

Purpose: Use the Doppler shift of a stellar spectrum to determine the velocity of the Earth as it revolves around the sun and to determine the length of 1 Astronomical Unit (AU)

References: Activities in Astronomy p. 113-117

Procedure: See Activities in Astronomy p. 114-116

Data: In spectra a), we observe a small red shift, while spectra b) exhibits a large blue shift. This tells us that Arcturus must be moving towards us (see Appendix A).

Lambda	a (mm)	b (mm)
4294.13	0.5	0.4
4233.61	0.1	1
4260.48	0.5	0.6
4202.03	0.4	0.7
average	0.375	0.675

Calculations: To convert the above values to angstrom units, we need to determine the dispersion. This is done using the formula:

$$S = \frac{|\lambda_2 - \lambda_1|}{L} = \frac{|4282.41 - 4235.94|}{85} = .546 \text{ \AA/mm}$$

This gives us an Average shift in Spectrum A) of 0.205 A and an average shift in Spectrum B) of .369 A.

We can now calculate the relative velocity between the Earth and Arcturus on both July 1st 1939 and Jan 19th 1940 using the equation:

$$V = c \frac{\Delta\lambda}{\lambda}, \text{ Where } c \text{ is the speed of light in Km/s.}$$

Va (Km/s)	14.63578
Vb (Km/s)	26.34441

Now, by solving the system of equations:

$$Va = (Ve - V_*)$$

$$Vb = -(Ve + V_*)$$

we can calculate the orbital velocity of the Earth. This value is approximately 5.85 Km/s. Solving this system also gives us the velocity of Arcturus with respect to the sun. Arcturus is approaching at about 20.5 Km/s.

Now, by assuming that the orbit of the Earth around the sun is circular, we can estimate it's distance from the sun using the formula:

$$V_e = \frac{2\pi R}{P}$$
, where P is the period of rotation in seconds. This gives the length of 1 AU as being 3.0×10^7 Km.

$$\% \text{ diff} = \frac{|calculated - accepted|}{|calculated + accepted|} * 200 = 92.7\%$$

Results:

Ve (Km/s)	10.9
Vs (Km/s)	38.3
1 AU (Km)	5.50E+07

Conclusion:

The experimental uncertainty in this experiment is enormous. An acceptable error of .4 mm in the initial calculations explodes to a final uncertainty of 1.46×10^8 Km, or about 98 % of the accepted value of 1.5×10^8 Km.

The value achieved for 1 AU is within the values permitted by the experimental uncertainty. Better results could be achieved if finer techniques were used to perform the initial measurements.

Discussion Questions:

1. In general, the Earth is approaching those stars that display a pronounced red or blue shift. Some examples include Betelgeuse shines red and Regal shines blue.
2. Yes, stars that are not directly approached or receded from can be used. However, the phase shifts will be less well defined and the velocity of the Earth must be altered so that only the velocity of the Earth in the direction of the star is used.