"The Planets"
Astro/EPS C12 (CCN 17045 or 32505)

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PMTs

- linear response
- only one "pixel" so poor spatial resolution
- became popular in 1950s

photomultiplier tubes

PHILIPS
**PLUTO’S LIGHTCURVES**

![Graph of Pluto's lightcurve](image)

*Fig. 2.2: The change in Pluto's lightcurve over almost 30 years, from 1954 to 1982.*

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**IAPETUS**

- Cassini image
- Moon of Saturn
- Discovered 1671 by Giovanni Cassini

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**IAPETUS**

- Leading hemisphere is dark!!
**LIGHTCURVE INVERSION**

- adaptive optics imaging verifies accuracy of shape inversion

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**PLUTO’S LIGHTCURVES**

Fig. 2.2: The change in Pluto’s lightcurve over almost 30 years, from 1954 to 1982.
OBLIQUITY is the angle between an object’s ROTATIONAL axis and its ORBITAL axis.

PLUTO’S OBLIQUITY
- first estimated using the changes in Pluto’s lightcurve
ROTATION AROUND THE CELESTIAL POLE
SEASONS

EXTREME LATITUDES

SEASONS ON URANUS

Summer above the Arctic Circle
SEASONS ON MARS

MARS SEASONS

- plot shows amount of solar radiation received at Mars (color) at different latitudes (y-axis) and times of year (x-axis)

MENTAL EXERCISE

OBLIQUITY
A. \(~0^\circ\)
B. \(~25^\circ\)
C. \(~90^\circ\)
D. not enough info

ORBITAL ECCENTRICITY
A. \(~0.0\)
B. \(~0.05\)
C. \(~0.25\)
D. not enough info

ESTIMATE OBLIQUITY AND ECCENTRICITY FOR THIS OBJECT
**FIRST PLUTO SPECTRUM**

1970 error bars quantify uncertainty in the results

**SCIENCE**

- scientific method: results that can be repeated and verified
- data -> hypothesis -> theory

**COMPOSITION AFFECTS REFLECTANCE SPECTRA**
THE SPECTRUM

- white light can be broken up into colors
- Newton noticed this in the 1600s
- visible: 400–650 nm (4000–7000 Å)

LIGHT WAVES

- $\lambda \nu = c$
- photon energy $E = h \nu = h c / \lambda$

WAVES

- Wavelength
- Crest
- Amplitude
- Undisturbed state
- Trough
- Direction of wave motion

THE SPECTRUM
MENTAL EXERCISE

High-energy radiation (light) can damage DNA molecules in our body, causing damage such as cancer.

WHICH OF THESE TYPES OF LIGHT IS THE LEAST LIKELY TO CAUSE CANCER?

A. ultraviolet A (350 nm)
B. ultraviolet C (200 nm)
C. radio (100 cm)
D. x-ray (1 Å)

UV in the news

- ultraviolet is at shorter wavelengths than visible light
- UVC blocked by ozone layer
RADIO INTERFEROMETRY

Very Large Array (VLA) in NM

ANGULAR RESOLUTION:

- $0.002 \frac{\lambda}{D}$  
  (wavelength in Å, diameter in cm)

- $2000 \frac{\lambda}{D}$  
  (wavelength in cm, diameter in m)

Very Large Baseline Array (VLBA)

OPTICAL / IR INTERFEROMETRY

Very Large Telescope
SPACE TELESCOPES

Hubble Space Telescope

INFRARED

Spiral Galaxy NGC 7331

Spitzer Space Telescope • IRAC

IRAS Infrared Astronomical Satellite

Orion Nebula
SPACE TELESCOPES

Chandra X-ray Observatory

FILTERS

- filters for WFC3 camera to be installed on the final Hubble servicing mission, October 2008

FROST SPECTRA

- when compared to Pluto’s reflectivity, CH4 gave a good match

TITAN

- Cassini/Huygens mission images
- Spectra obtained with infrared photographic film identified methane (CH4) in 1944
- Voyager 1 image
- First extra-terrestrial volcanic eruption witnessed

A "DOUBLE PLANET"

DISCOVERY OF CHARON