

UNIT 8.2 THE DOPPLER EFFECT

OBJECTIVE

To learn how the position of spectral lines gives astronomers a sense of the movement and motions of objects in space. By calculating how the wavelengths (or frequencies) of photons have shifted from their at-rest values, it will become apparent how radial motions may compress or expand the wavelength of photons.

INTRODUCTION

The Doppler effect was first proposed by Christian Doppler in 1842, an Austrian physicist with respect to sound (acoustic waves). It is commonly heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer. Compared to the emitted frequency, the received frequency is higher during the approach, identical at the instant of passing by, and lower during the recession. Regarding the wavelength, the behavior is quite the opposite: the received wavelength is lesser during the approach, identical at the instant of passing by, and increased during the recession.

However, in astronomy and astrophysics, the Doppler effect is mostly discussed and utilized with respect to visible light as well as the other segments of the electromagnetic spectrum. Therefore, in the following, this will be our main focus. Specifically, we will investigate and explore the Doppler effect with respect to distinct spectral lines. The motion of objects becomes obvious by the effect that motion has on the star's spectrum. Spectral lines not only tell astronomers about the composition of a light emitting object, but also the motion of that object.

The word velocity does not simply refer to how fast an object is moving, but also accounts for the direction in which that speed is oriented. Velocities are given in units of length per time (for example, miles per hour or kilometers per second). The velocity describes how a distance between objects changes over time. A 90 kilometer per second velocity translates as a distance either growing or shrinking by 90 kilometers per second. Velocities can be either negative or positive, depending on the orientation of the moving object. A baseball thrown has a velocity that is dependent on who is observing the ball. The observer throwing the baseball may see the ball traveling at +100 mph, as the ball is traveling away from her/him and its distance is increasing (+) as it travels. The person being thrown at will observe the ball traveling at -100 mph. The negative sign is indicative of an object that is decreasing its distance from the observer. Depending on where an observer is standing, she/he will register a different velocity for the baseball in motion. An observer standing aside watching the ball fly directly across her/his line of sight will calculate a velocity of 0 m/sec (since the baseball is neither getting closer to that person nor further away from her/him, simply passing in a straight line through his field of view).

Velocities can have a measureable effect on the way we perceive moving objects. The motion of an object can distort the wavelength of absorbed or emitted photons in much the same way as the motion of a car will distort the sound of its horn to a listener standing on the street. The sound of a car horn will be distorted by the car's approach (where the frequency or pitch of the horn will increase) or by the car's recession (where the frequency or pitch of the horn will decrease) for a listener. Motion *toward* an observer will *compress* sound waves and lead to *shorter* wavelength sound waves (a higher "pitch" sound). Motion *away* from an observer will stretch out sound waves and lead to *longer* wavelength sound (a lower "pitch" sound). Photons can undergo the same expansion and compression; therefore, giving vital information about the motion of stars, gas clouds, and entire galaxies. The speed of light is a fixed quantity and the speed at which photons travel cannot be altered by motion. For example, a star moving toward the Earth at 50% the speed of light will not emit photons which are traveling 50% faster than