Astrobiology News April 2014:
Illuminating Patterns in Light

Cosmos: A Spacetime Odyssey episode 5, *Hiding in the Light*, explored how spectroscopy (the detailed study of light from an object) turned astronomy into astrophysics, enabling astronomers to determine the actual compositions of celestial objects - stars, nebulae, galaxies, and so on. In the early 19th century, Joseph von Fraunhofer mounted a prism in front of a small telescope, making a crude spectroscope. He found that the spectrum produced by the Sun and bright stars contained patterns of dark lines. A few decades later, Gustav Kirchoff and Robert Bunsen discovered that when certain chemicals were heated, bright lines appeared – in some cases at exactly the same points in the spectrum as Fraunhofer's dark lines. In fact, every chemical element produces a unique spectrum – sort of like a "fingerprint" (or DNA match, if you will) – which can confirm the presence of that chemical. Bright (or *emission*) lines come from hot gas, whereas the dark (or *absorption*) lines in the Sun's spectrum show where cooler gas above the Sun's surface absorb some of the Sun's light. In this month's article, I'd like to explore briefly the contributions of a few other pivotal scientists to the birth of astrophysics, and how spectroscopy is applied today in the search for life beyond Earth.

Angelo Secchi, SJ was a Jesuit priest who made important contributions to multiple scientific fields. His various interests included astronomy, astrophysics, meteorology, geomagnetism, limnology (the study of inland waters), geodesy (the science of accurately measuring and understanding the Earth's geometric shape, orientation in space, and gravity field), as well as paleontology and archaeology. Since he devised the first classification of stars by their spectra, Father Secchi has often been called the "Father of Astrophysics". Noticing that the patterns of spectral lines varied with a star's color, his initial classification scheme included separate categories for white-blue stars that predominantly show spectral lines due to hydrogen; luminous red stars that show complicated spectral bands; and yellow stars like our Sun that have narrow spectral lines. He later expanded this scheme to include faint reddish stars that predominantly show lines due to carbon, and stars that show hydrogen emission, rather than absorption, lines.

Edward Pickering and his "computers" at the Harvard College Observatory expanded Secchi's scheme in the late 19th century. The "computers" were actually a team of women hired to do the tedious work of cataloguing stellar spectra. Although they were paid at half the wage of men doing similar tasks, "Pickering's Harem", as they were called, had the opportunity to participate in the science they loved, and their performance exceeded that of the men. One of the "computers", Annie Jump Cannon, was recognized as the world's expert in identifying and classifying stars with incredible accuracy and at the rate of up to 300 per hour. Cannon catalogued over a quarter million stars and developed the scheme that astronomers use to classify stars today.

In the early 20th century, Cecilia Payne (known as Cecilia Payne-Gaposchkin after she was married) became the first person to earn a Ph.D. in astronomy from Radcliffe. The astronomer Otto Struve considered her dissertation to be the most brilliant Ph.D. thesis ever written in astronomy, and I have heard a similar opinion expressed by the noted

Harvard historian of science, Owen Gingerich. Payne's work enabled her to relate the spectral classes of stars to their temperatures, and to conclude that hydrogen was the main constituent of stars. In 1934, she received the Annie Jump Cannon award from the American Astronomical Society – an award that was established to honor outstanding research by women in astronomy.

Presently, astrophysicists are using spectroscopy to study properties of the atmospheres of exoplanets that orbit distant stars. A strong motivation for this is the possibility of finding exoplanets with atmospheres similar to that of Earth. While detecting Earth-like exoplanet atmospheres hasn't been done yet, we've started to characterize the atmospheres of some large, hot exoplanets from observations of exoplanets whose orbits pass in front of and behind their stars. A "primary eclipse" (when the exoplanet passes in front of its star) yields information about the composition of the exoplanet's atmosphere. A "secondary eclipse" (when the exoplanet passes behind its star) allows the exoplanet's temperature to be measured as the exoplanet's thermal radiation disappears and then reappears.

In 1835, Auguste Comte, a prominent French philosopher, stated that humans would never be able to understand the chemical composition of stars. How might he have reacted to the suggestion that, in less than 200 years, humans would not only characterize the composition of stars, but of planets orbiting those stars?

Until next month,

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Suggested web resources:
1) The American Institute of Physics History Programs: http://aip.org/history-programs
2) She is an Astronomer, a Cornerstone Project of the International Year of Astronomy 2009: http://www.sheisanastronomer.org/