MAGIC

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A newsletter for non-scientists (and scientists) interested in MAGIC

Radars transmit pulses of radio waves of a given frequency and receive signals that are reflected, or scattered, from objects such as cloud drops, raindrops, airplanes, or moving automobiles. Based on the time and strength of the returned signal, the distance to the objects and information about their properties can be determined. Information on the speeds of the objects can also be determined using an important physical phenomenon called the Doppler effect, named after Christian Doppler, an Austrian physicist of the 19th century. Everyone is aware of this effect in everyday life, and it is used by radar scientists in a very clever way to detect ***sizes*** of raindrops.

The Doppler effect pertains to the change in frequency of a wave emitted by or scattered from a moving object. Our familiarity with this phenomenon is predominantly with sound waves, but the effect is the same for any wave. When a siren, for example, is moving toward us, the pitch (i.e., the frequency of the sound) is greater, whereas when it is moving away from us the pitch is lower—this is the Doppler effect in a nutshell. The amount by which the pitch is greater or lower, called the Doppler shift, is related to the speed of the object and to the speed of sound. Similarly, for radars, the amount by which the frequency of the radio waves reflected from a moving object changes depends on the speed of the object and the speed of propagation of radio waves, which is the speed of light.

To understand why the Doppler effect works, first consider the simple situation of a wave, such as a radio wave, that is being emitted by a stationary object and detected by a receiver (the situation for a wave being emitted by a radar and scattering off a moving object is a bit more involved, but the results are essentially the same). Radio waves, as discussed in a previous update, consist of oscillations that occur a given number of times every second, which by definition is the frequency of the wave. Each of these oscillations propagates at the speed of light toward the receiver, where they will be detected at a later time which is determined by the distance to the object and the speed of light. As all oscillations travel the same distance and at the same speed from the object to the receiver, the receiver detects the same number of oscillations every second as are being created by the object; i.e., it detects the wave at the same frequency at which it was emitted.

For the situation in which the object is moving toward the radar receiver, the same number of oscillations is being created every second, but each successive oscillation occurs closer to the receiver, and takes less time to travel to the receiver than the previous one. Thus, the receiver detects the oscillations at a higher rate—each second it will detect the number of oscillations that it would have been receiving if the object were stationary, plus the additional number of oscillations it will receive because these oscillations are occurring at a closer distance to the receiver and require less travel time to travel to the receiver. As the motion of the object toward the radar results in more oscillations being received by the radar every second, the frequency is higher. If the object is moving away from the radar the oscillations will be received less often, and the frequency will be lower.

Probably the most common application of the Doppler effect in everyday life is the radar gun, whether used for measuring the speed of baseballs or of automobiles. The radar gun has been around for quite some time, and the first speeding ticket based on its use was issued in Chicago in 1954 (how's that for trivia?). Radar detectors (which are illegal in some states) are merely receivers for the outgoing radio waves from radar guns. Modern radar guns typically operate in the K- or Ka-bands, although they are being replaced by lidars. Lidar, analogous to radar, stands for **LI**ght **D**etection and **R**anging, and lidars use visible light instead of radio waves. There will be a lidar on the MAGIC deployment (a possible topic for a future update).

The Doppler effect is employed by the radars in MAGIC, as stated above, to determine the ***sizes*** of raindrops. This may at first seem puzzling, as the magnitude of the Doppler effect (i.e., the Doppler shift) depends on the speed of an object, not its size. The speed at which a drop is moving toward or away from the radar might not be the same as the speed at which it would normally fall because of updrafts and downdrafts in clouds (and in the atmosphere in general). The next update will explain how radars employ the Doppler effect to determine raindrop sizes. This explanation will necessitate discussion of how fast water drops (i.e., cloud drops and raindrops) fall in still air, and also of some interesting new physics on how the ability of a water drop to reflect electromagnetic radiation depends on the size of the drop and on the frequency of the radiation.

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Please address any questions or comments to elewis@bnl.gov.
All updates and other MAGIC information can be found at http://www.ecd.bnl.gov/MAGIC.html.