AGA0414
Space Based Observations

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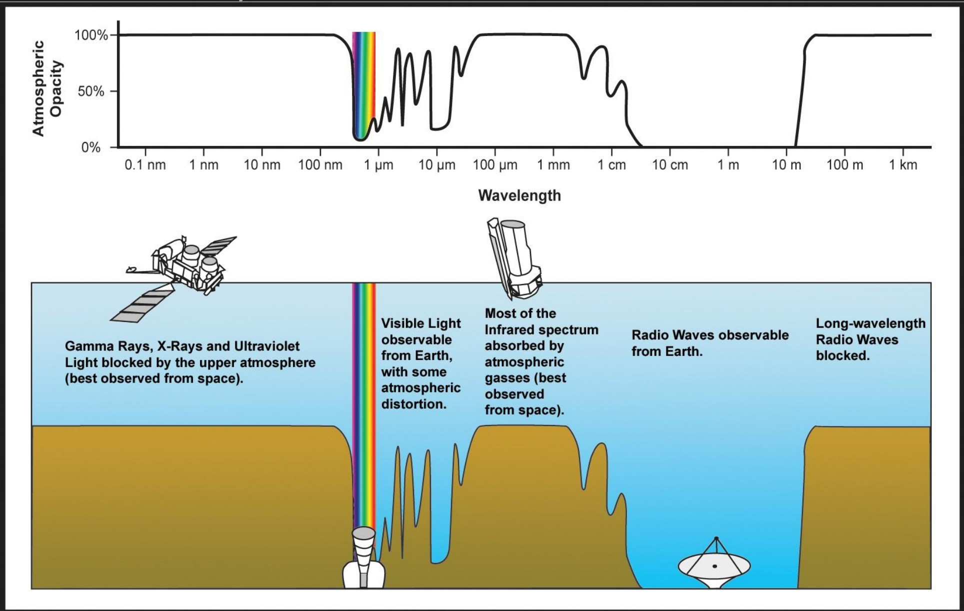
This is where I get out of my comfort zone.

Why do we go to space?

1. Get rid of atmospheric absorption
2. Optical imaging at diffraction limit (remember θ=1.22 r/λ ?)
3. In situ observations (like landing on a comet!)

https://en.wikipedia.org/wiki/File:Comet_67P_on_19_September_2014_NavCam_mosaic.jpg



Btw, Starlink!

Starlink is a constellation of 24,000+ telecommunication satellites put in orbit by private company SpaceX.

When reaching their final orbit, these things are BRIGHT (rivalling bright stars and obviously naked eye objects).

When in position, since they reflect sunlight, they will be brighter in the direction of the Sun for a couple of hours in the night. Still, for professional astronomy, they are bright (brighter than 19mag)... and they MOVE (an AI optimises the deployment of the network to maximise coverage).

Who goes to space?

Currently, few countries have the means to send payload to space:

- USA (NASA)
- Russia (Roscosmos)
- Europe (ESA)
- China (CNSA)
- India (ISRO)
- Japan (JAXA)
- Brazil - Projeto Jupiter

https://en.wikipedia.org/wiki/Ariane_5

The pros and cons of space

Pros

- Space missions can bring unique results

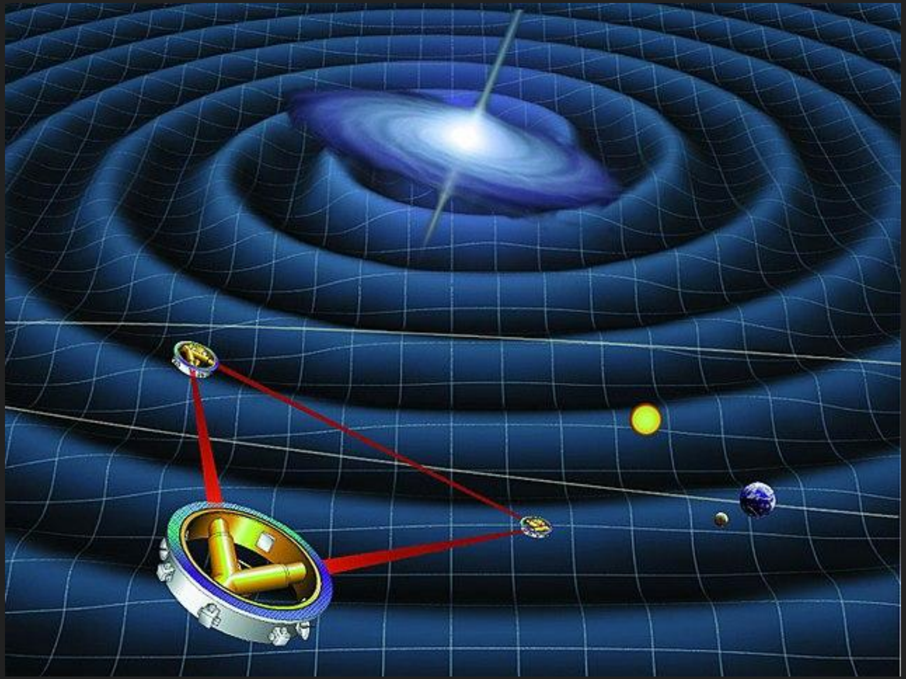
Cons

- Space is dangerous
- No screwing up (if you make a mistake, you may not be able to fix it)
- Flying a mission is expensive
- Space missions need to stay within size and weight (not necessarily budget)
- Space agencies are difficult to deal with (they have a lot of strict rules)
- Missions can have dramatic failures (e.g. explode during launch,...)

Technology for Space

Most large missions are based on reliable hardware and software (typically they fly hardware which is at least 10 years old at the moment of launch).

The famous legend is NASA paying millions to develop a pen which would work at zero gravity, while the USSR used a pencil to write in orbit.

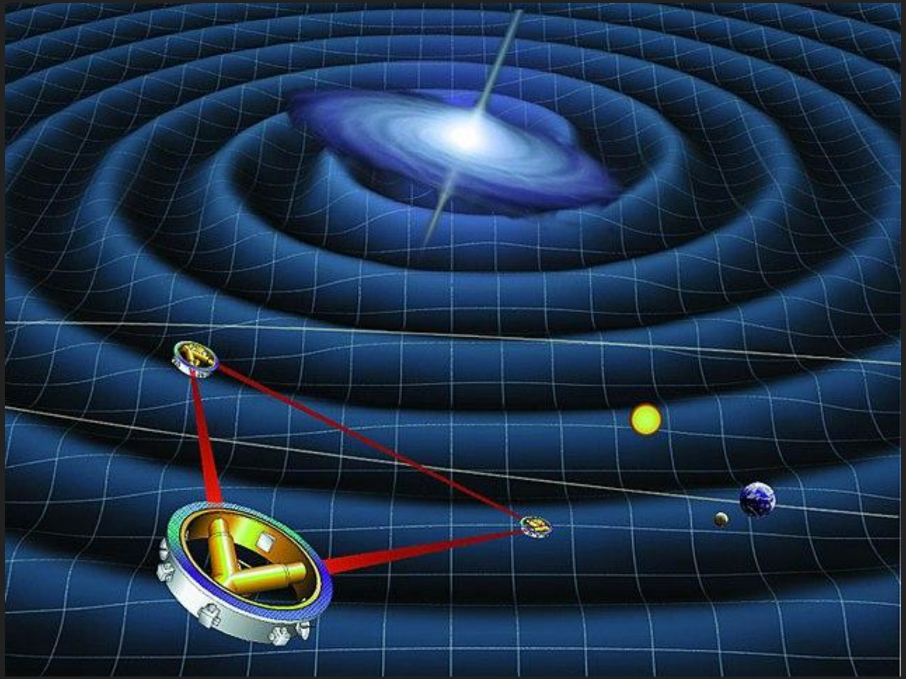


https://en.wikipedia.org/wiki/Laser_Interferometer_Space_Antenna

Technology for Space

Some missions are “pathfinders” or technology demonstrators (LISA, *at right*, had a pathfinder a few years ago).

Most missions are unique and even their science instruments are unique (e.g. GALEX or WISE, *see later*). This causes little reproducibility of some observations.



https://en.wikipedia.org/wiki/Laser_Interferometer_Space_Antenna

Getting out of the atmosphere

You need a spaceship

During launch, your rocket shakes a lot! Think of your polished mirror or the alignment of your spectrograph (first thing to do in space is to check your optics and, if needed, re-align it).

Size and weight are a big deal. Your telescope needs to fit the cargo of your vector (rocket or shuttle). This is why HST is a 2.5m telescope.

Price! (~22,000 US$/kg)

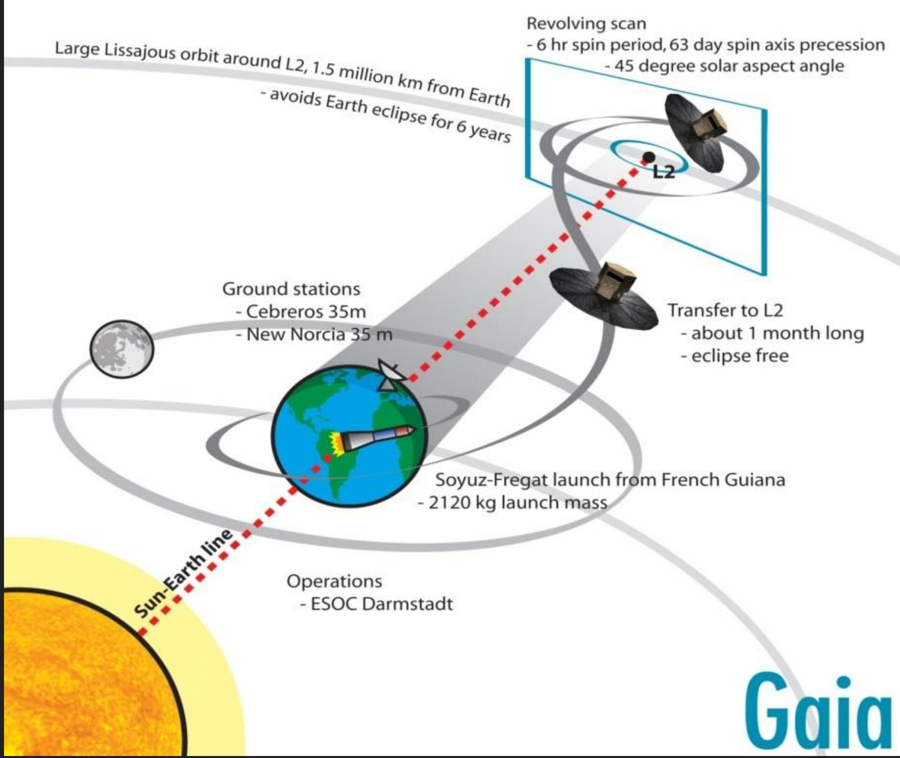
https://en.wikipedia.org/wiki/Soyuz_(rocket_family)

Flight Dynamics

You need to keep your spacecraft “on track”

People’s favourite places:

- Low Earth orbit (HST)
- Wondering about (Pioneer, Voyager, Rosetta, New Horizon,...)
- L2 (most missions these days)
- TESS https://youtu.be/-AIbD2WxyN8



Not only you put your mission there, you need to keep it there! Often you will need “attitude” corrections. For this, you need fuel.

Science Operations

How do you point towards an object? Either use thrusters or reaction wheels (use conservation of angular momentum).

You can not send an astronomer to operate the telescope *(on the right, operation of IUE telescpe from Villafranca del Castillo, Spain, in the 1980s)*.

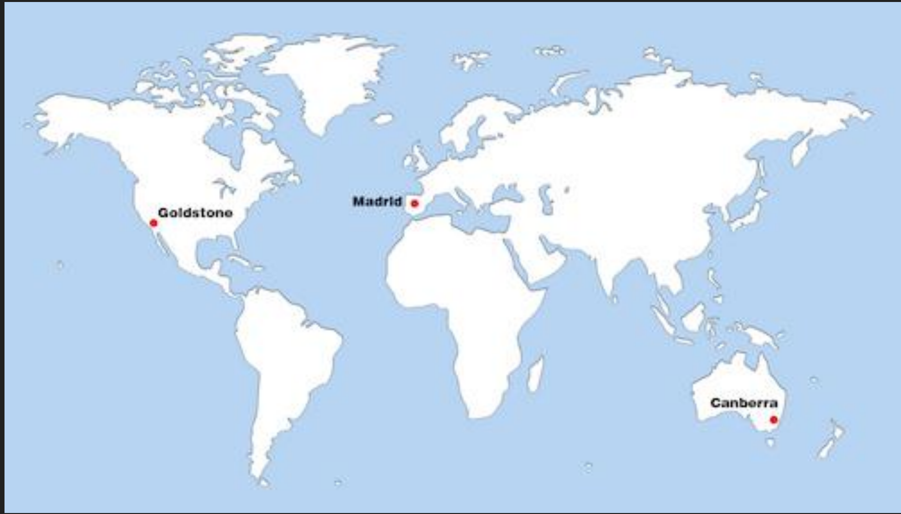
http://sci.esa.int/iue/2424-iue-storm-signals/?fbodylongid=988

Most operate in “queue mode”.

Communications

You need to send both telemetry and science data to Earth.

NASA has a “Deep Space Network”.



https://spaceplace.nasa.gov/dsn-antennas/en/

A few famous missions

There are many more than you know

Missions/Telescopes vs Observatories (rough definition)

Missions

- Dedicated science case
- Defined observing strategy
- Publish a catalogue at the end of the mission

Observatories

- Multi-purpose
- (Almost) anyone can apply to get observations
    - Instrument teams have reserved time/targets
- Publish data through an archive (typically data become public after a given time)

International Ultraviolet Explorer

High resolution ultraviolet observatory.

Telescope: Ritchey-Chretien

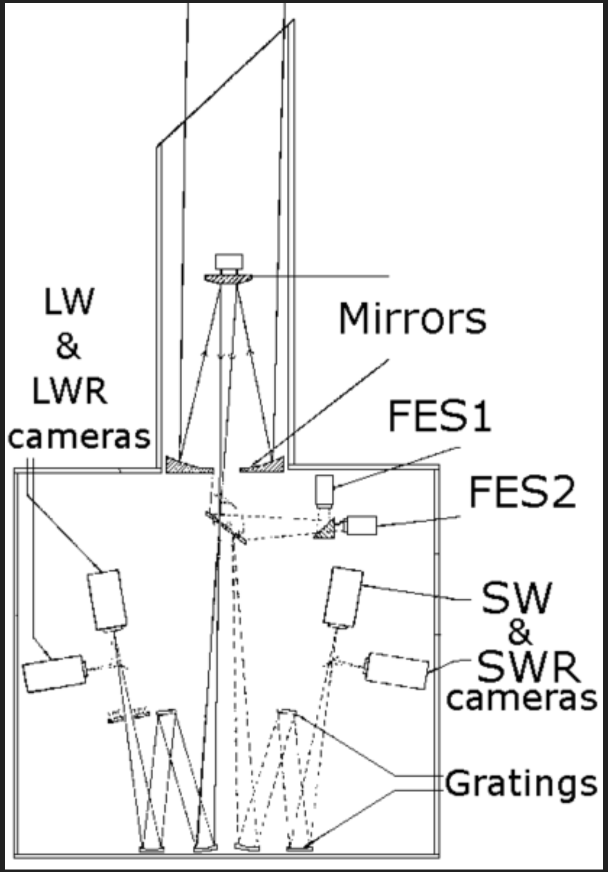
Diameter: 45cm

Focal ratio: f/15

Instruments:

- 115nm-198nm echelle spectrograph
- 180nm - 320nm echelle spectrograph

http://sci.esa.int/iue/



https://en.wikipedia.org/wiki/International_Ultraviolet_Explorer

GALEX (GALaxy EXplorer)

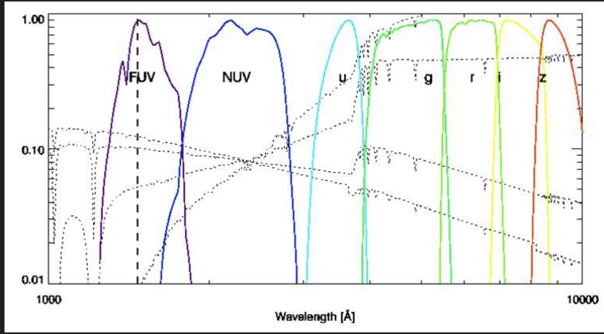
Survey of the (extragalactic) sky in the UV.

Telescope: Ritchey-Chretien

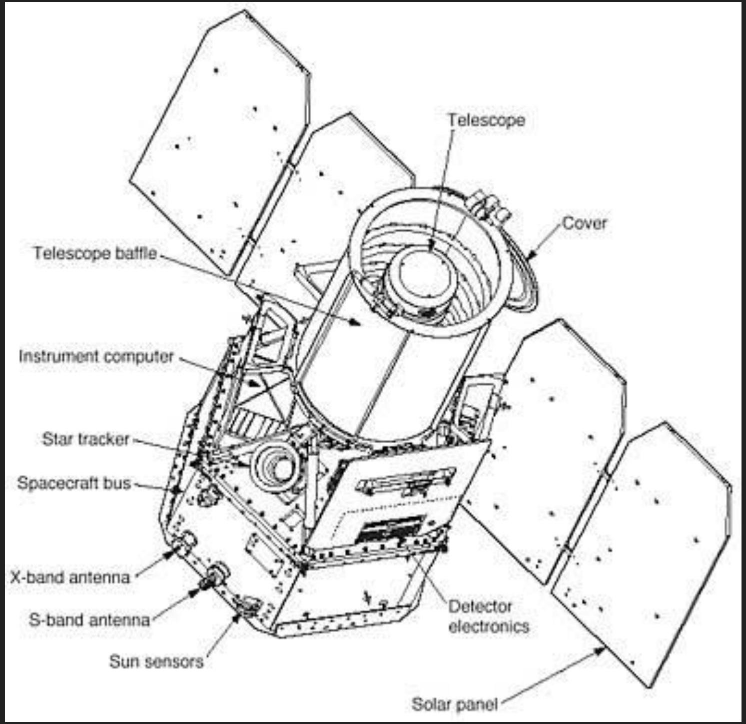
Diameter: 50cm

Focal ratio: f/6

2 filters: NUV & FUV



http://www.galex.caltech.edu/



https://en.wikipedia.org/wiki/GALEX

https://spaceflightnow.com/pegasus/galex/030424galex.html

Hubble Space Telescope

Multi-instrument space observatory (NASA/ESA).

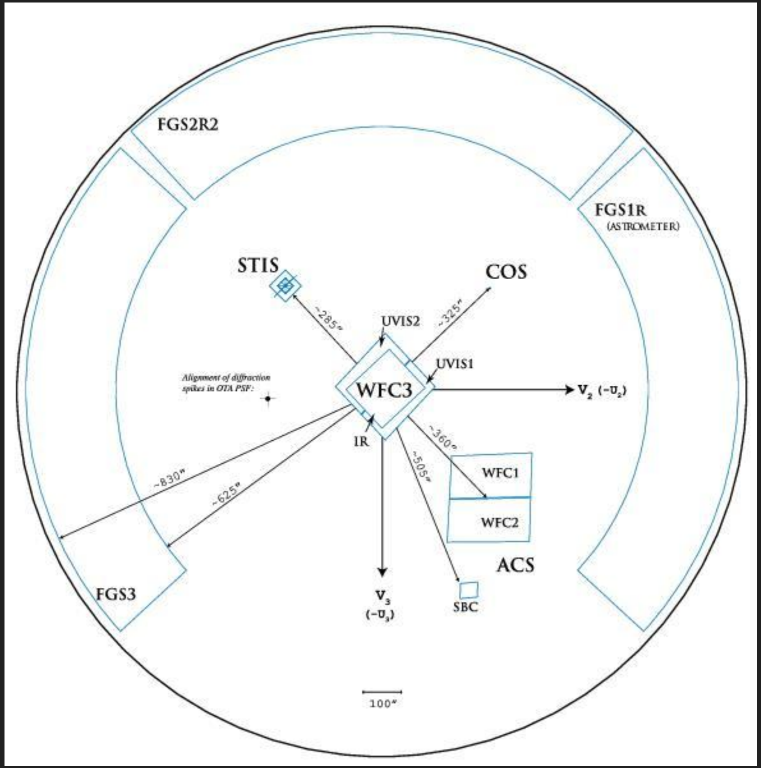
Telescope: Ritchey-Chretien

Diameter: 2.4m

Focal ratio: f/24

Current Instrumentation:

- ACS - Advanced Camera for Surveys
- COS - Cosmic Origins Spectrograph
- FGS - Fine Guidance Sensor
- WFC3 - Wide Field Camera 3



http://www.stsci.edu/hst/wfc3/documents/handbooks/currentIHB/c02_instr_descript3.html

https://en.wikipedia.org/wiki/Hubble_Space_Telescope

https://www.nasa.gov/mission_pages/hubble/main/index.html

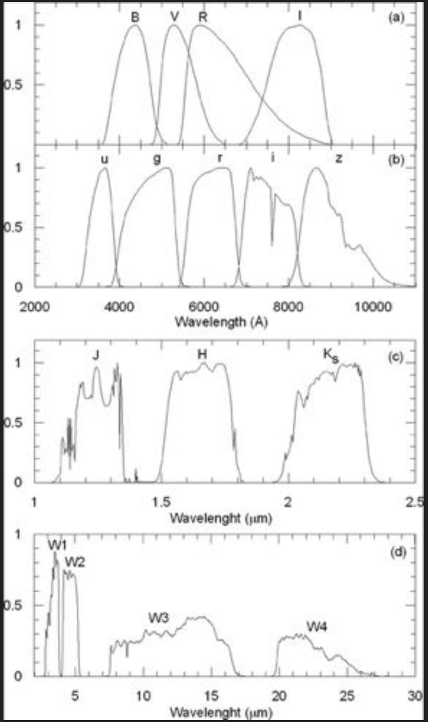
Wide-field Infrared Survey Explorer

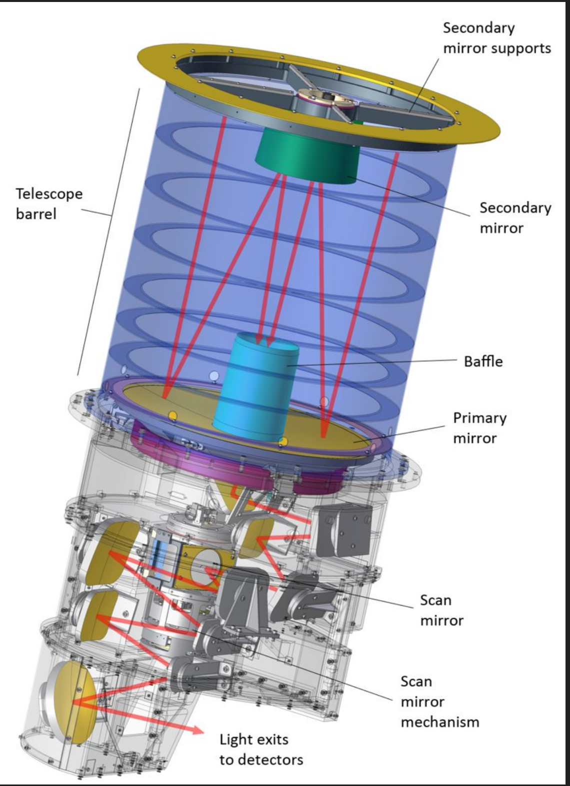
WISE

Infrared survey mission.

Diameter: 40cm

FoV = 47’





https://en.wikipedia.org/wiki/Wide-field_Infrared_Survey_Explorer

https://www.nasa.gov/mission_pages/WISE/main/index.html

http://www.planetary.org/multimedia/space-images/charts/wise-telescope-design.html

Herschel Space Observatory

Infrared observatory (operated for 3 years only!).

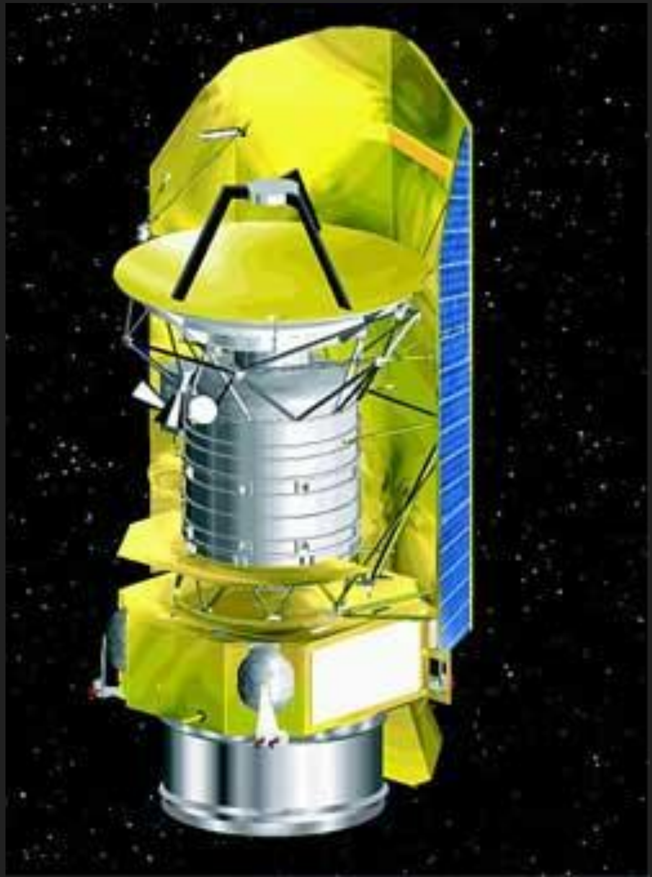
Telescope: Ritchey-Chretien

Diameter: 350cm

Focal ratio: f/8.7

Instruments:

- HIFI - Heterodyne Instrument for Far Infrared
- PACS - Photodetector Array Camera and Spectrometer
- SPIRE - Spectral and Photometric Imaging Receiver



http://sci.esa.int/herschel/

https://en.wikipedia.org/wiki/Herschel_Space_Observatory

X-ray astronomy

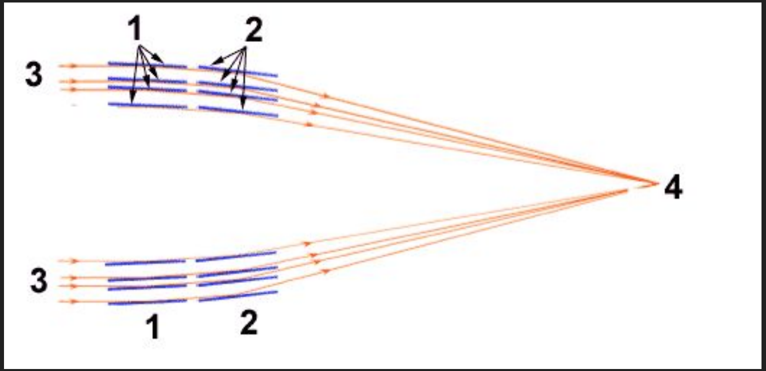
Focussing X-rays
Detecting X-rays

Focussing X-rays

Some high-energy missions use calorimeters and do not need focussing.

X-rays tend to go through matter (remember the hand of Röngten's wife? *Upper right*).

Hans Wolter (1952) designed the "grazing mirrors" *(lower right)*.



https://en.wikipedia.org/wiki/Wolter_telescope

https://en.wikipedia.org/wiki/XMM-Newton

X-ray detectors

CCDs :-)

X-ray photons produce enough electrons that one can measure their energy directly!

Uhuru

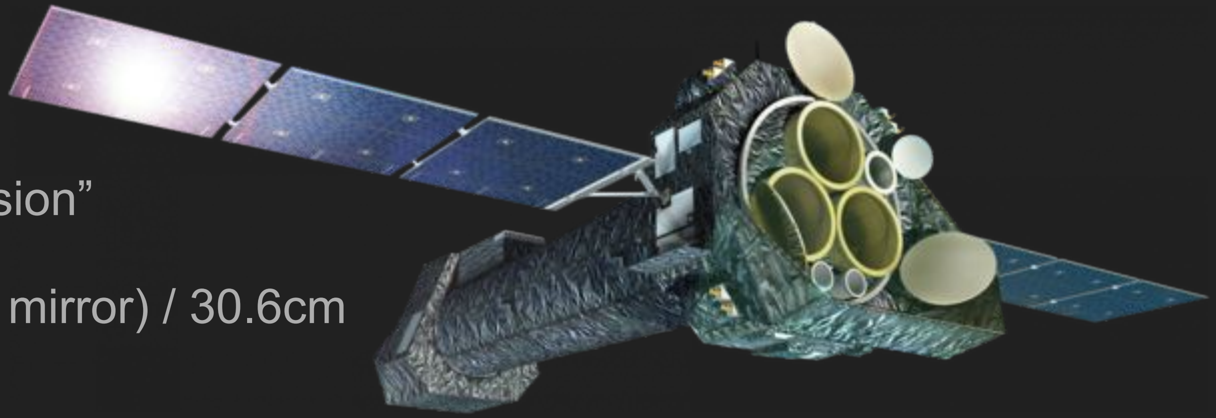
FIrst satellite for X-ray astronomy

Launched by the San Marco Base (Kenia)

https://heasarc.gsfc.nasa.gov/docs/uhuru/uhuru.html

https://en.wikipedia.org/wiki/Uhuru_(satellite)

XMM/Newton



“X-ray Multi Mirror Mission”

Diameter: 70cm (outer mirror) / 30.6cm (inner mirror)

Focal: 7.5m

Spatial resolution: 5 - 14 arcsec

Spectral coverage 0.1-12 keV (0.1-12nm)

http://sci.esa.int/xmm-newton/

Instruments:

- EPIC - European Photon Imaging Camera
- RGB - Reflection Grating Spectrometer

https://en.wikipedia.org/wiki/XMM-Newton

Chandra

Diameter: 1.2m

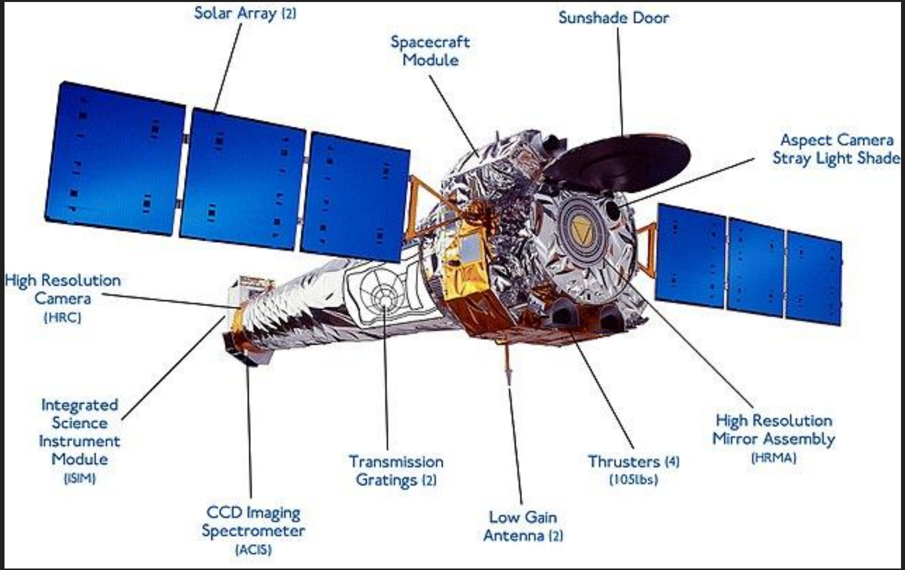
Focal length: 10m

Resolution: 0.5 arcsec

Spectral resolution: 40-2000

Instruments:

- ACIS: Advanced CCD Imaging Spectrometer
- HRC - High Resolution Camera
- HETG - High Energy Transmission Grating
- LETG - Low Energy Transmission Grating



https://en.wikipedia.org/wiki/Chandra_X-ray_Observatory https://www.nasa.gov/mission_pages/chandra/main/index.html

Neil Gehrels *Swift* Observatory

Instruments:

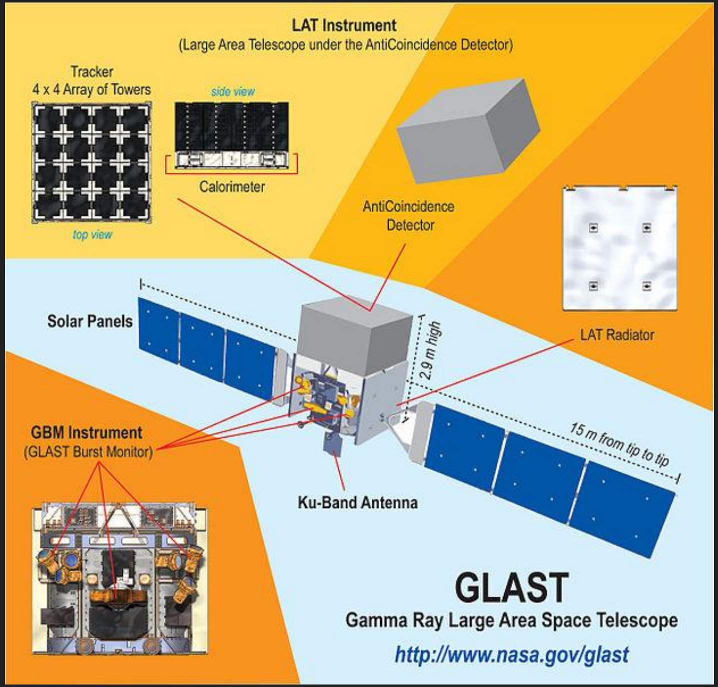
- BAT - Burst Alert Telescope
- XRT - X-Ray Telescope
    - Diameter 30cm
    - Focal: 3.5m
- UVOT - Ultraviolet/Optical Telescope
    - Diameter: 30 cm

https://en.wikipedia.org/wiki/Neil_Gehrels_Swift_Observatory https://swift.gsfc.nasa.gov/

Fermi (the mission once known as GLAST)

Instruments:

- GBM - Gamma-ray Burst Monitor (FoV - all sky not blocked by Earth)
- LAT - Large Area Telescope (Fov ~ 20% of sky)



https://en.wikipedia.org/wiki/Fermi_Gamma-ray_Space_Telescope https://www.nasa.gov/content/fermi-gamma-ray-space-telescope

INTEGRAL

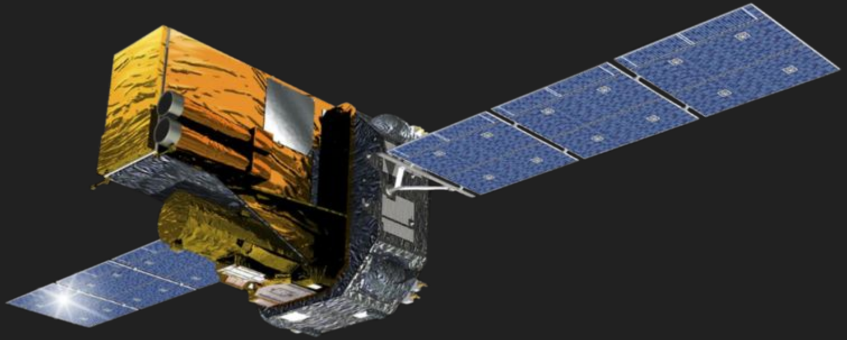
"Coded mask telescope!"

Diameter: 3.7m

Focal length: 4m

Instruments:

- IBIS - Imager on Board the INTEGRAL Satellite (15 keV - 10MeV); angular resolution 12 arcmin
- SPI - SPectrometer for INTEGRAL (15 keV - 10MeV); spectral resolution 450



https://en.wikipedia.org/wiki/INTEGRAL

http://sci.esa.int/integral/

Check the new kids in town:

New big space missions of the next decade:

- James Webb Space Telescope (aka Just Wait Space Telescope)
- Nancy Grace Roman Space Telescope (formerly known as Wide Field InfraRed Survey Telescope. WFIRST)