# Decoding messages from atoms and molecules

*By J.H. Taylor*

*Editor's note: This is the tenth and final installment in a series of lecture demonstrations on radiation exchange. The author teaches in the Physics Department at Rhodes College in Memphis, Tenn.*

The subject of "radiation exchange" is quite open-ended and provides the teacher with many options for presentation. It could be argued that a good pedagogical approach would be to present at least some of the material along the line of decoding messages from atoms and molecules. At this stage in the careers of most students taking introductory physics, they probably will not have given much thought to the fact that atoms and molecules are constantly communicating with us, so-to-speak, and that we want to try to be clever enough to decode their messages.

A teacher following this approach would find that many of the things discussed in this series of articles can be of help in this decoding approach. For example, when one locates a spectrometer in the focal plane of a telescope and points it toward empty space in the skies, will one be clever enough to decode the messages contained within the cosmic refrigerator or what is called "3 K background radiation"? This would provide a good opportunity to let the students know that atoms and molecules sign their names with their "optical signatures" or "spectrum" and that the science of using a spectrometer to read and decode messages from atoms and molecules is called "spectroscopy." Atoms and molecules also tell us many other things about themselves and their environment. They tell us how hot or cold they are, whether they are moving toward us or away from us, and at what velocities. Even the presence or absence of magnetic and electric fields is included in these communications.

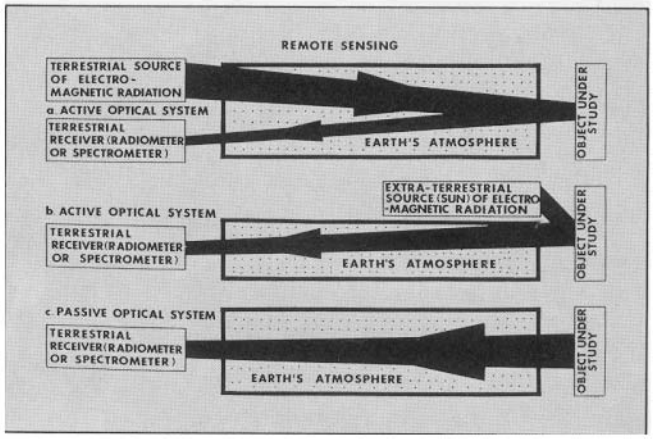


***FIGURE 1. Active versus passive optical systems for carrying out remote sensing (or remote sampling).***

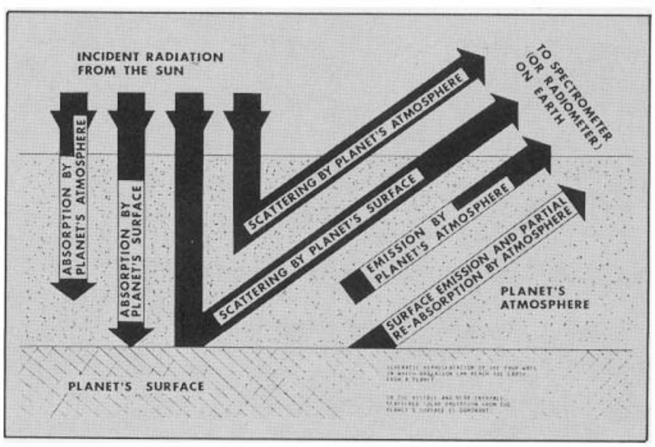


***FIGURE 2. Schematic representation of the four ways in which radiation can reach the Earth from a planet.***

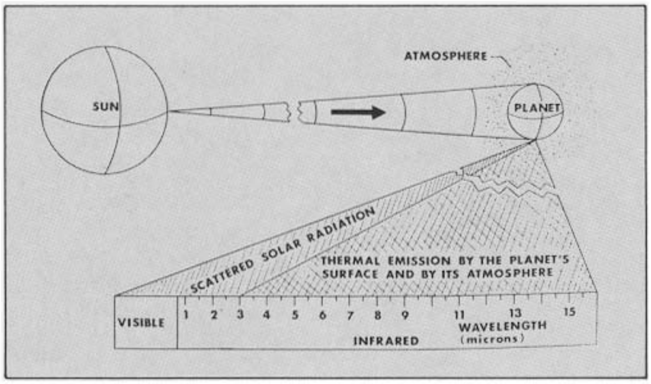


*FIGURE 3. Origin of a planet's spectrum.*

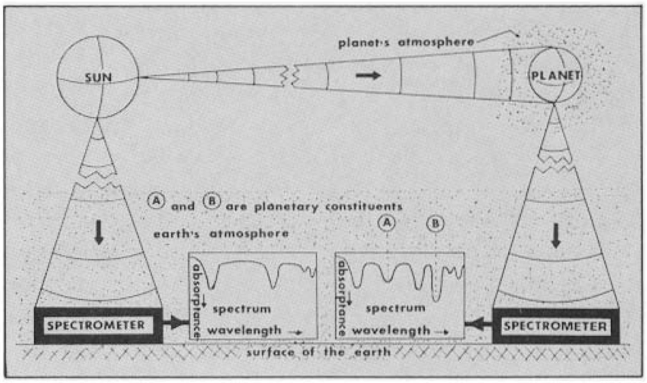


*FIGURE 4. Determining the constituents in a planet's atmosphere.*

## Remote sampling

Decoding the messages from distant atoms and molecules is referred to as "remote sampling" or "remote sensing." If one is carrying out remote sampling experiments from the surface of the Earth or through the Earth's atmosphere from space, say, it is necessary to know about how the Earth's atmosphere can modify the electromagnetic radiation coming from the atoms and molecules. Obviously, such measurements would have to be carried out in the "atmospheric windows."

When students begin to think about carrying out remote sampling experiments, they will realize there are only two ways of doing this—study the self-radiation (often referred to as thermal radiation) emitted by the object (the "passive" approach) or reflect (or scatter) radiation from the object (the "active" approach). Figure 1 illustrates these two methods. From these drawings, one can see very clearly the importance of the part played by the Earth's atmosphere. The following listing should help to understand this figure.

**Active optical system**

Figure 2(a)

- Radar studies of planets or some object in the Earth's atmosphere
- Use of lasers to study atmospheric pollution
- Radar and laser ranging

Figure 2(b)

- Planetary studies with the Sun as the source of reflected (or scattered) electromagnetic radiation

Figure 2(c)

- Studies of thermal electromagnetic radiation from objects located in the Earth's atmosphere or outside the atmosphere
- Studies of thermal electromagnetic radiation from planets
- Studies of solar electromagnetic radiation.

At this point, the teacher is faced with the decision of which example or examples of remote sampling to present to the students. There are obviously many topics from which to choose. It has been the author's experience that the students are going to be interested in your choice, regardless of what it is. They just seem to be interested in this type of physics.

Suggestions that come immediately to mind would be discussions of some of the very interesting observations made from man-made satellites of the distribution of crops on the planet as well as meteorological observations. One might also want to discuss some of the schemes that have been used to try to detect "clear air turbulence" in the atmosphere. The example below deals with planetary radiometry and spectroscopy.

## Planetary radiometry and spectroscopy

It is important to be sure that one fully understands the origin of planetary radiation. Figure 2 is a schematic representation of the four ways in which radiation can reach the Earth from a planet. In the visible and near infrared, scattered solar radiation from the planet's surface is dominant. Figure 3 is an attempt to illustrate the origin of a planet's spectrum. In this figure, "thermal emission" is what we have previously called "self-radiation."

Figure 4 illustrates what is involved in determining the constituents in a planet's atmosphere. Basically, one looks at the Sun with a spectrometer and records its spectrum. Next, one looks at the planet with a spectrometer and records its spectrum. One then looks for differences, such as (A) and (B) in Fig. 4. One then has to determine in the laboratory what gas, or gases, absorb in the regions indicated by (A) and (B).

## Acknowledgment

The author's first interest in experiments dealing with the exchange of radiation between Earth and space was due to the report "On the exchange of radiant energy between the Earth and the sky," by Clay P. Butler (Naval Research Laboratory Report 3984, June 11, 1952).