Today's Class: NASA's Space Telescopes

- Read: Skim over NASA document on Project Artemis linked on class website for Oct. 9. *Guest lecture next class by Lockheed Martin Chief Exploration Architect, Tim Cichan.*

1

- United States *China Taskforce Report* brings up the potential danger of competing with China in LEO and in space as a whole
- Senate Commerce Committee notes that "*Great power competition in space is a reality*" - Sen. Roger Wicker (R-Miss.)
- "They're working very hard to attract our international partners . We're working to prevent that from happening."
  - NASA Administrator Jim Bridenstine
- NASA doesn't want to be responsible for combating threats from China but there is growing pressure for it to do so

SPACENEWS

Presented by Sean Streb

Report backs NASA exploration efforts as response to Chinese space program

Question for the Class: Should NASA play a role in combating China, and how do you see future international conflicts playing out in Space?

2

Last few classes

- **Why do we put telescopes in space?**
  - Access to more of the electromagnetic spectrum
  - Turbulence in the atmosphere
- **The Hubble Space Telescope (HST) & the Cosmic Origin Spectrograph (COS)**
- **The James Webb Space Telescope**

3

Today's Class

- NASA's current and near-term space telescope missions
  - Astrophysics mission themes.
- Sample of current NASA space telescopes:
  - Chandra X-ray Observatory
  - NuSTAR
  - Kepler Space Telescope
  - Fermi γ-ray Telescope
  - SOFIA infrared Telescope

4

NASA's Current & Planned Astrophysics Missions

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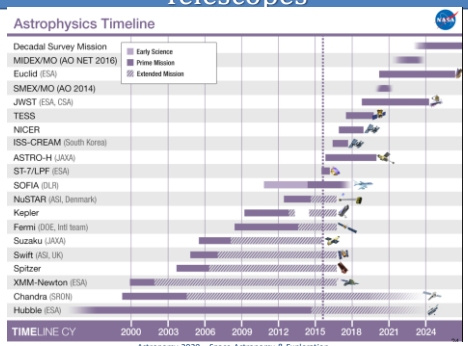
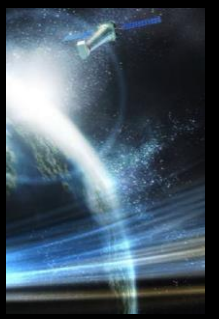
Timeline for Astrophysics Space Telescopes



6

Introduction to Chandra X-ray Observatory

- The Chandra X-ray Observatory is the third of NASA's "Great Observatories"
- Launched July 23, 1999 by Space Shuttle and boosted to high Earth orbit for initial 5 year mission; mission has been extended several times.
- Orbits Earth every 64 hours, ranging as far as 140,000 km (87,000 mi) – about 1/3 the way to the moon
- Chandra detects astronomical x-rays by focusing them onto detectors by means of nested grazing-incidence mirrors
- Chandra's resolving power is 10 times greater than any previous x-ray telescope
  - — equivalent to the ability to read a stop sign at a distance of twelve miles
- Science instruments
  - — 2 imaging cameras, Advanced CCD Imaging Spectrometer (ACIS) and High Resolution Camera (HRC); 2 insertable gratings for more detailed x-ray energy analysis (spectroscopy)
  - — Instruments were developed by Penn State University, MIT, Smithsonian Astrophysical Observatory, and Utrecht



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Chandra's Namesake - Subrahmanyan Chandrasekhar

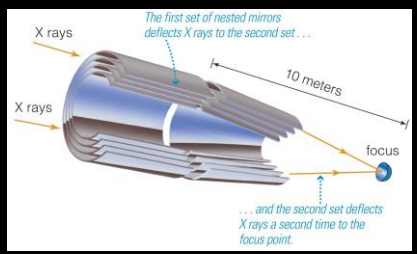
Awarded Nobel Prize in 1983 for his theoretical work on neutron stars & black holes.

8

Chandra X-ray Observatory

9

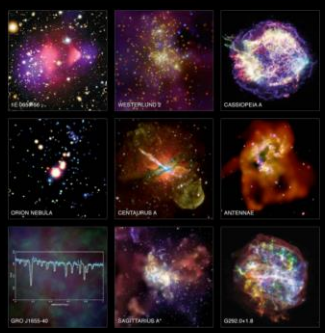
X-Ray Telescopes



- Focusing of X-rays requires special mirrors.
- Mirrors are arranged to focus X-ray photons through grazing bounces off the surface.

10

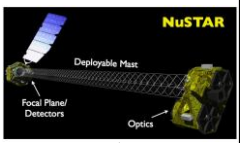
Opportunity for exploration and discovery with Chandra remains as high as at launch.



11

NuSTAR – Imaging High Energy X-ray Sources
Launched: June 2012

- NuSTAR has deployed the first orbiting telescope to focus light at high energy X-ray (6 - 79 keV) energies. Deployable Mast is 10-meters long.
- **Mission goals:**
  - Take a census of collapsed stars and black holes of different sizes by surveying regions surrounding the center of own Milky Way Galaxy and performing deep observations of the extragalactic sky;
  - Map recently-synthesized material in young supernova remnants to understand how stars explode and how elements are created; and
  - Understand what powers relativistic jets of particles from the most extreme active galaxies hosting supermassive black holes.

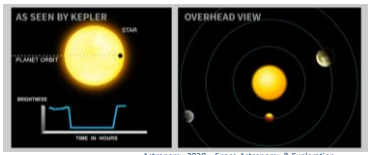


video

12

Kepler Space Telescope – Hunting Exoplanets
March 2009 – October 2018

- ***Kepler*** is a space observatory launched by NASA to discover Earth-like planets orbiting other stars. Spacecraft mission operations by student controllers here at CU LASP!
- **Mission Goals:**
  - Determine the abundance of terrestrial and larger planets in or near the habitable zone of a wide variety of stars;
  - Determine the distribution of sizes and shapes of the orbits of these planets;
  - Estimate how many planets there are in multiple-star systems;
  - Determine the variety of orbit sizes and planet reflectivities, sizes, masses and densities of short-period giant planets;
  - Identify additional members of each discovered planetary system using other techniques; and
  - Determine the properties of those stars that harbor planetary systems.
- **Results to date:** >2300 exoplanets confirmed. 30 are rocky & in habitable zone.



13

Class Exercise

The fact that we have not yet discovered an Earth-size extrasolar planet in an Earth-like orbit tells us that such planets must be VERY rare.

a) True

b) False

14

Class Exercise

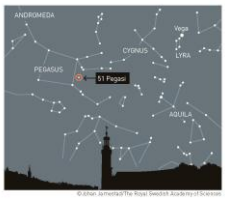
The fact that we have not yet discovered an Earth-size extrasolar planet in an Earth-like orbit tells us that such planets must be VERY rare.

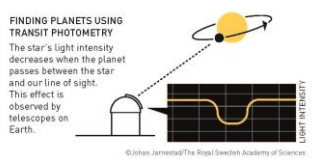
a) True

b) False

15

Nobel Prize awarded in 2019 for first discovery of exoplanet





In October 1995, **Michel Mayor** and **Didier Queloz** announced the first discovery of a planet outside our solar system, an exoplanet, orbiting a solar-type star in our home galaxy, the Milky Way. At the Haute-Provence Observatory in southern France, using custom-made instruments, they were able to see planet 51 Pegasi b, a gaseous ball comparable with the solar system's biggest gas giant, Jupiter.

16

Fermi Gamma-Ray Telescope
Launched: June 2008

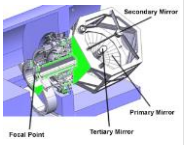
- Fermi studies the cosmos in the energy range 10 keV - 300 GeV (γ-ray).
- **Mission Goals:**
  - Explore the most extreme environments in the Universe, where nature harnesses energies far beyond anything possible on Earth.
  - Search for signs of new laws of physics and what composes the mysterious Dark Matter.
  - Explain how black holes accelerate immense jets of material to nearly light speed.
  - Help crack the mysteries of the stupendously powerful explosions known as gamma-ray bursts.
  - Answer long-standing questions across a broad range of topics, including solar flares, pulsars and the origin of cosmic rays.

video

17

SOFIA: Stratospheric Observatory for Infrared Astronomy; First light in May 2010

- **Mission Goals:**
  - study the composition of planetary atmospheres and surfaces;
  - investigate the structure, evolution and composition of comets;
  - determine the physics & chemistry of the interstellar medium;
  - explore the formation of stars and other stellar objects.
- Operates at Infrared wavelengths: ≈1-200 microns; 2.5-meter reflector telescope.



18