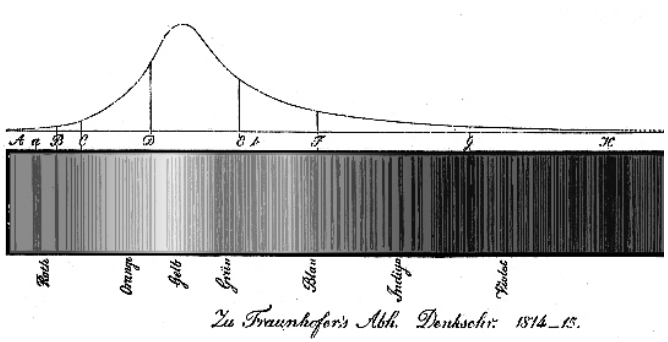
Life, the Universe, and Everything

The story starts in 1666, when Isaac Newton discovered that "white light" is a composite of many colors. . .

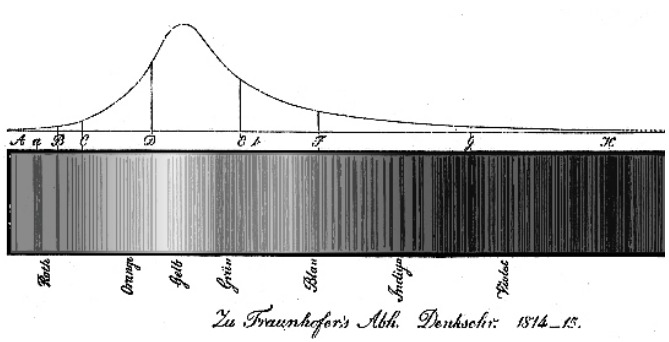
> Hence therefore it comes to pass, that Whiteness is the usual colour of Light; for, Light is a confused aggregate of Rays indued with all sorts of Colors, as they are promiscuously darted from the various parts of luminous bodies.
>
> -- Letter to Henry Oldenburg, 1671-2

Fast-forward to 1814, when a young telescope maker named Joseph von Fraunhofer passed light through a slit, and then through a prism—and discovered gaps in the spectrum!



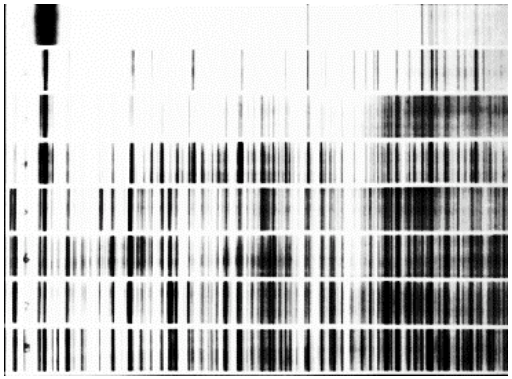
Fraunhofer's original diagram, "colorized"

Fraunhofer did note that the same lines appeared when you tried this trick with moonlight—but starlight gave slightly different lines. . . .



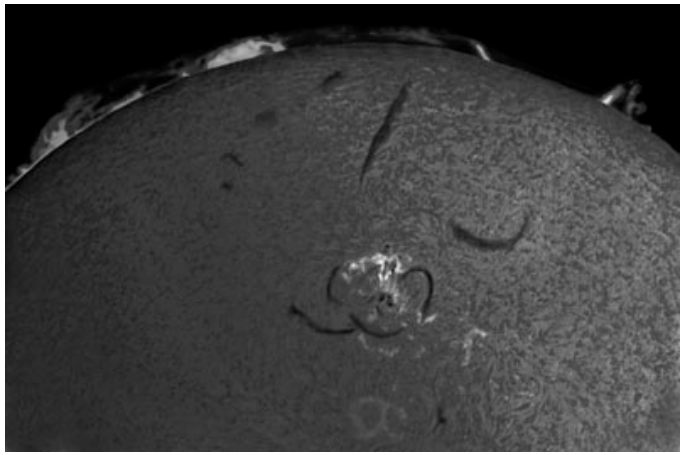
Fraunhofer's original diagram, "colorized"

Fraunhofer didn't follow up on what these lines were—but later physicists established that they were caused by atoms absorbing certain wavelengths of light. Each element has its own "fingerprint." This makes it possible to measure what the stars are made of!

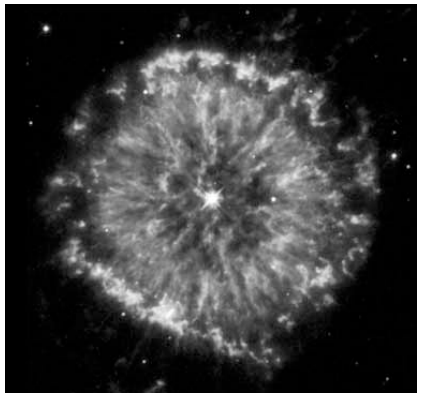


Spectra of several different stars

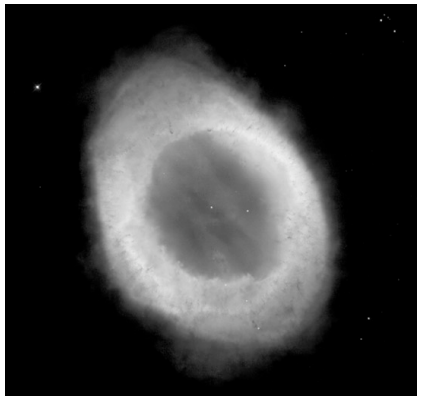
By the 1950s, Hans Bethe, Subrahmanyan Chanddrasekhar, and others had shown that stars shine by *nuclear fusion*—slamming atoms together to make heavier ones. In "normal stars", hydrogen is fused into helium. . . .



Heavier elements (up to iron) are made when a star runs out of hydrogen—and then are released into space when the star blows off its outer layers, which is what formed these nebulae. . .



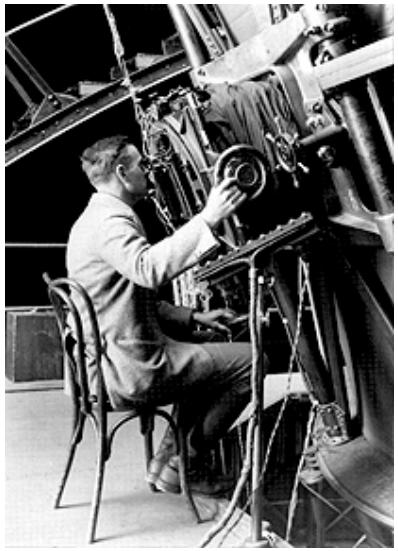
NGC 6751



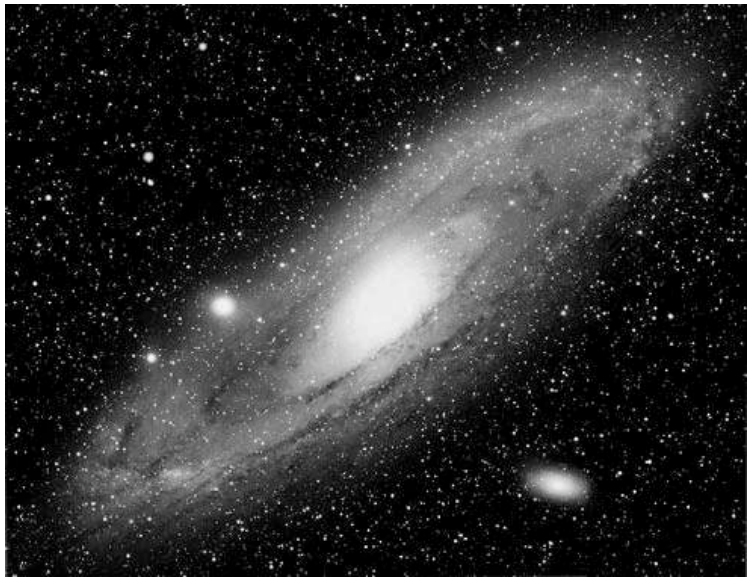
Messier 57

Even heavier elements form in stellar explosions — *supernovas*. It is now actually possible to observe this process happening in "real time" using spectroscopes.

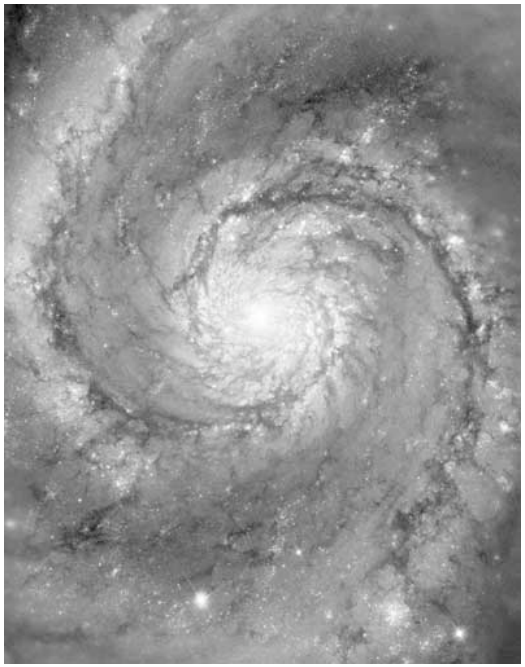
Messier 2, the "Crab Nebula", is a remnant of a supernova that was seen from Earth in 1092 AD



Using what was then the world's largest telescope, American astronomer Edwin Hubble (1889-1953) was able to show that some "nebulae" were actually enormous clusters of millions of distant stars—they were *galaxies*. The Sun was known to be part of a galaxy (the Milky Way)—but Hubble showed that there were countless more galaxies in the universe!



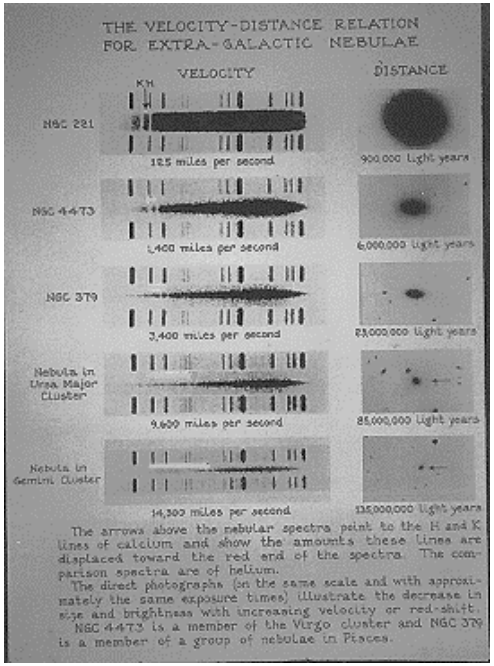
One of the galaxies. . .



Another galaxy—notice that you can see, not just individual stars, but clouds of gas and dust within the galaxy's arms. Appropriately, this image was taken by the Hubble Space Telescope. . .

Expanding Universe

- Hubble showed that the galaxies appear to be receding from our own
  - Doppler effect: wavelengths emitted from something moving away from the observer are "stretched" and lengthened
  - Light emitted from something moving away appears redder—this is the *redshift*
  - Hubble observed that the spectral "fingerprints" of elements were shifted towards the red.
- What's more, the farther a galaxy is, the faster it is receding *(Hubble's Law*).



Some of Hubble's original data—the green arrows above each spectrum indicate how far a certain pair of spectral lines is shifted relative to their standard position.

Expanding Universe

- Hubble suggested that this was all explicable if you assumed that the universe was expanding, and had once been much smaller
- Space and time began when the universe started expanding from a state of infinite density, about 14 billion years ago
- Theory contemptuously named "Big Bang" by one of its detractors—this is a misleading name, but we're stuck with it

Expanding Universe

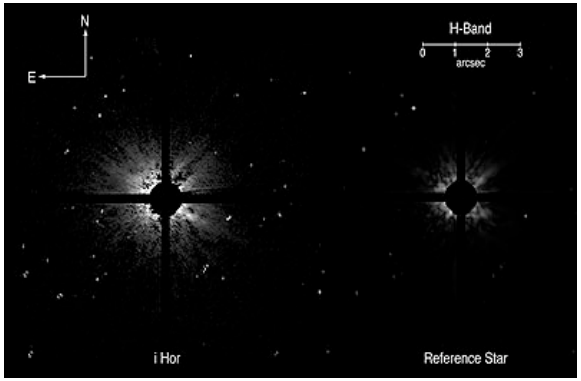
- Confirmation
  - Hubble's original observations have been refined and confirmed with new ways of measuring galactic distances
  - Theory predicts that background radiation of a particular energy level (2.73 K blackbody) should be coming from all parts of the universe—Penzias and Wilson detected this in the 1960s
  - Theory predicts that older galaxies should have less heavy elements and faster star formation than younger ones—this has been confirmed spectroscopically

Start with a cloud of interstellar gas and dust—a *diffuse nebula*— in which new stars form.

(This and other astronomical images courtesy of the SEDS Online Messier Catalog)

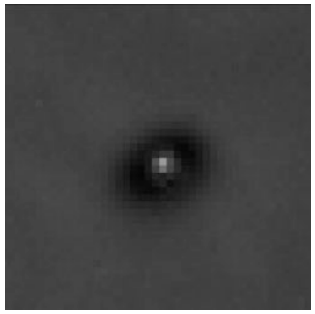
(These newly-formed stars haven't yet shed all remnants of the nebula where they formed. . .)

. . . and not unlike this one, around the Southern Hemisphere star Iota Horologii—which also has at least one planet orbiting it. . .

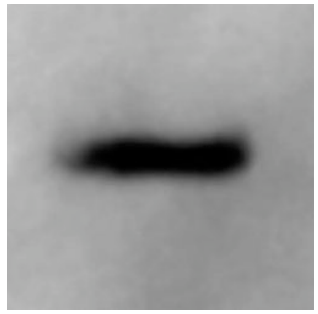


(Check out the Extrasolar Planets Encyclopedia for more. . .)

The solar system arose from a rotating disk of gas and dust within such a nebula—not unlike these, inside the M42 nebula in the constellation Orion. . .

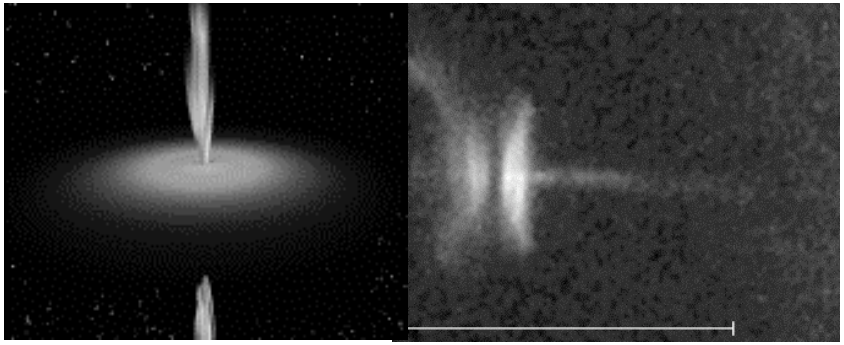


A disk seen nearly face-on



A disk seen nearly end-on

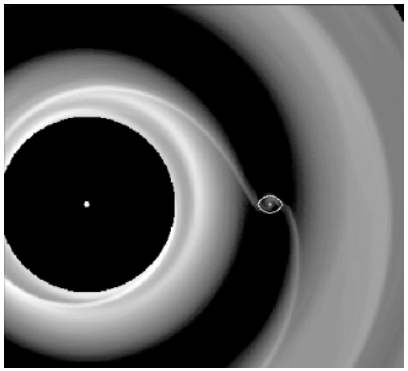
Accretion disks form as the spinning disk begins to collapse on itself, with the center of the disk giving rise to a new star. . .



Artist's conception

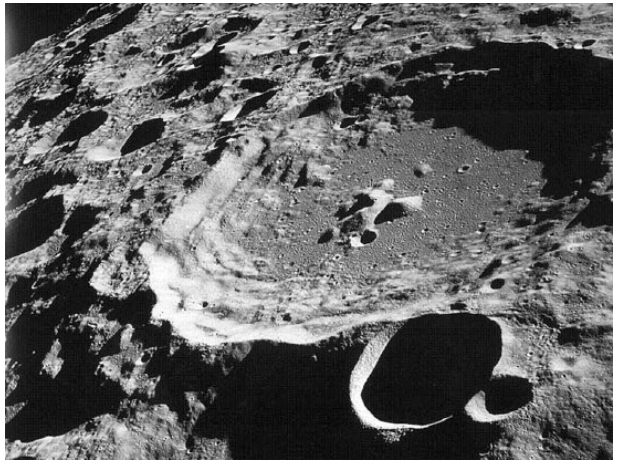
Hubble Space Telescope image

. . . and within the disks, away from the center, matter clumps together to form protoplanets.

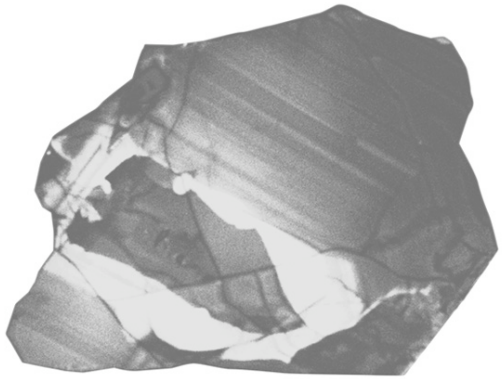


Computer model of planet formation—from this article

Between 4.6 and 3.9 billion years ago (the *accretion period*) the "proto-Earth" and other bodies (such as the Moon) were constantly bombarded. . .



Partly as a result of the accretion period, almost no rocks older than 3.8 billion years old have survived on Earth. (This microscopic zircon crystal from Australia, 4.4 billion years old, is one of the few exceptions. . .)



Meteorites, however, include the oldest rocks in the Solar System. They're "leftovers" from the accretion period, and date as far back as 4.5 billion years.

Different meteorites, each dated by different methods, all give ages of about 4.5 billion years for the Solar System.

(And there's yet more data here. . .)

METEORITE	SAMPLE	ISOTOPES	DATE
Guarena	whole rock	Ar-Ar	4.44 +/- 0.06
	13 samples	Rb-Sr	4.46 +/- 0.08
Saint Severin	4 samples	Sm-Nd	4.55 +/- 0.33
	10 samples	Rb-Sr	4.51 +/- 0.15
	whole rock	Ar-Ar	4.43 +/- 0.04
Weekeroo Station	4 samples	Rb-Sr	4.39 +/- 0.07
	silicates	Ar-Ar	4.54 +/- 0.03