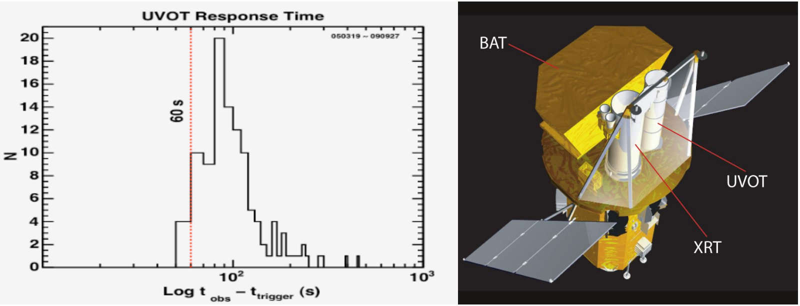
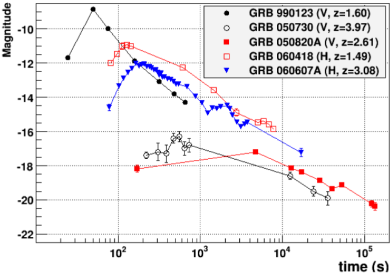


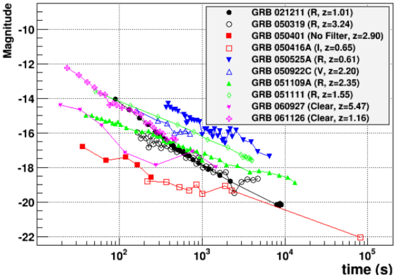
Figure: The distribution of UVOT response time. Only 4 events less then 60 secs.

Photon Measurements

Importance of Early Photon Measurements



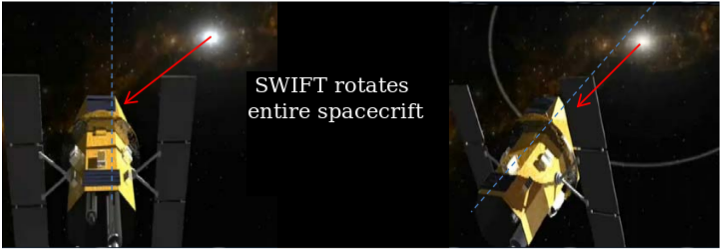
Fast-Risingclass

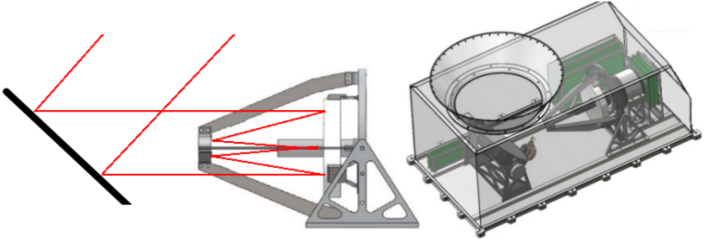


Decay class

Figure: Left Panel: The fastest-rising light curves are poorly sampled of the early time. Right Panel: The light curves of the decay class. Since the rise time is not known for the decay class bursts, the correlation cannot be tested among all these bursts.

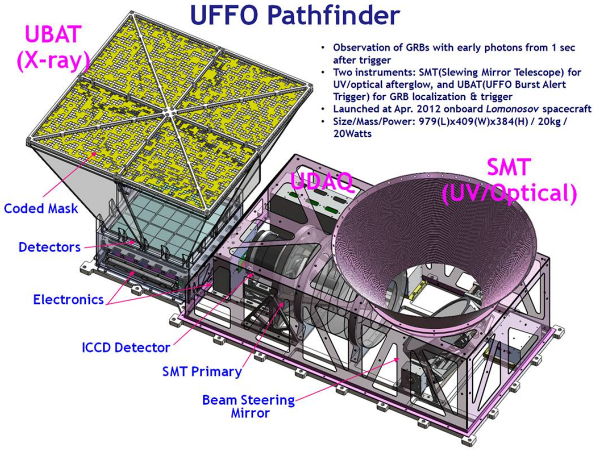
III. Why should we need the new telescope





UFFO rotates the mirror instead of the spacescrft

UFFO pathfinder?



UFFO Collaboration

The Operation of UFFO

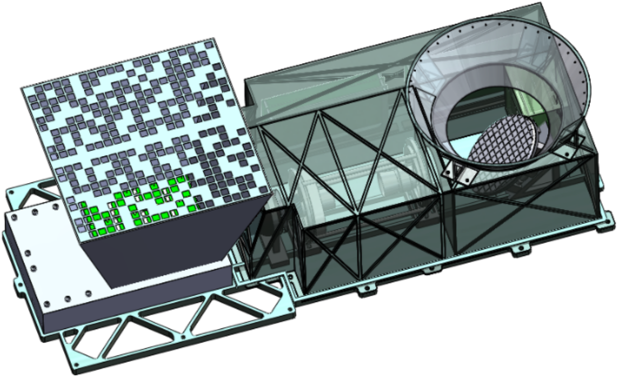


Figure: UFFO-Pathfinder

The Operation of UFFO

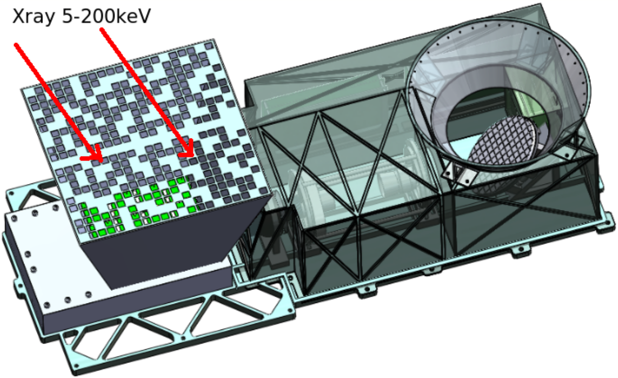


Figure: UFFO-Pathfinder

The operation of UFFO

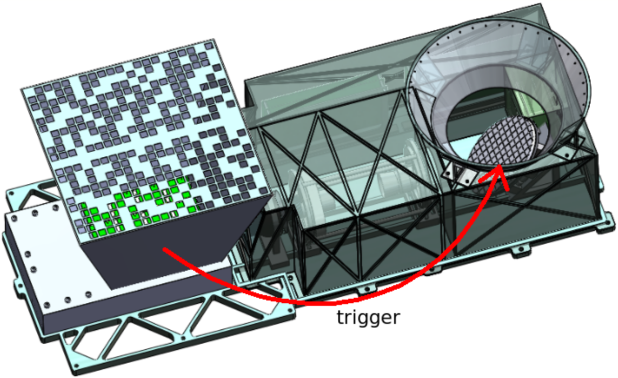


Figure: UFFO-Pathfinder

The Operation of UFFO

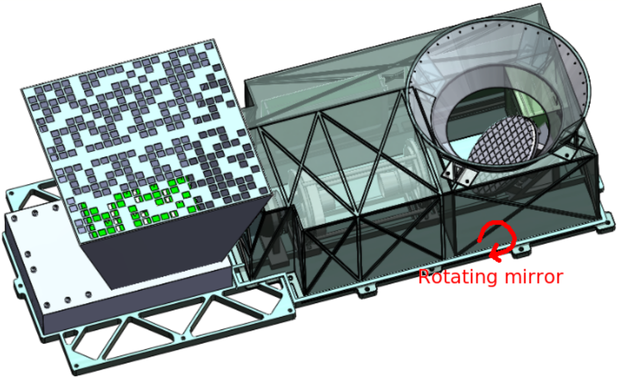


Figure: UFFO-Pathfinder

The Operation of UFFO

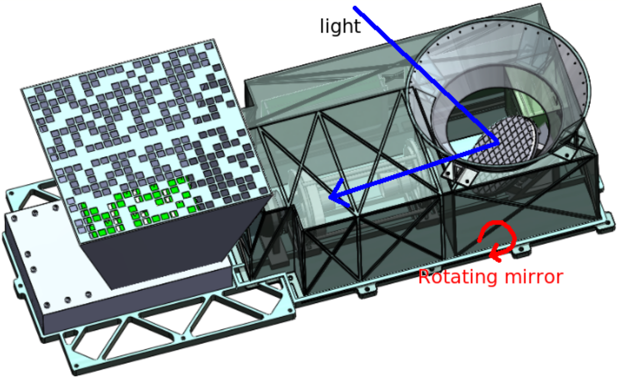


Figure: UFFO-Pathfinder

The Operation of UFFO(UBAT part)

UFFO Burst Alert & Trigger telescope

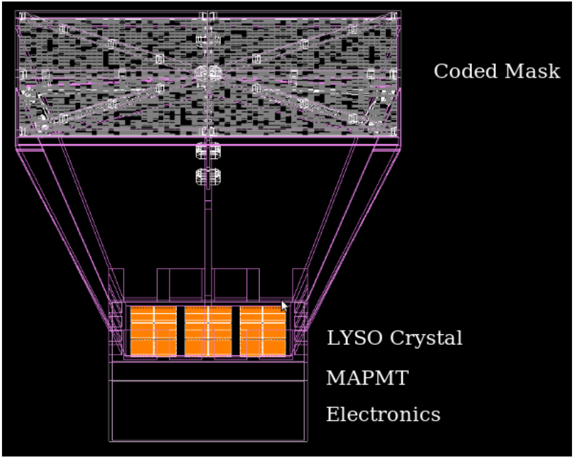


Figure: UBAT, sensitive energy range of 10 - 250 keV.

The Operation of UFFO(Coded Mask)

UFFO Burst Alert & Trigger telescope

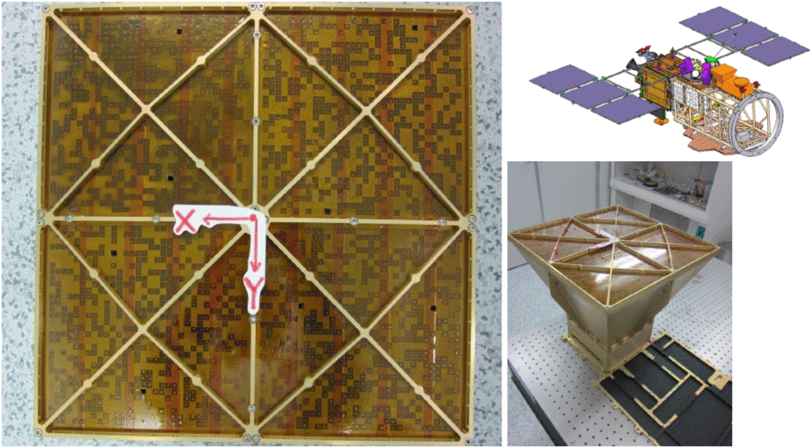
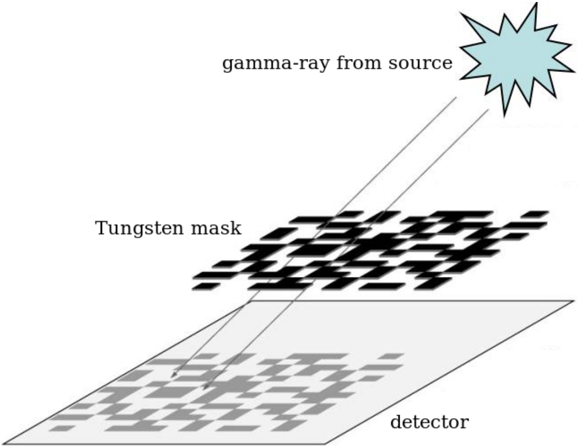


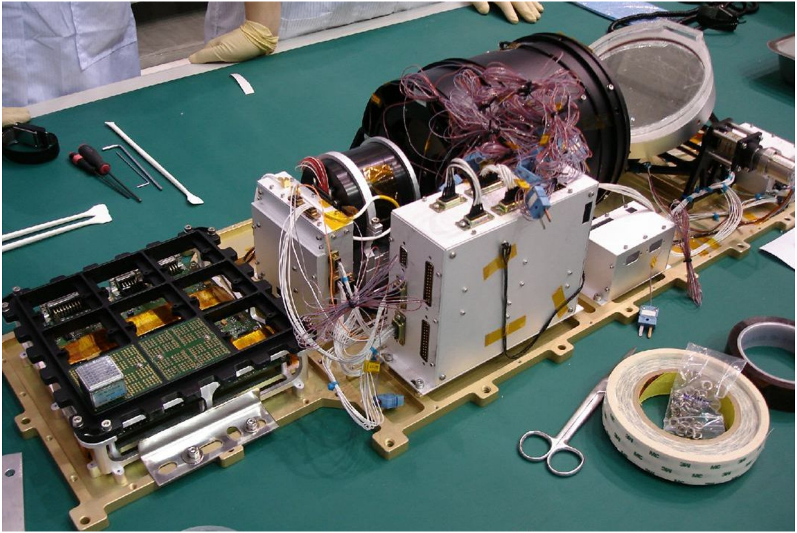
Figure: Code mask is made by 1 mm thickness tungsten and is pasted by 12.7μm Kapton tape.

The Operation of UFFO (Coded Mask)



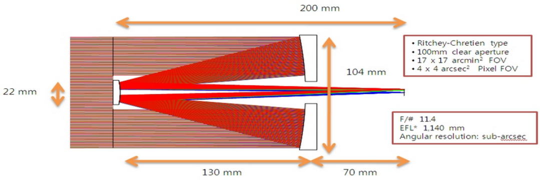
Gamma rays are stopped by mask and form the particular pattern on the detector plane.

The Operation of UFFO (SMT part)



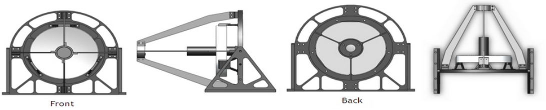
The Operation of UFFO (SMT part)

The Operation of UFFO (SMT part)



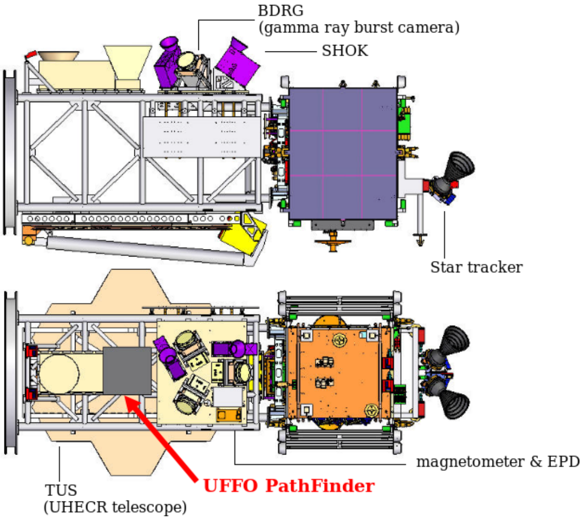
Optomechanics

Total mass = 953 g
Obscuration ratio(area) = 13%
180(H) X 235(W) X 180(L) mm³



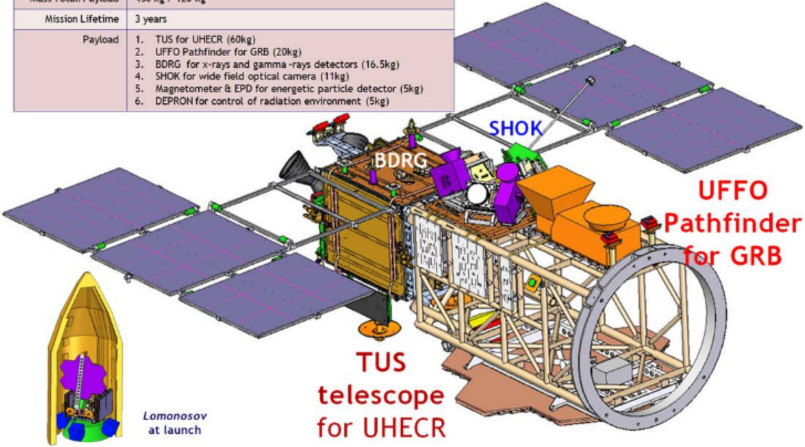
Intensified CCD

The Location of UFFO



Lomonosov

Spacecraft & Builder	*Lomonosov* & FGUM-VNIIEM
Launch Date	Apr. 2012
Orbit	Circular solar synchronous, height: 550 ± 10 km
Mass Total/Payload	450 kg / 120 kg
Mission Lifetime	3 years
Payload	1. TUS for UHECR (60kg) 2. UFFO Pathfinder for GRB (20kg) 3. BDRG for x-rays and gamma -rays detectors (16.5kg) 4. SHOK for wide field optical camera (11kg) 5. Magnetometer & EPD for energetic particle detector (5kg) 6. DEPRON for control of radiation environment (5kg)

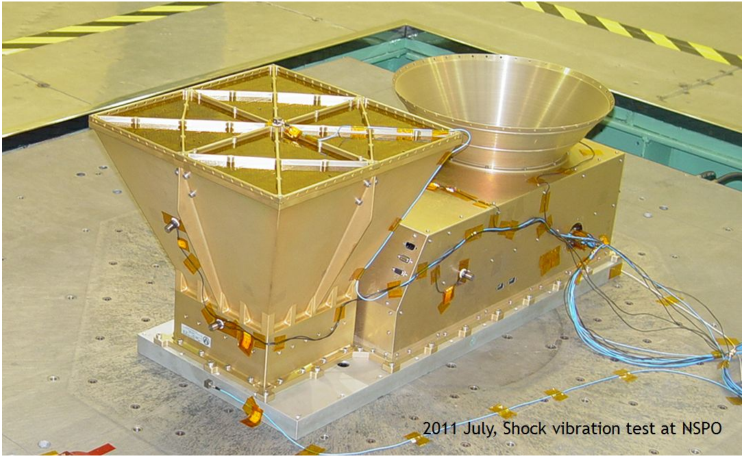


Works in Taiwan

- A. Thermal Vacuum and Vibration Test.
- B. MAPMT Calibration, YSO crystal intrinsic background measurement and simulation.
- C. Cosmic background simulation. (cosmic ray, diffuse gamma ray, and e^- & e^+)
- D. Alignment and calibration of optical system.
- E. Damage test.

Vibration Test in NSPO (Launch Environment)

Vibration Test in NSPO (Launch Environment)



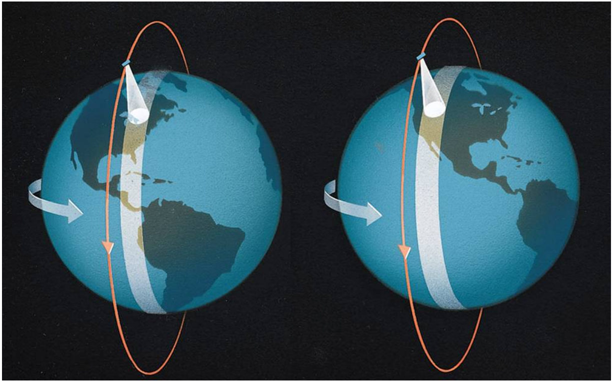
Vibration Test in NSPO (Launch Environment)

Video!!!

Video!!!

Video!!!

Thermal-vacuum test (space environment)



height:550 $\pm$ 10km, period:90 minutes

Thermal-vacuum test (space environment)

The optical devices of UFFO operated successfully under the rigorous thermal-vacuum cycles, from $+40^o$ to $-30^o$and 10^{-7} mbar.

MAPMT and Crystal Test

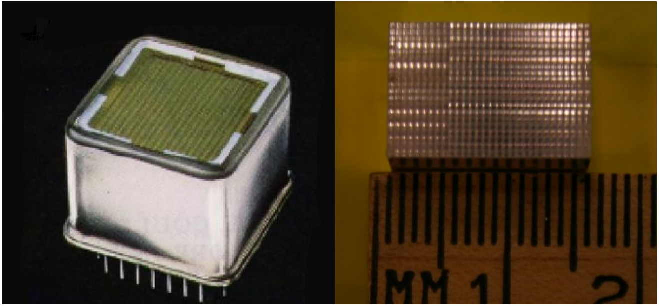
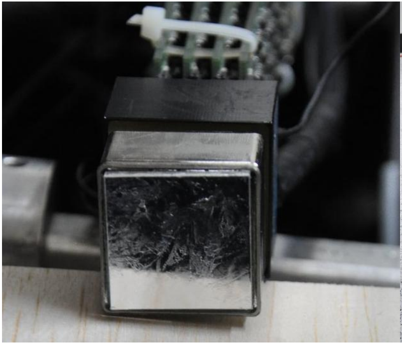


Figure: Crystal and MAPMTs

MAPMT Calibration



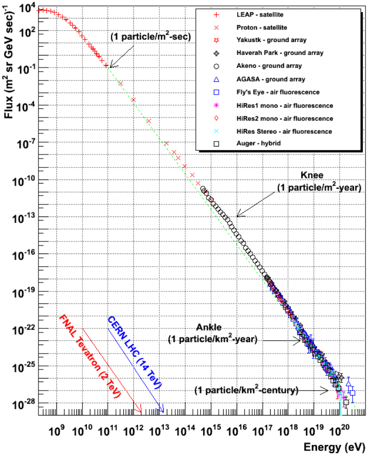
64 channels MAPMT

Dark box

Background Simulation

- Cosmic ray.
- Diffuse gamma ray.
- e^+ and e^-.
- Solar wind.

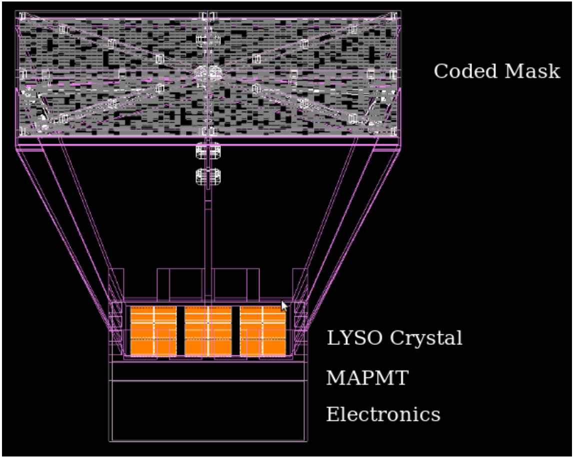
Cosmic Background Flux



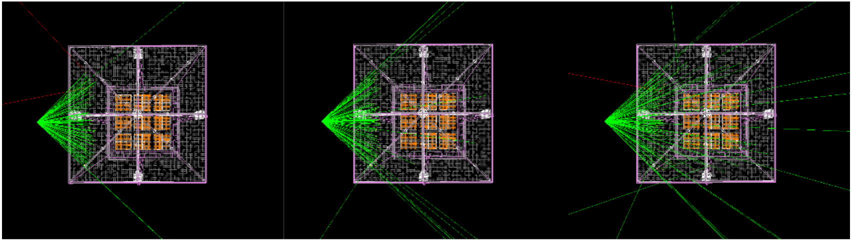
Cosmic ray spectra of various experiment

UBAT Model Building

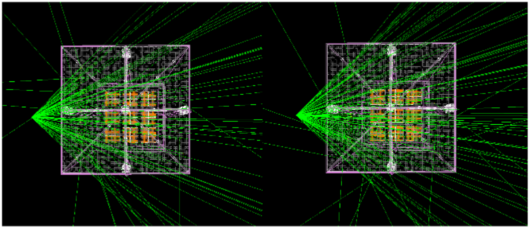
We build the upper UBAT system, which over the MAPMT plane by GEANT4.



Diffuse Gamma Ray Background

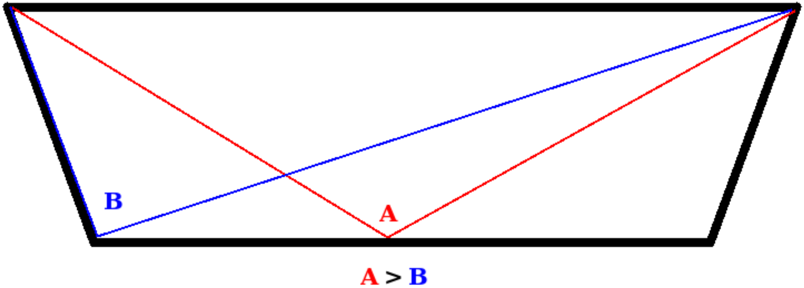


10, 20, & 30keV from left to right



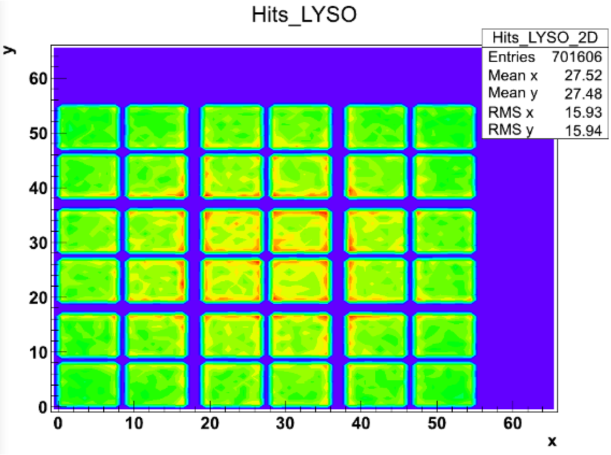
50 & 70keV

Diffuse Gamma Ray Background

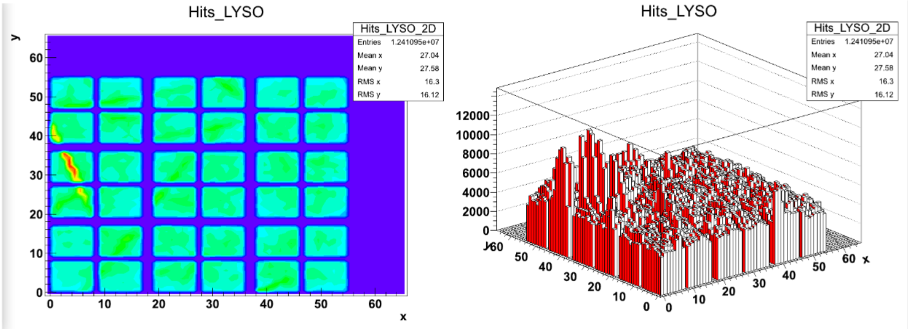


Low energy photons stop by the wall.

30 keV Photon

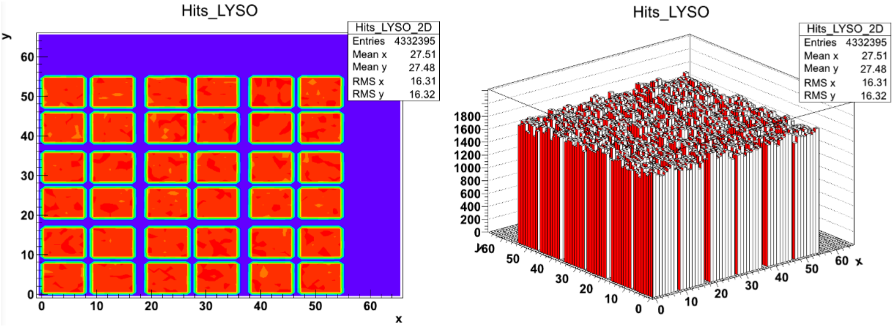


Cosmic Ray Background Result

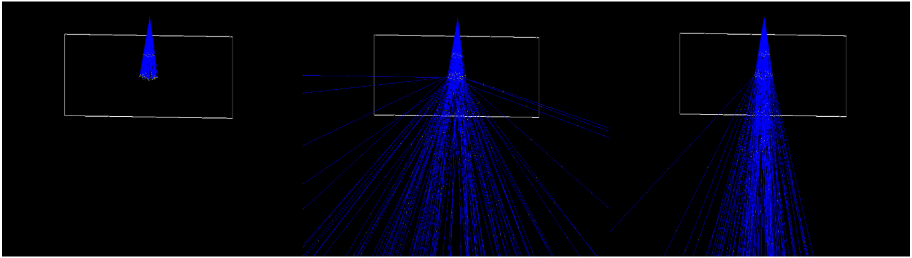


Shower events

Diffuse Gamma Ray Background Result

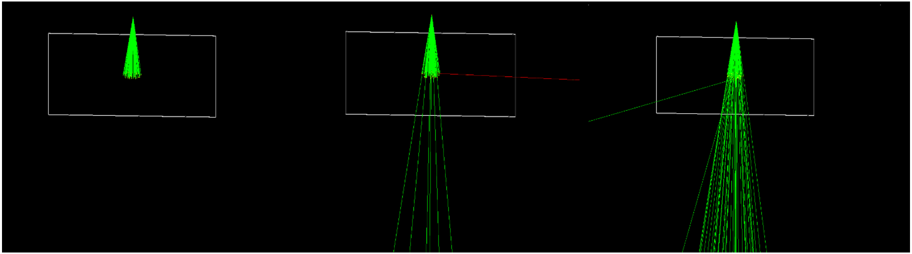


Protons Hit 1mm Thickness Tungsten Mask



20 MeV 30 MeV 40 MeV

Photons Hit 1mm Thickness Tungsten Mask



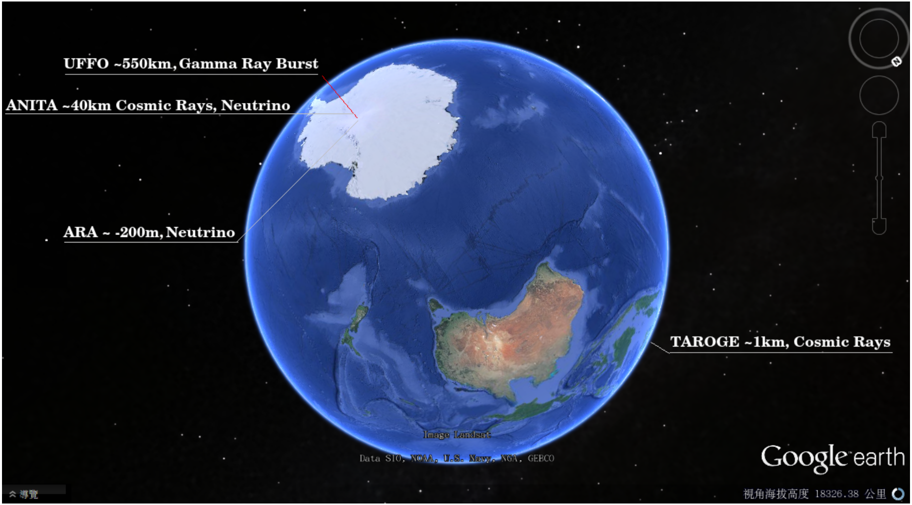
130 keV 150 keV 230 keV

The mask cannot stop the high energy photon. In other words, the upper limit of energy range is about 250 keV.

Launch Schedule

Launch time : 2014, Auguest

Outline: The Distribution of Experiments



S. AHMAD[2], K. AHN[3], P. BARRILLON[2], S. BLIN-BONDIL[2], S. BRANDT[4], C. BUDTZ-JϕRGENSEN[4], A.J. CASTRO-TIRADO[5],P. CHEN, H.S. CHOI[6], Y.J. CHOI[7], P. CONNELL[8], S. DAGORET-CAMPAGNE[2], C. DE LA TAILLE[2], C. EYLES[8], B. GROSSAN[9], I. HERMANN[7], M.-H. A. HUANG[10], S. JEONG[11], A. JUNG[11], J.E. KIM[11], S.H. KIM[3], Y.W. KIM[11], J. LEE[11], H. LIM[11], E.V. LINDER9[9,11], T.C. LIU[1], NIELS LUND[4], K.W. MIN[7], G.W. NA[11], J.W. NAM[1], K. NAM[11], M.I. PANAYUK[12], I.H. PARK[11], V. REGLERO[8], J.M. RODRIGO[8], G.F. SMOOT[9,11] , Y.D. SUH[7], S. SVELITOV[12], N. VEDENKEN[12], M.-Z WANG[1], I. YASHIN[12], M.H. ZHAO[11]

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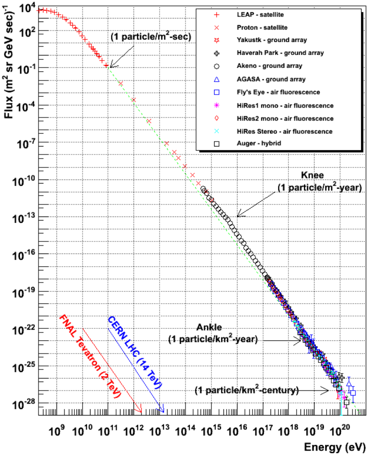
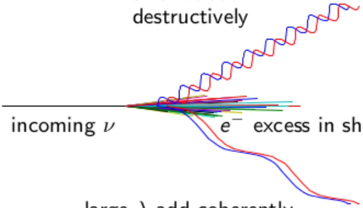
Cosmic Background Flux



Cosmic ray spectra of various experiment

Askaryan Effect

- Askaryan effect: Neutrinos with energy above $\sim 30\,\text{PeV}$ most efficiently detected with radio
- Delta-ray production, Compton scattering and positron annihilation give charge excess
- Compact bunch moves together
- Long wavelengths add coherently



The South Pole has the perfect combination of ice volume, ice RF-transparency, and existing science infrastructure for this experiment.

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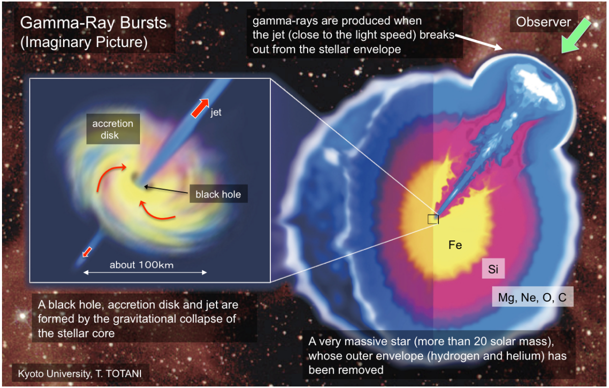
Massive Star Collapse (Long-Soft)

Types & Basic Proprieties



The massive star collapse.

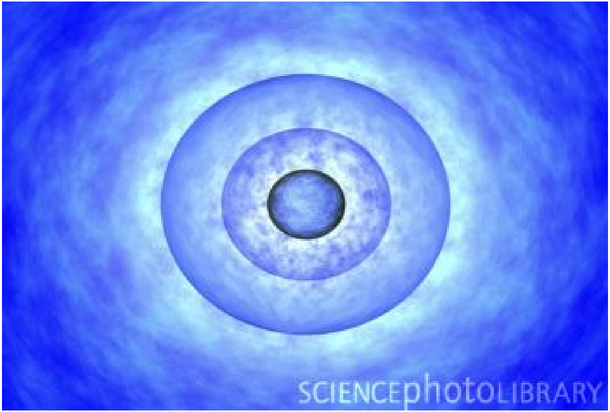
Massive Star Collapse (Long-Soft)

Types & Basic Proprieties

A massive star with 10-15 solar masses just before its core collapses during a gamma ray burst (GRB) event.

Massive Star Collapse (Long-Soft)

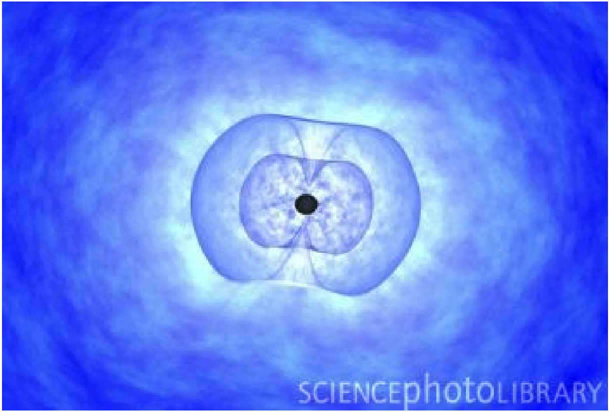
Types & Basic Proprieties



The core of a massive star just before the inner core (centre) collapses under its own weight in a gamma ray burst (GRB) event.

Massive Star Collapse (Long-Soft)

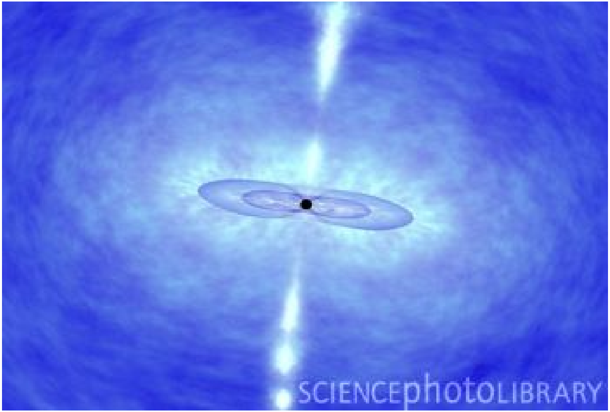
Types & Basic Proprieties



The core of a massive star just after the inner core (centre) collapsed to form a black hole in a gamma ray burst (GRB) event.

Massive Star Collapse (Long-Soft)

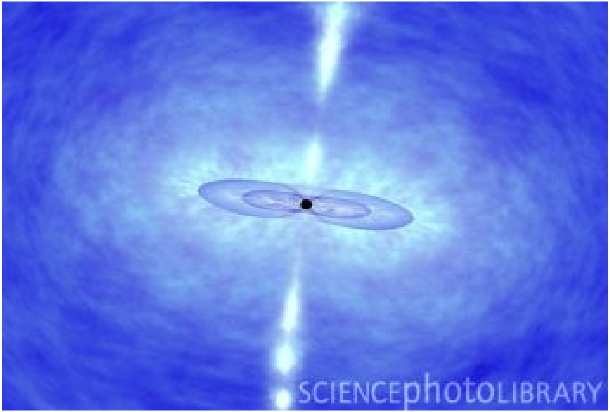
Types & Basic Proprieties



The black hole is ejecting the surrounding material as jets (white) from the poles of the black hole towards the star's surface.

Massive Star Collapse (Long-Soft)

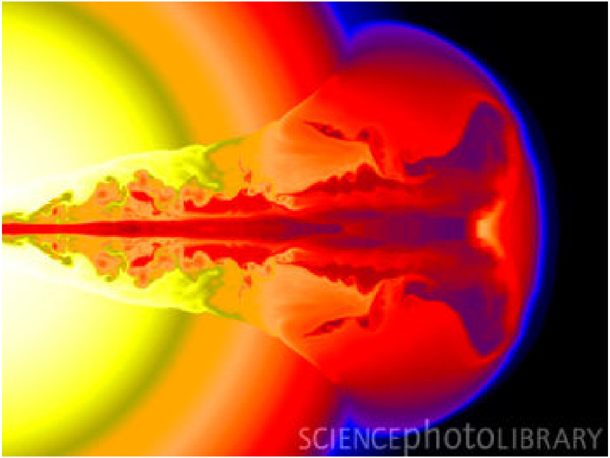
Types & Basic Proprieties



It says the spin or magnetic field of the black hole forms these jets that are the source of the gamma rays of the GRB, a massive short-lived burst of energy that is 100s of times brighter than an ordinary supernova.

Jet from Massive star Collapse

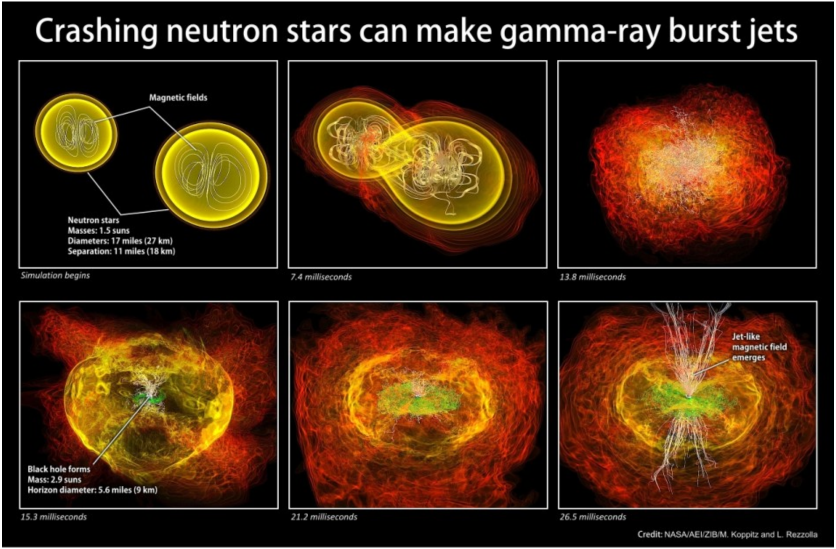
Types & Basic Proprieties



A relativistic jet 10 seconds after its creation. Colours, representing density from low to high, are blue, red and yellow.

The Mergers of Binary stars(Short-Hard)

Types & Basic Proprieties



UBAT Model Building

name		material	color	thickness
hopper		Aluminum	purple	3 mm
mask		Tungsten	gray	1 mm
kapton tape		kapton($C_{22}H_{10}N_2O_5$)	white	0.0127 mm(0.5 mil)
LYSO		LYSO	orange	1.96mm
reflector		PEN($C_{14}H_{10}O_4$)	white	60μm
electric box		Aluminum	purple	6.4mm