Astro 233

Basri & Brown, 2006 Astro-ph/
Planetesimals to Brown Dwarfs: What is a Planet?

• Find a link to this article on the Astro 233 web page.
• You should be able to access this from any internet connection because it is available on the “Astrophysics Preprint Archive”

Questions:

Is Pluto a “planet”?

How many planets are there in the Solar System?

What is a “planet”, anyway?
The Solar System

- The Sun is an “average” star
- What does “average” mean?
  - Size (radius)
  - Luminosity
  - Surface temp
  - Mass
  - Chemical comp (?)
  - Age (?)
  - Single star (?)
  - Has planets (?)
  - Configuration of planets (?)

How are other stars/stellar systems/planetary systems different?

Why?
• Titus-Bode Law
• “The first exoplanets discovered are actually terrestrial, but were found in orbit around a neutron star. ... since their current orbits would have been inside the supergiant star that preceded the central pulsar.”
• Transit method
• Gravitational microlensing
• Brown dwarfs (“failed stars”)
• “A modern ‘star’ is an object whose luminosity is derived solely from hydrogen fusion from some period of time.”
• “For stars, the fundamental variable that determines the nature and fate of the object is mass.”
• “Rocks are supported by bound electron degeneracy (in atoms and molecules”.
• “Comet Shoemaker-Levy 9... impacted Jupiter in 1994”
Issues in defining “planet”

- Focus on scientific (physical) criteria
- What/where is the center of mass of the object’s trajectory? (Sun alone?)
- How massive is the planet? (Enough to tend toward sphericity.)
- Orbital/neighborhood characteristics? (Idea that it dominates its orbital path around Sun.)
Trojan asteroids around Jupiter

- 60° ahead of and behind Jupiter in its orbit
- “orbital resonance”
- “equilibrium point”

What is the orbit of the Hubble Space Telescope?
What is the orbit of the Spitzer Space Telescope?
What is the proposed orbit for the James Web Space Telescope?
Why?
Hubble, E. 1947
The 200-inch Telescope and Some Problems It May Solve

- Find a link to this article on the Astro 233 web page.
- You should be able to access this from computer on the Cornell University network, via the Cornell library

Questions:
- What advantages does large aperture bring to imaging?
- What advantages does large aperture bring to spectroscopy?
- What are the science questions Hubble proposes that this new telescope will answer? Was he right?
- How has astronomical observing changed since 1947?
Tools of the astronomer

• The electromagnetic spectrum and light
  • What objects are visible to the Chandra X-ray Observatory, the Spitzer Space Telescope, or the Arecibo Observatory?
• What does the spectrum of an object tell us?
  • Thermal radiation and Wien’s Law
  • Kirchhoff’s Laws
  • Emission and absorption lines
  • Atomic structure
  • Doppler shift (motions)
Astronomical Images

- Position on the sky
- Morphological appearance
- Apparent brightness (flux)

- Images at different times:
  - Does source move?
    - => parallax?
  - Does it change size/shape?
    - Does it change brightness?

- Images in different wavelength bands
  - Flux => temperature, if thermal source
Astronomical spectra

Details of the brightness of a source at different wavelengths

• Temperature
• Chemical composition
• Pressure of gas
• Radial velocity (motion towards or away)

1. Planck’s Law
2. Wien’s Law
3. Kirchhoff’s Laws
4. Doppler Effect
One final point.....

- Not all sources that exhibit continuous spectra are thermal, meaning that their temperature does not determine how their apparent brightness changes with wavelength. => non-thermal sources
- The most important source of non-thermal radiation is synchrotron emission, which is emitted when very fast moving electrons are accelerated as they spiral around lines of magnetic field.

For example, the radio source SgrA*: a supermassive black hole at the center of the Milky Way.
Astronomical observations

• We use telescopes equipped with powerful cameras and powerful spectrographs to gather clues about astronomical objects.

• In some cases, we observe at different times to note changes in the source position, apparent brightness, and apparent shape/form.

• Not all objects are the same......
Powerful telescopes

Adaptive optics-compensated image of selected star field.

Uncompensated image of Galactic Center
Our view depends on the wavelength at which we observe

Bluer (shorter) wavelengths => higher energy => higher temperature
Redder (longer) wavelengths => lower energy => colder temperature

• Often, we need to glean clues from observations at multiple wavelengths in order to deduce the multiple details of the physical conditions in a region or object.

• In other cases, an object/phenomenon is visible only at a single wavelength and invisible (emits too weakly to be detected) at other wavelengths)
Darkness: Absence of (visible) light

Extinction due to foreground dust: makes a star appear redder and fainter
The Orion Constellation

**Orion region:**
- one of most extensively studied regions
- Relatively nearby: only about 500 pc from the Sun
- Hot, young stars + expanding regions of ionized gas + dense molecular clouds (cold and “dark”)
The Orion Constellation

Ultraviolet image from MidEx space telescope:
Very hot stars
Recently formed!
The Orion Constellation

Infrared telescope:
Warm/hot dust (silicates, graphite grains)
The Orion Constellation

Radio: cold clouds of carbon monoxide
Where stars will form in the future
Globular cluster M13

M13 Globular Cluster

Xray image: hottest stars

Jacobus Kapteyn Telescope + CCD Camera
The globular cluster M13, also called the 'Great Globular Cluster in Hercules', is one of the most prominent and best known globular star clusters of the Northern celestial hemisphere. It was selected in 1974 as target for one of the first radio messages addressed to possible extraterrestrial intelligent races, and sent by the big radio telescope of the Arecibo Observatory. This “true-colour” CCD image was taken using the Jacobus Kapteyn telescope and a CCD detector.

Credit: Simon Tellesch (W3).
Globular cluster M13

M13 Globular Cluster

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Credit: Simon Tubbs (WDS), 1999

Infrared image from IRAS: Not much to write home about..
Globular cluster M13

Radio continuum: Not much... Sources not associated with M13
The Crab Nebula: a supernova remnant at 6300 light years

Star in constellation Taurus was observed to brighten so much that it could be seen during the daytime. 1054 A.D.

A supernova: the implosion of the star’s core at the end stage of its life. This phenomenon only occurs in stars significantly more massive than the Sun.
The Crab Nebula

Optical: hot gas in expanding remnant

UV: hot gas
The Crab Nebula

Optical: hot gas in expanding remnant

X-rays: hottest gas
The Crab Nebula

Optical: hot gas in expanding remnant

Radio: high energy electrons
Crab Nebula

Optical + radio + Xray
What is the purpose of a telescope?

1. A telescope acts like a light bucket, to gather photons.
   • The bigger a telescope is, the more photons it can catch.
What is the purpose of a telescope?

2. In addition to gathering light, a telescope allows a more detailed view of the structure of a celestial object and/or to discern the presence of multiple objects. This is called the telescope’s **ANGULAR RESOLUTION**.
What is the purpose of a telescope?

2. In addition to gathering light, a telescope allows a more detailed view of the structure of a celestial object and/or discern the presence of multiple objects. This is called the ANGULAR RESOLUTION.

Minimum angular separation of two objects that can be seen as separate

Remember there are 206,265 seconds of arc in one radian (a useful number to remember).
A Telescope’s Diffraction Limit

The ANGULAR RESOLUTION of a (single) telescope is always limited by its DIFFRACTION LIMIT.

Minimum angular separation of two objects that can be seen as separate

\[
\text{Minimum angular separation} = \frac{1.22 \times \text{wavelength (cm)}}{\text{diameter of telescope (cm)}}
\]

Remember there are 206,265 seconds of arc in one radian (a useful number to remember).
**Diffraction Limit**

In radians

\[
\Theta = \frac{1.22 \times \text{wavelength (cm)}}{\text{diameter of telescope (cm)}}
\]

Example: Hubble Space Telescope HST
The diameter of the telescope is 2.4 m = 240 cm
Let's find the diffraction limit at 5000 Angstroms.

\[
\Theta = \frac{1.22 \times 5000 \, \text{Å} \times 10^{-8} \, \text{cm/Å}}{240 \, \text{cm}} = 2.54 \times 10^{-7} \, \text{radians}
\]

= 2.54 \times 10^{-7} \, \text{radians} \times 206,265 \, \text{arcsec/radian}

= 0.05 \, \text{arc seconds}

Remember there are 206,265 seconds of arc in one radian (a useful number to remember).
The “seeing” of an image is a measure of its quality or sharpness.
The “seeing” of an image

• The seeing of an image is a measure of its quality or sharpness.
• Because stars are so far away, they appear as points of light in our images.
• The seeing then is the angular extent of a star in an image.
• The seeing is always bigger than either (1) the diffraction limit or (2) the atmospheric seeing, whichever is greater.
Reading Assignment


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**Questions:**
What are the major advances that Hubble predicts the 200-inch telescope will offer to astronomers?
Was he correct?