Evidence for Star Evolution

Using Spectroscopy to Understand Stars

Crab Nebula Mosaic from HST

Image Credit: NASA, ESA, J. Hester, A. Loll (ASU)

What is the most abundant element in the universe?

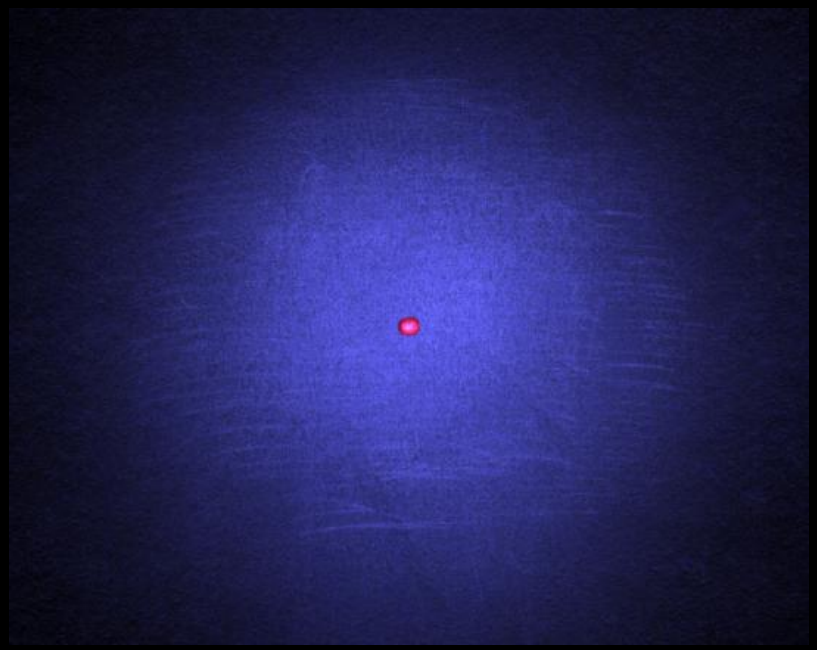
- A) Carbon
- B) Oxygen
- C) Silicon
- D) Hydrogen

Hydrogen

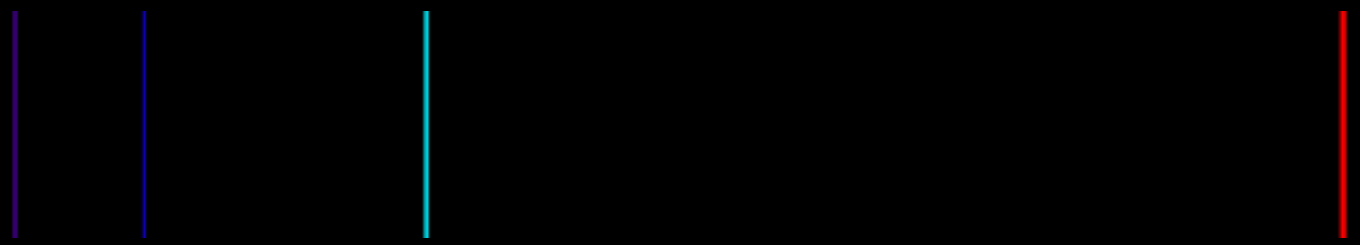
Clouds of glowing hydrogen gas mingle ominously with dark dust lanes in this close-up of IC 1396, an active star forming region some 2,000 light years away in the constellation Cepheus. In this and other similar emission nebulae, energetic ultraviolet light from a hot young star strips electrons from the surrounding hydrogen atoms. As the electrons and atoms recombine they emit longer wavelength, lower energy light in a well known characteristic pattern of bright spectral lines. At visible wavelengths, the strongest emission line in this pattern is in the red part of the spectrum and is known as "Hydrogen-alpha" or just H-alpha. Part of IPHAS, a survey of H-alpha emission in our Milky Way Galaxy

- IC 1396 H-Alpha Close-Up
- Credit: Nick Wright (University College London),

Hydrogen Energy Levels



Energy Level	Energy
1	-13.6 eV
2	-3.4 eV
3	-1.51 eV
4	-.85 eV
5	-.54 eV

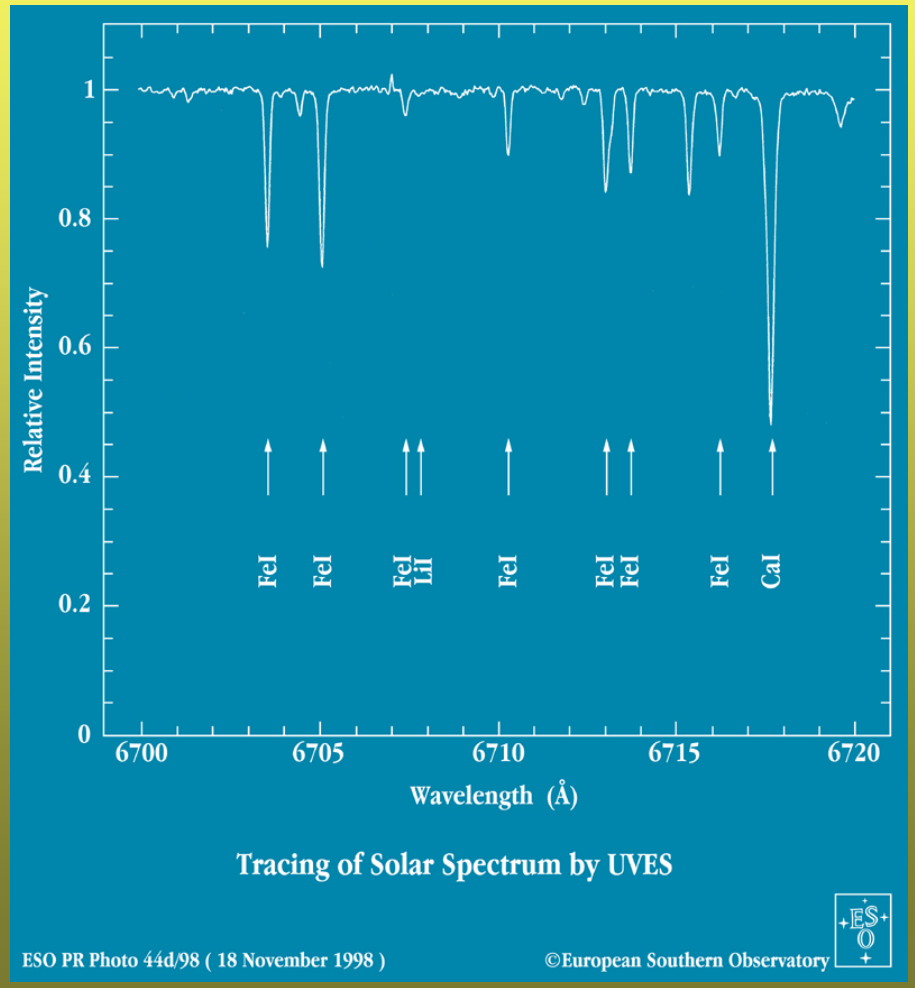


The four visible hydrogen emission spectrum lines in the Balmer series. H-alpha is the red line at the right.

Line Absorption Spectra

Line absorption spectra is just the negative of a line emission spectra

The bottom chart gives a quantitative value for the brightness of the lines.



DETERMINING THE COMPOSITION OF STARS

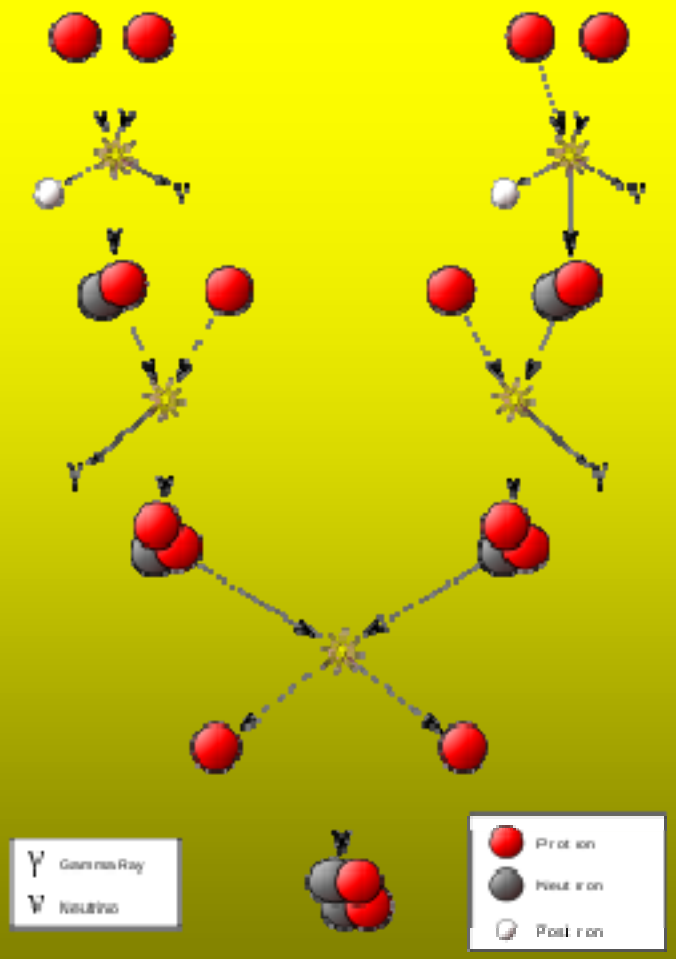
- When energized atoms and molecules vibrate, they give off massless light particles called photons. These photons travel as a wave, but because of quantum energy effects, a particular type of atom or molecule gives off only certain wavelengths of photon light. For example, when hydrogen atoms are giving off energy in the form of light, they emit light specifically at wavelengths of 410.2 nm, 434.0 nm, 486.1 nm, and 656.3 nm. This is called the emission spectra of hydrogen.
- Scientists can use the emission spectra of atoms and molecules to study the composition of stars. Scientists need simply to look very carefully at the intensity and wavelengths of the light given off by the star. A star containing hydrogen, for example, would have intense peaks of energy at 410.17 nm, 434.05 nm, 486.13 nm, and 656.28 nm. These hydrogen emission peaks would be in addition to the ones associated with the other elements contained in the star.

Where are most of the other elements made?

- A) in the Big Bang
- B) in a Star
- C) in the Earth
- D) in a scientific laboratory

NGC 3603: From Beginning To End
Credit: Wolfgang Brandner (JPL/IPAC), Eva K. Grebel (U. Wash.), You-Hua Chu (UIUC), NASA

Nuclear Fusion



From Wikipedia

- The most important fusion process in nature is that which powers the stars. The net result is the fusion of four protons into one alpha particle, with the release of two positrons, two neutrinos (which changes two of the protons into neutrons), and energy, but several individual reactions are involved, depending on the mass of the star. For stars the size of the sun or smaller, the proton-proton chain dominates. In heavier stars, the CNO cycle is more important. Both types of processes are responsible for the creation of new elements as part of stellar nucleosynthesis.

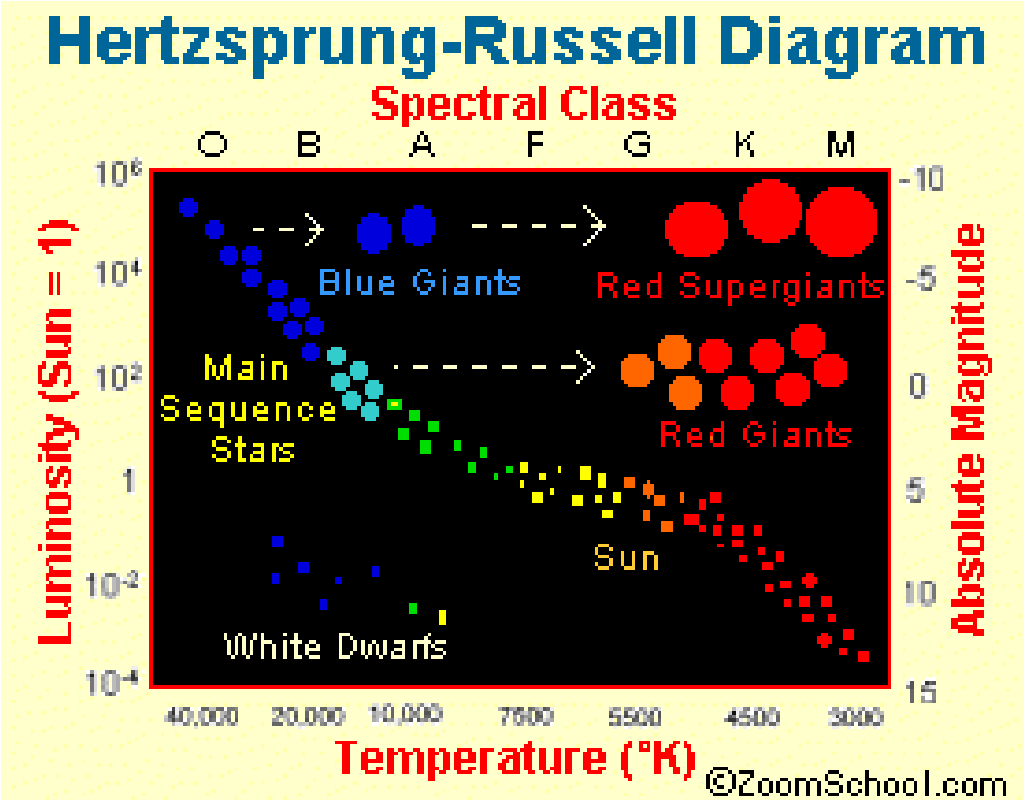
Classes of Stars

- The traditional spectral types are denoted by the letters O,B,A,F,G,K,M

- *And then there is:*

  Tom Cruise and

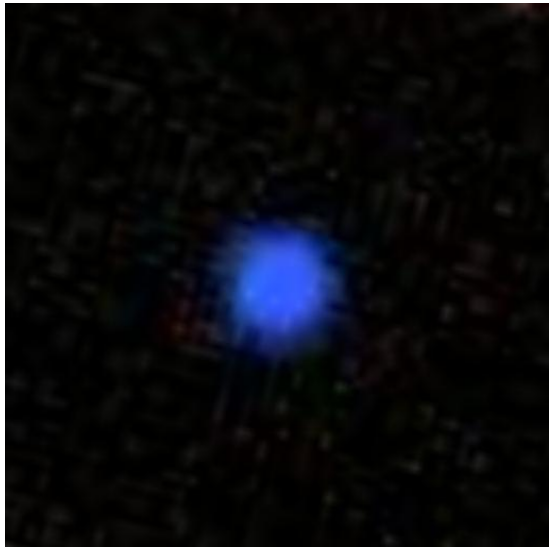
  Kate Beckinsale

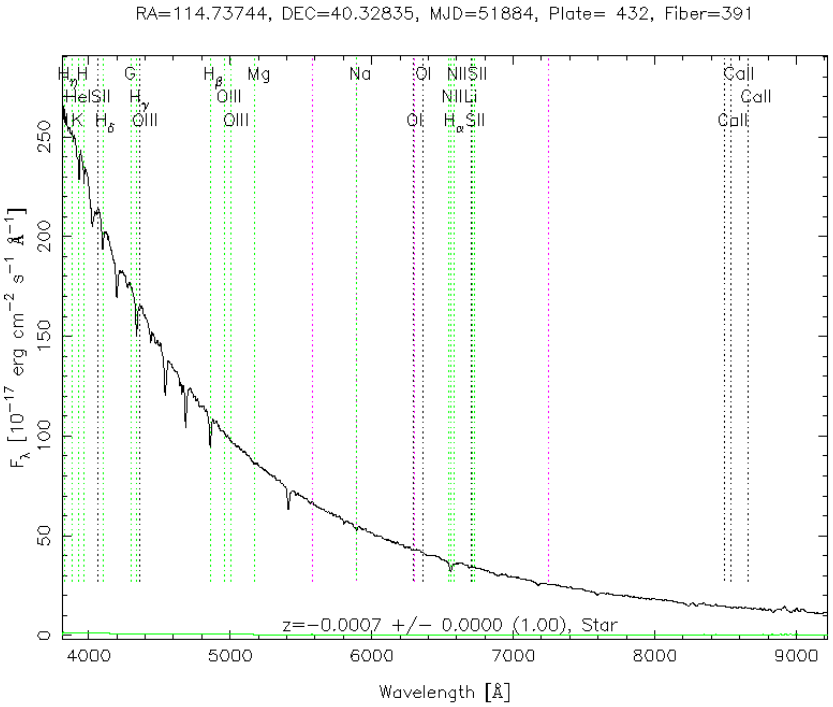


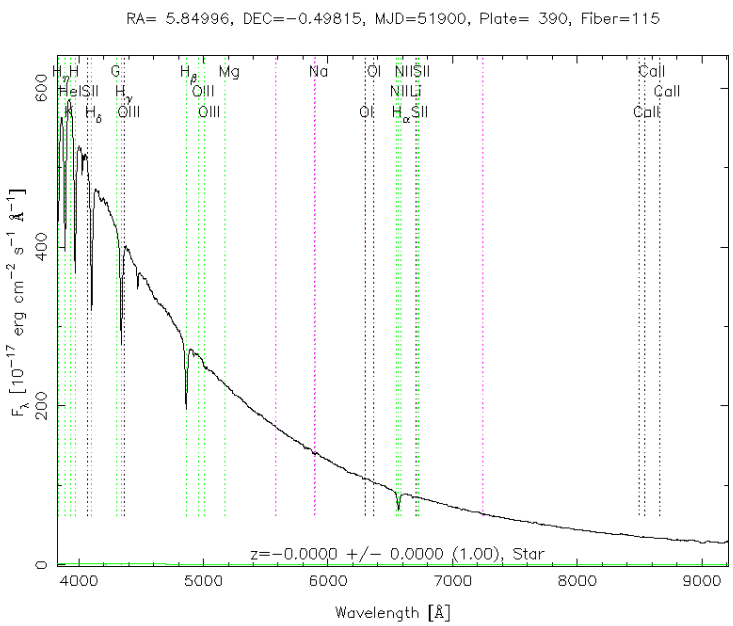
B

- B stars are so hot

(T = 35,000 K) that the hydrogen atoms are mostly in very excited states. Since few are in the first excited state, few absorb photons with these wavelengths. Therefore, the lines appear weak.





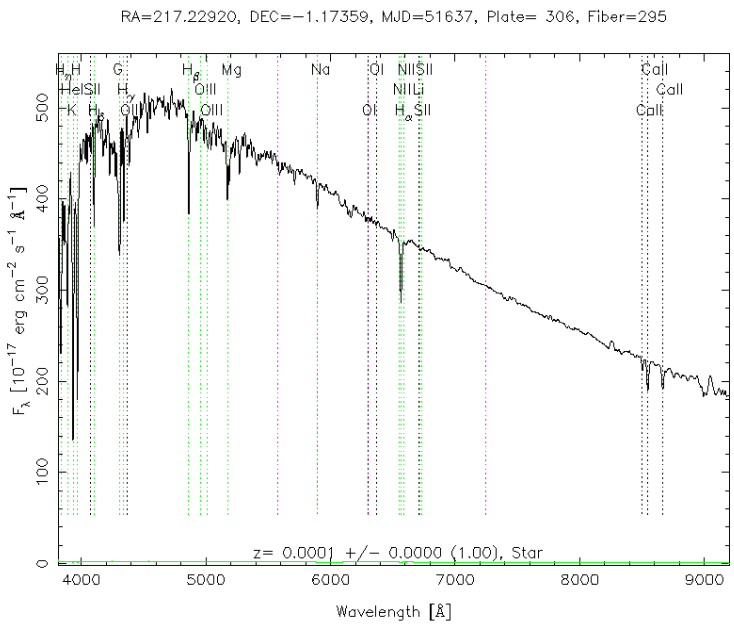


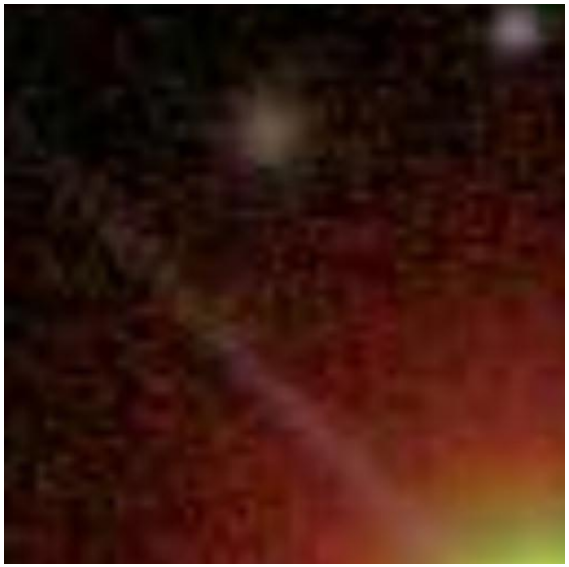
A

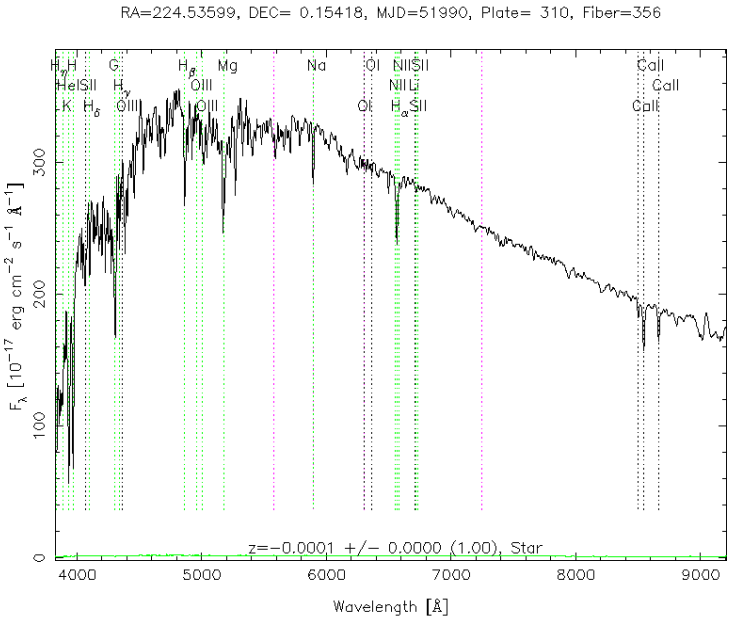
- A stars are just about the right temperature (T = 9,500 K) for most hydrogen atoms to be in the first excited state. Therefore, many atoms absorb photons with these wavelengths, and the lines appear very strong.

F

- F stars are at a lower temperature (T = 7,300 K), so many of their hydrogen atoms are in the ground state. These atoms can't absorb photons of Balmer wavelengths, so the lines appear weaker.





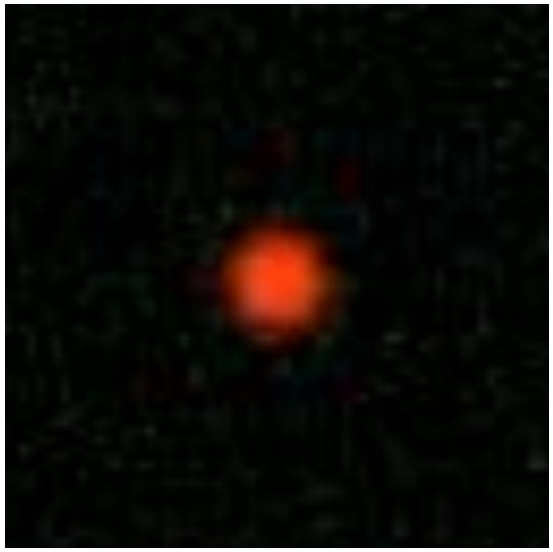


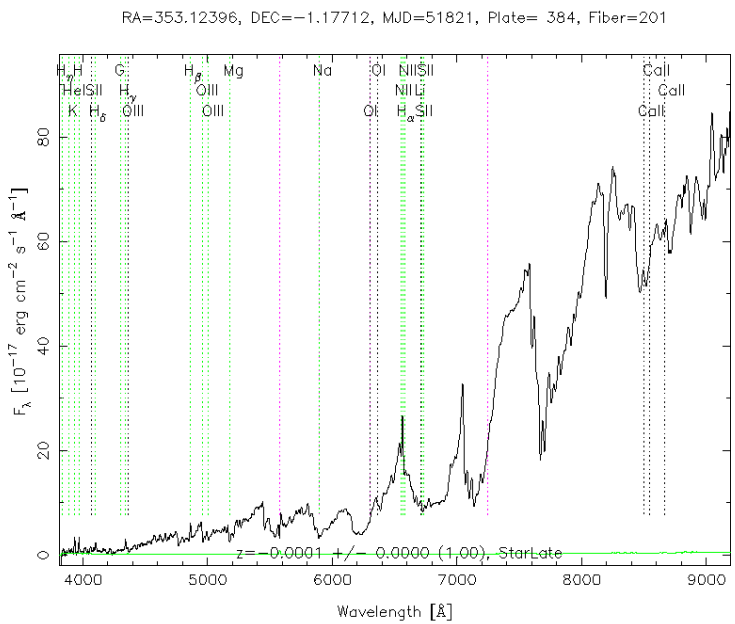
G

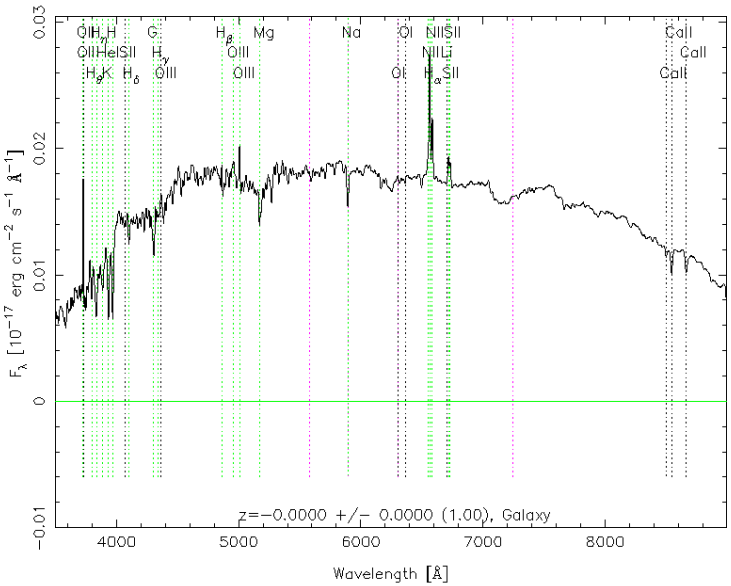
- G stars are so cool (T = 5,900 K) that very few of their atoms are in the first excited state. The lines are very weak.
- Any idea for the name of this particular star?

M

- Betelgeuse (sounds a lot like "beetle juice"), a red supergiant star about 600 light years distant. While Betelgeuse is cooler than the Sun, it is more massive and over 1000 times larger. If placed at the center of our Solar System, it would extend past the orbit of Jupiter.







Galaxies of Stars

- Galaxies like the Andromeda galaxy (M31) contains a broad spectrum of light do to the huge range of stars throughout the galaxy.

What atoms make up a large part of the human body?

- A) Carbon
- B) Calcium
- C) Oxygen
- D) Plutonium
- E) Sodium

- (there may be more than one answer)

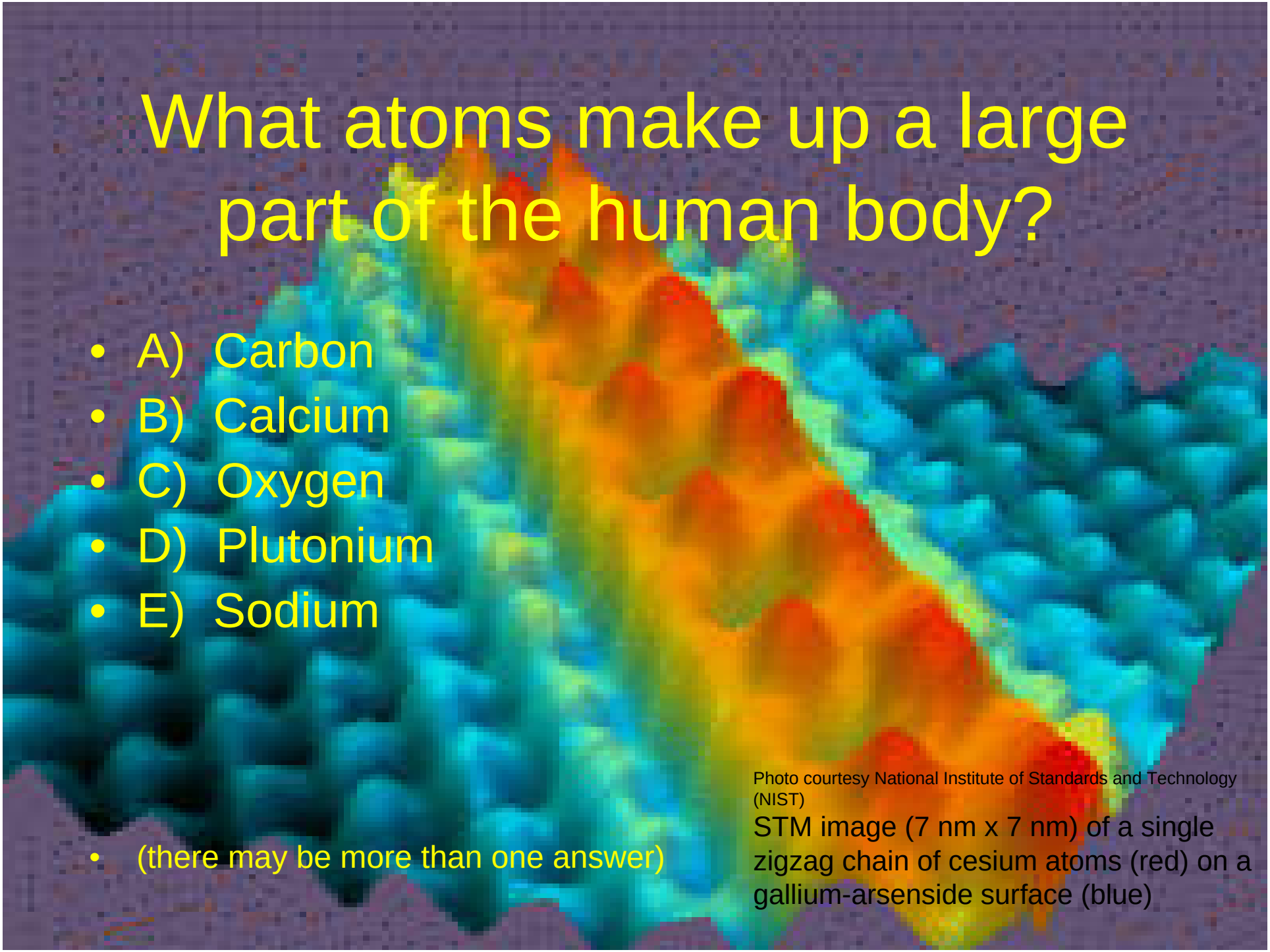
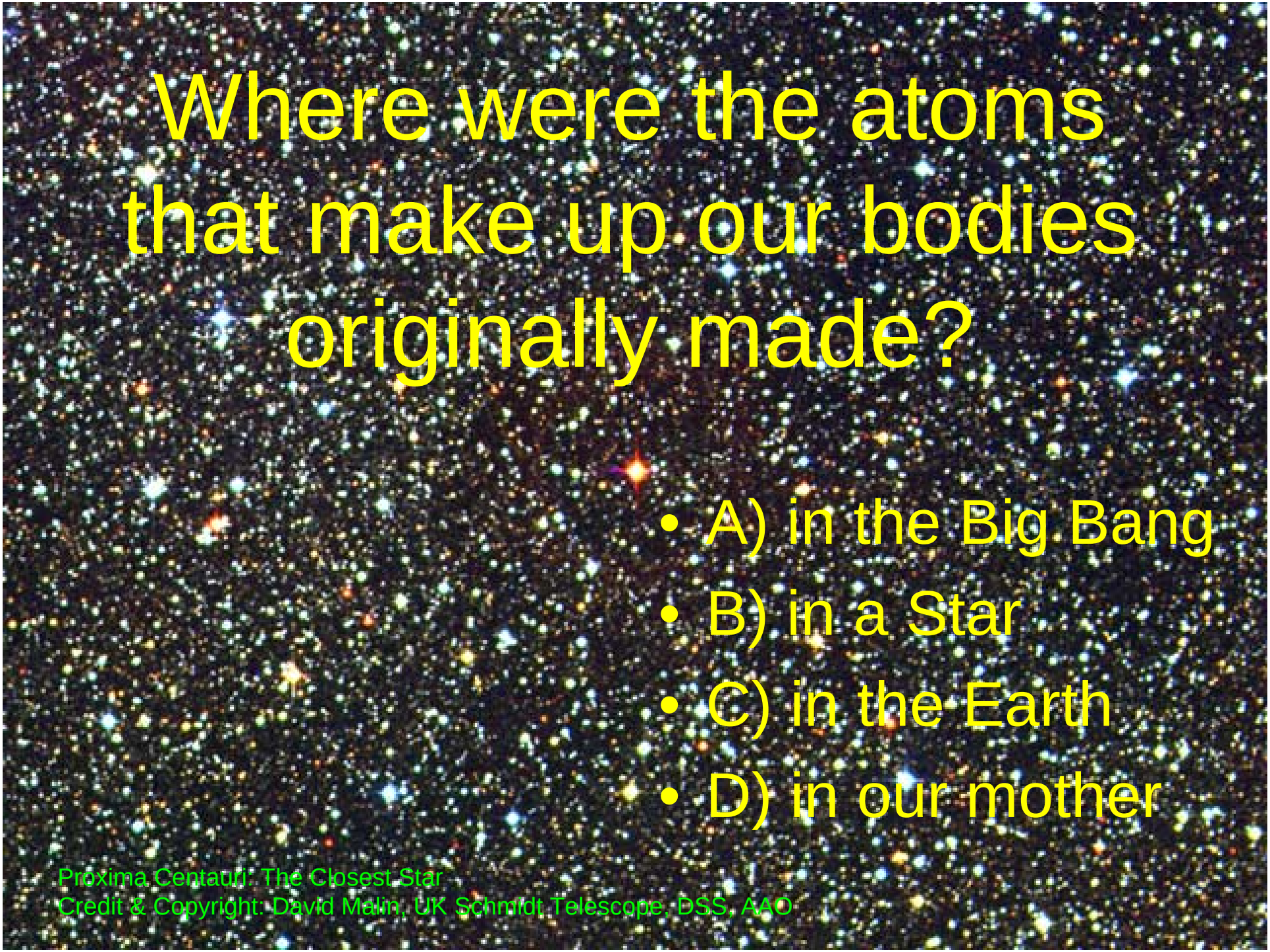


Photo courtesy National Institute of Standards and Technology (NIST)

STM image (7 nm x 7 nm) of a single zigzag chain of cesium atoms (red) on a gallium-arsenside surface (blue)

Where were the atoms that make up our bodies originally made?

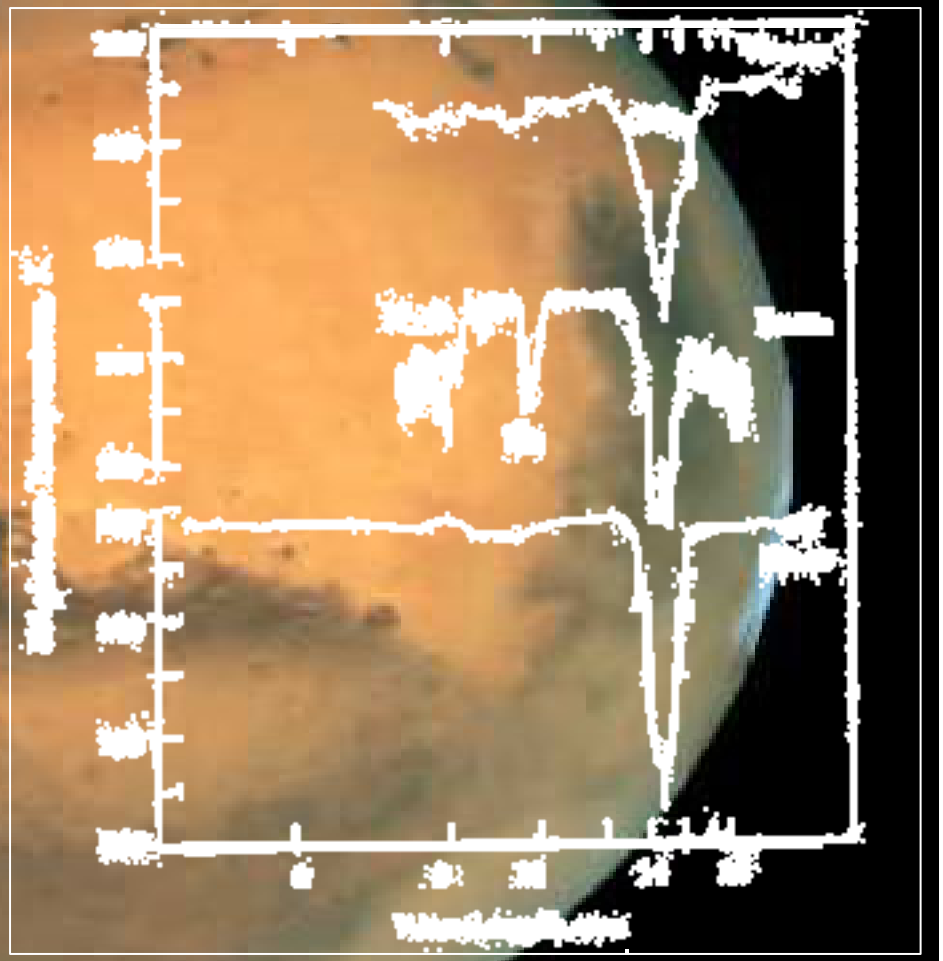
- A) in the Big Bang
- B) in a Star
- C) in the Earth
- D) in our mother



Proxima Centauri: The Closest Star
Credit & Copyright: David Malin, UK Schmidt Telescope, DSS, AAO

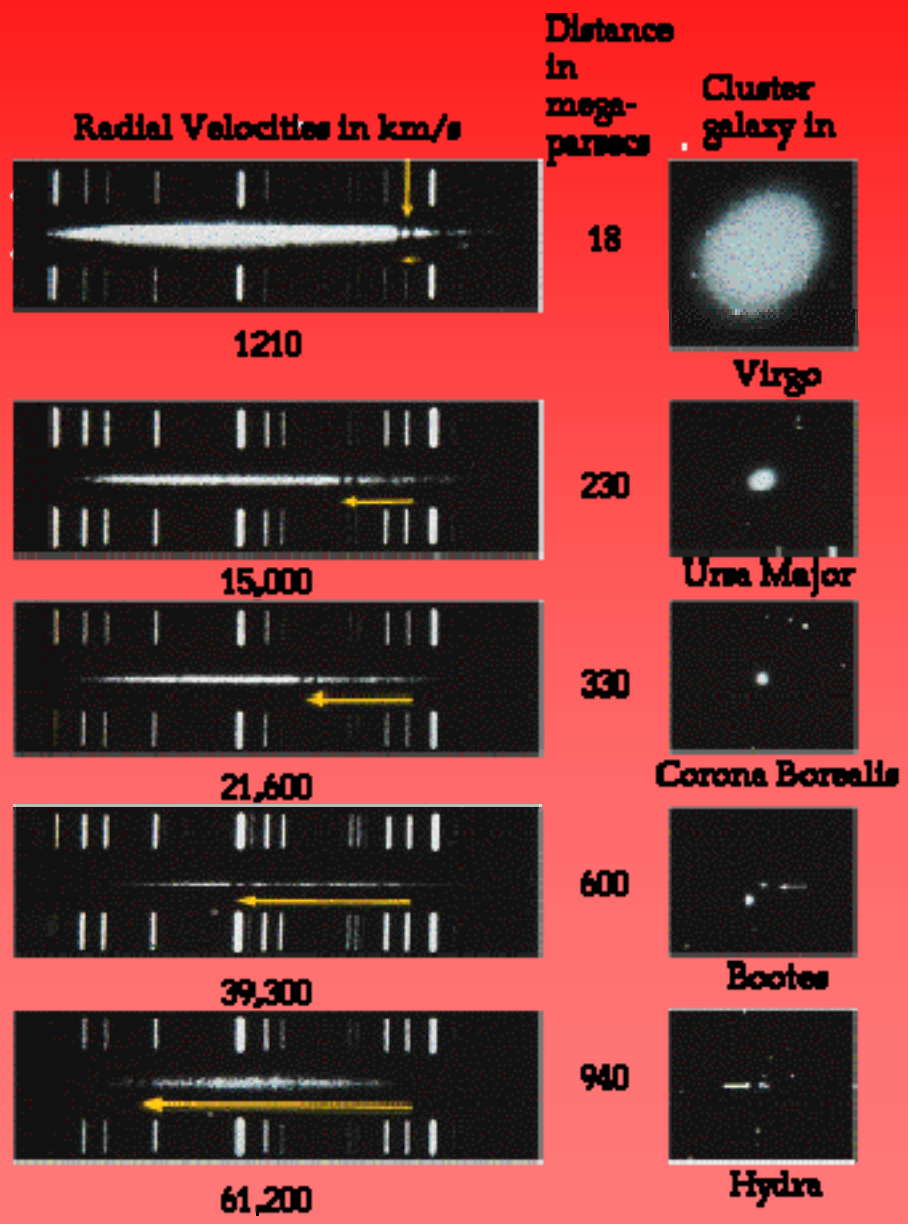
How about Planets?

- Looking at the absorption spectrum for these planets, what gases would you look for when searching other distant planets for possible life?



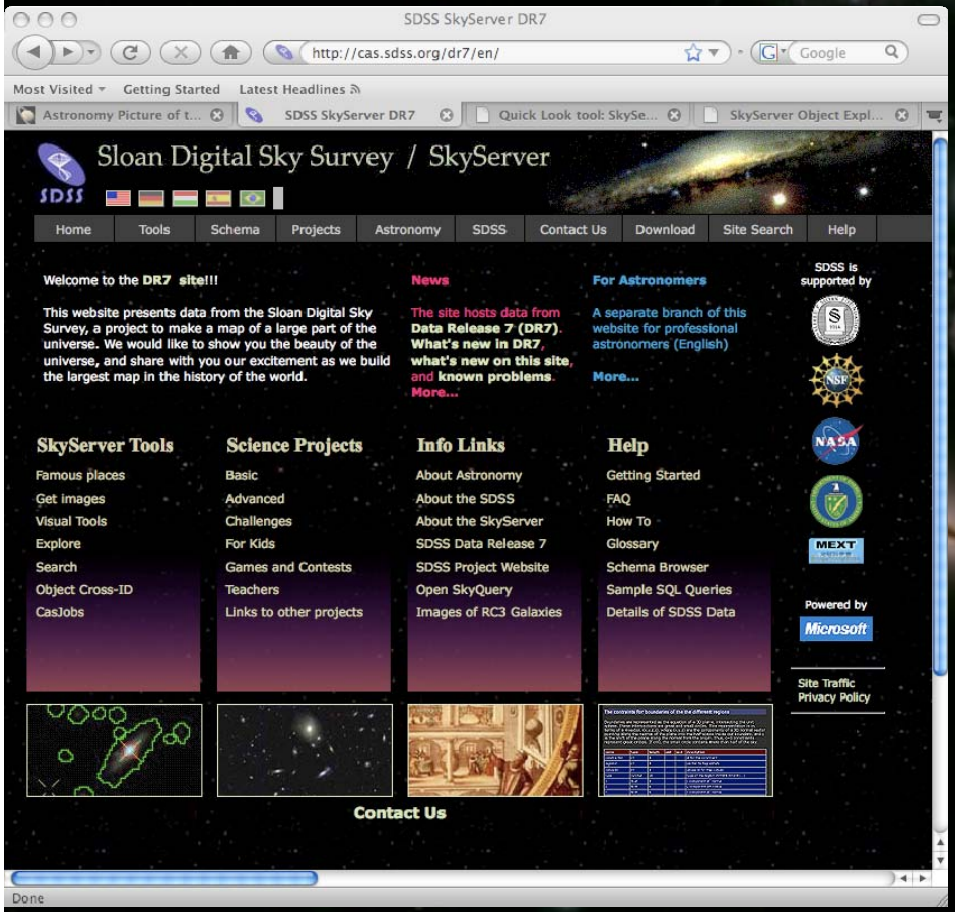
A) CO_2
B) O_3
C) H_2O
D) all of the above

Red Shift



- Study the diagrams carefully, and you will notice that the spectra for each galaxy is shifted, with those moving at a higher velocity displaying the greatest doppler redshift (in this case the velocity of the galaxy has been calculated for you. In the raw data form the horizontal axes of the spectra would be labeled "wavelength" or "energy." Measuring the shift in wavelength from the laboratory frame would enable you to calculate the galaxy's velocity.)

SDSS Project

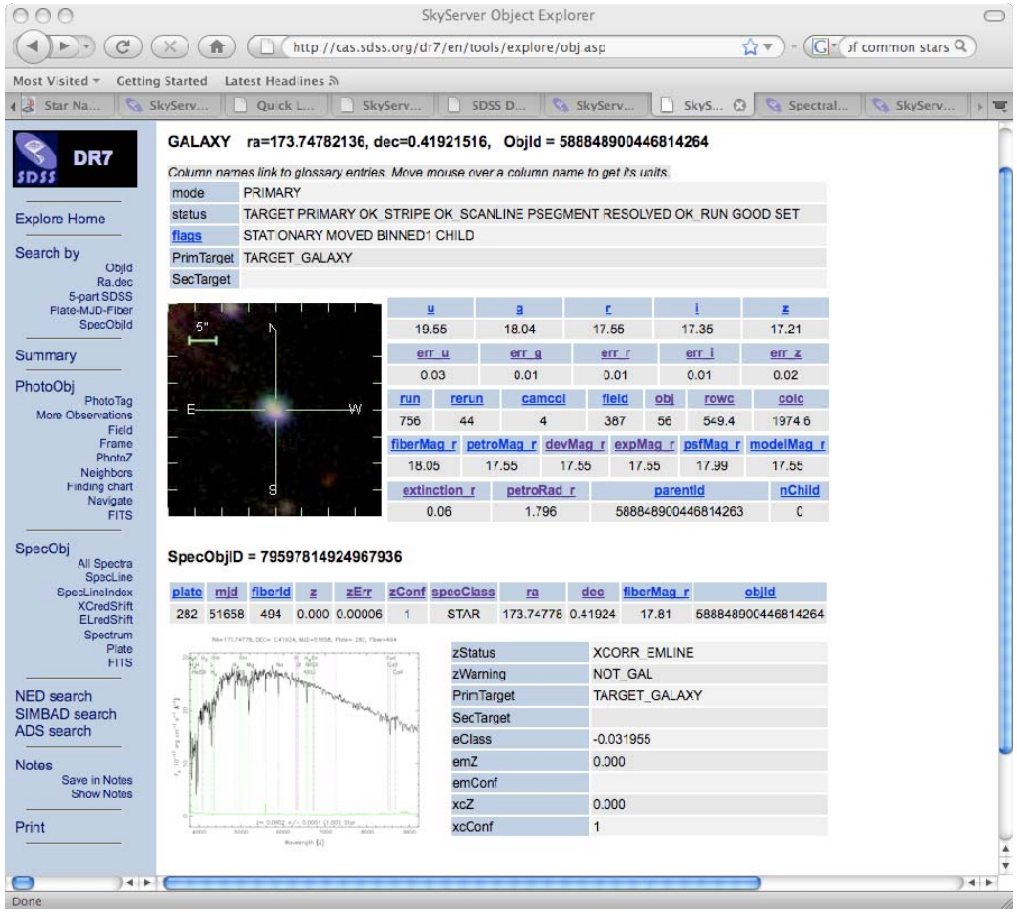


- http://cas.sdss.org/dr7/en/
- Choose One
  - Basics
    - Types of stars
    - The Universe
    - Color
  - Advanced (worth more points)
    - Spectral Types

Create one page abstract summarizing what you did and learned through this activity and present to class your experience.

Pick a Star Homework Assignment

- Using the SDSS site.
  - From my list of stars, get a star assigned and get information about it
  - Enter ra and dec in the navigator and get information about your star
- Print out information about the star be sure to include the spectrum.
  - *Note:You will want to have a separate larger image of the spectrum so print out a larger copy it.*



SDSS Stars to be studied and named

- *Teacher will do this for students*
- Using the SDSS data base, select SQL search and use command:

```
SELECT specObjID, ra,
   dec, fiberMag_g,
   fiberMag_r, fiberMag_i
  FROM SpecObj
  WHERE
   (SpecClass=dbo.fSpec
   Class('STAR')) and
   (fiberMag_r between
   15.0 and 16.0)
ORDER BY fiberMag_r
```

Star Poster

Using the line emission spectrum data, determine at least 3 different elements present in your star.

- Using the information about your star create a poster about your star.
- Include:
  - A proper name for your star
  - *Interesting facts*
  - *Where it is located in the sky*
  - *At least 3 elements found using the spectrum*
  - *What class of star it is*

Young Stars of NGC 346
Credit: Antonella Nota (ESA/STScI) et al., ESA, NASA

Google earth

- In the latest versions of Google earth is a google sky option. You can use this to find and navigate to your star.

- http://earth.google.com/

Now you are the Star

- Present your poster to the class with a 5 min presentation about your star.
- Ask if anyone has any questions about your star.