Astronomy 105 Laboratory

LAB 06
THE EARTH'S ORBITAL VELOCITY

Lab 06
\[ c = \lambda \times f \]
The Doppler Effect

- **Blue shift**: Wavelength is shorter; frequency is higher.
- **Red shift**: Wavelength is longer; frequency is lower.
- No shift observed
The Doppler Effect

Velocity = 0

Increasing Velocity

Increasing Velocity
The Doppler Effect indicates my velocity is 0 mph?

The Doppler Effect indicates I'm approaching the bus at 20 mph.

The Doppler Effect indicates I'm receding from the ambulance at 20 mph.

The Doppler Effect indicates I'm approaching the sports car at 160 mph? YIKES!!
The Doppler Effect: Measuring the Radial Velocity of a Star

Radial Velocity - 

Radial Velocity + 

Laboratory - No Radial motion

Laboratory Spectrum

Spectral Lines Match

Radial Velocity = 0

Laboratory Spectrum

Spectral Lines Match

$\nu_r = \frac{\Delta \lambda \cdot c}{\lambda_o}$

Redshift

Blueshift

Earth

Distant Star

Radial Velocity - 

Radial Velocity - 

Radial Velocity + 

Radial Velocity + 

$\lambda_o \ \Delta \lambda$
Relative velocity between star and Earth from Doppler shift

\[ V_A = V_{\text{star}} + V_{\text{Earth}} \]
\[ V_B = V_{\text{star}} - V_{\text{Earth}} \]

\[ V_{\text{Earth}} = \frac{1}{2}(V_A - V_B) \]
\[ V_{\text{star}} = \frac{1}{2}(V_A + V_B) \]

\[ V_{\text{Earth}} = \frac{1}{2}(V_A - V_B) \]
\[ 0.86 \]

\[ V_{\text{star}} = \frac{1}{2}(V_A + V_B) \]
Arcturus is about 30° from the Ecliptic and about 30° to the north of the Ecliptic.
Important: Do not write or mark on the Arcturus Handout
Emission Lines *(no Doppler shift)*

Absorption Lines *(Arcturus Spectra)*
Bluer: 426.048 nm and 427.176 nm
Redder: 429.413 nm and 430.791 nm

same wavelength: 427.176 nm and 429.413 nm
\[ \Delta \lambda \]

\[ c = 300,000 \text{ km/s} \]

\[ V_B = \frac{c \cdot \Delta \lambda}{\lambda_o} \]
<table>
<thead>
<tr>
<th>Ref. No.</th>
<th>nm</th>
<th>Shift (mm)</th>
<th>$\Delta \lambda$ Shift x P.S.</th>
<th>$V_B$ (km/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>426.048</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>427.116</td>
<td></td>
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<td>3</td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>429.413</td>
<td>-1.2</td>
<td>-0.0461</td>
<td>-32</td>
</tr>
<tr>
<td>5</td>
<td>429.413</td>
<td>-1.2</td>
<td>-0.0461</td>
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<tr>
<td>6</td>
<td></td>
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<tr>
<td>7</td>
<td>430.791</td>
<td>-1.2</td>
<td>-0.0461</td>
<td>-32</td>
</tr>
</tbody>
</table>

P.S. = $\frac{430.791 \text{ nm} - 426.048 \text{ nm}}{\text{distance between 1 and 7 (mm)}} = \frac{4.743 \text{ nm}}{123.5 \text{ mm}} = 0.03840 \text{ nm/mm}$

$\Delta \lambda = -1.2 \text{ mm} \times 0.03840 \frac{\text{nm}}{\text{mm}} = -0.0461 \text{ nm}$

$v_B = \frac{c \cdot \Delta \lambda}{\lambda_o} = \frac{300,000 \text{ km/s} \cdot (-0.0461 \text{ nm})}{429.413 \text{ nm}} = -32.2 \text{ km/s}$
Lab Objectives

- By measuring the Doppler shift of Arcturus’ absorption lines you will
  - Determine the Earth’s orbital velocity
    - \( V_{\text{earth}} = \frac{1}{2}(V_A - V_B)/0.86 \)
  - Determine the radial velocity of Arcturus
    - \( V_{\text{star}} = \frac{1}{2}(V_A + V_B) \)
  - Determine the radius of the Earth’s orbit
    - \( R = \frac{(V_{\text{earth}} \times \text{time})}{2\pi} \)
Finding the **Radius** of the Earth’s Orbit

The distance the Earth travels around sun in one year is approximately the circumference of the Earth's Orbit ($2\pi R$)

$$V_{\text{earth}} = \frac{\text{distance}}{\text{time}}$$

$$V_{\text{earth}} = \frac{2 \pi R}{\text{time}}$$

$$R = \frac{(V_{\text{earth}})(\text{time})}{2 \pi}$$

$V_{\text{earth}} = 1$ year = 31,600,000 seconds

$\pi = 3.1416$
THE END