Astronomy in 2012

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Harvard-Smithsonian Center for Astrophysics
Welcome to the Harvard-Smithsonian Center for Astrophysics (CfA).

We are one of the largest - possibly the largest – astronomy research institutions on the planet

*(indeed, as far as we know, in the entire spiral arm)*

The CfA consists of two interwoven institutions, the Harvard College Observatory (HCO) and the Smithsonian Astrophysical Observatory (SAO); its buildings also house the Department of Astronomy of Harvard University.

Here at the CfA we:
- observe the universe, with ground-based telescopes in Arizona, Chile and Hawaii, and instruments in Earth orbit and deep space.
- design, develop and build astronomical instruments, telescopes and space payloads
- carry out theoretical investigations of the planets, Sun, stars, galaxy and universe
- house some of the crucial global services for the astronomy community (ADS, ds9, IAU-MPC, US Simbad-mirror)
- operate NASA's Chandra X-ray Observatory spacecraft for the community
Who we are

Chandra X-ray Center (CXC)

Harvard-Smithsonian Center for Astrophysics (CfA)
60 Garden St, Cambridge

MIT Kavli Institute
1 Hampshire St, Cambridge

Harvard College Observatory (HCO)

Smithsonian Astrophysical Observatory (SAO)

Chandra Operations Control Center (OCC)
1 Hampshire St, Cambridge
Charles Alcock (Director)  
“MACHO” project discovered microlensing

Bob Kirshner – supernova cosmology, discovery of dark energy

Julia Lee – black hole accretion

Dave Charbonneau  
Spectrum of an extrasolar planet

Margaret Geller – mapping the universe

Stella Offner – studying how stars form
Divisions of the CfA

- **OIR**: Optical/InfraRed
  - galaxies,
  - star formation
  - supernovae

- **SSP**: Solar, Stellar, Planetary
  - ultraviolet and optical
  - corona, chromosphere;
  - extrasolar planets
  - asteroids
  - solar X-rays

- **HEA**: High Energy Astrophysics
  - x-rays
  - neutron stars
  - black holes
  - supernova remnants
  - clusters of galaxies

- **R&G**: Radio and geoastronomy
  - radio waves, submillimeter
  - star formation
  - jets from black holes
  - masers
  - continental drift

- **TA**: Theoretical Astrophysics
  - early universe
  - stellar evolution

- **AMP**: Atomic and Molecular Physics
  - fingerprinting the light of different elements
CfA's Early History

1839  Harvard College Observatory founded
1842  HCO moves to Garden St
1847  The Great Refractor makes first observations
1847  Early daguerrotypes of the Moon
1848  Bond discovers Saturn VII (Hyperion)
1882  Harvard Photometry list of bright stars
1887  Plate surveys begin
1890  SAO founded in Washington, DC
       Studies solar energy output
1890  Pickering and Fleming classify star types
1918-1924  Annie Cannon's HD catalog of stellar spectra published
1955  SAO moves to collocate with HCO
1957  Moonwatch project tracks Sputnik and other satellites
1973  SAO and HCO form the CfA
       X-ray group joins CfA
1978  Einstein satellite studies X-ray sources
1981  CfA Redshift survey maps the cosmos
The CfA Space Program

Orbiting Solar Observatory – 1962
OAO Celescope – 1968
Gravity Probe A - 1976
Einstein Observatory – 1978
Spacelab 2 IRT - 1985
ROSAT HRI telescope – 1990
SOHO UVCS telescope – 1995
Spartan 201 - 1995
TRACE – 1998
SWAS - 1998
Chandra – 1999
Spitzer IRAC camera - 2003
XRT on Hinode - 2006
Solar Dynamics Observatory - 2010
What's happening in the Universe these days?

We often divide up astronomy by the different WAYS WE LOOK AT THE SKY...

- RADIO telescopes
- X-RAY telescopes...
But I'll focus more on .. WHAT ARE WE LOOKING AT?

PLANETS
STARS
NEBULAE
GALAXIES

and the universe as a whole!
No, it's NOT a planet.

(but the New Horizons probe will visit it in 2015)
The Dawn space probe is orbiting the planetoid Vesta in the asteroid belt.
Moons of the Solar System Scaled to Earth's Moon

- Earth: Moon
  - Phobos
  - Deimos

- Mars: None

- Asteroid Ida: None

- Jupiter: Io (Deimos)
  - Enceladus
  - Tethys
  - Dione
  - Rhea
  - Titan
  - Iapetus
  - Phoebe

- Saturn: Mimas
  - Enceladus
  - Tethys
  - Dione
  - Rhea
  - Titan
  - Iapetus
  - Phoebe

- Uranus: Miranda
  - Ariel
  - Umbriel
  - Titania
  - Oberon

- Neptune: Triton
  - Nereid

- Pluto: Charon
The Methane Lakes and Ice Shoreline of Titan
EXOPLANETS

1989: Dave Latham finds object around HD114762 – planet or brown dwarf?

1995: Discovery of 51 Pegasi b (Mayor and Queloz, Geneva)
   a “Hot Jupiter”, only 5 million mi (8 million km) from its parent star

2007-2009: Gliese 581 system
   Gliese 581d, mass of 6-10 Earths
   A “super-Earth” in the habitable zone

2012: 760 exoplanets now known
   Kepler mission finding many new ones, including multiple-planet solar systems and **Earth-sized planets**
Infrared image of Cygnus X star forming region

The Spitzer telescope lets us peer through regions otherwise opaque and see the young stars shaping the environment around them.
Fermi data reveal giant gamma-ray bubbles

Credit: NASA/DOE/Fermi LAT/D. Finkbeiner et al.
The local neighbourhood
(closest half-billion light years!)

Legend: image shows 2MASS galaxies color coded by redshift (Jarrett 2004); familiar galaxy clusters/superclusters are labeled (numbers in parenthesis represent redshift). Graphic created by T. Jarrett (IPAC/Caltech)
NGC 3393, unusual galaxy with a pair of black holes in the middle

With Hubble we can directly image galaxies with quasars in them (image by Bill Keel)
Galaxies with big central black holes (~ light-hour across) also have massive central bulges (on 1000-lightyear-scale)

What's with that?

“Feedback” - the BH grows as the galaxy grows, and then pumps energy back into the galaxy which switches off star formation

We are just beginning to understand the life cycle of galaxies
The Bullet Cluster, 1E0657-56

Two clusters in collision: studying this object let us measure the dark matter

Right: what we see directly in X-rays (red) and optical

Below: blue shows the matter distribution we infer
SUPERNOVAE

Type 1a SN:
- White dwarf star in binary system
- Steals extra mass from companion
- Reaches critical mass
- Runaway fusion converts part of the star to energy within a few seconds
- Star flies apart
- Radioactive decay of newly made elements releases energy over months
- Can tell how much energy it's putting out from how long it takes to fade, so can tell how far away it is!
- Use them to map out the scale of the universe
WMAP: Imaging the universe as it was 13.7 billion years ago
The specks are the seeds from which galaxy clusters will form
From their size we can work out the age of the universe