Potential Impacts of EATS to Space Astronomy

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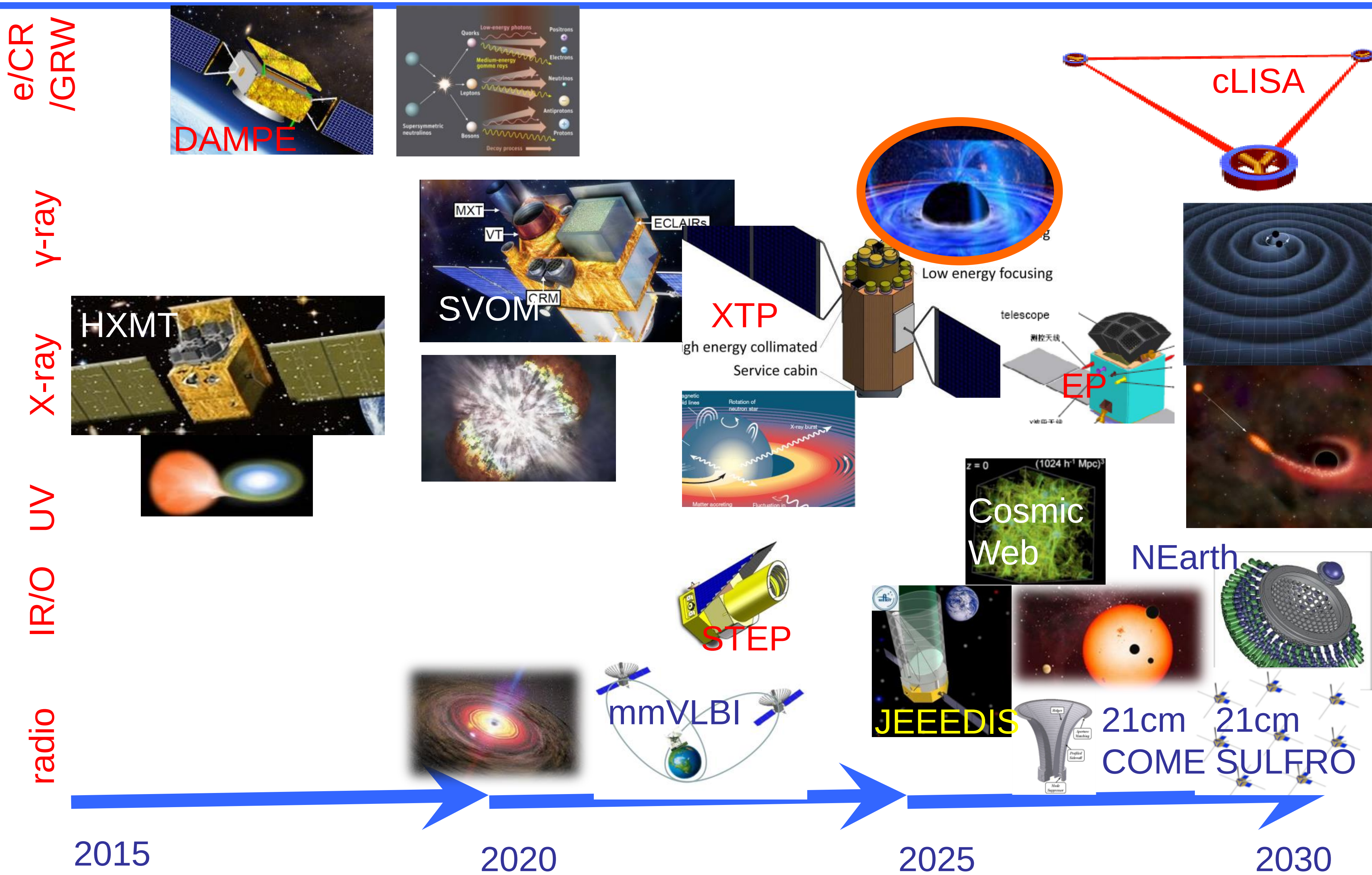
China's Space Astronomy Satellites



China's Space Station Program

2020

Phase -II

2016

Phase -II

2011

Phase -I

2003

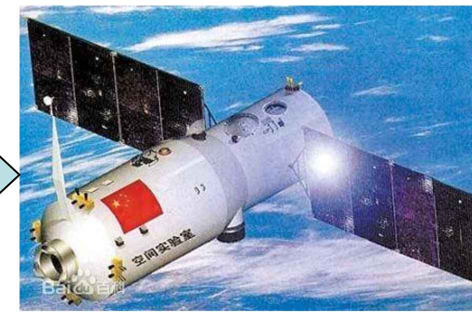
Space Station

3 large modules

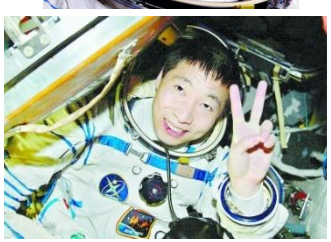
+ 2 m telescope

~10-year lifetime

Space lab: no living cabin

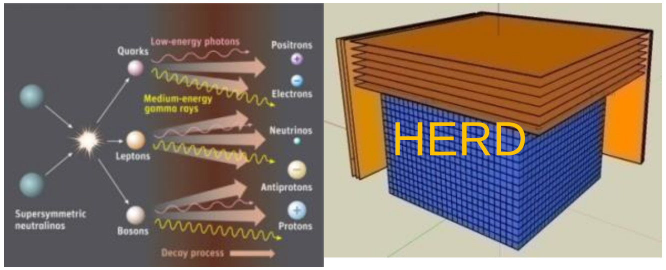


10 astronauts in 5 flights → space walk



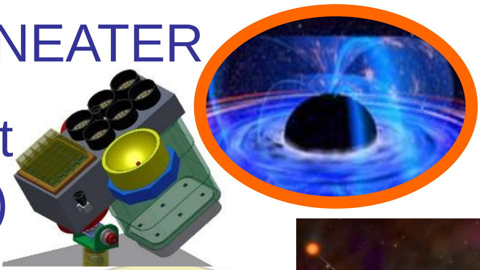
China's Space Station Astronomy Program

e/CR



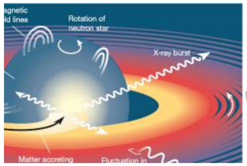
γ-ray

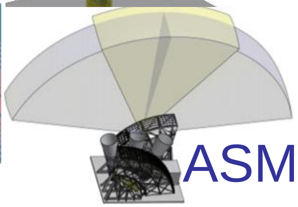
NEATER



(a mini XTP but with low-E pol.)

X-ray





ASM

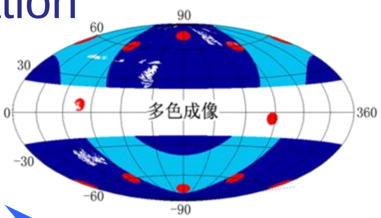
(EP in scanning mode without XFT)

?

IR/O

Chinese Space Station Optical Survey

Dark Energy



2015 2020 2025 2030

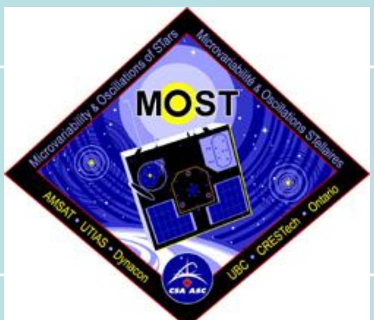
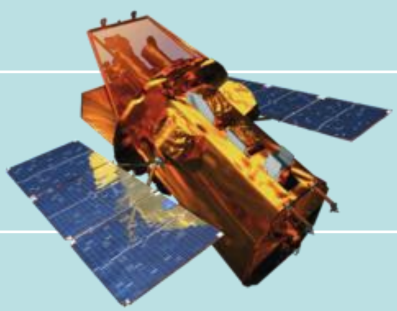
World's largest optical telescopes: ground

10 telescopes with aperture diameter > 8 meters
42 telescopes with aperture diameter > 3 meters

World's largest optical telescopes: space

None with aperture diameter > 3 meters

World's optical telescopes: space

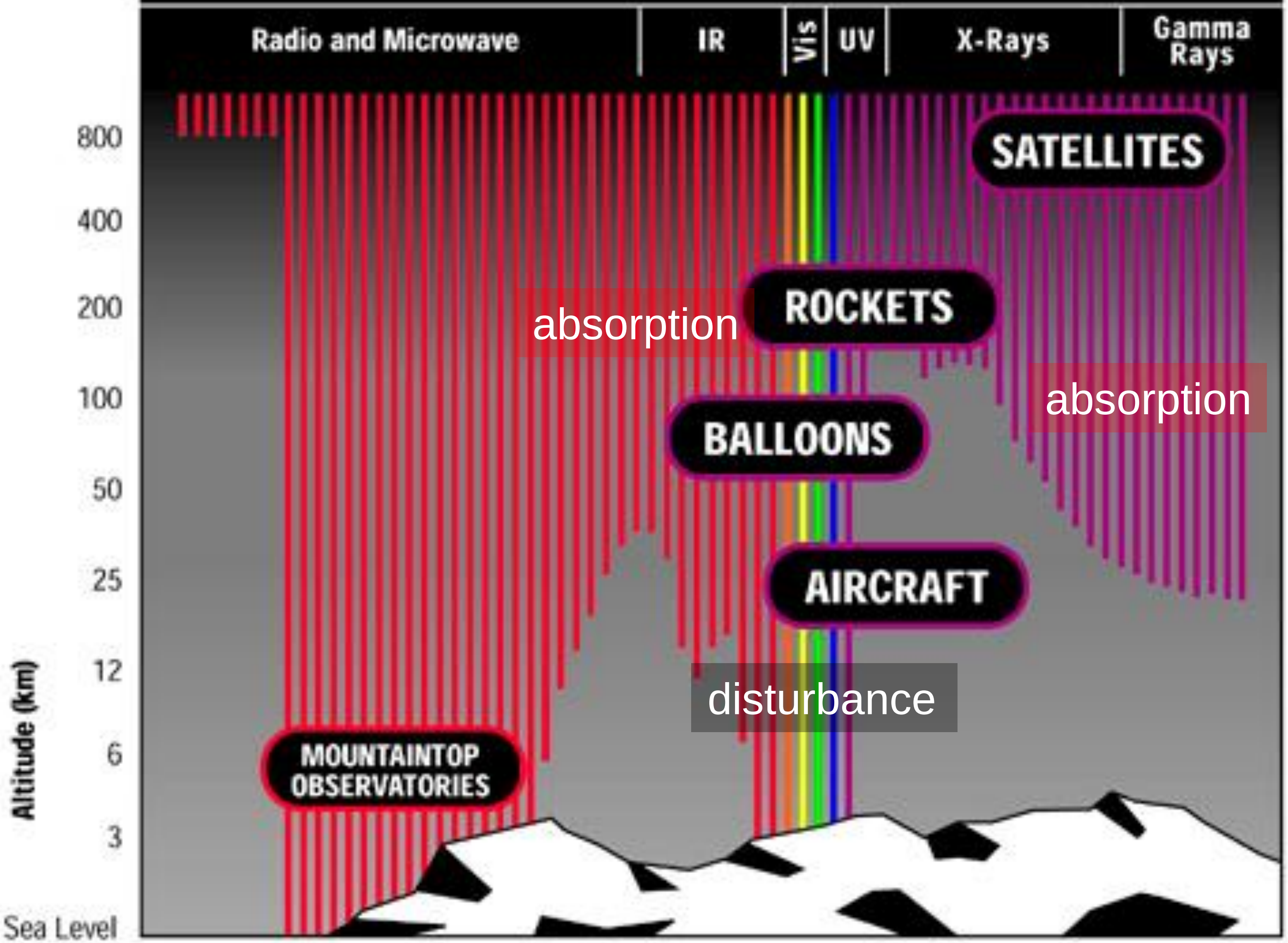
Photo	Name	Space Agency	Launch	Aperture
	Hubble	ESA&NASA	1990	2.4 m
	Kepler	NASA	2009	1 m
	MOST	CSA	2003	15 cm
	Swift	NASA	2004	30 cm
	Gaia	ESA	2013	~1 m

1 for every 5 years: largest and oldest one is Hubble

Why so few and so small in space?

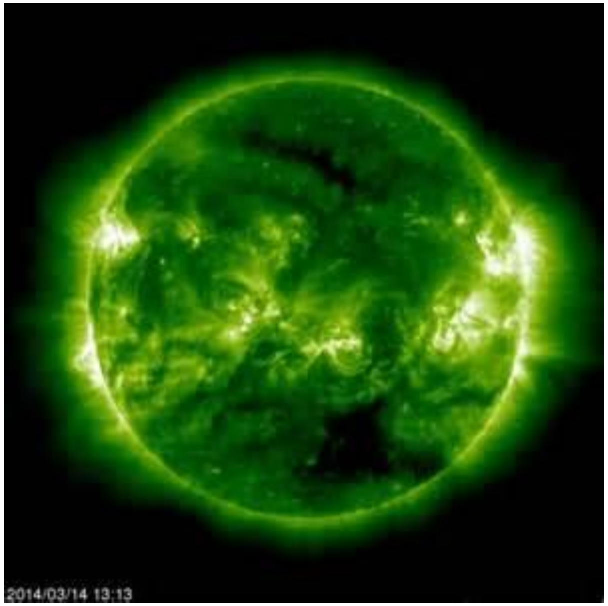
- Telescopes
  - Cost of 2.4 meter telescope on ground: $10-20 M
  - Cost of 2.4 meter telescope in space: $1-2 B
- Experiments
  - The CMS particle spectrometer at CERN: 12500 Ton for $0.5 B
  - The AMS particle spectrometer at ISS: 8.5 Ton for $1 B

Why space astronomy?

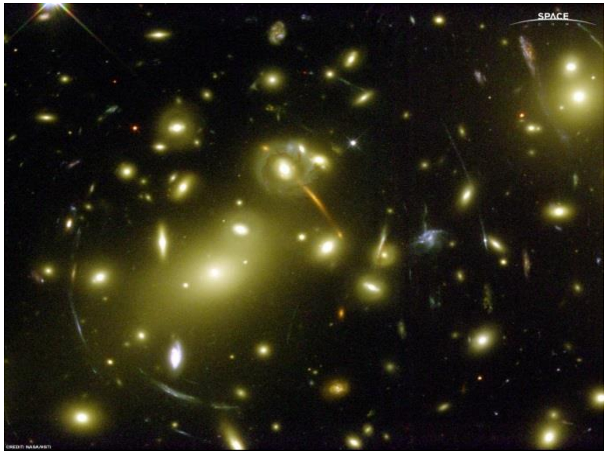


Exploring the Universe in & from space

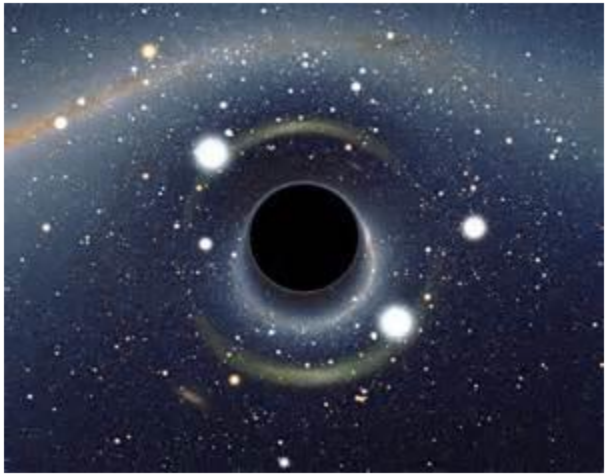
Stars & Galaxies



Sun & Planets



Dark Matter
Black Hole



Why so expensive to & in space?

+Cost

Launching
Can not fail

+Cost

Rocket
Can not fail

Instrument
Can not fail

$$$$$$$
$$$$$$
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+Cost

+Cost

Spacecraft
Can not fail

Spacecraft
Can not fail

+Cost

Light Spacecraft
Mechanical Quali.

+Cost

Impacts of high costs to space science

- Limited opportunities & ridiculous competition
  - Science instruments
    - One chance for one kind of instruments: no "manufacturing" → higher costs
    - Conservative technologies: less powerful
    - Proven technologies: less new capabilities
  - Science goals
    - Completely and clearly justified
    - Consensus in the communities
    - Contrived to instrumental capability

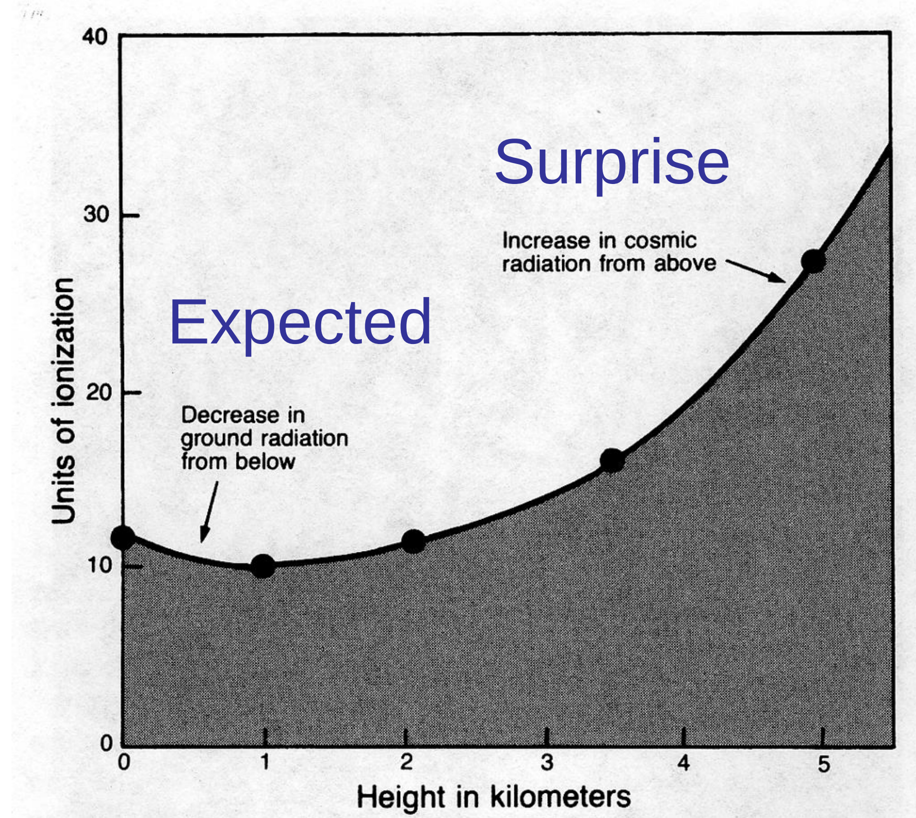
Long term and expensive development programs
Predictive goals & limited discovery chance

Scientific explorations are full of surprises!

- Most pioneering astronomy discoveries come as surprises
  - Cosmic rays (Nobel prize): hot ballooning to study attenuation of radioactivity with atmospheric height
  - Cosmic microwave background (Nobel prize): removing antenna noise
  - Pulsar (Nobel prize): studying interstellar radio scintillation
  - Cosmic X-ray sources (Nobel prize): studying stellar X-ray
  - Cosmic neutrinos (Nobel prize): studying decay of protons
  - Gravitational wave (Nobel prize): studying neutron stars
  - Gamma-ray bursts (Shaw prize): nuclear test monitoring
  - Accelerating expansion of the Universe (Dark Energy) (Nobel prize): studying decelerating expansion

Instruments fit to pre-defined goals → no or little surprises!

Discovery of cosmic rays by Hess



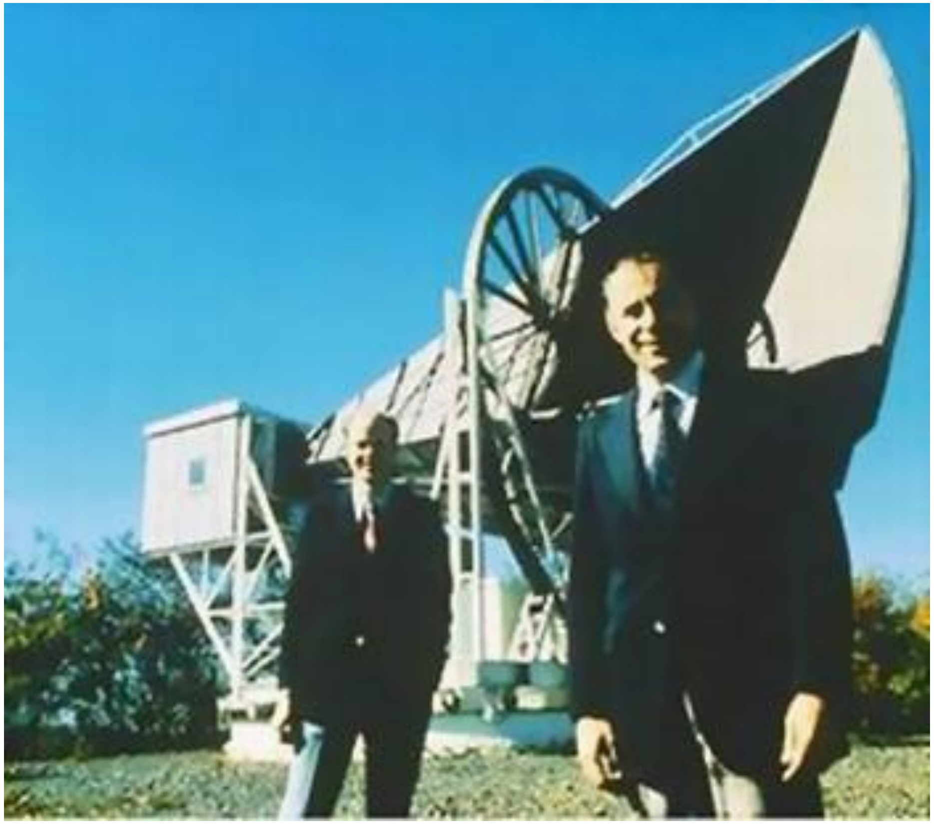
Readings on ionization chamber Victor Hess carried aloft in the Böhmen. Above four kilometers the ionization rose rapidly indicating "that rays of very great penetrating power are entering our atmosphere from above".

1912 by Hess to study attenuation of radioactivity with height

Discovery of Cosmic microwave background

A MEASUREMENT OF EXCESS ANTENNA TEMPERATURE AT 4080 Mc/s

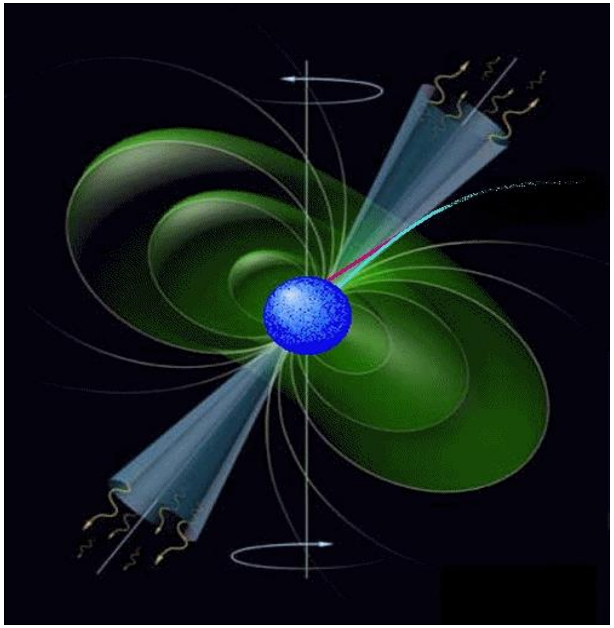
Measurements of the effective zenith noise temperature of the 20-foot horn-reflector antenna (Crawford, Hogg, and Hunt 1961) at the Crawford Hill Laboratory, Holmdel, New Jersey, at 4080 Mc/s have yielded a value about 3.5° K higher than expected. This excess temperature is, within the limits of our observations, isotropic, unpolarized, and



1965ApJ...142..419P

1965 by Penzias and Wilson when trying to removing antenna noise: after cleaning even bird nests, unexpected signals still coming from all directions, not just from the Milky Way.

Discovery of pulsars in 1967 by Bell

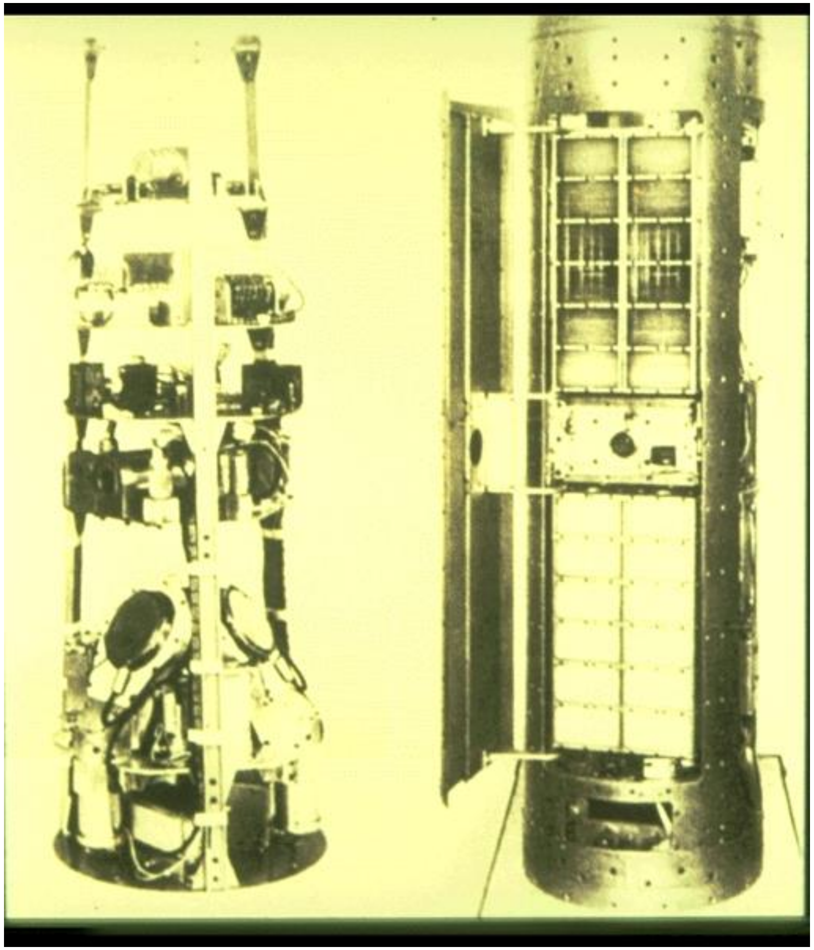


With Jocelyn Bell Burnell at IAU GA 2015, Hawaii

Remains of the IPS Array in June 2014

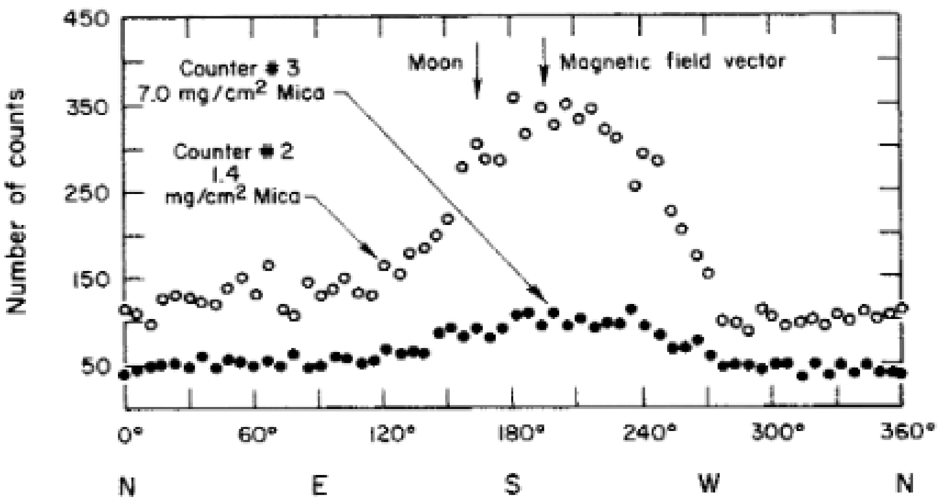
Designed to measure the high-frequency fluctuations of IPS (interplanetary scintillation) from plasma, but discovered pulsars.

Discovery of cosmic X-ray sources



1962 third ASE-MIT experiment (1st two failed

Bruno Ricardo Giacconni 2012 Nobel: led to the discovery of cosmic X-ray sources (neutron stars & black holes)

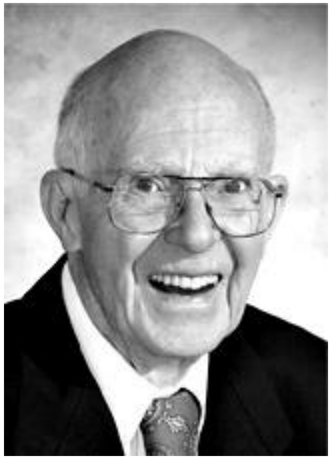


To study possible X-rays from stars, planets and the moon.

Discovery of cosmic neutrinos

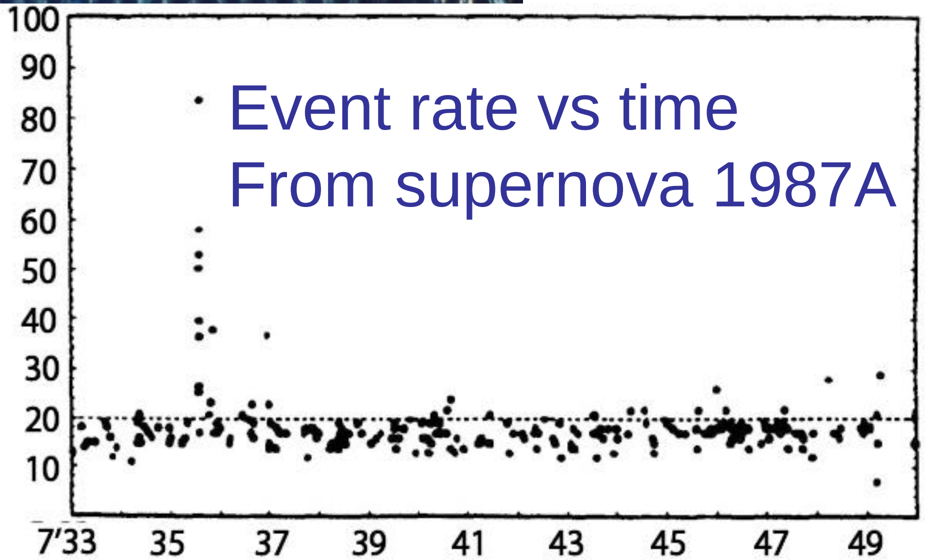
Nobel 2002: detection of cosmic neutrinos.

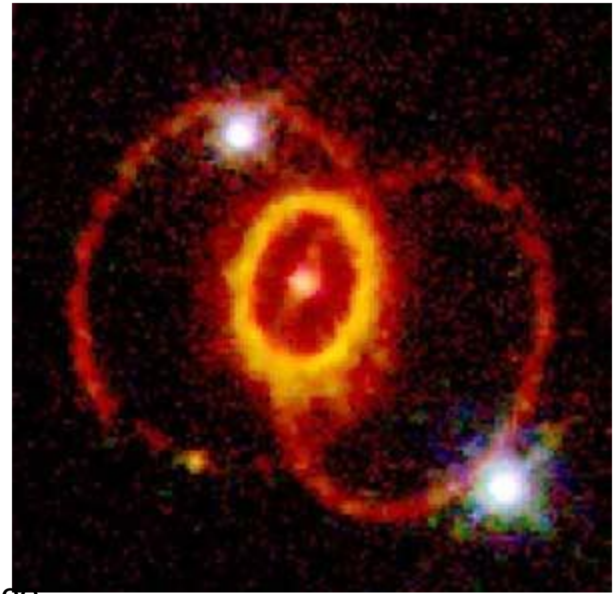
Original goals: proton decay → solar neutrinos



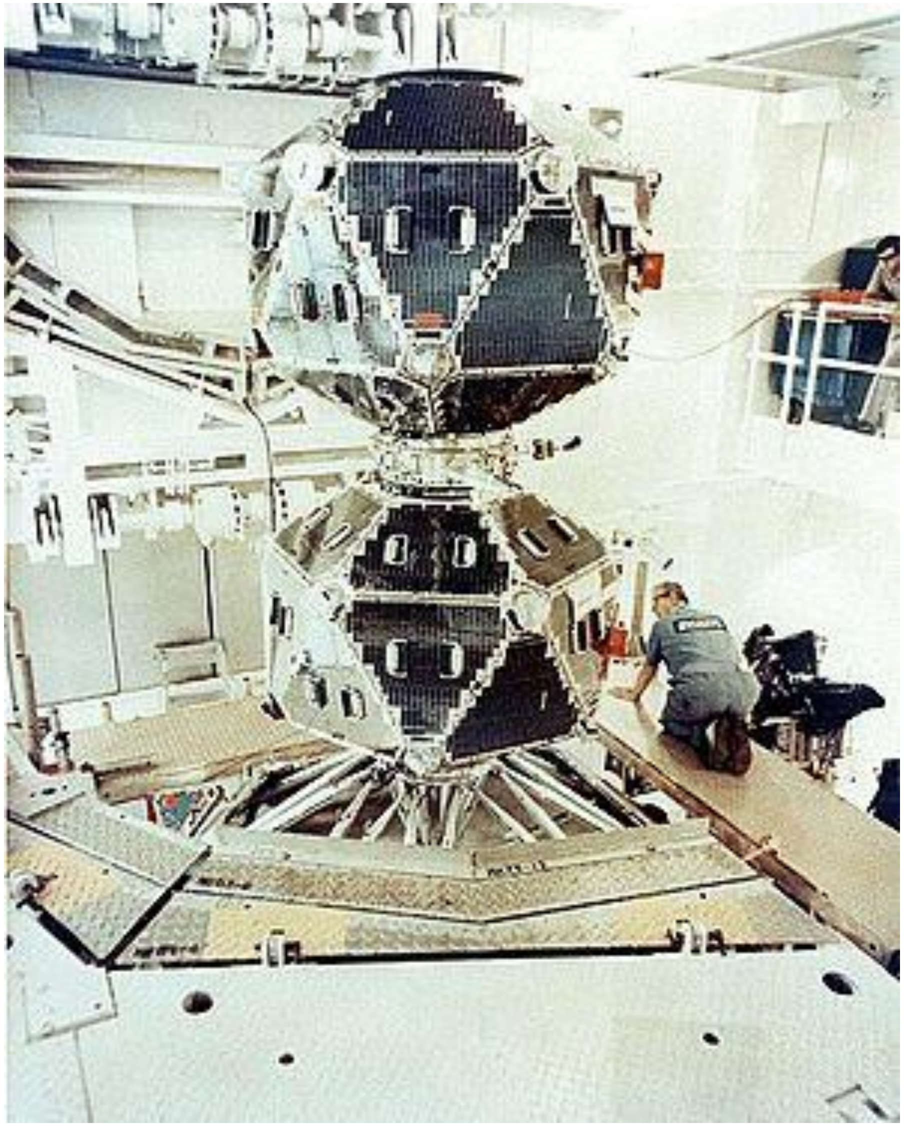
Raymond Davis Jr.

Masatoshi Koshiba

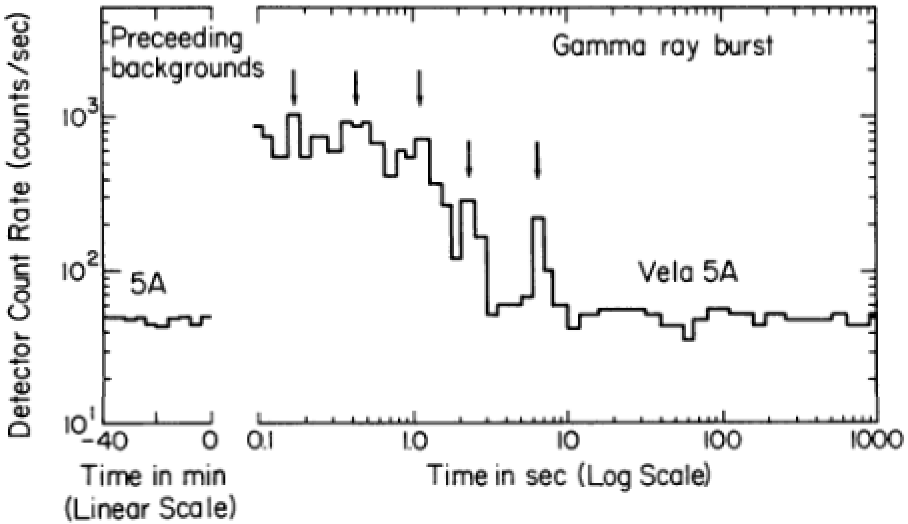




Discovery of gamma-ray bursts



Vela: to monitor compliance with the 1963 Partial Test Ban Treaty by the Soviet Union.



Biggest explosions since the Big Bang!

Impacts of low costs to space science

- More opportunities & reasonable competition
  - Science instruments
    - More chances for each kind of instruments: "manufacturing" → lower costs for each
    - More risky but ambitious technologies: more powerful
    - Innovative technologies: new capabilities
  - Science goals
    - Leave sufficient discovery space for unknowns
    - Allow controversial ideas to be tested
    - Used as observatory for explorations

→ Faster and cheaper development programs
Exploratory goals & huge discovery chance

CATS or EATS?

- CATS: cheap access to space
  - Can be misleading: “cheap” but with low reliability or high failure rate is very destructive!
- EATS: efficient access to space
  - Luxury: expensive but with very high reliability or very low failure rate
  - Good: moderate cost but with high reliability or low failure rate
  - Fair: low cost but with fair reliability or tolerable failure rate

How to achieve EATS? Chinese perspective

- Break monopoly of huge SOEs: encouraged by the government but not by SOEs
  - – More players + fresh ideas: university and other public research institutes (working quite well!)
    - So far limited to only small/micro/cube satellites

- Private sector: also encouraged

China's SpaceX?

  - One private aerospace company
  - – No issue of military or national security → Foreign investment/joint venture/international cooperation

CJSC 中联空间

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(Disclaimer: no interest involved)