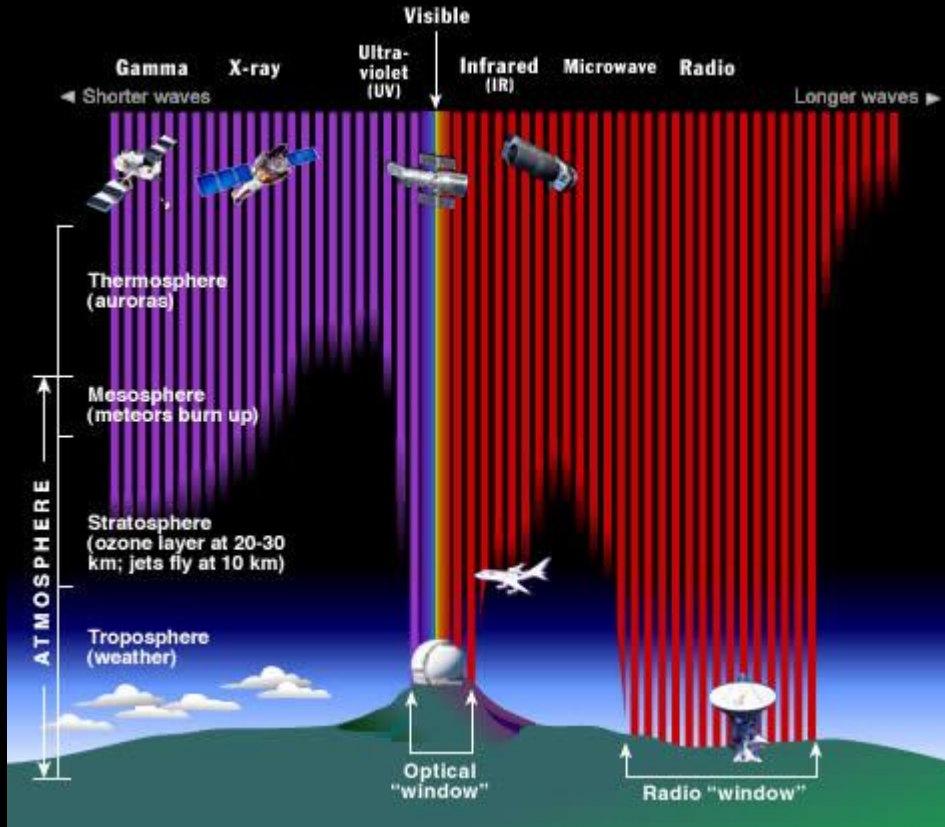


Why go to space?

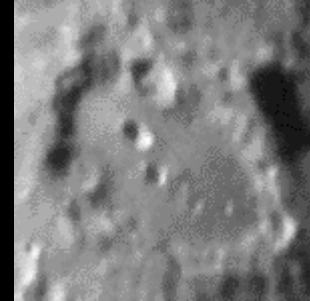


Why go to space?

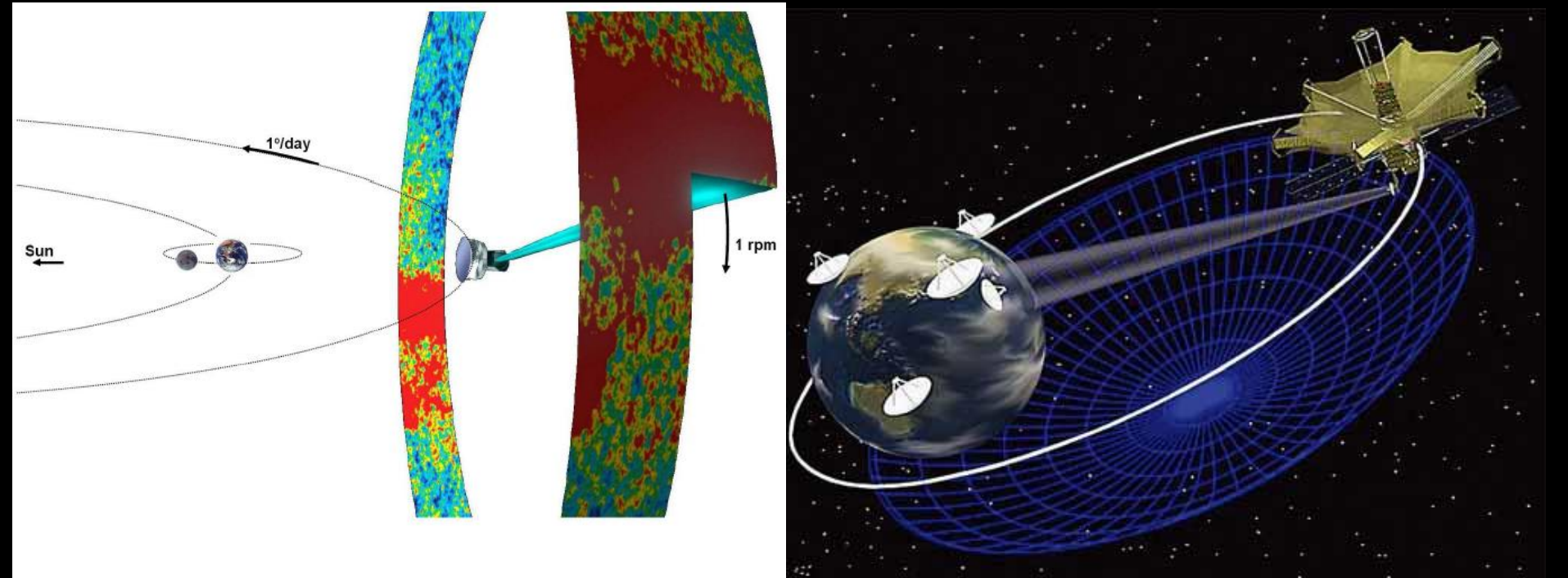


Astronomers' point of view!
(Not including remote sensing, space weather & solar system science)

Atmospheric effects + interference

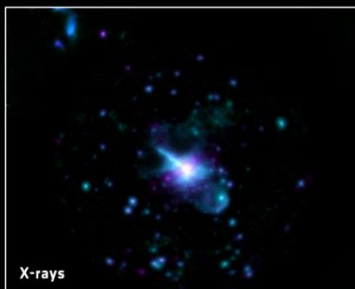


Observational considerations

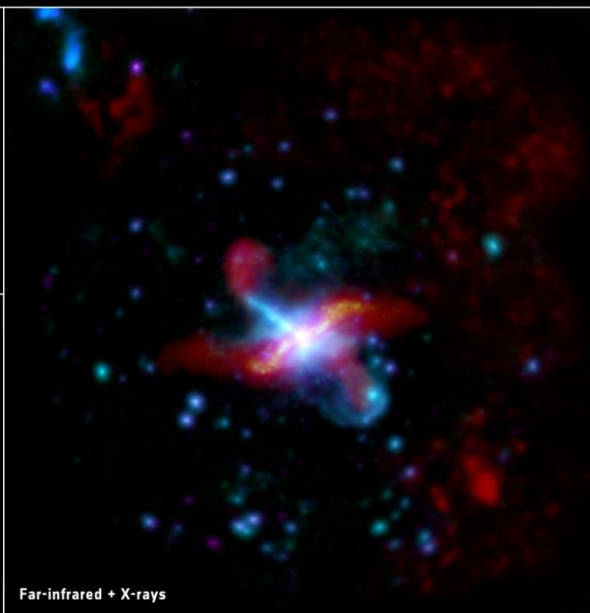


We want to see
fainter objects at
greater distances
at all wavelengths





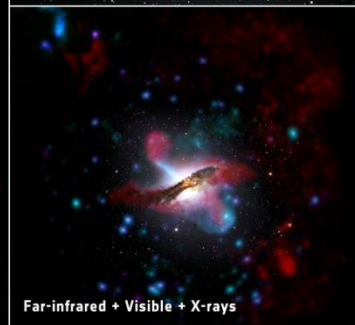
X-rays



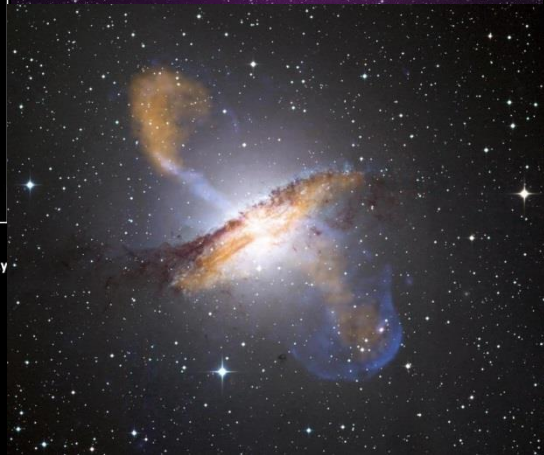
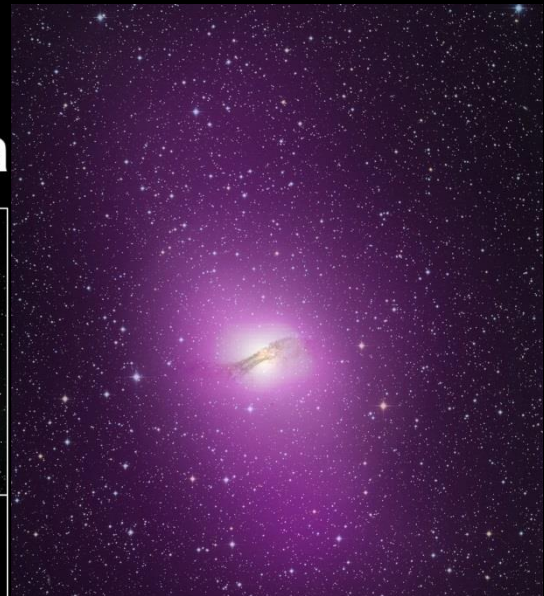
Far-infrared + X-rays



Visible



Far-infrared + Visible + X-rays



Astronomical satellites come in many flavours

OBSERVATORIES

XMM-Newton

Herschel

Hubble

Chandra

...

SURVEYS

Planck

Fermi

Gaia

Kepler

...

"TARGET OF OPPORTUNITY"

Swift

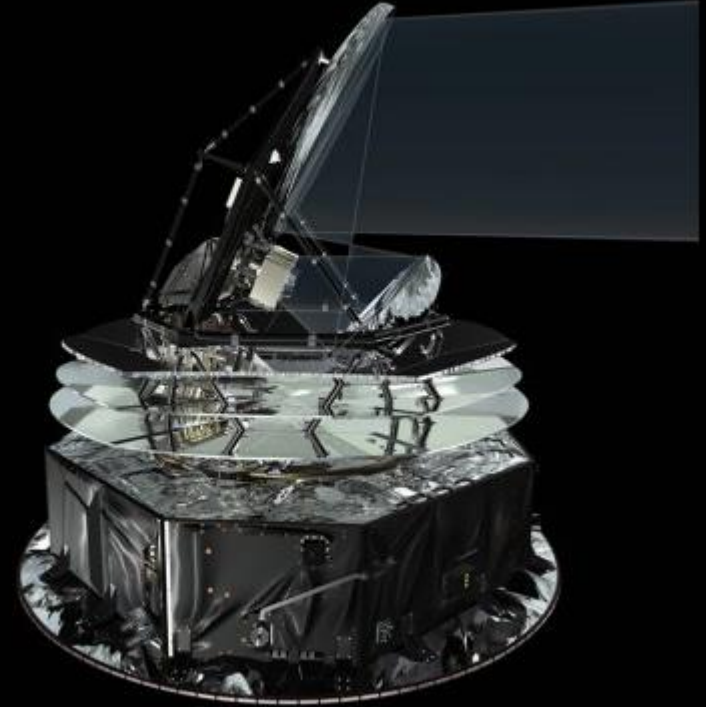
(Fermi)

...

Planck

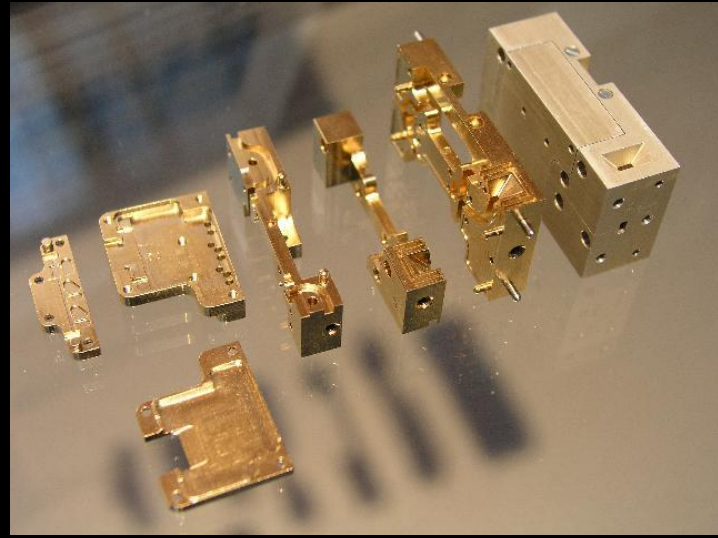


- Cosmic microwave background (CMB) survey mission
- Frequencies 30 – 857 GHz (9)

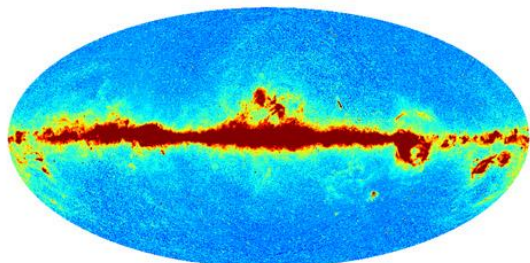


70 GHz receivers

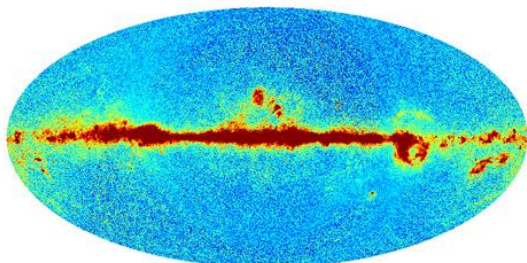
- Designed and built in Finland by Millilab, DA Design (Ylinen, Elektrobit Microwave), Metsähovi



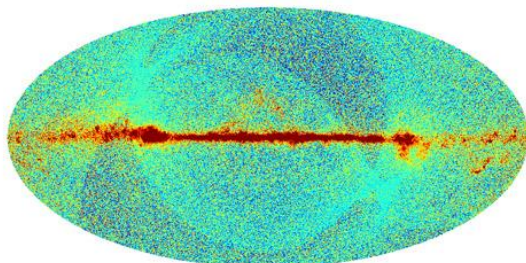
Planck all-sky foreground maps



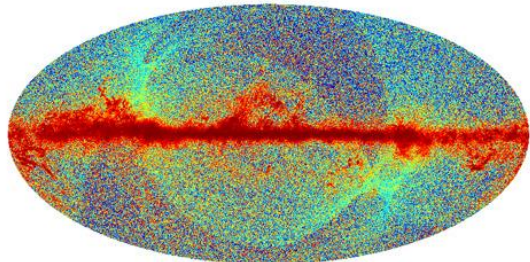
LFI 30 GHz



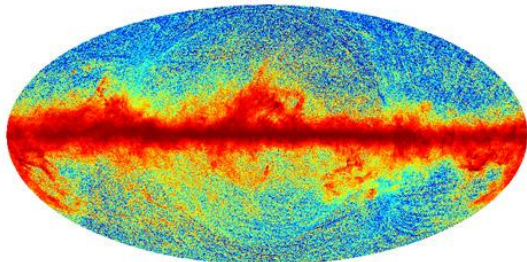
LFI 44 GHz



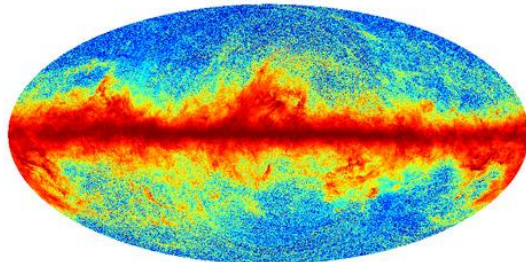
LFI 70 GHz



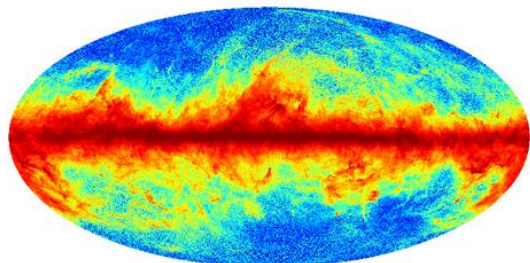
HFI 100 GHz



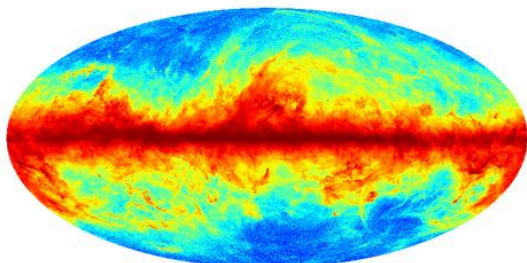
HFI 143 GHz



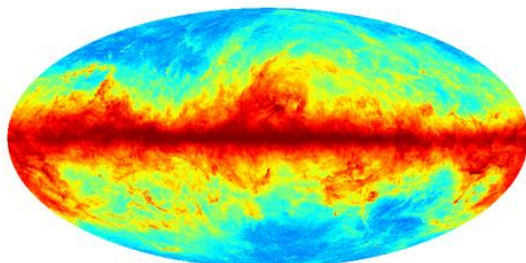
HFI 217 GHz



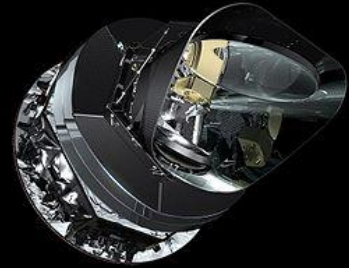
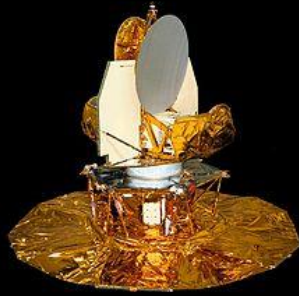
HFI 353 GHz



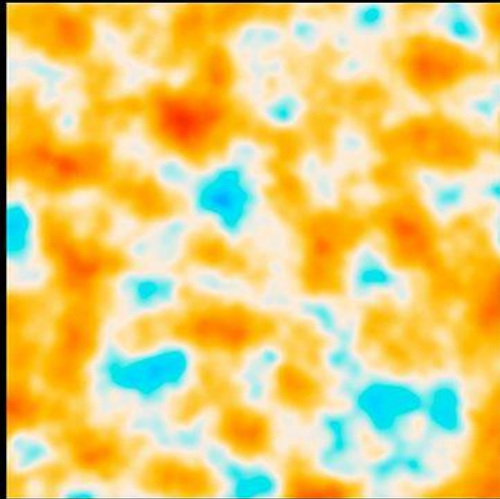
HFI 545 GHz



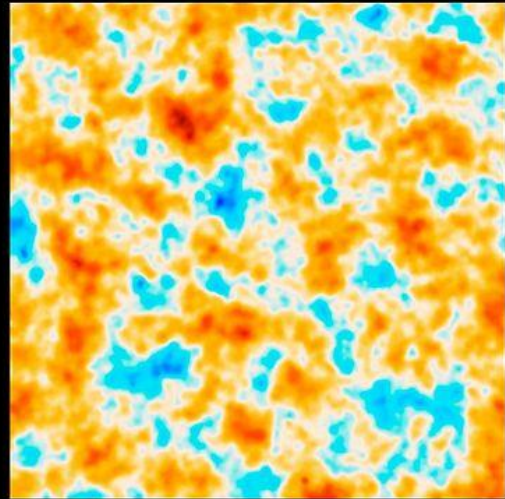
HFI 857 GHz



COBE



WMAP



Planck

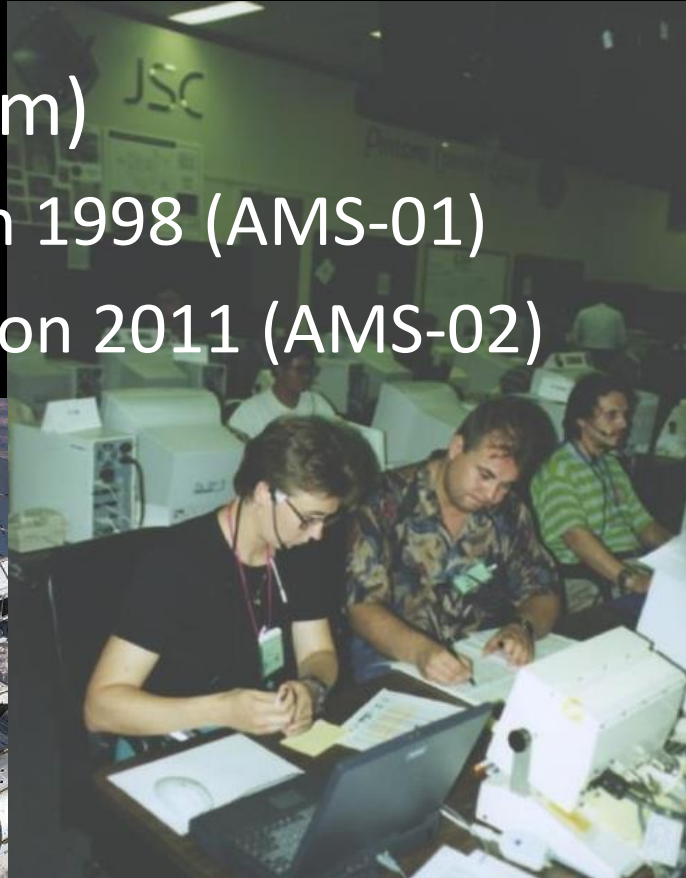
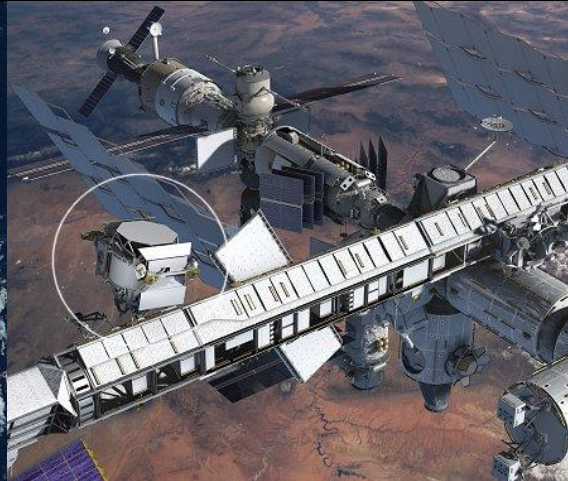
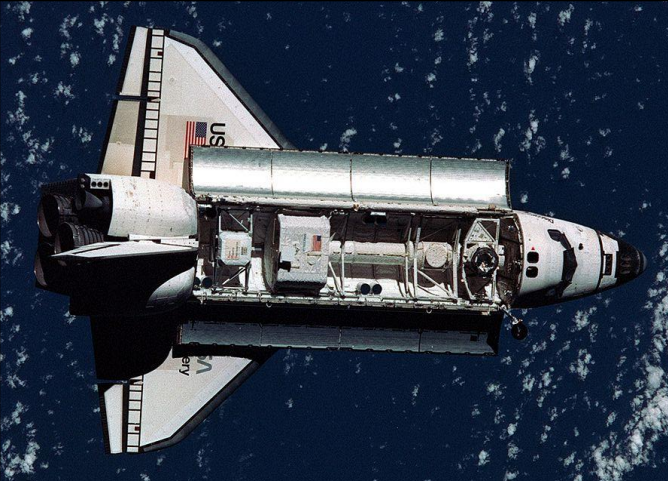
The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada



Planck is a project of the European Space Agency -- ESA -- with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

Alpha Magnetic Spectrometer AMS

- Measures antimatter (antihelium)
 - first on space shuttle Discovery in 1998 (AMS-01)
 - then on International Space Station 2011 (AMS-02)



Gamma-ray satellites

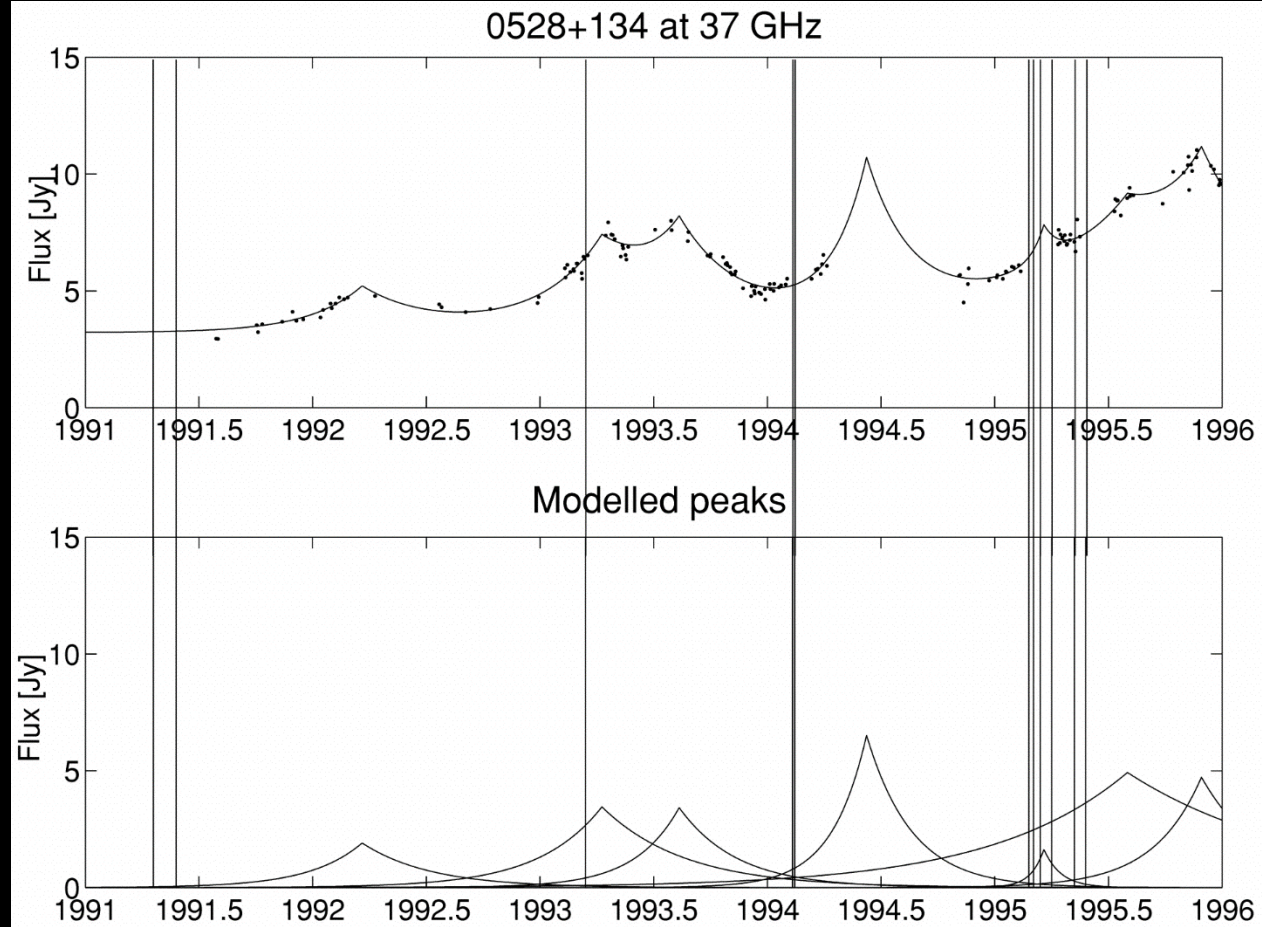
- Compton Gamma-Ray Observatory (1991)
 - Energetic Gamma Ray Experiment Telescope (EGRET) instrument
- Fermi Gamma-ray Space Telescope (2008)
 - Large Area Telescope (LAT) instrument



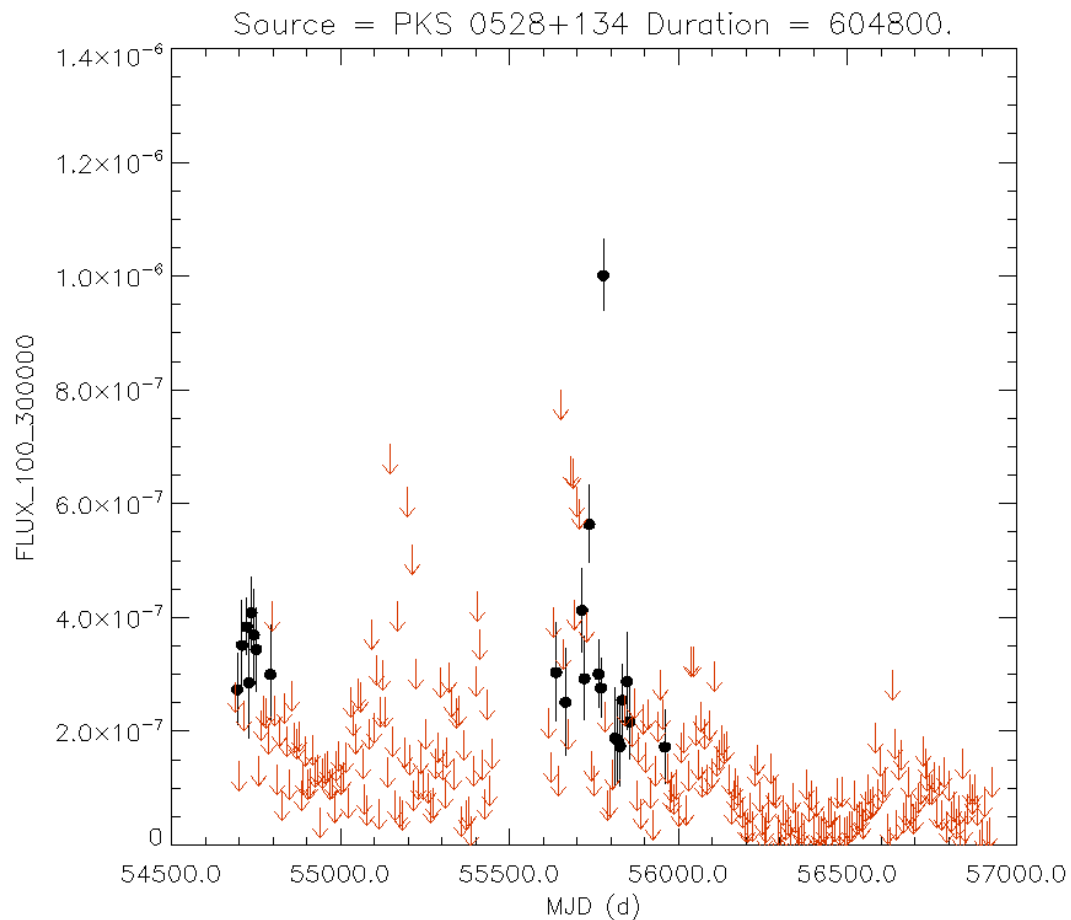
CGRO data

vertical lines

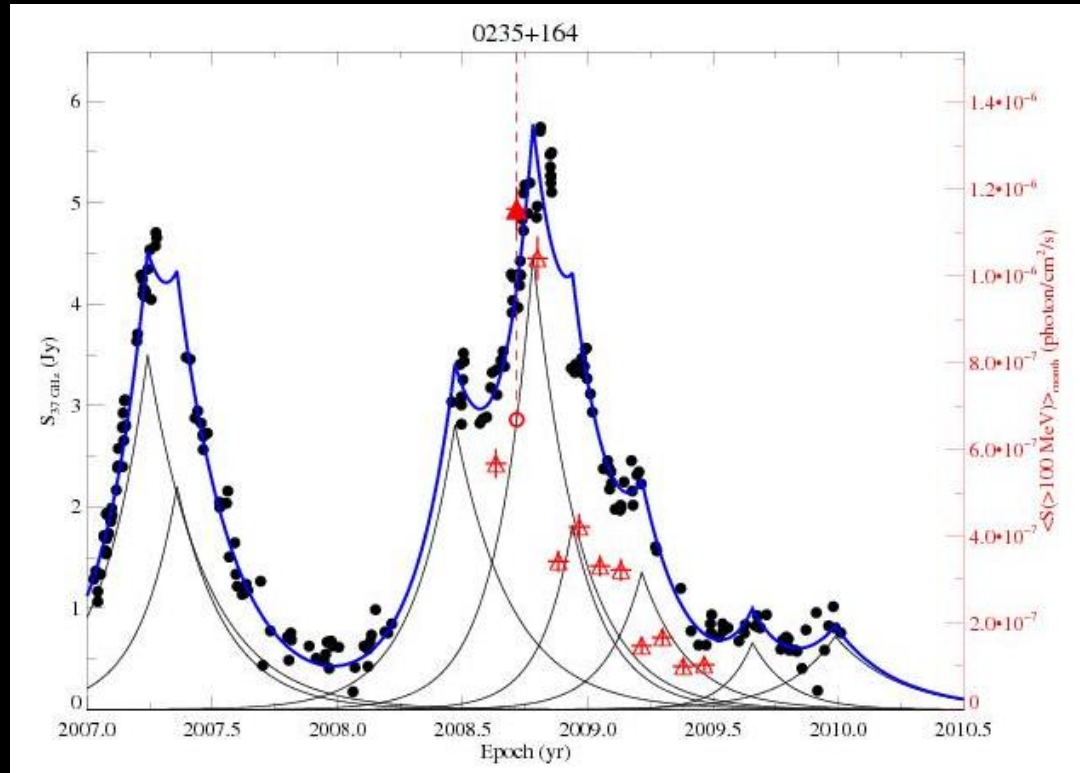
+ Metsähovi data
(points & curve)



Fermi data

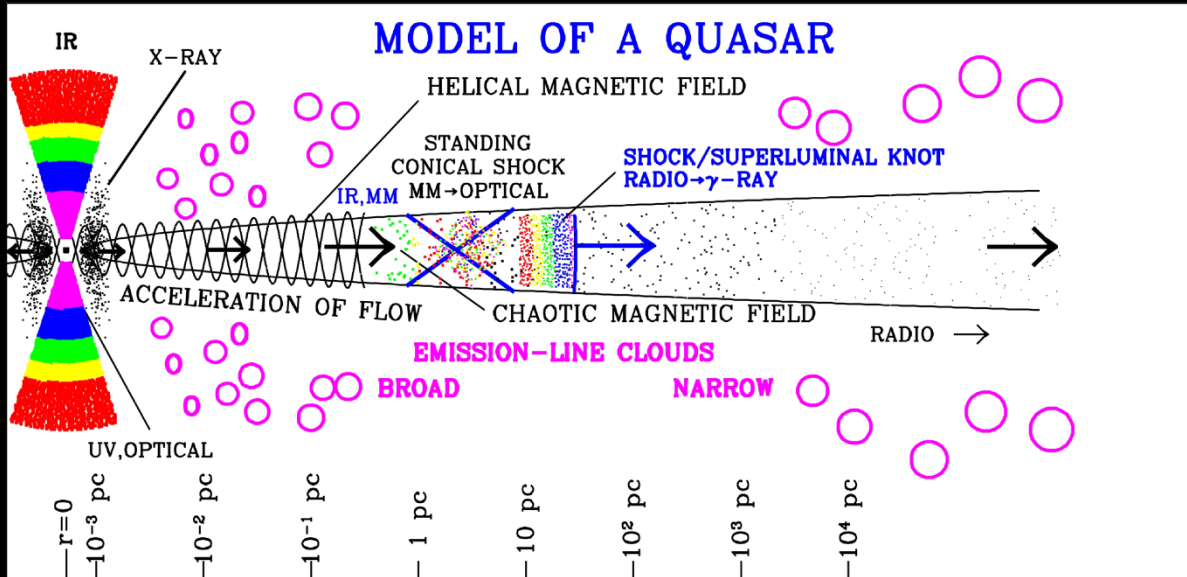


Metsähovi + Fermi lightcurves

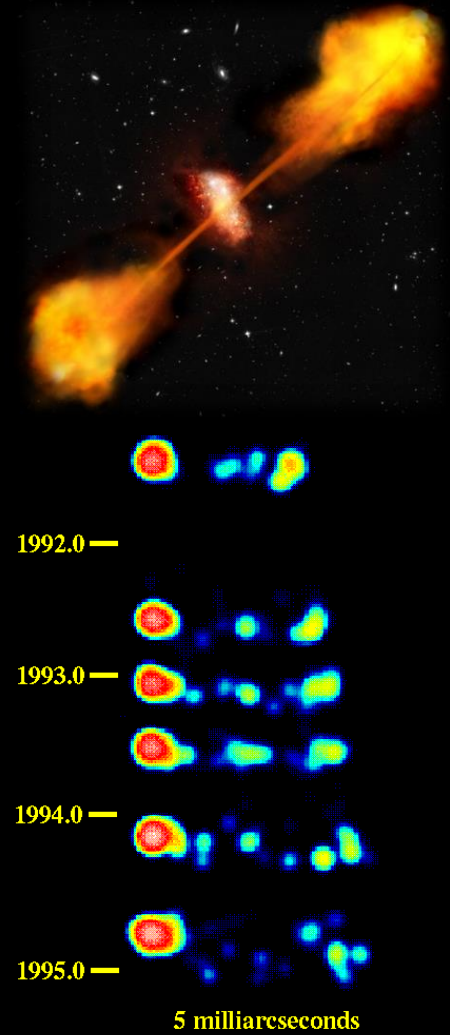


Radio and gamma-ray flares

Marscher et al., Nature 2008



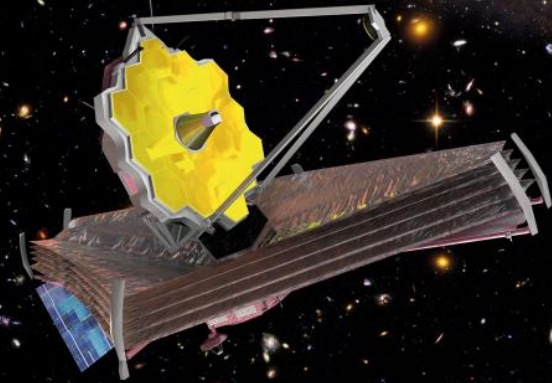
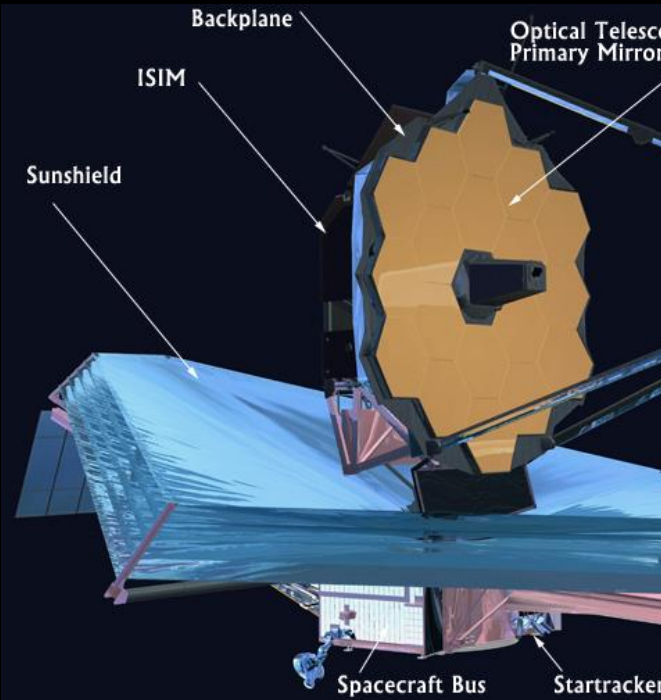
<http://www.bu.edu/blazars/>



Future missions

James Webb Space Telescope JWST

- Infrared observatory (2021)



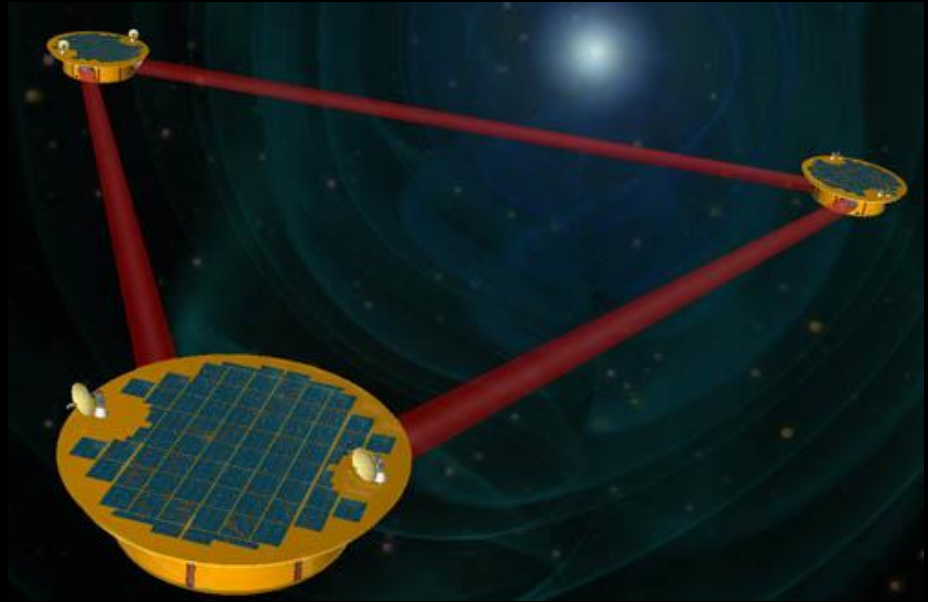
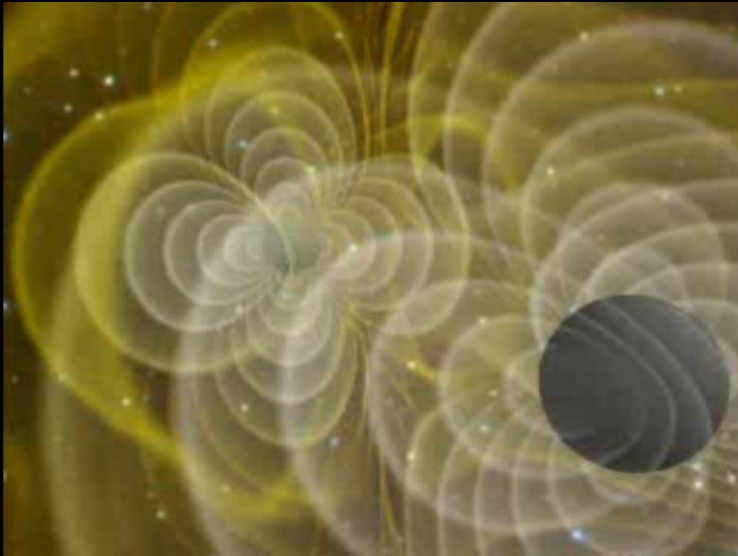
james webb space telescope

→ CAPTURING THE LIGHT
FROM THE FIRST GALAXIES

The James Webb Space Telescope is an international collaboration of NASA, ESA and the Canadian Space Agency

Gravitational waves

- LISA Pathfinder (2015), LISA (2034)



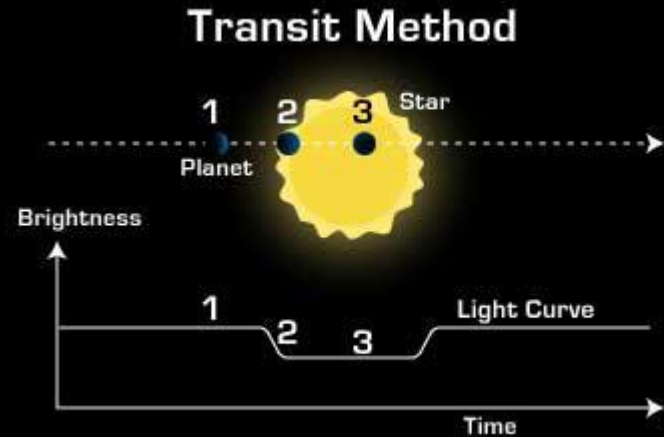
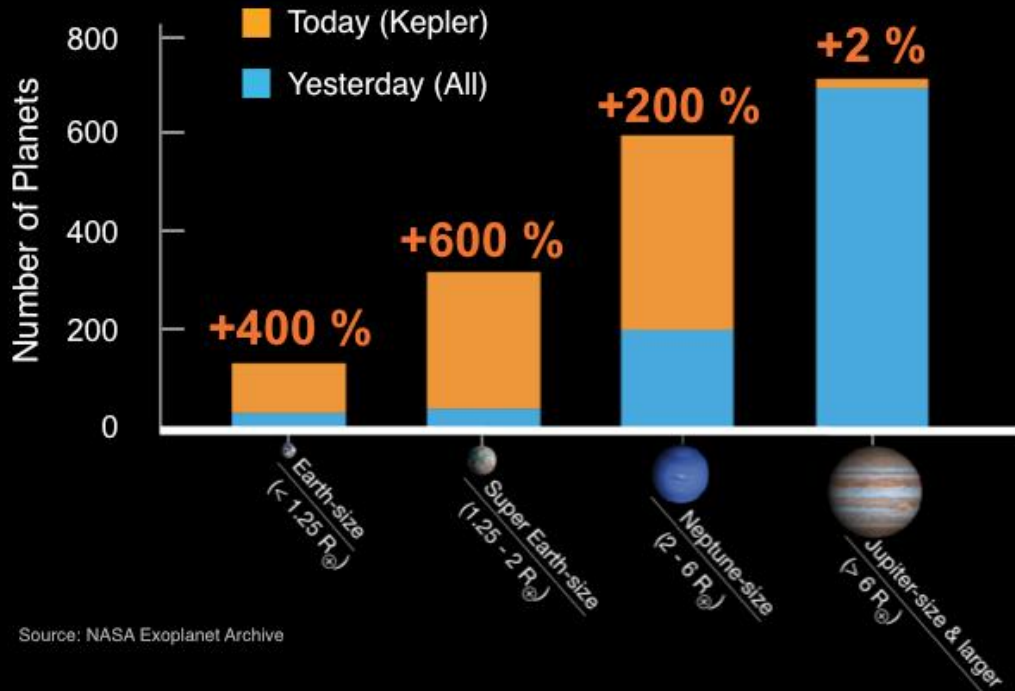
Exoplanets found with Kepler:

>2400 candidates, >2600 confirmed

Kepler

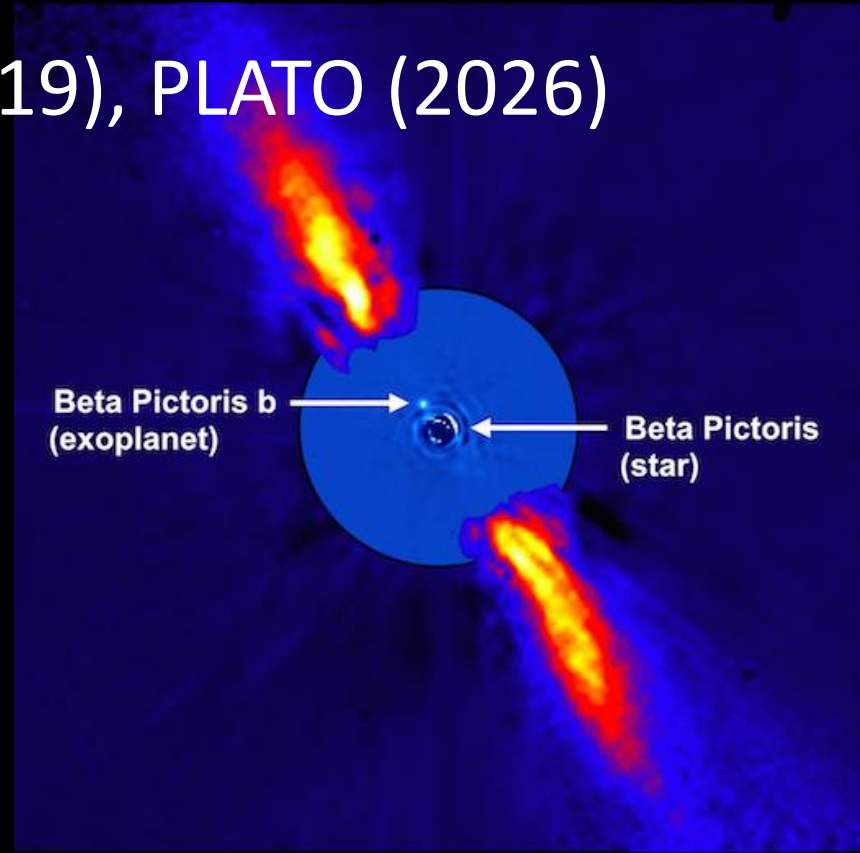
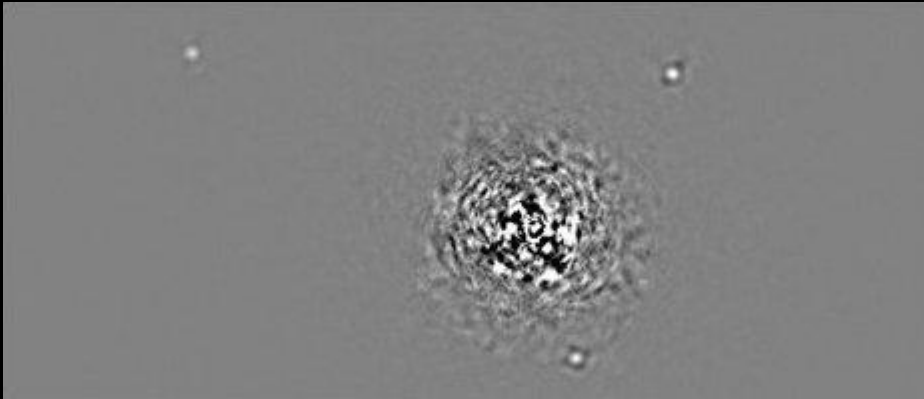
Sizes of Known Exoplanets

As of February 26, 2014



Exoplanets: >4200 confirmed so far

- TESS (2018), CHEOPS (2019), PLATO (2026)



“Dark universe”

- Euclid (2022)

