Tuesday, October 3, 2017 | 7:30 PM
Clayton Hall Conference Center

Preventing to Explore the Universe with the James Webb Space Telescope

Like a giant golden eye, NASA's James Webb Space Telescope will peer back to the beginning of time and watch galaxies collide. It will capture gorgeous images of stars and planets being born. It will search for new planets and pursue the age-old question: Is life out there?

Astrophysicist Jane Rigby, who grew up in Sussex County, Delaware, is the deputy project scientist for this amazing new space tool. She will show us how it will revolutionize our view of the universe and fill us in on preparations for the telescope's launch in October 2018.

Jane Rigby
Deputy Project Scientist
for Operations - JWST,
NASA

Free and open to the public. Please register online at mountcuba.org

Sponsored by the Delaware Astronomical Research Center at the University of Delaware, Mount Cuba Astronomical Observatory & Mount Cuba Astronomical Foundation
Assignments

• For Wed.
  – Do Online Exercise 08 (“Doppler shift” tutorial)

• Tues. 03 Oct, Vernon lecture, 7:30 p.m. Clayton Hall
  – with signed attendance, get chance to correct 1st midterm for half-back on up to 10 points lost (up to 5 point net).

• 1st Midterm is Friday, Oct. 13 (not on purpose!).
Which forms of light are lower in energy and frequency than the light that our eyes can see?

A. ultraviolet and X ray
B. infrared and ultraviolet
C. visible light
D. infrared and radio
Suppose you know the frequency of a photon and the speed of light. What else can you determine about the photon?

A. its acceleration
B. the chemical composition of the object that emitted it
C. its temperature
D. its wavelength and energy
Chapter 5
Light: The Cosmic Messenger
Wavelength, Frequency, and Energy

\[ \lambda \times f = c \]

\( \lambda = \text{wavelength, } f = \text{frequency} \)

\( c = \text{speed of light} = 300,000 \text{ km/s} \)

\[ E = h \times f = \text{photon energy} \]
Four Ways that Light Interacts with Matter

1. **emission** – matter releases energy as light

2. **absorption** – matter takes energy from light

3. **transmission** – matter allows light to pass through it

4. **reflection** – matter repels light in another direction
Reflection and Scattering

Mirror reflects light in a particular direction.

Movie screen scatters light in all directions.
Interactions of Light with Matter

Interactions between light and matter determine the appearance of everything around us.
Thought Question

Why is a rose red?
A. The rose absorbs red light.
B. The rose transmits red light.
C. The rose emits red light.
D. The rose reflects red light.
Light as Information Bearer

We can separate light into its different wavelengths (spectrum).

By studying the spectrum of an object, we can learn its:

1. Composition
2. Temperature
3. Velocity
Interaction of Light with Matter

- Electron can only have certain energies in an atom.
- Electrons can
  - absorb light & gain energy
  - emit light & lose energy.

- Only photons with energies (colors) matching the “jump” in electron energy levels can be emitted or absorbed.
Hydrogen energy levels
Kirchoff’s laws

1. hot solid/dense-gas: \textit{continuous} spectrum
2. hot gas: \textit{emission line} spectrum
3. cold gas + continuous source: \textit{absorption line} spectrum
Emission Spectra

• The atoms of each element have their own distinctive set of electron energy levels.
• Each element emits its own pattern of colors, like fingerprints, or bar codes.
• If it is a hot gas, we see only these colors, called an emission line spectrum.
Absorption Spectra

- If light shines through a gas, each element will absorb those photons whose colors match their electron energy levels.
- The resulting absorption line spectrum has all colors minus those that were absorbed.
- We can determine which elements are present in an object by identifying emission & absorption lines.
Absorption of Light

Production of Absorption Lines

Cloud of atomic hydrogen gas
White light from star
Star
Telescope

Remove Gas Cloud

Spectrum

Intensity

Wavelength (nm)

400 450 500 550 600 650 700

Telescope

How To Use

Credits
Spectral lines & Doppler shift

- Atoms of a gas absorb & emit light at discrete frequencies
- Motion of atoms shifts frequency by Doppler effect
The Doppler Effect

1. Light emitted from an object moving towards you will have its wavelength shortened. **BLUESHIFT**

2. Light emitted from an object moving away from you will have its wavelength lengthened. **REDSHIFT**

3. Light emitted from an object moving perpendicular to your line-of-sight will not change its wavelength.
The Doppler Effect

\[ \Delta \lambda = \frac{\lambda_{obs} - \lambda}{\lambda} = \frac{v}{c} \]

observe \hspace{2cm} infer
How does light tell us the temperatures of planets and stars?
Thermal Radiation

- Nearly all large or dense objects emit thermal radiation, including stars, planets, and you.

- An object’s thermal radiation spectrum depends on only one property: its temperature.
Thermal Radiation

1. Hotter objects emit photons with a higher average energy.
2. Hotter objects emit more light at all frequencies per unit area.
Temperature dependence of wavelength at peak intensity

Wien’s law

\[ \lambda_{\text{max}} = \lambda_{\text{max, sun}} \frac{T_{\text{sun}}}{T} = 500 \text{nm} \frac{6000 \text{K}}{T} \]

observed color depends on temperature

15,000 K star
the Sun (5800 K)
3000 K star
310 K human
Temperature dependence of total energy flux

Stefan-Boltzmann law

\[ F = \sigma T^4 \]

\( \sigma = \) Stefan-Boltzman constant

flux = power/area  
depends on temperature
Temperature dependence of total energy flux

Stefan-Boltzmann law

power/area depends on temperature

$$F \sim T^4$$
Luminosity

luminosity=total power=flux*area    depends on temperature and radius

\[ L = F \ A = \sigma T^4 \ 4\pi R^2 \]

Using the sun as reference gives:

\[ \frac{L}{L_{\text{sun}}} = \left( \frac{T}{T_{\text{sun}}} \right)^4 \left( \frac{R}{R_{\text{sun}}} \right)^2 \]