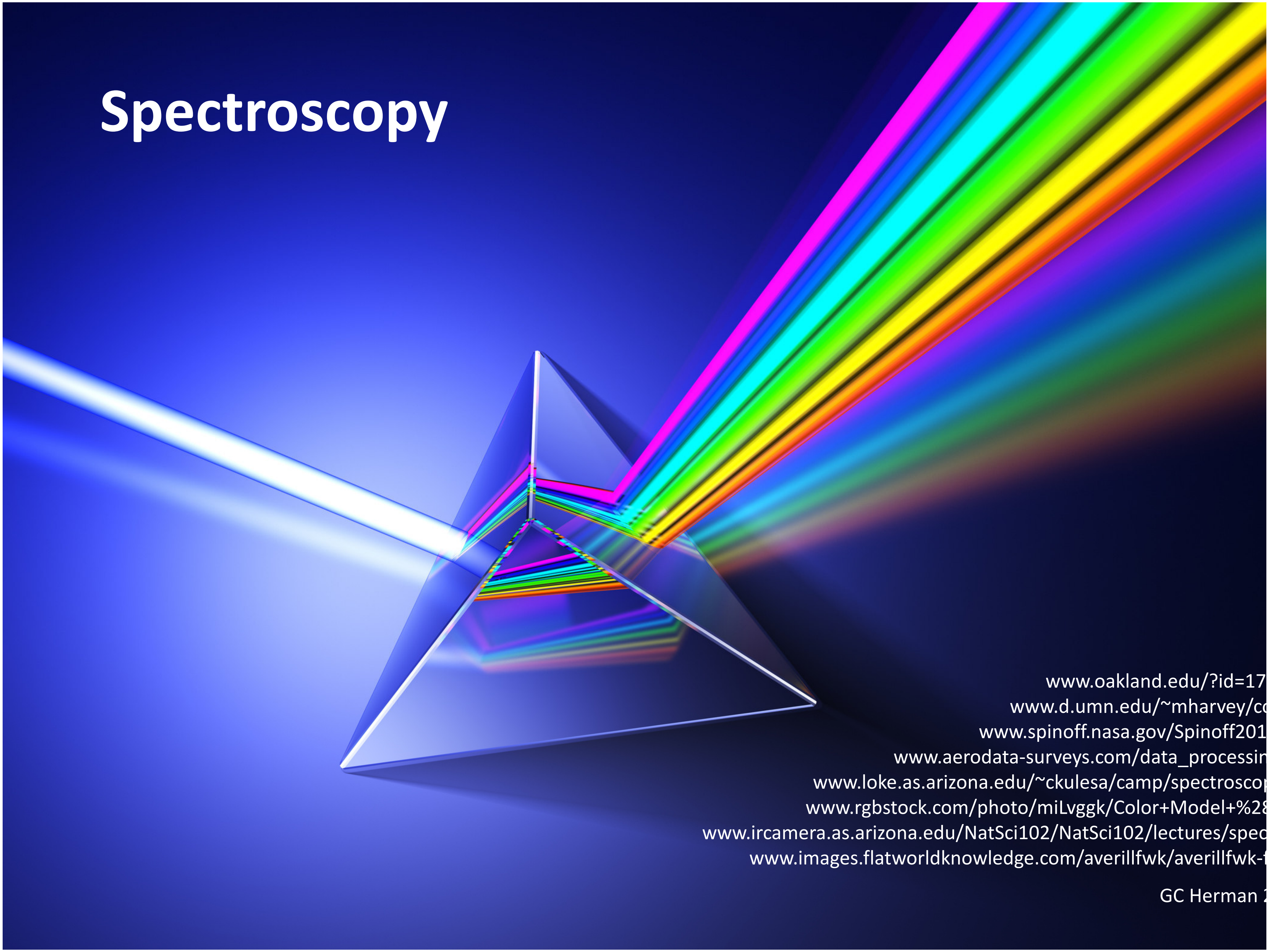
Spectroscopy
www.oakland.edu/?id=17
www.d.umn.edu/~mharvey/c
www.spinoff.nasa.gov/Spinoff201
www.aerodata-surveys.com/data_processin
www.loke.as.arizona.edu/~ckulesa/camp/spectrosco
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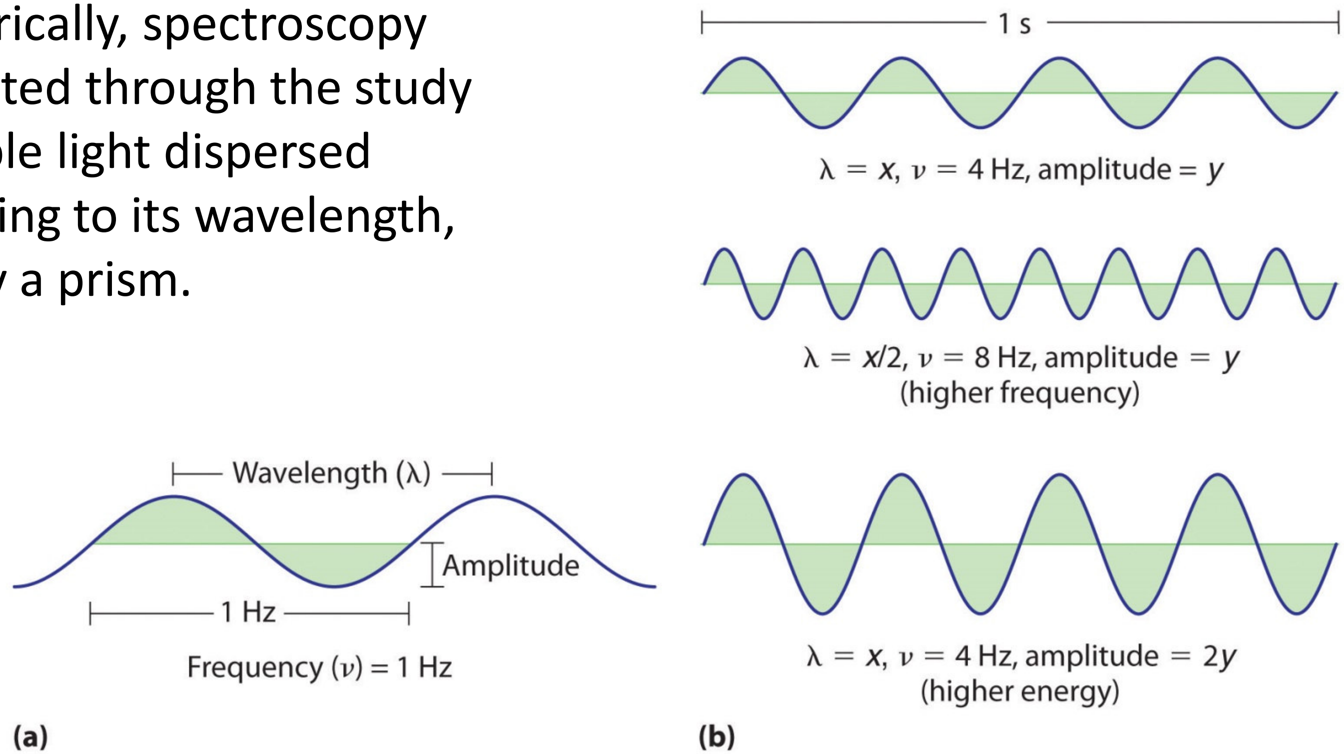
www.ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/spe
www.images.flatworldknowledge.com/averillfwk/averillfwk-
GC Herman

Spectroscopy - is the study of the interaction between matter and radiated energy.

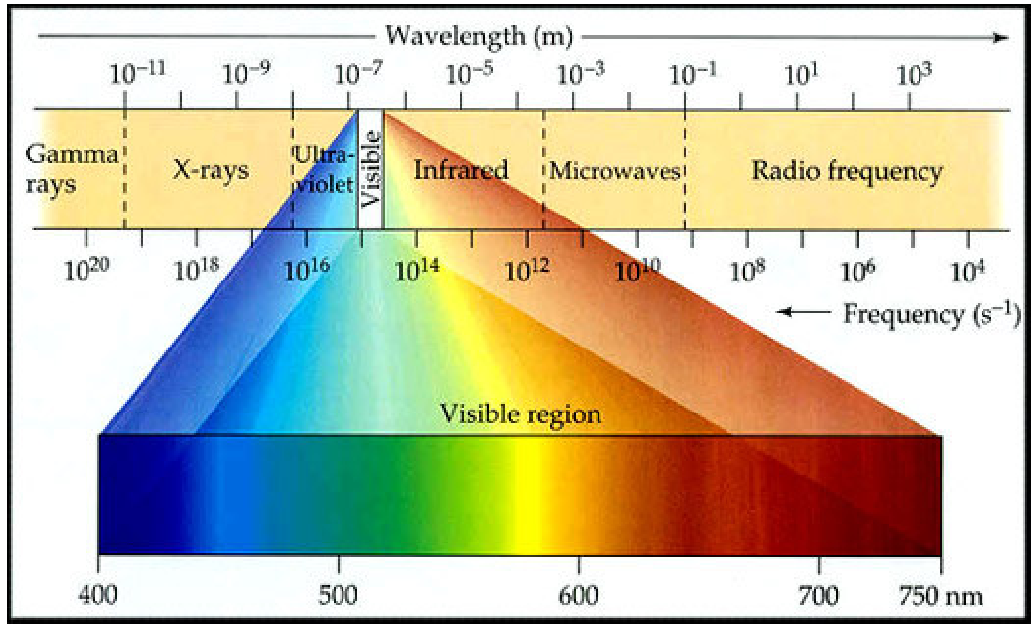
- Historically, spectroscopy originated through the study of visible light dispersed according to its wavelength, e.g., by a prism.



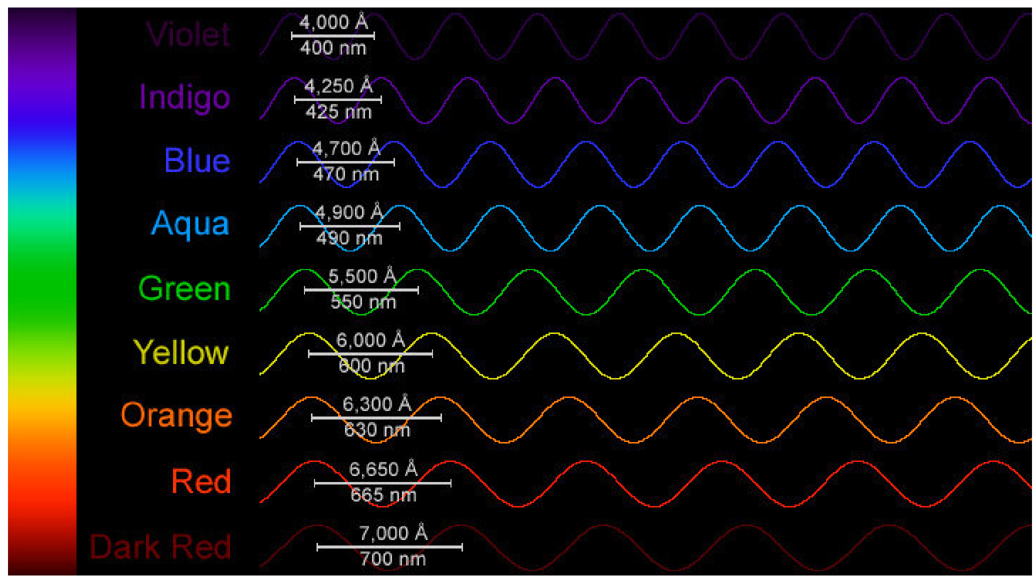
- Later the concept was expanded greatly to comprise any interaction with radiative energy as a function of its wavelength or frequency.

Spectroscopy

- The visible light spectrum with respect to wavelength and frequency



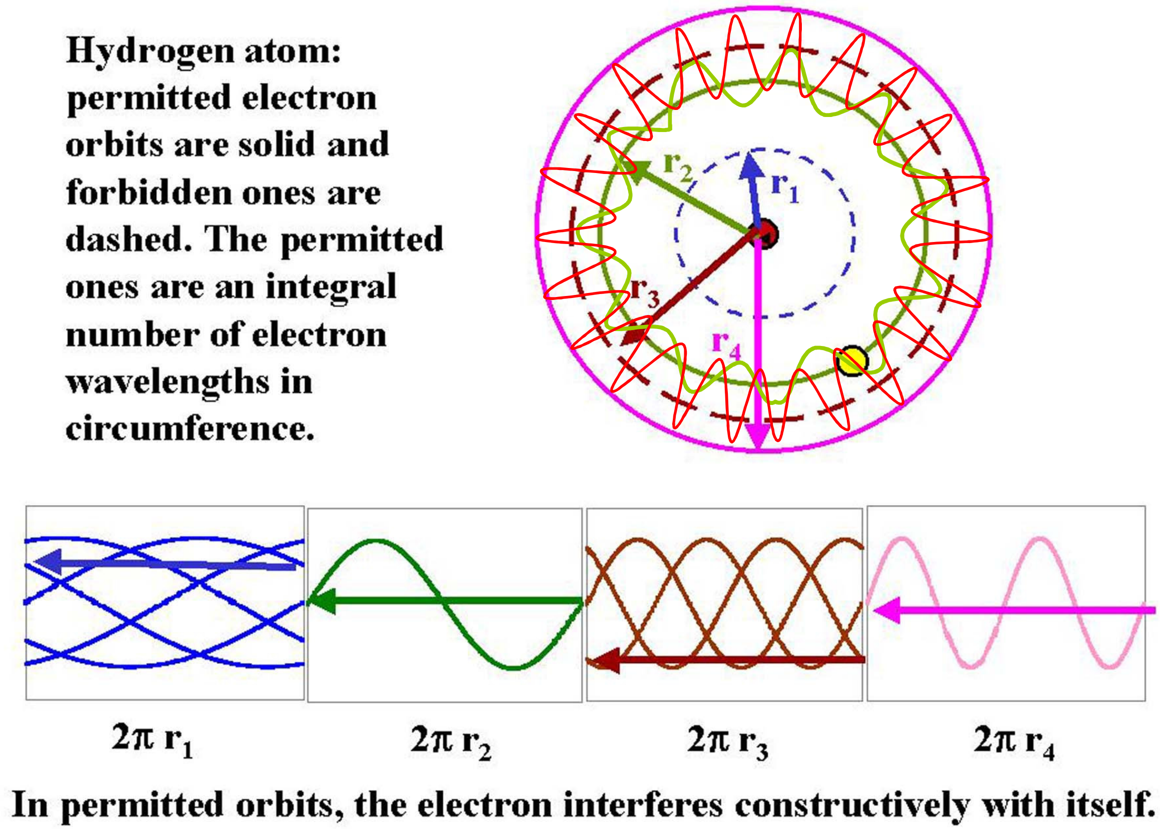
- The visible light spectrum with respect to wavelength



Spectroscopy

• The elementary particle of light and all other forms of electromagnetic radiation is a *photon.*

• Like all elementary particles, photons are currently best explained by quantum mechanics and exhibit *wave–particle duality*, exhibiting properties of both waves and particles, i.e. particles moving in waves of fixed length.



<u>**Electrons can only be in certain energy levels in an atom**</u> because wave-particle duality means they interfere with themselves in the other levels. This behavior is described by the branch of physics called quantum mechanics.

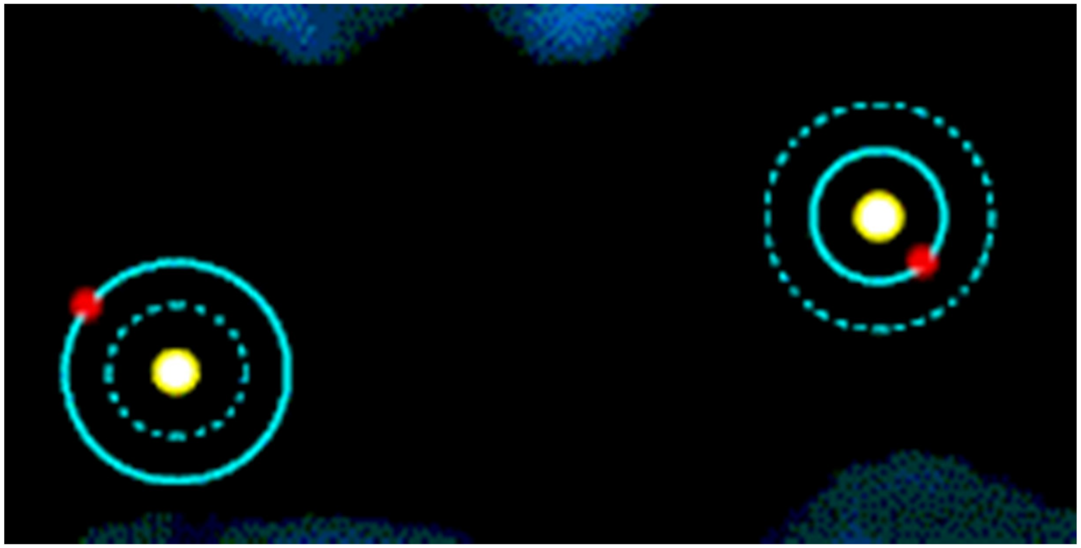
Spectroscopy

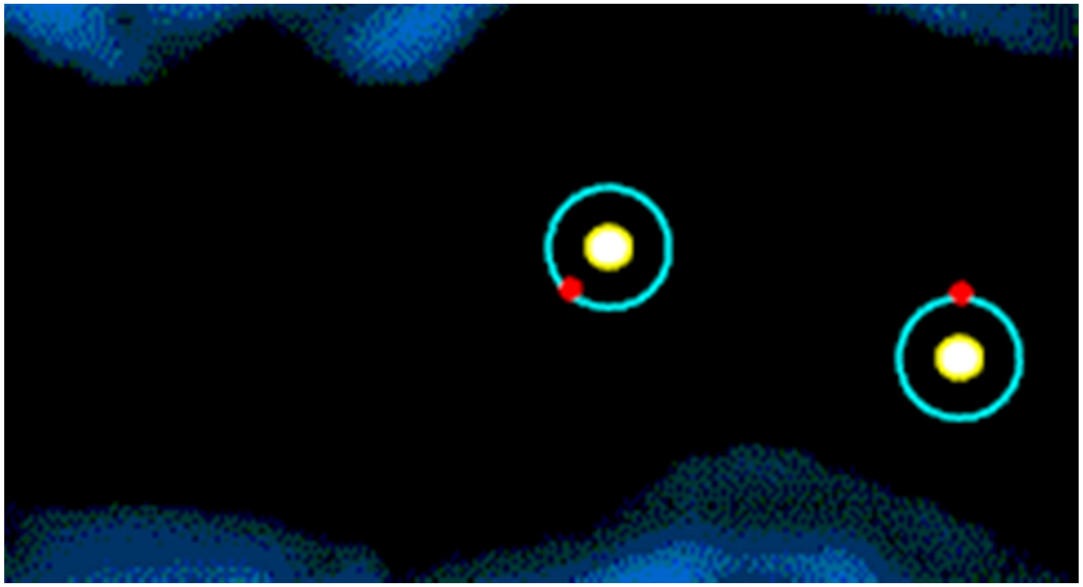
- If a photon of exactly the right energy "hits" an atom, it can be absorbed and causes an electron to jump to an outer, higher energy orbit.

- A photon of the same energy is emitted when the electron falls back down to its original orbit after a short period of time.

- Electrons can also be raised to outer orbits when atoms collide.

- A photon of the characteristic energy is emitted along a different path when the electron falls back to its original orbit, resulting in dispersion of that wavelength of light.





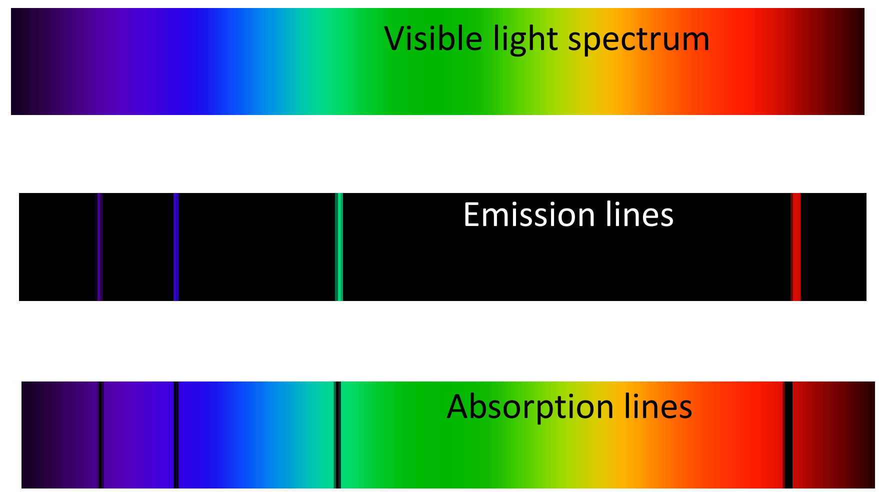
Spectroscopy

• When an electron moves from an outer, higher energy orbit to an inner, lower energy orbit, energy is released in the form of photon.

•The properties of this photon depend on the energy difference between the orbits.

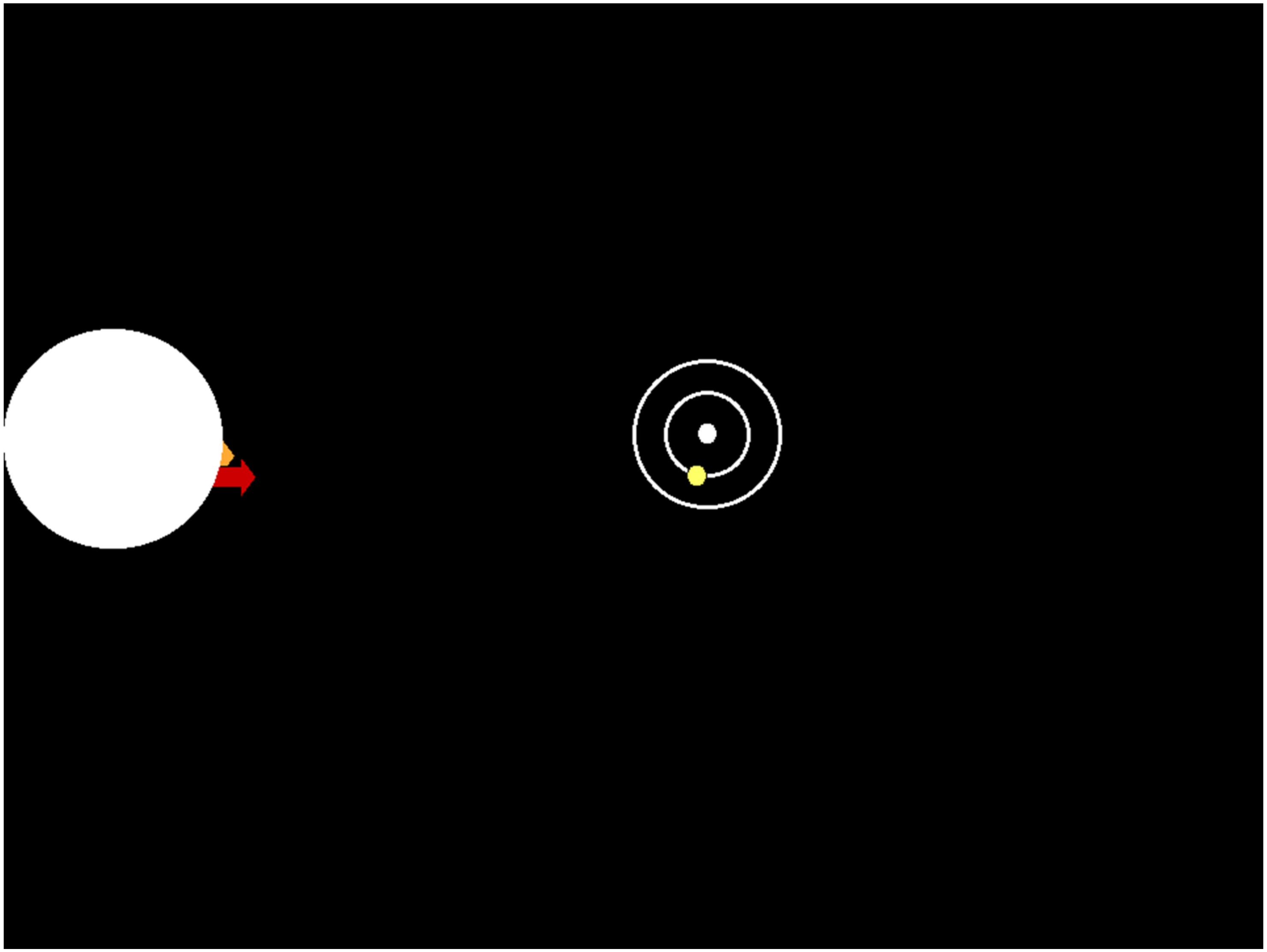
• When photons from a source travel through a gas and reach the eye, or an instrument detector, either an emission line or an *absorption line* will be produced.

•Dark lines in a broad spectrum are produced when a cold gas lies between a broad spectrum photon source and the detector because some light is selectively, and temporarily, absorbed and dispersed.



• By contrast, if the detector sees photons emitted directly from a (hot) glowing gas, then the detector often sees photons emitted in a narrow frequency range by quantum emission processes in atoms in the gas, and this results in an *emission line.*

Spectroscopy



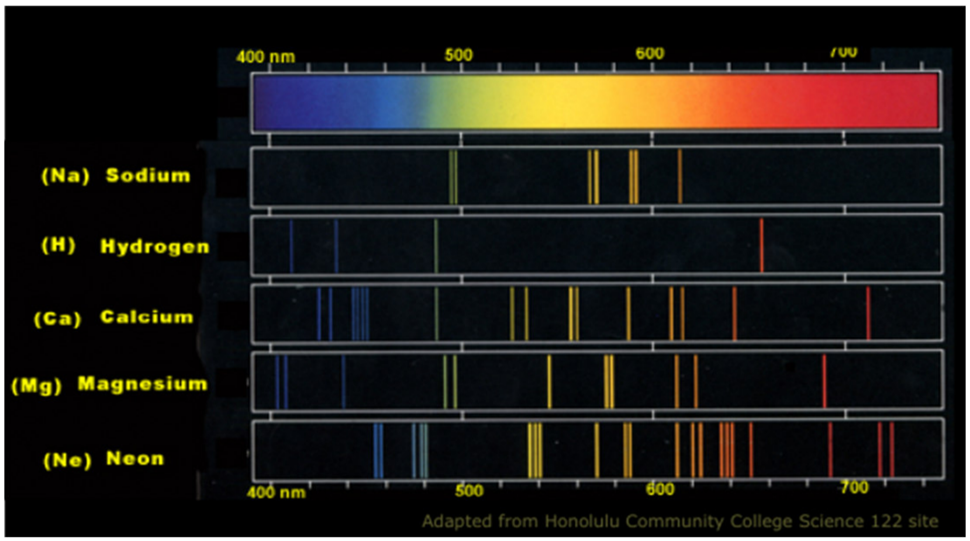
Spectroscopy

• Although it is convenient to draw protons, neutrons, and electrons as little dots, quantum mechanics tells us that they cannot be located accurately and are in fact more like fuzzy little fog clouds. We cannot predict precisely what they will do, leading to a scientific confrontation with the philosophy of determinism: science shows that there is fundamental uncertainty in what will happen in the future

Spectroscopy

•Every element in the periodic table has a characteristic *spectrum* to it. When those atoms are heated up, the transitions back down to lower-energy states cause emission lines, and when a background, multi-spectral light is shone on them, they absorb energy at those very same wavelengths.

• Spectral lines can be used to identify the chemical composition of any medium capable of letting light pass through it (typically gas is used).

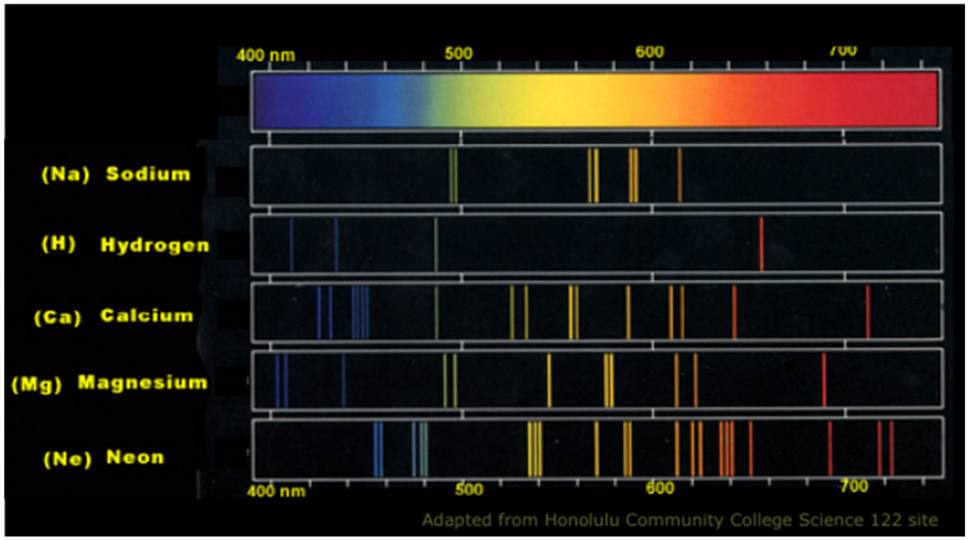


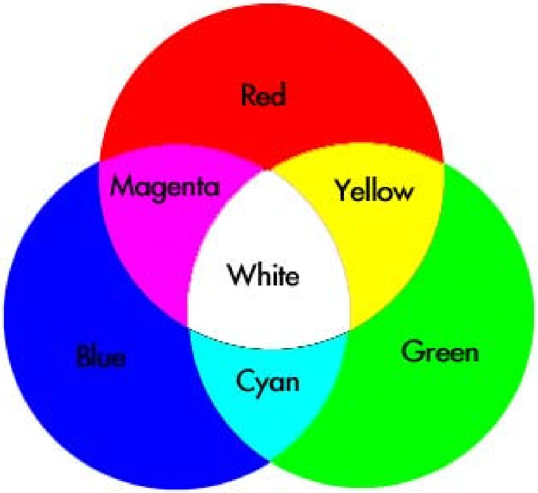
spectral emission lines for the associated elements

•Spectral lines also depend on the physical conditions of the gas, so they are widely used to determine the chemical composition of stars and other celestial bodies that cannot be analyzed by other means, as well as their physical conditions.

•Several elements were discovered by spectroscopic means, such as helium, thallium, and cerium.

Spectroscopy



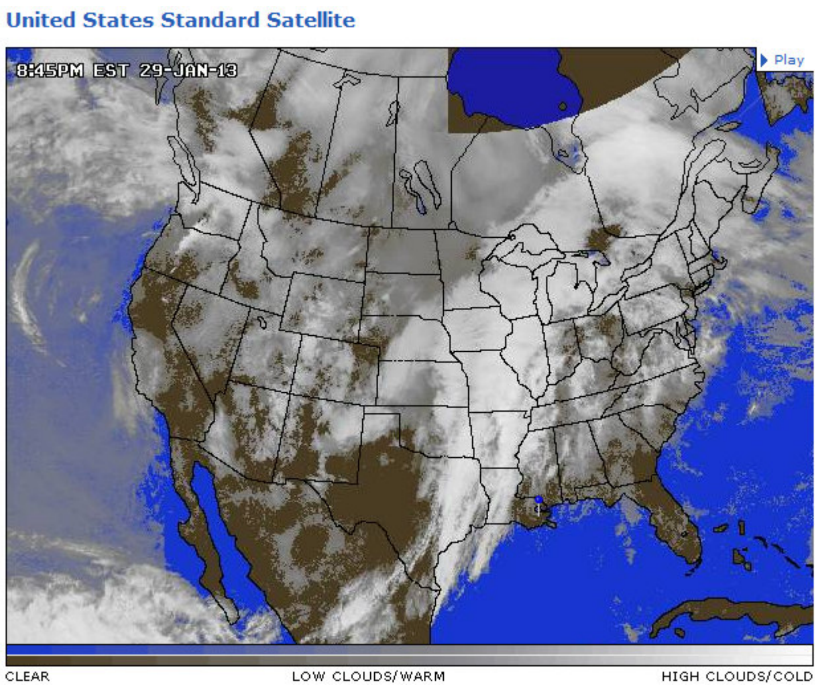


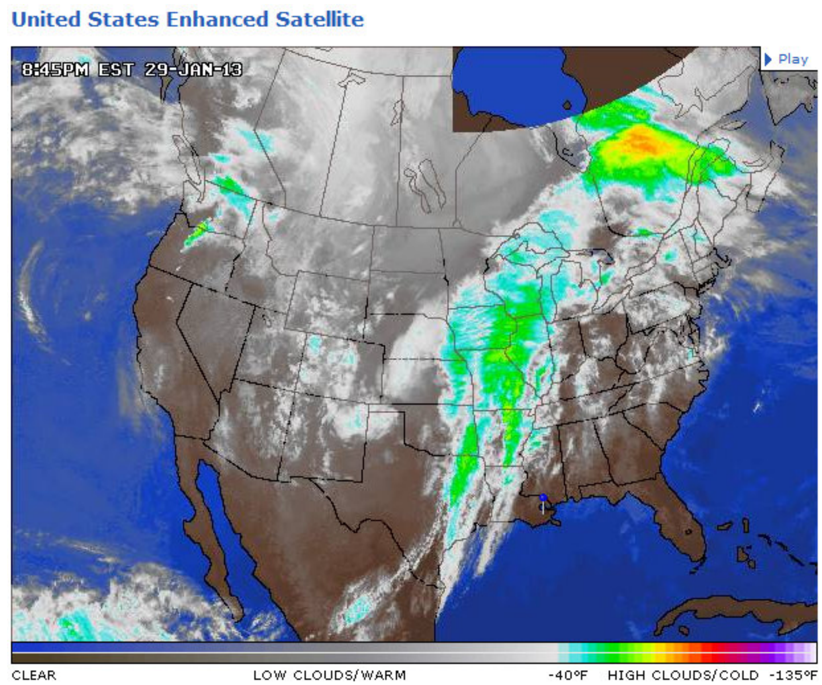
- The composite set of emission lines for a substance form a unique color signature for that substance.

Hyperspectral imaging

- The human eye can see a narrow range of light waves

•Hyperspectral imaging is a technology that allows people to see wavelengths outside of the range of visible light, to get a glimpse at how objects look in the ultraviolet (UV) and infrared (IR) wavelengths—the ranges on either side of visible light on the spectrum.





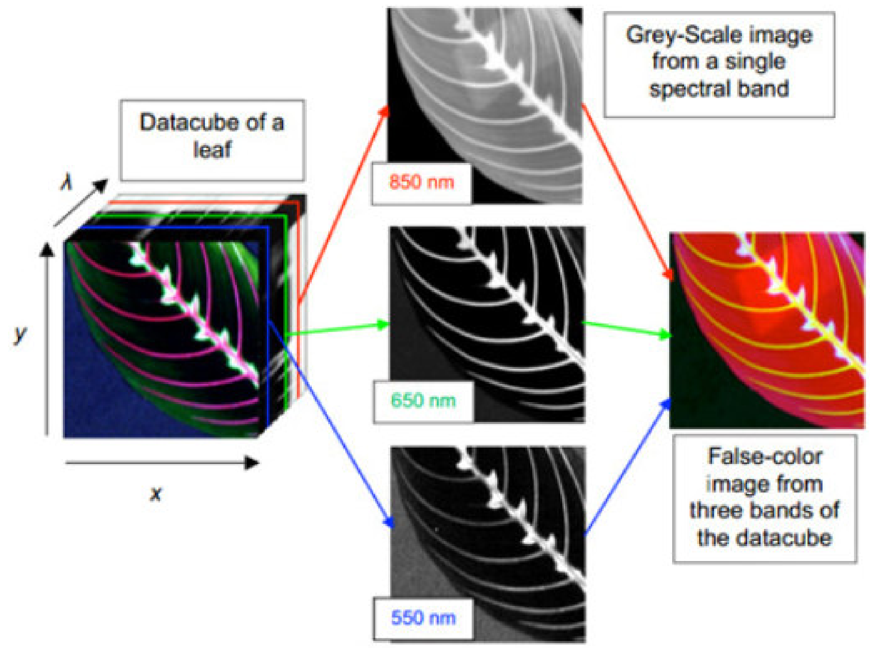
Hyperspectral imaging

• Hyperspectral imaging is the process of scanning and displaying an image within a section of the electromagnetic spectrum.

•To create an image the eye can see, the energy levels beyond our visible perception are targeted, color-coded, and then mapped in layers.

•This set of *false-color images* provides specific information about the way an object transmits, reflects, or absorbs energy in various wavelengths.

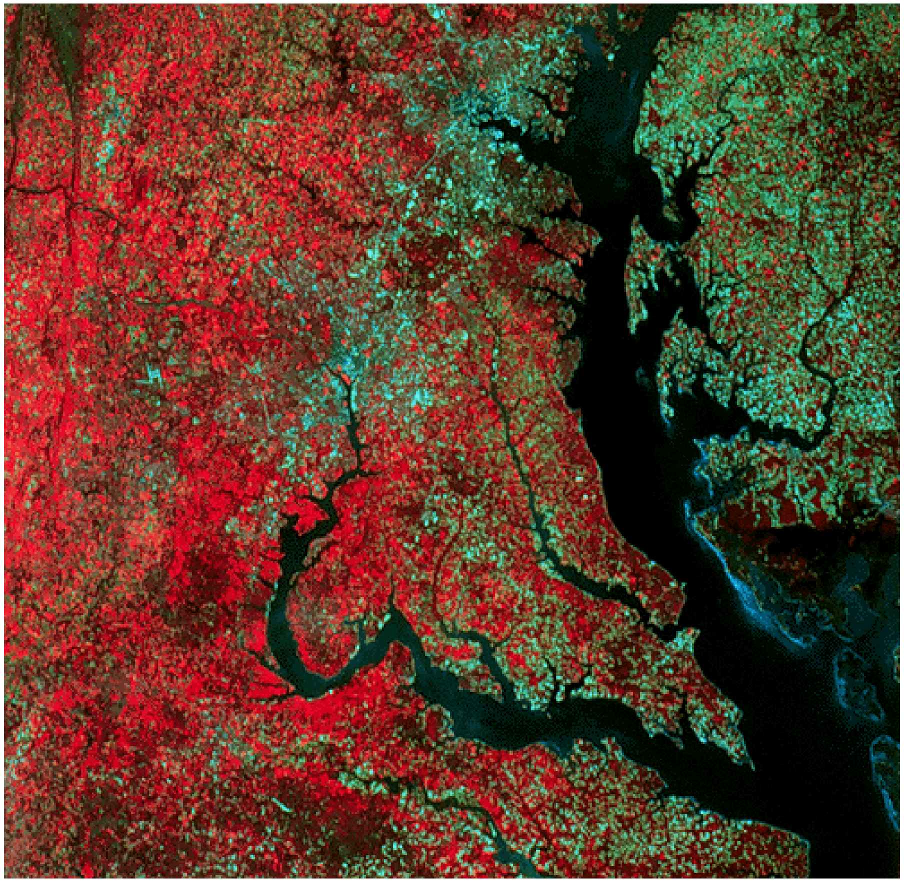
Using this procedure, the unique spectral characteristics of an object can be revealed by plotting its energy levels at specific wavelengths on a line graph. This creates a unique curve, or signature. This signature can reveal valuable information otherwise undetectable by the human eye, such as fingerprints or contamination of groundwater
or food.



Hyperspectral imaging

• Originally, NASA used *multispectral imaging* for extensive mapping and remote sensing of the Earth's surface.

•In 1972, NASA launched the Earth Resources Technology Satellite, later called Landsat 1. It had the world's first Earth observation satellite sensor—a multispectral scanner—that provided information about the Earth's surface in the visible and near-infrared regions.



www.lockley.net/images/balt-dc_landsat_16_33-500x488.gif

•Like hyperspectral imaging, multispectral imaging records measurements of reflected energy. However, multispectral imaging consists of just a few measurements, while hyperspectral imaging consists of hundreds to thousands of measurements for every pixel in the scene.

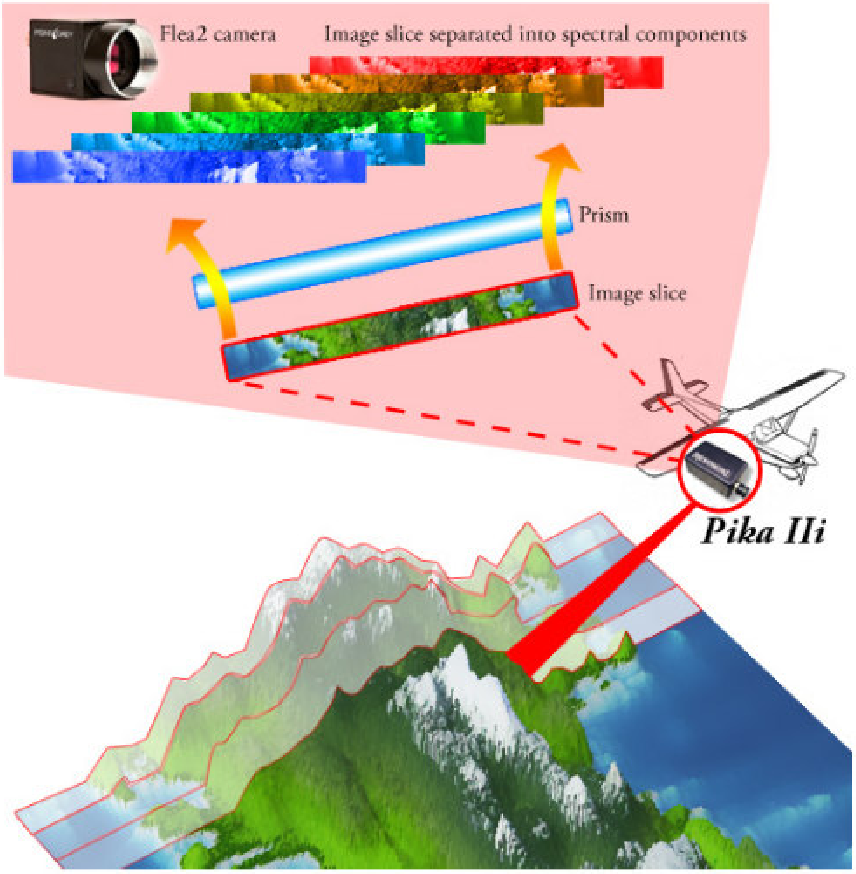
Hyperspectral imaging

In 1983, NASA started developing hyperspectral systems at the Jet Propulsion Laboratory.

The first system, the Airborne Imaging Spectrometer, led to the development of the powerful Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) that is still in use today.

AVIRIS is connected to the outside of aircraft and is used to gather information to identify, measure, and monitor the environment and climate change.

In 2001, NASA launched the first on-orbit hyperspectral imager, Hyperion, aboard the Earth Observing-1 spacecraft.



www.ptgrey.com/news/pressreleases/details.asp?articleID=639

Sent: Friday, January 11, 2013 4:38 PM
Subject: [AASG]: Message from Marcia McNutt to USGS staff

Marcia McNutt

Director of the United States Geological Survey

Early Edition of the Monday Message:
All Good Things Must Come to an End

It is with a heavy heart that I write to let you
all know that as of February 15 I will be leaving the USGS.

Top Moments at the USGS

6. Our hyperspectral survey of the nation of Afghanistan discovered 1 million metric tons of mineral wealth in more than 2 dozen world-class deposits of copper, gold, lithium, rare earth elements, and other commodities. In commenting on our work, Scientific American speculated that replacing "opium and Taliban strongholds with a mining bonanza" could "change U.S. foreign policy and world stability."

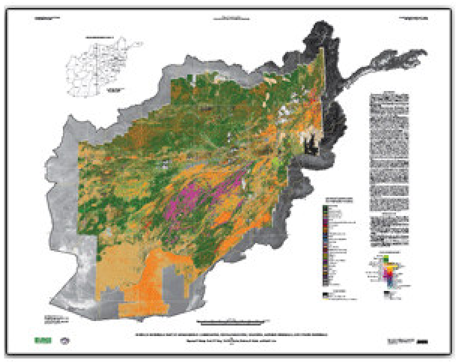
Best wishes to you all,

Marcia

Prepared in cooperation with the Afghanistan Ministry of Mines and Industries pubs.usgs.gov/sim/3152/A/

Surface Materials Map of Afghanistan: Carbonates, Phyllosilicates, Sulfates, Altered Minerals, and Other Materials

By Raymond F. Kokaly, Trude V.V. King, Todd M. Hoefen, Kathleen B. Dudek, and Keith E. Livo



Abstract

This map shows the distribution of selected carbonates, phyllosilicates, sulfates, altered minerals, and other materials derived from analysis of HyMap imaging spectrometer data of Afghanistan. Using a NASA (National Aeronautics and Space Administration) WB-57 aircraft flown at an altitude of ~15,240 meters or ~50,000 feet, 218 flight lines of data were collected over Afghanistan between August 22 and October 2, 2007. The HyMap data were converted to apparent surface reflectance, then further empirically adjusted using ground-based reflectance measurements. The reflectance spectrum of each pixel of HyMap data was compared to the spectral features of reference entries in a spectral library of minerals, vegetation, water, ice, and snow.

This map shows the spatial distribution of minerals that have diagnostic absorption features in the shortwave infrared wavelengths. These absorption features result primarily from characteristic chemical bonds and mineralogical vibrations. Several criteria, including (1) the reliability of detection and discrimination of minerals using the HyMap spectrometer data, (2) the relative abundance of minerals, and (3) the importance of particular minerals to studies of Afghanistan's natural resources, guided the selection of entries in the reference spectral library and, therefore, guided the selection of mineral classes shown on this map. Minerals occurring abundantly at the surface and those having unique spectral features were easily detected and discriminated. Minerals having similar spectral features were less easily discriminated, especially where the minerals were not particularly abundant and (or) where vegetation cover reduced the absorption strength of mineral features. Complications in reflectance calibration also affected the detection and identification of minerals.

First posted July 17, 2012

- **SIM 3152–A** PDF (91.4 MB)
- **Order a copy** from the USGS Store

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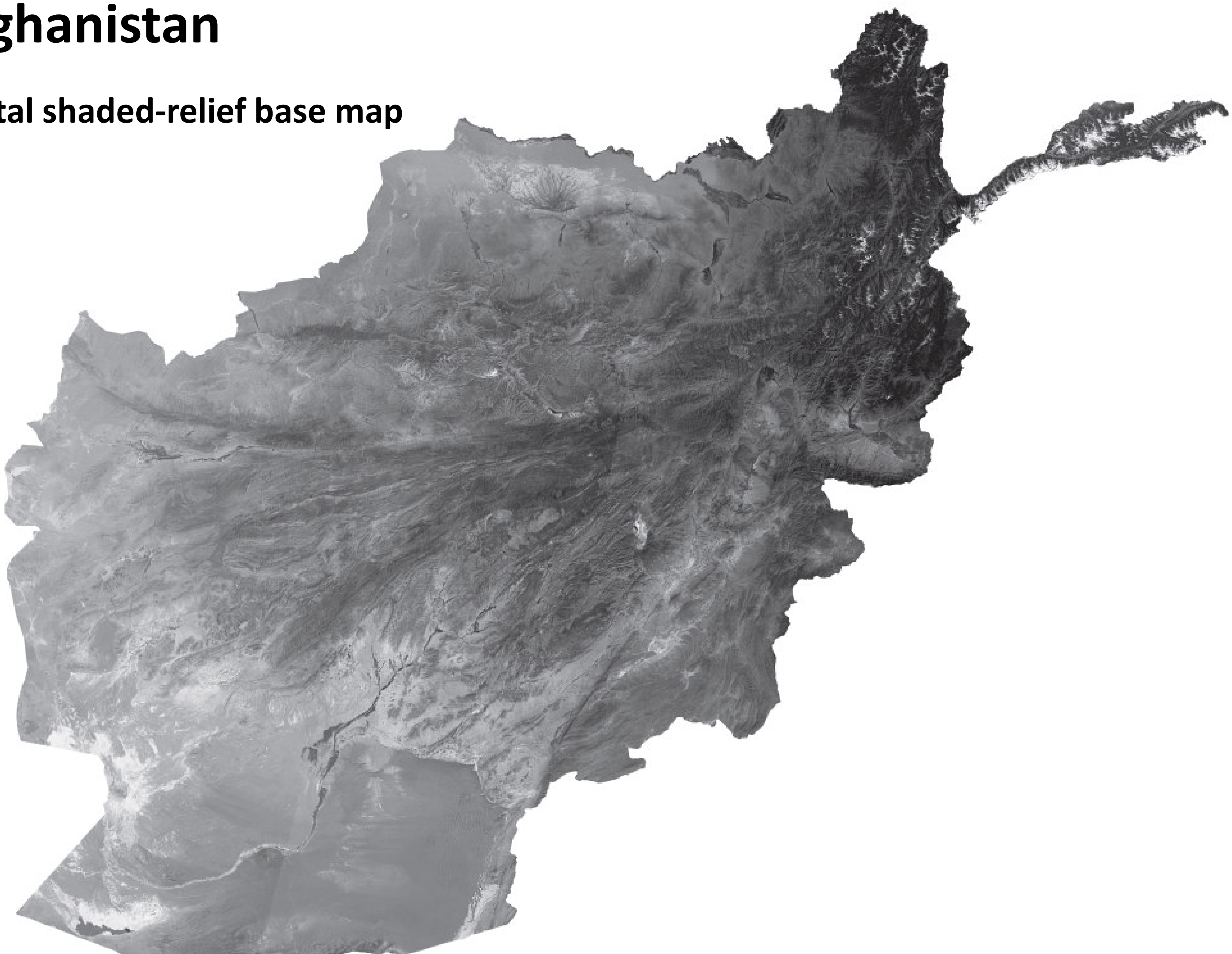
Phone: 303–236–1359
raymond@usgs.gov/

Suggested citation:

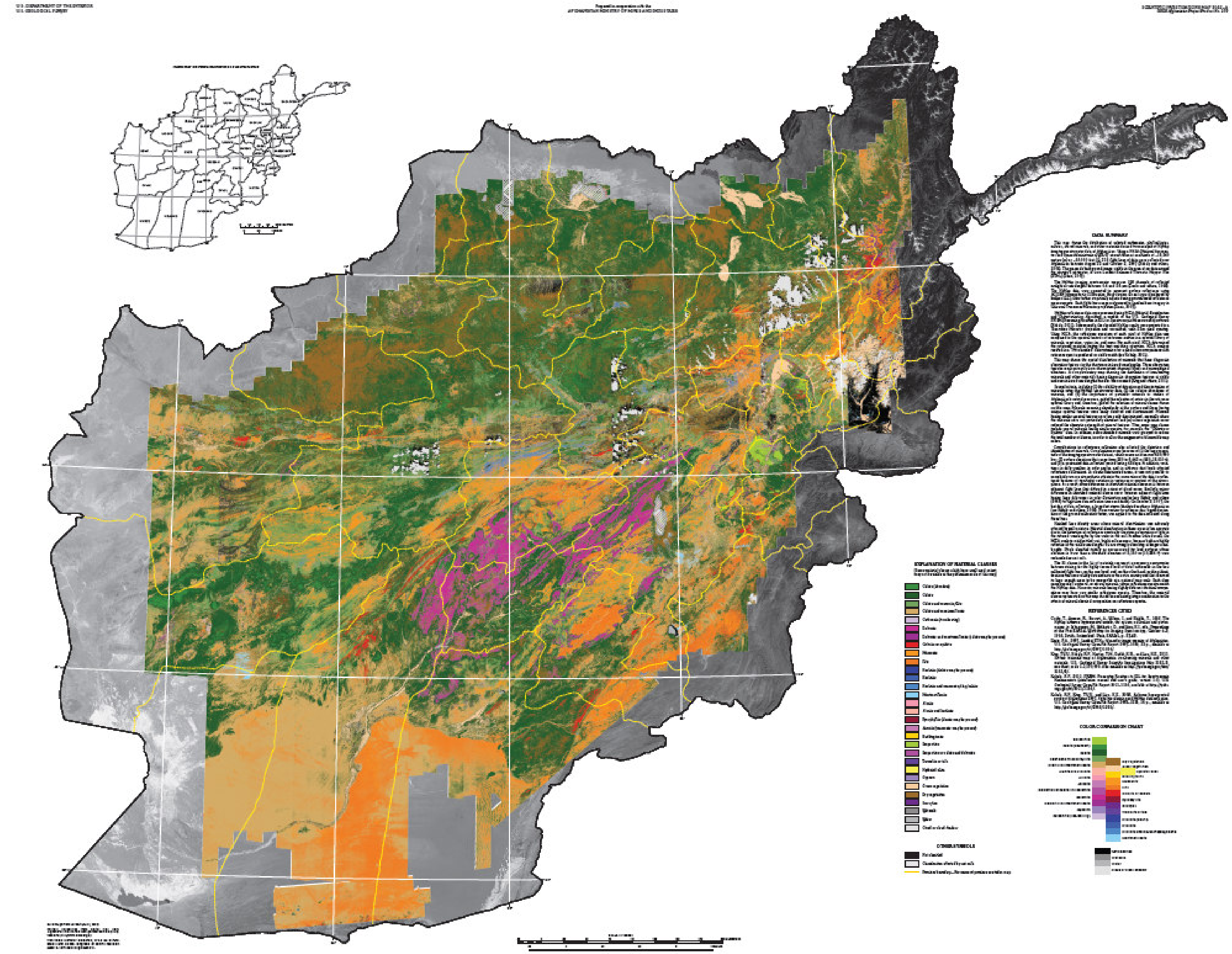
Kokaly, R.F., King, T.V.V., Hoefen, T.M., Dudek, K.B., and Livo, K.E., 2011, Surface materials map of Afghanistan: carbonates, phyllosilicates, sulfates, altered minerals, and other materials: U.S. Geological Survey Scientific Investigations Map 3152–A, one sheet, scale 1:1,100,000. Also available at http://pubs.usgs.gov/sim/3152/A/.

Afghanistan

Digital shaded-relief base map



TCNJ PHYS-120C GC Herman 2016



SURFACE MATERIALS MAP OF AFGHANISTAN: CARBONATES, PHYLLOSILICATES, SULFATES, ALTERED MINERALS, AND OTHER MATERIALS

By

Raymond F. Kokaly, Trude V.V. King, Todd M. Hoefen, Kathleen B. Dudek, and Keith E. Livo

2013

COLOR COMPARISON CHART

Serpentine
Calcite (abundant)
Calcite
Calcite and muscovite/illite
Calcite and montmorillonite
Alunite and kaolinite
Alunite
Jarosite
Serpentine or calcite and dolomite
Dolomite
Dolomite and montmorillonite
Gypsum
Carbonate (iron-bearing)

Dry vegetation
Green vegetation
Hydrated silica
Buddingtonite
Muscovite
Illite
Chlorite or epidote
Pyrophyllite
Snow/ice
Tremolite or talc
Kaolinite (dickite)
Kaolinite
Kaolinite and muscovite/clay/calcite
Montmorillonite

Not classified
Wet soils
Water
Cloud or cloud shadow

TCNJ PHYS-120C GC Herman 2016

EXPLANATION OF MATERIAL CLASSES

[Some material classes which have small areal extent may not be visible at the publication scale of this map]

Calcite (abundant)
Calcite
Calcite and mucovite/illite
Calcite and montmorillonite
Carbonate (iron-bearing)
Dolomite
Dolomite and montmorillonite (calcite may be present)
Chlorite or epidote
Muscovite
Illite
Kaolinite (dickite may be present)
Kaolinite
Kaolinite and muscovite/clay/calcite
Montmorillonite
Alunite
Alunite and kaolinite
Pyrophyllite (alunite may be present)
Jarosite (muscovite may be present)
Buddingtonite
Serpentine
Serpentine or calcite and dolomite
Tremolite or talc
Hydrated silica
Gypsum
Green vegetation
Dry vegetation
Snow/ice
Wet soils
Water
Cloud or cloud shadow

Afghanistan Holds Enormous Bounty of Rare Earths, Minerals

Geologists actually mapping the country's mineral bounty suspect its prime cache of coveted rare earth elements is considerably larger than the latest estimate lets on

By Sarah Simpson

Recent exploration of rare volcanic rocks in the rugged, dangerous desert of southern Afghanistan has identified world-class concentrations of rare earth elements, the prized group of raw materials that are essential in the manufacture of many modern technologies, from electric cars to solar panels. So far, geologists say, they have mapped one million metric tons of these critical elements, which include lanthanum, cerium and neodymium.

RICH ORE: Afghanistan boasts rich deposits of rare earths and other minerals, according to new surveys.
Image: Courtesy of Robert Tucker, USGS

That's enough to supply the world's rare earth needs for 10 years based on current consumption, points out Robert Tucker, the U.S. Geological Survey (USGS) scientist who is the lead author on a report released on September 14. And from clues his team gathered during three high-security reconnaissance missions to the site, he suspects the deposit is actually much larger.

More In This Article

Overview
Afghanistan's Buried Riches

"I fully expect that our estimates are conservative," Tucker told *Scientific American*. "With more time, and with more people doing proper exploration, it could become a major, major discovery." [Click here to read a feature on "Afghanistan's Buried Riches" in *SA*'s October 2011 issue]

The USGS's exploration time has been strictly limited due to the deposit's location in the most dangerous part of the country, near the southern border with Pakistan. The geologists were delivered to the site in Black Hawk helicopters, and armed soldiers watched over them as they scoured the ground for clues.

"It's one of the most challenging things I've ever done," Tucker says. "Walking around with 30 to 40 pounds of protective gear is very difficult." But even the rushed, conservative estimate for the tonnage of this single deposit puts Afghanistan sixth on a list of countries with the largest rare earth reserves. (China ranks first with about 50 million metric tons and U.S. reserves are around 12 million metric tons.)

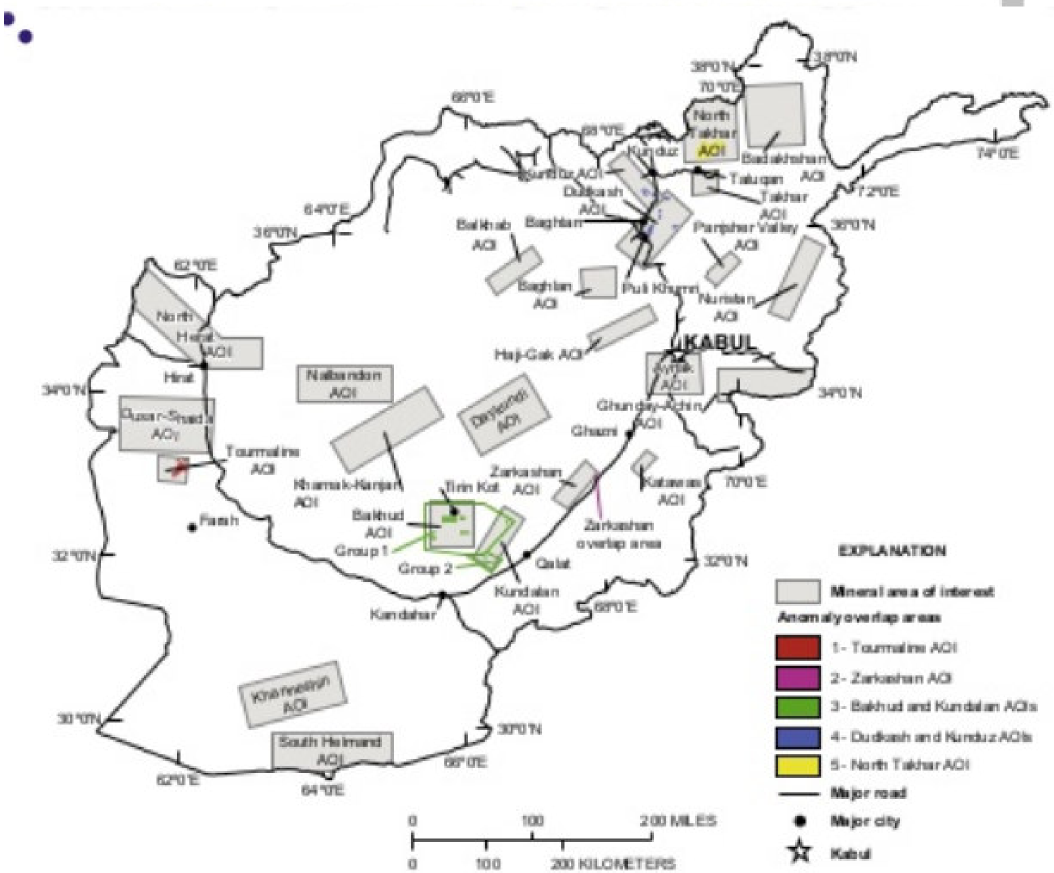
Already, then, Afghanistan could provide an alternative source of rare earth elements for industrial countries concerned that China currently controls 97 percent of the world's supply, Tucker says. Chemical analyses of rock samples his team collected in February show that the concentration of so-called light rare earth elements in the Afghan deposit are on par with the premier site mined in China, at Bayan Obo in Inner Mongolia.

The new rare earth findings are a crown jewel of the USGS's new, 2,000-page assessment of Afghanistan's vast mineral bounty, which will be rolled out September 29 at the Afghan embassy in Washington, D.C. This new science, funded by the Pentagon's Task Force for Business and Stability Operations, also characterizes 24 areas of economic interest, half a dozen of which are world-class mineral deposits in the northern two thirds of the country.

Vast deposits of copper and iron in the northeast near the nation's capital, Kabul, are together worth hundreds of billions of dollars. The Afghanistan Ministry of Mines has already tendered an exploration lease for a copper prospect called Aynak, in Logar Province, and they plan to do the same for several additional sites in the coming months, including a massive iron ore deposit valued at $420 billion.

The hope of senior government officials in both countries is that tapping Afghanistan's underground wealth could transform it from one of the world's poorest nations into a prosperous major global mining center. The plan is to get iron and copper mining established in the north, where the risk of violence is lower, with an eye toward eventually opening up the rare earth deposit in the south.

https://www.slideshare.net/ElsevierConnect/natural-resources-in-afghanistan-by-john-f-shroder-chapters-13-and-14



metry was developed to a robust degree in WWII, and the science of remote sensing was a similar product of the Cold War to detect what the enemy was doing. Afghanistan was a country that had been flown over repeat-

Natural Resources in Afghanistan, Chapters 13, by John F. Shroder, PhD (Elsevier 2014)

$1 Trillion Trove of Rare Minerals Revealed Under Afghanistan

By Charles Q. Choi, Live Science Contributor | September 4, 2014 07:35am ET

Rare Earths, clockwise from top center: praseodymium, cerium, lanthanum, neodymium, samarium and gadolinium.

Credit: U.S. Department of Agriculture / Peggy Greb

Despite being one of the poorest nations in the world, Afghanistan may be sitting on one of the richest troves of minerals in the world, valued at nearly $1 trillion, according to U.S. scientists.

Afghanistan, a country nearly the size of Texas, is loaded with minerals deposited by the violent collision of the Indian subcontinent with Asia. The U.S. Geological Survey (USGS) began inspecting what mineral resources Afghanistan had after U.S.-led forces drove the Taliban from power in the country in 2004. As it turns out, the Afghanistan Geological Survey staff had kept Soviet geological maps and reports up to 50 years old or more that hinted at a geological gold mine.

In 2006, U.S. researchers flew airborne missions to conduct magnetic, gravity and hyperspectral surveys over Afghanistan. The magnetic surveys probed for iron-bearing minerals up to 6 miles (10 kilometers) below the surface, while the gravity surveys tried to identify sediment-filled basins potentially rich in oil and gas. The hyperspectral survey looked at the spectrum of light reflected off rocks to identify the light signatures unique to each mineral. More than 70 percent of the country was mapped in just two months. [Facts About Rare Earth Minerals (Infographic)] https://www.forbes.com/sites/timworstall/2017/07/27/dear-president-trump-afghanistans-minerals-arent-very-valuable-theyre-really-not/#7847695f2615

9,041 views | Jul 27, 2017, 07:04am

Dear President Trump, Afghanistan's Minerals Aren't Very Valuable, They're Really Not

Tim Worstall Contributor

This is almost amusing actually, Donald Trump is reported, in the New York Times, as thinking that Afghanistan's valuable mineral deposits might be a good reason for the US to stay in that country. The humour here coming from the role of the New York Times in misreporting the value of the minerals in Afghanistan some 7 years ago. True, they weren't the original source but they certainly propagated the mistake enthusiastically.

The point being that there are a lot of rocks in Afghanistan, those rocks contain metals and if the metals were out of the rocks and out of Afghanistan then they'd be valuable. But they're not out and out, the metals are still in the rocks in Afghanistan and thus aren't valuable. As we can tell from the fact that no one is lining up to pay for them.

Thus the idea that the US should stay there in order to aid in exploiting this value doesn't really work out, there's no value to be exploiting. This is the bit the NY Times just doesn't get:

> The third is niobium at $80bn. You'd think that US-based boosters would at least check with their own experts on niobium at the USGS. There they would find out that this is some 600 years' supply for the US. Try bringing that sort of volume to market and of course prices are going to plunge.
>
> No, the basic problem with this "analysis", this $1 trillion number, is that it's measuring what everything would be worth as metal, outside Afghanistan, rather missing the point that it's currently not metal and is inside Afghanistan.

Global Witness has been known to make this same mistake, as have rather too many of those asteroid miners. The value of a mineral deposit is not the value of the metal once it has been extracted. It's the value of the metal extracted minus the costs of doing the extraction. And as a good enough rough guess the costs of extracting those minerals in Afghanistan will be higher than the value of the metals once extracted. That is, the deposits have no economic value.

Sad to say but President Trump is getting some seriously bad economic advice if he believes that Afghanistan has swathes of mineral deposits of huge value. It doesn't, it has some rocks with metals in them, not the same thing at all.