
The Stars: Hosts for Other Planetary Systems
Are they like the Sun, or different?

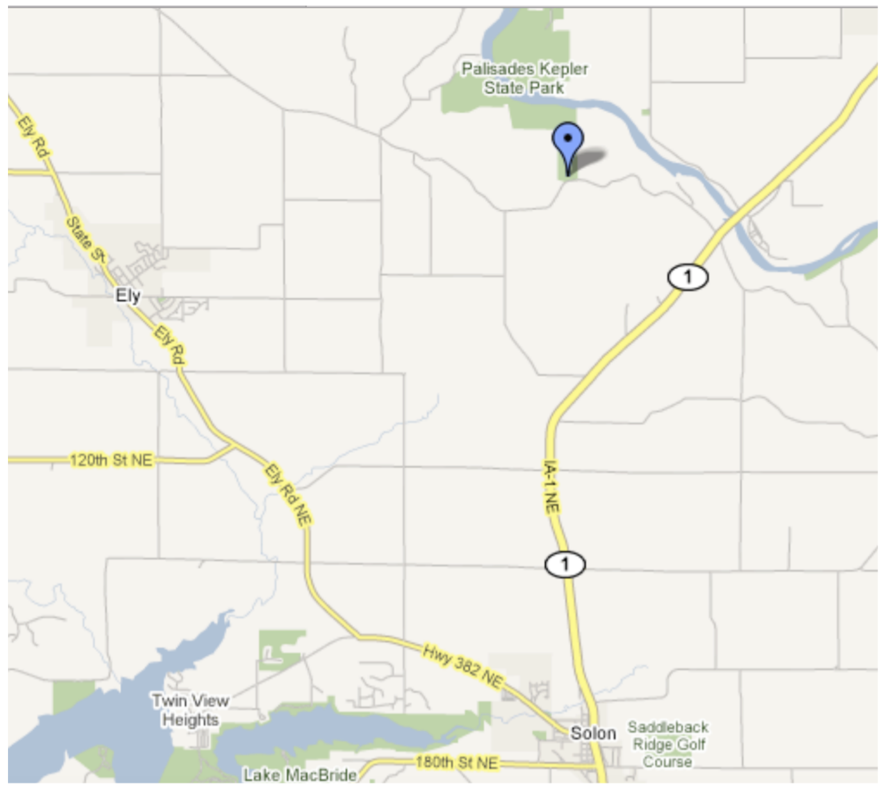
Field Trip for *Other Worlds …*

- Location: EIOLC (near Mt. Vernon)
- Prime Date: Wednesday, April 11
- Backup Date (in case of clouds): Thursday, April 12
- Time: 7:45 PM for about 2 hours
- See some of the things we talk about (e.g. Venus)

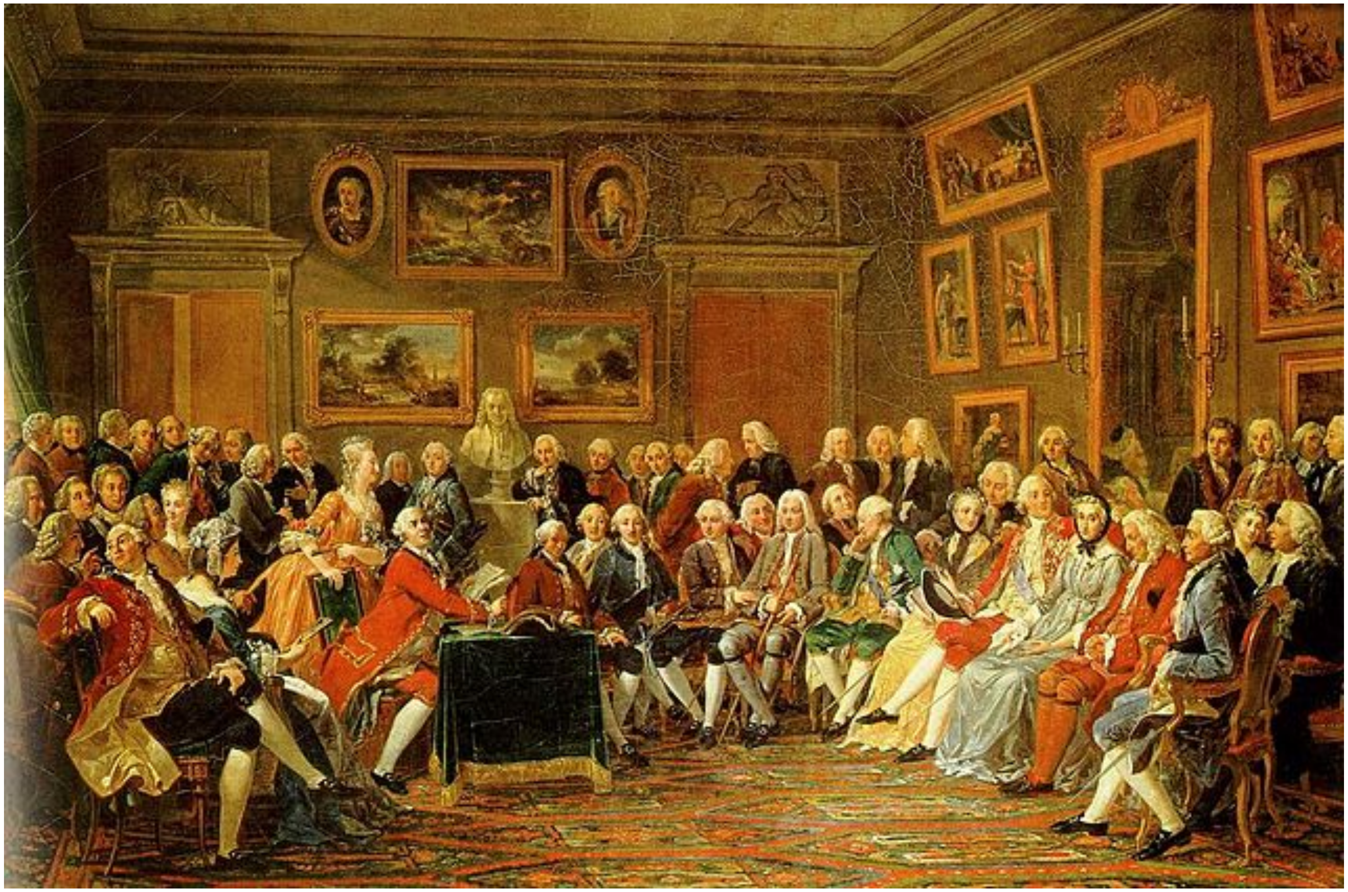
The Eastern Iowa Observatory and Learning Center at Palisades-Dows Preserve.

Field Trip (continued)

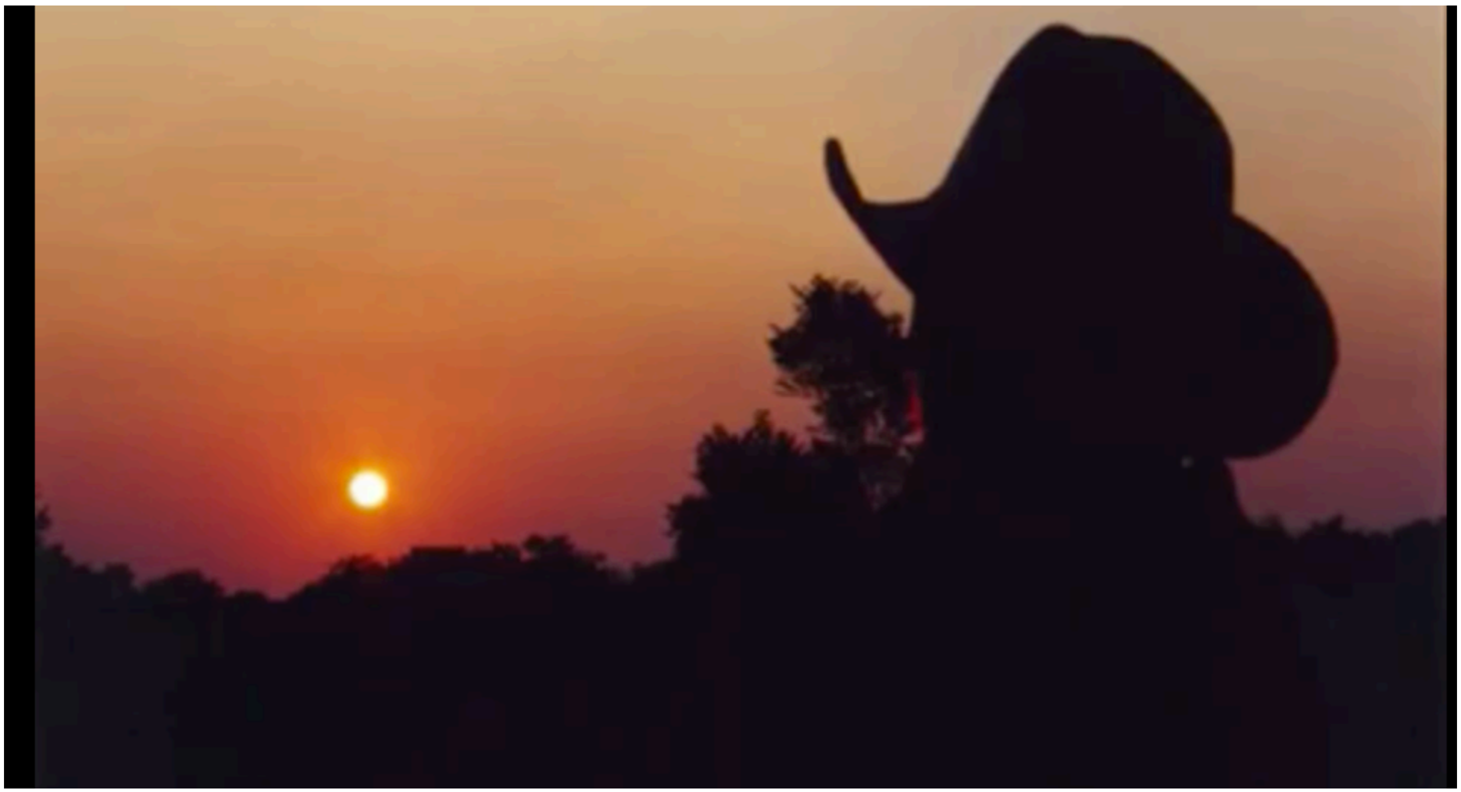
- Carpooling good
- Think about it now
- Will ask for a show of hands next time to judge participation
- Further details next week



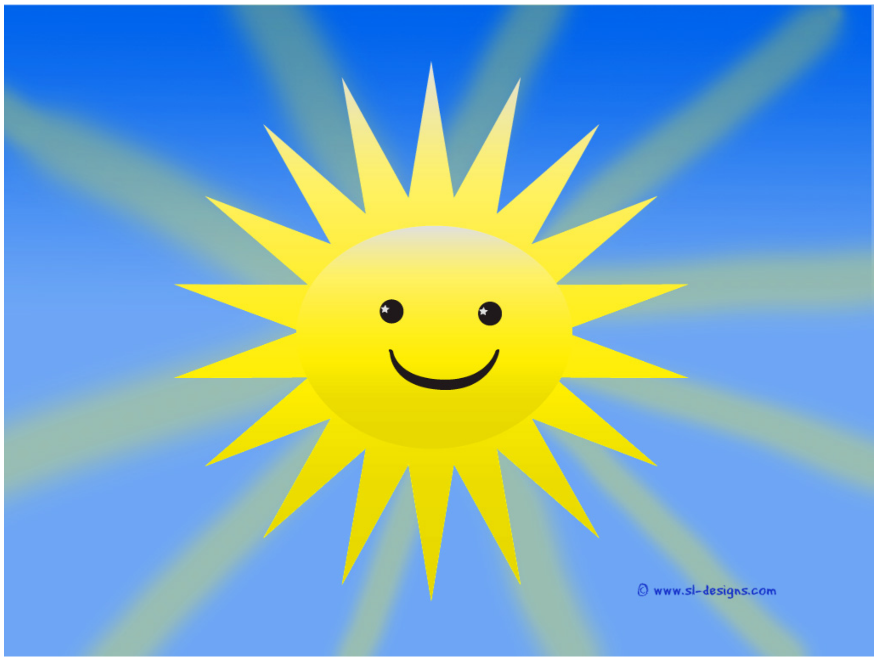
Questions from the learned assembly?

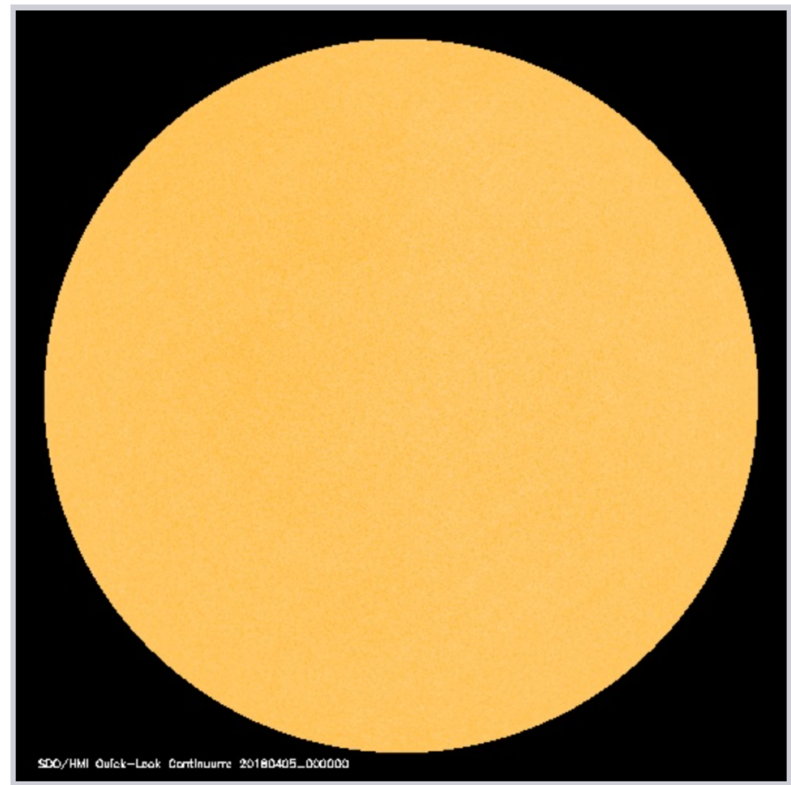


Starting Point: The Sun is a remarkable object



To get a reference object for the other stars, let's look at our own nearby star, the Sun

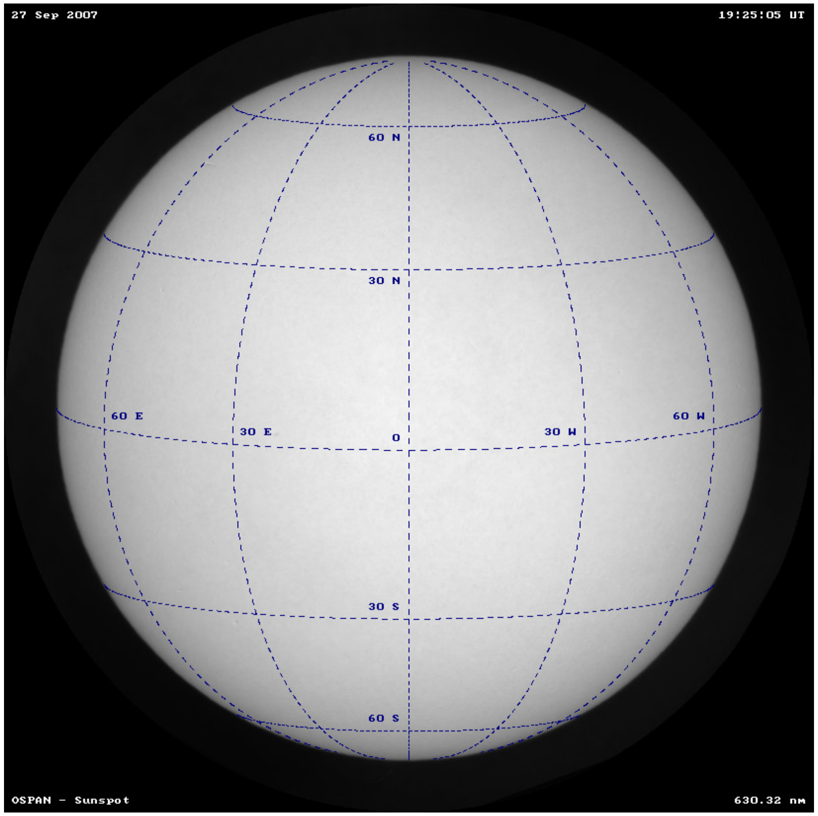




The importance of the Sun as an astronomical object has been recognized through human history

The Sun: summary of basic physical properties

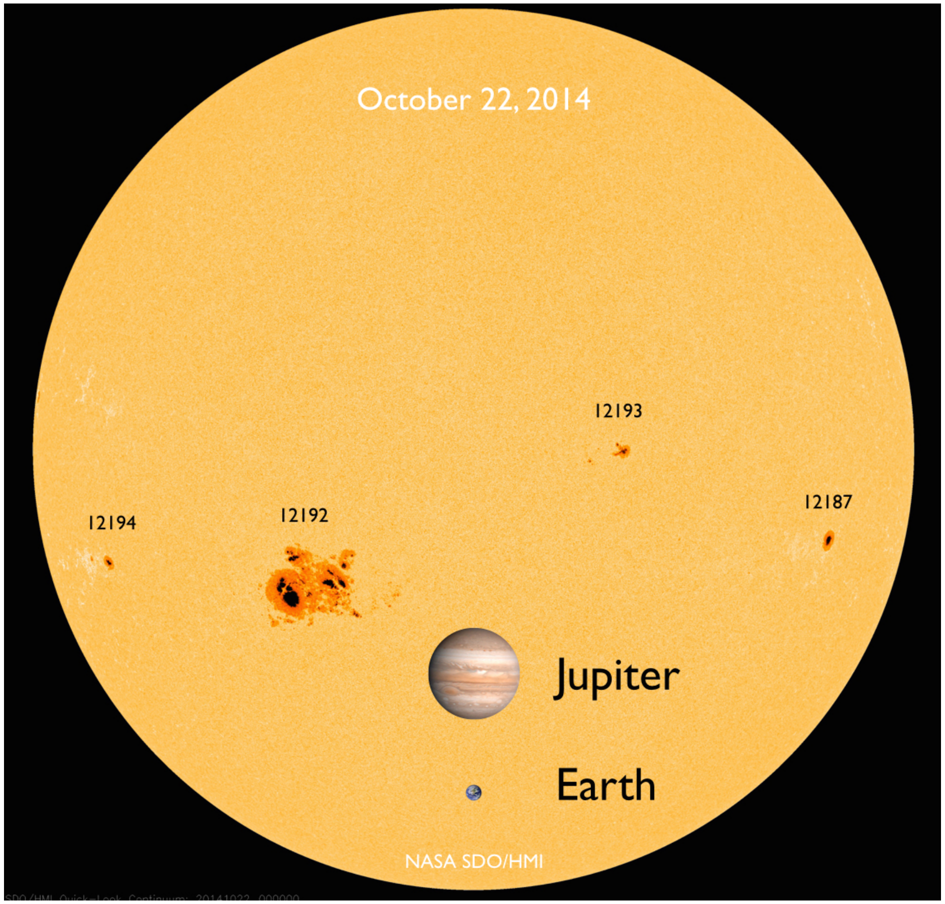
- Mass: 1.989E+30 kg (330,000 mass of Earth)
- Radius: 696,000 km (109 times than of Earth)
- Density: 1.5 g/cc
- Surface temperature 10,000 degrees F



The Sun: 330,000 times the mass and 109 times the diameter of the Earth

"a picture is worth a thousand words…"

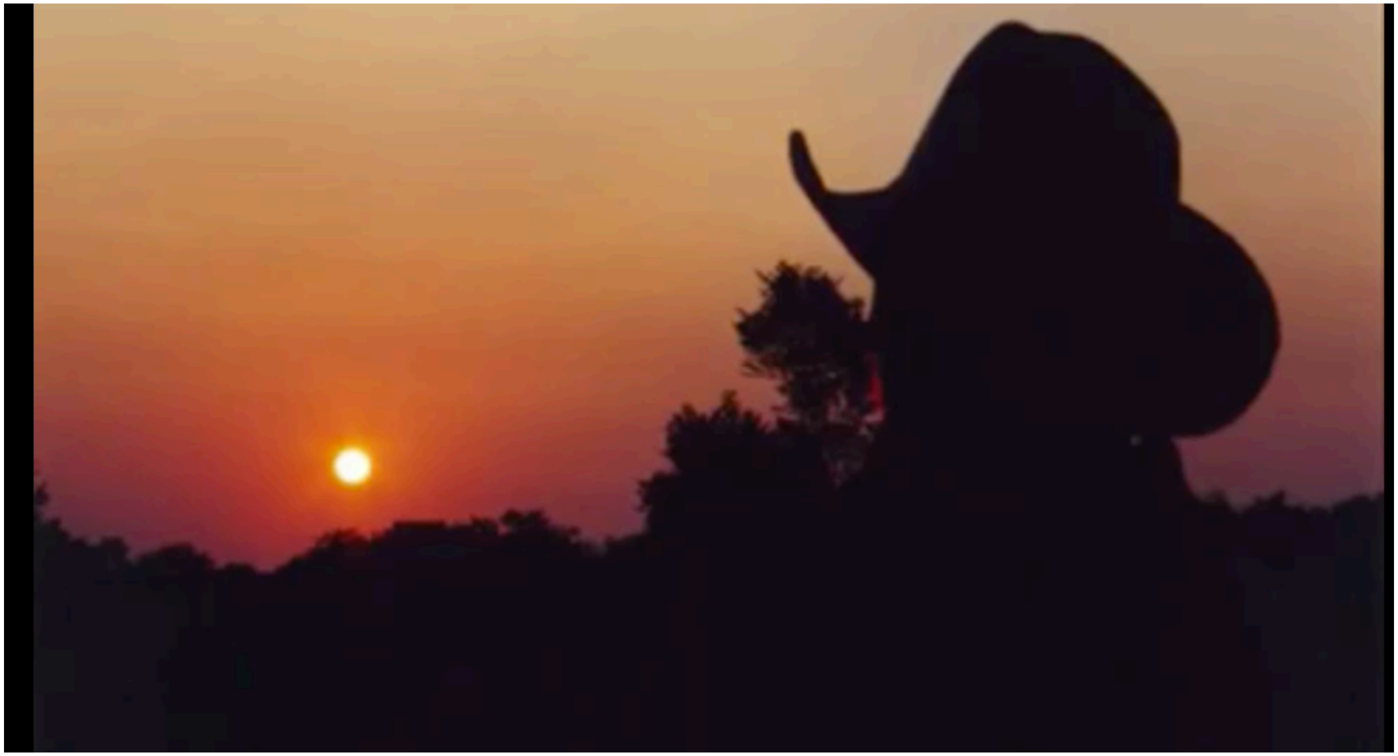
The relative scale of a planet and a star



Further properties of the Sun

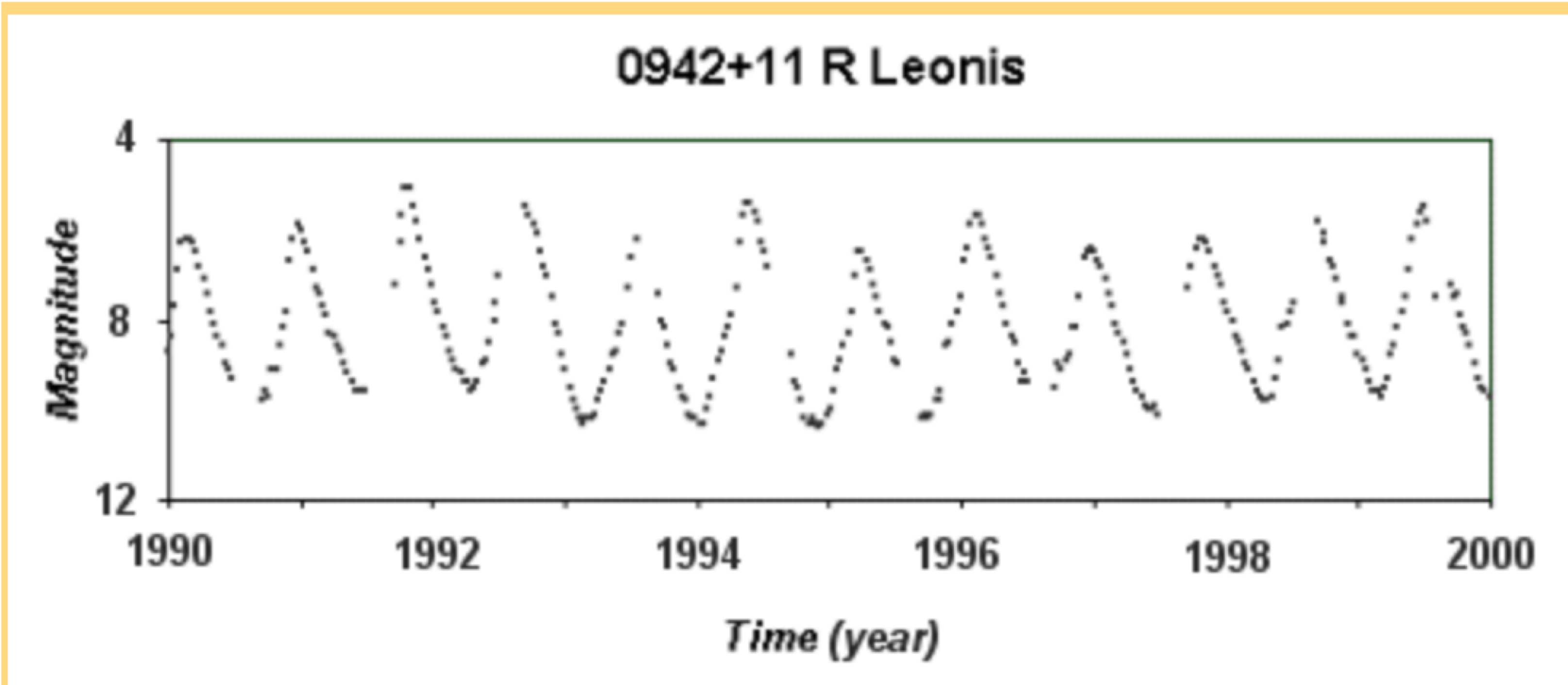
- The chemical composition of the Sun: *cosmic composition*
- The *luminosity* of the Sun = 3.85E+26 Watts
- The age of the Sun: 4.55 Billion years (how could we know this?)
- Comparison with other objects (Vega, Arcturus, stars in M13, etc)

The luminosity of the Sun is just right



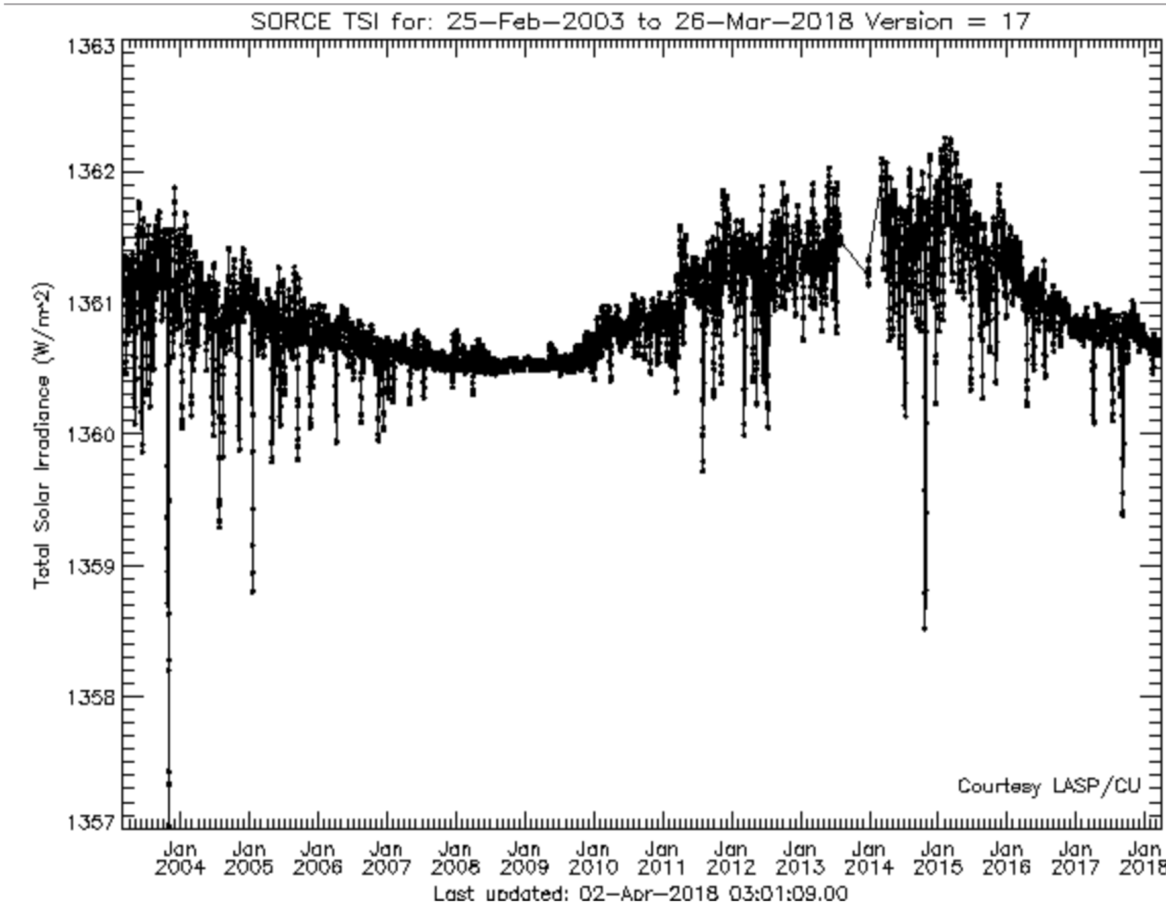
It keeps the temperature of the Earth perfect, right at triple point for water

The Sun is (apparently) constant in its power output



Not true for all stars, e.g. R Leonis: ~ factor of 100 from peak to peak!

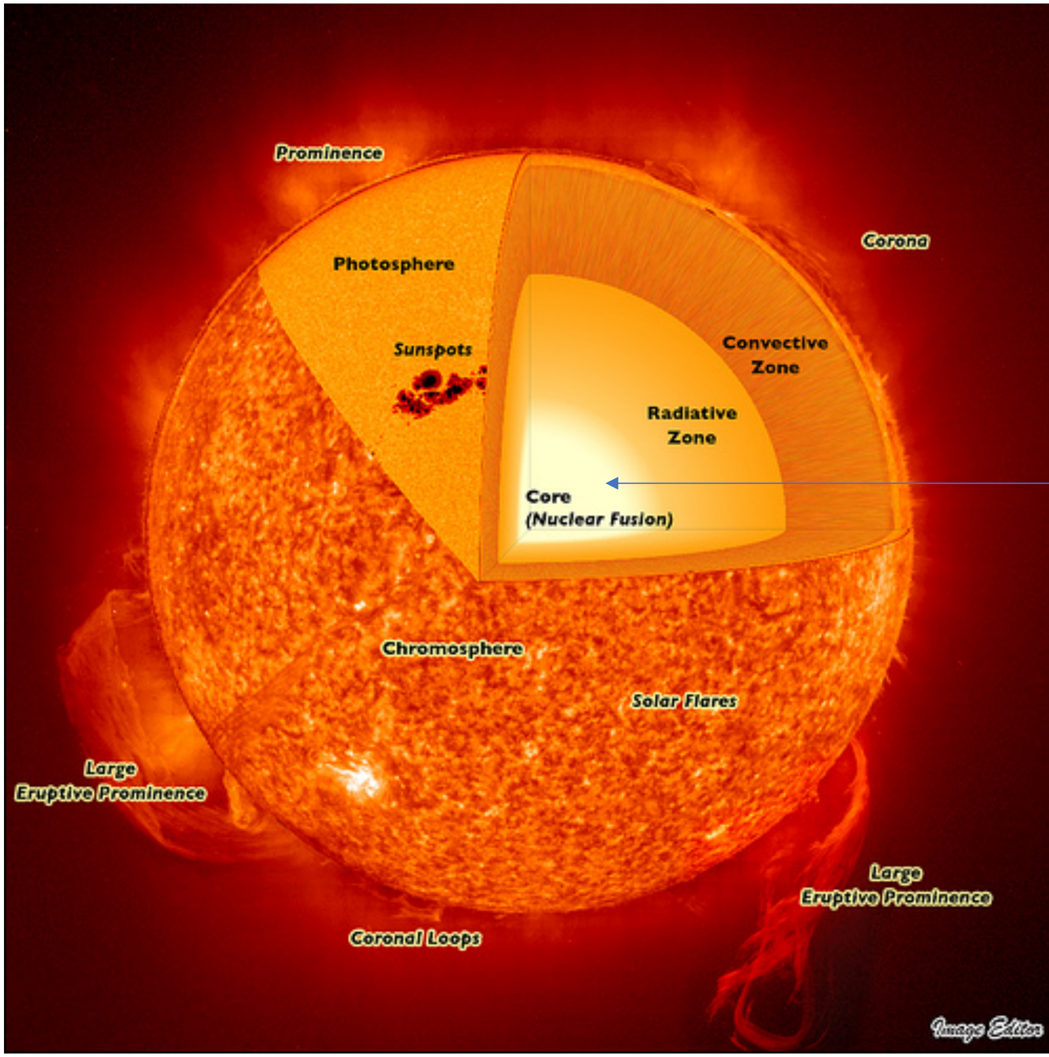
The "light curve" of the Sun, precisely measured by a spacecraft



It would be tricky to engineer a light source this constant

The Sun has been shining at this constant power for 4.5 billion years

The Structure of the Sun…*The Powerhouse*



The Powerhouse

Another important attribute of the Sun

It produces pleasing yellow light with just the right amount of blue, green, and violet light (*photosynthetically active radiation)*

The Solar Spectrum as an astronomer would study it

66 | 3 Solar Spectroscopy

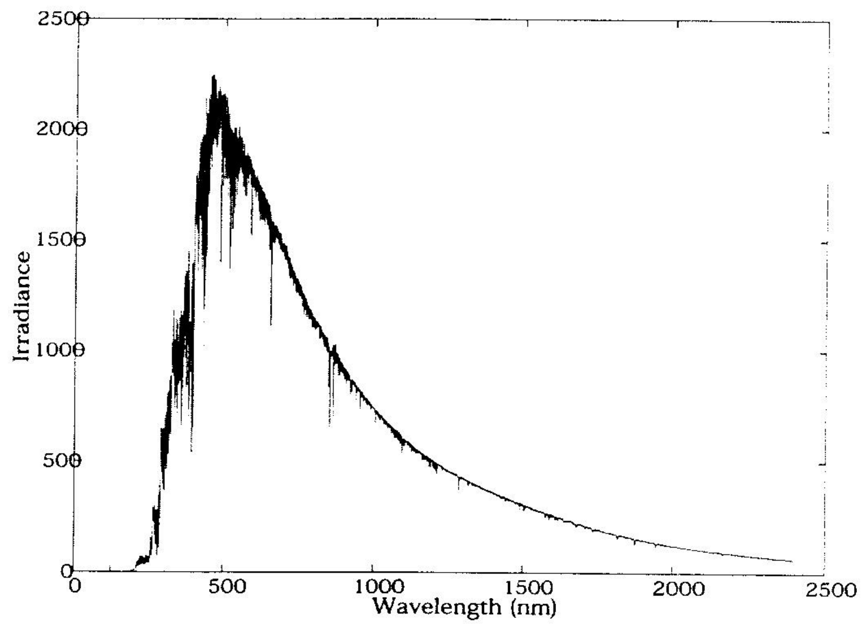
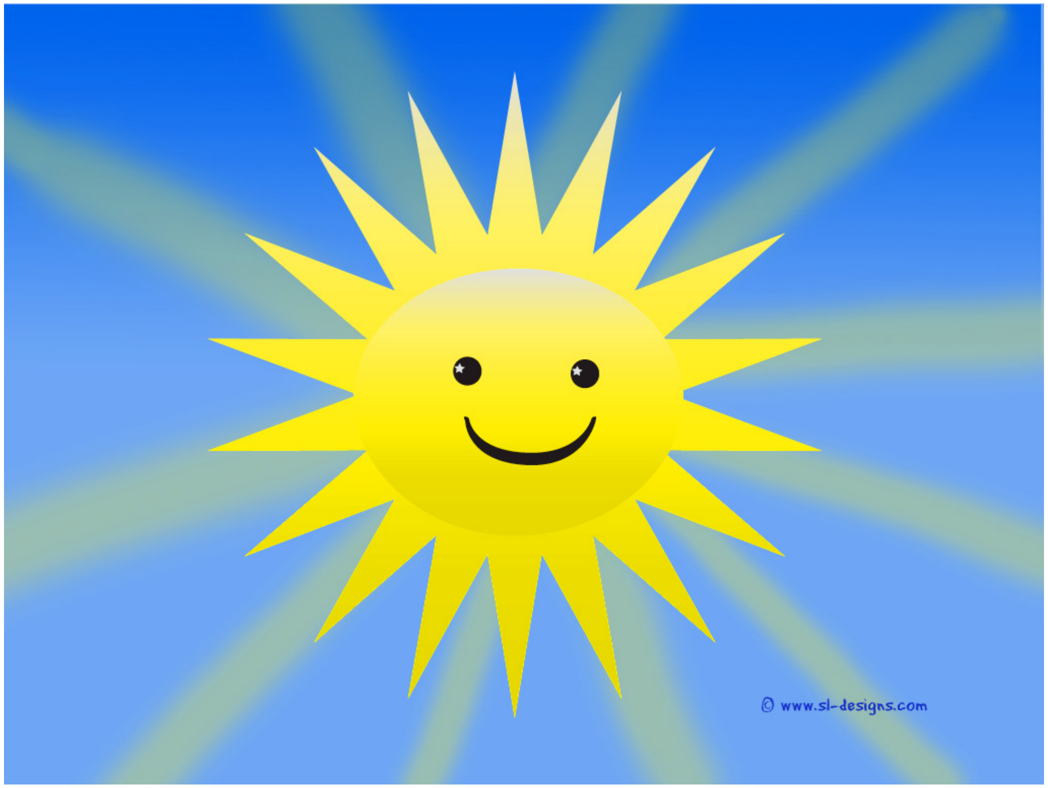


Fig. 3-1 The spectral distribution of solar irradiance measured above the Earth's atmosphere, in units of mW/sq.meter/nanometer. Kindly provided by G. Thuillier (see G. Thuillier et al., "Sun Irradiance Spectra" in *"Solar Variability and Its Effect on Climate"*, J. Pap et al., Eds., AGU Monograph Series (2003).

The spectrum of the Sun's light is a **direct** consequence of its surface temperature

The Sun seems so perfect for making the Earth the way it is; could any other stars be just as suitable, or more so?




Basic Stellar Properties
Let’s start with some basic things we can say about stars

Basic Stellar Properties

- (1) Some are bright and some are faint
- (2) They have different colors (red ones are particularly noticeable)
- (3) What does this mean?
- (4) Let’s put numbers on their brightness

System we still use today (with modifications) … *stellar magnitude system*

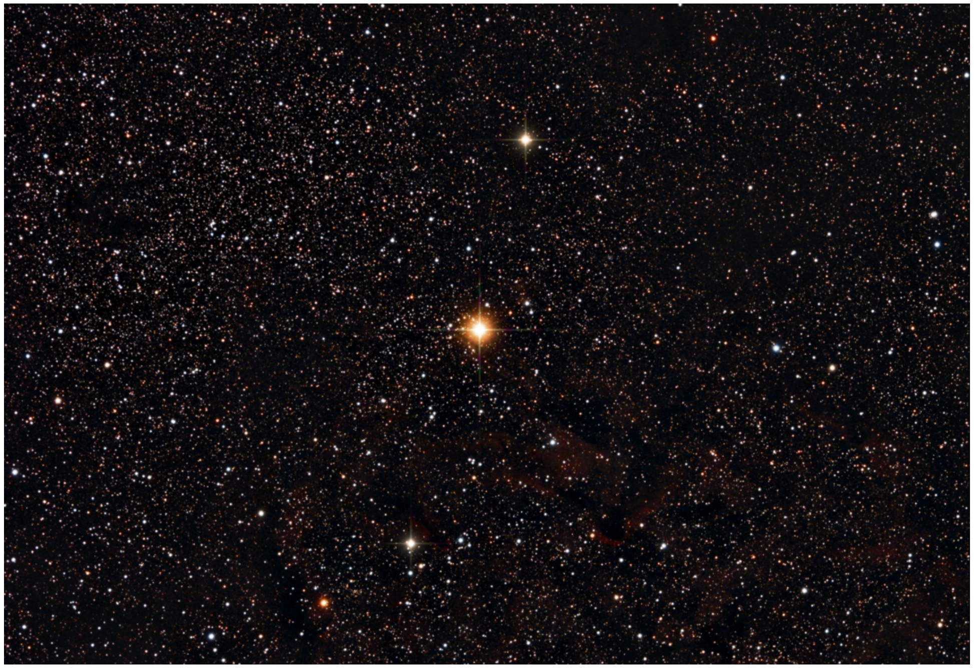
- Developed by Hipparchus of Rhodes, 160 – 130 BCE
- Consisted of 5 – 6 classes. Brightest stars are *first magnitude,* next brightest class *second magnitude,* down to *sixth magnitude* (barely visible by someone with really good eyes in a really dark sky)
- Check it out for yourself in the night sky; you really can see the difference

What are the magnitudes of some of the stars in the night sky right now?

Venus	(not a star!)	-3.9
Betelgeuse	Alpha Orionis	0.50
Rigel	Beta Orionis	0.12
Sirius	Alpha Canis Maj	-1.46
Aldebaran	Alpha Tauri	0.85
----------	Gamma Tauri	3.65
Mintaka	Delta Orionis	2.23
-------------	41 Arietis	3.63
Mirzam	Beta Canis Maj	1.98

Stars do have different colors; usually rather subtle

Mu Cephei…
"Herschel's
Garnet Star"

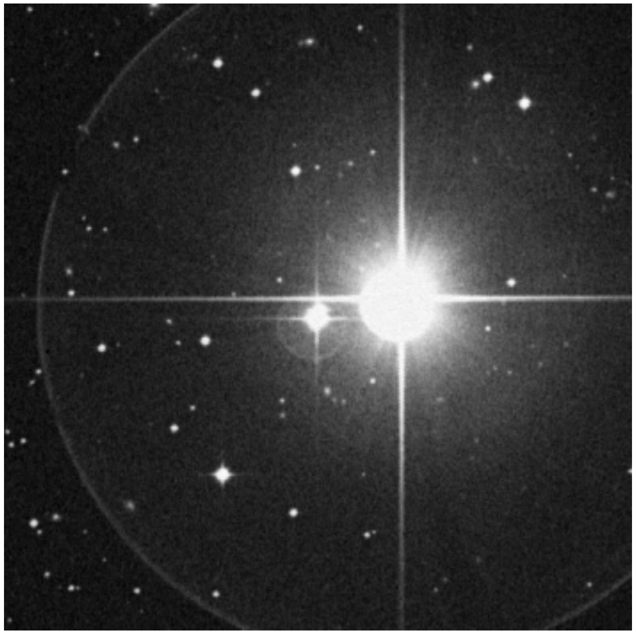


Why do different stars have different colors?

Next basic stellar property to think about: how far away are the stars?

How do the distances compare with that to the Sun, 1 **astronomical unit =**

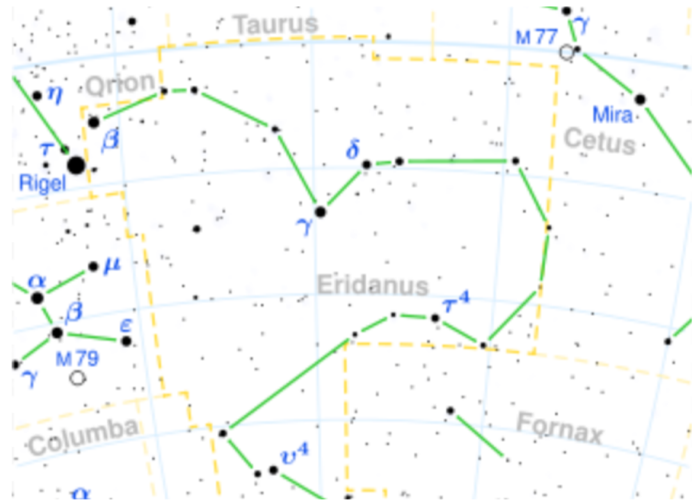
$$1.496 \times 10^{8}\ km = 1.496 \times 10^{11}\ meters$$



The basic idea was realized by Aristotle about 350 BCE, but the measurement was not made until the 19th century: **stellar parallax**

The light year and the parsec

- 1 light year = $9.460 \times 10^{15}\ meters$
- 1 parsec = $3.086 \times 10^{16}\ meters$
- Conversion between the two: 1 parsec = 3.26 light years



Distance to 40 Eridani:
5.04 parsecs or
16.43 light years

1 parsec = 206,265 astronomical units!

Let's look at the list of the *nearest* stars. It is not the same as the brightest stars

Lots of them have funny names. What does that mean? Look at the apparent magnitudes of these stars

This indicates many of the stars are feeble emitters

The Nearest Stars, as Seen from the Earth

Adapted from Norton's 2000.0, 18th edition (copyright 1989, Longman Group UK)

These are our closest neighbors!

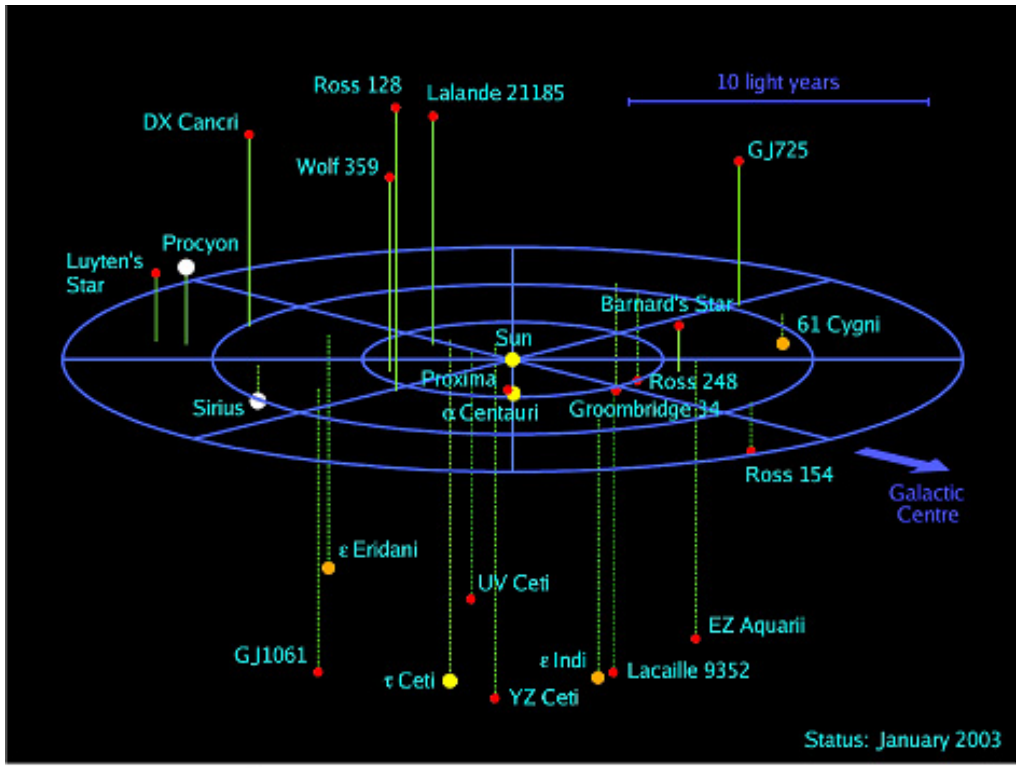
Note that this list is continually changing as astronomers discover nearby stars with
small stars emit their energy. Recall that the brightest magnitudes are the largest neg

Common Name	Scientific Name	Distance (light years)	Apparent Magnit
Sun		-	-26.72
Proxima Centauri	V645 Cen	4.2	11.05 (var.)
Rigil Kentaurus	Alpha Cen A	4.3	-0.01
	Alpha Cen B	4.3	1.33
Barnard's Star		6.0	9.54
Wolf 359	CN Leo	7.7	13.53 (var.)
	BD +36 2147	8.2	7.50
Luyten 726-8A	UV Cet A	8.4	12.52 (var.)
Luyten 726-8B	UV Cet B	8.4	13.02 (var.)
Sirius A	Alpha CMa A	8.6	-1.46
Sirius B	Alpha CMa B	8.6	8.3
Ross 154		9.4	10.45
Ross 248		10.4	12.29
	Epsilon Eri	10.8	3.73
Ross 128		10.9	11.10
	61 Cyg A (V1803 Cyg)	11.1	5.2 (var.)
	61 Cyg B	11.1	6.03
	Epsilon Ind	11.2	4.68
	BD +43 44 A	11.2	8.08

The distances to the stars are truly enormous

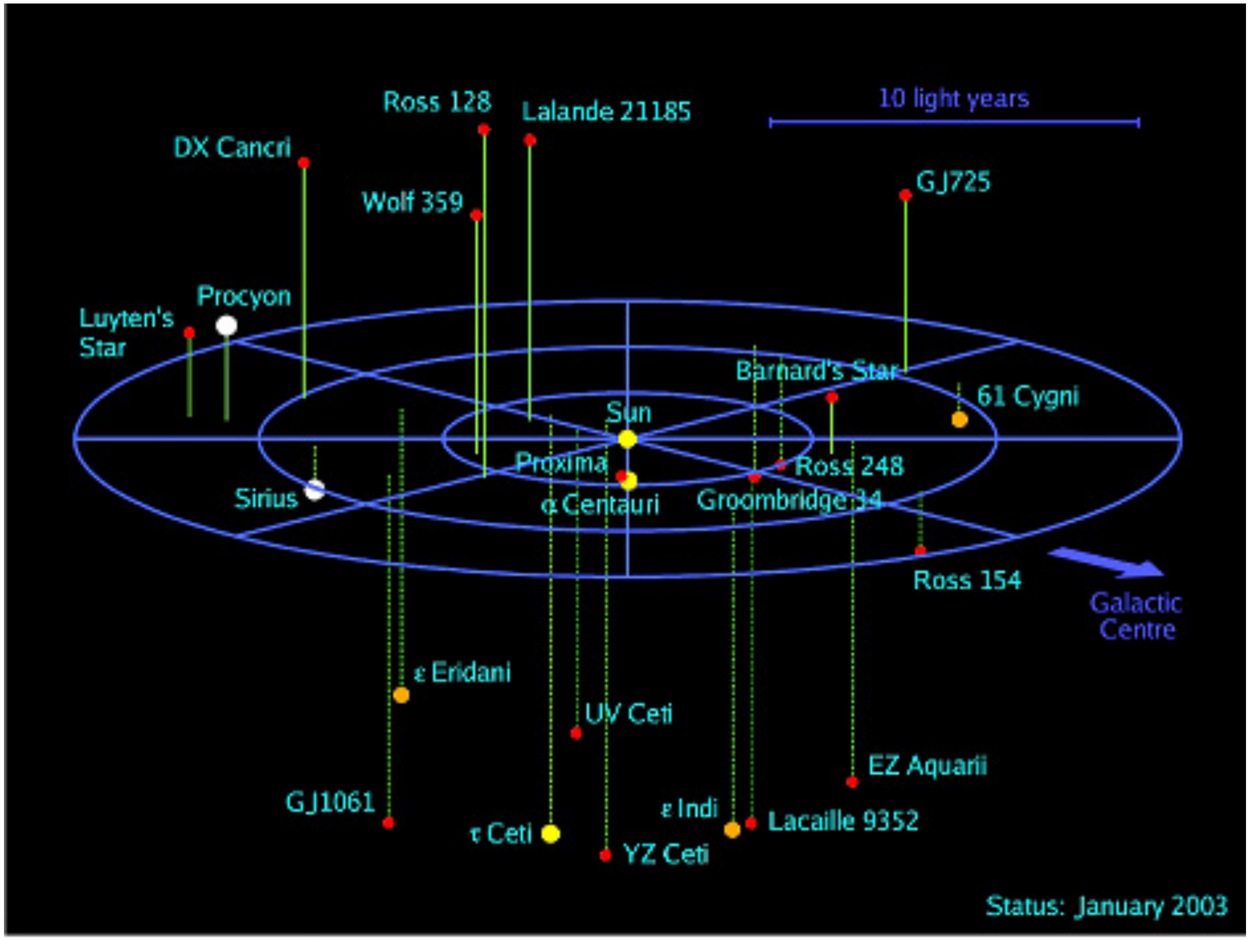
- If the distance between the Earth and Sun were shrunk to 1 cm (0.4 inches), Alpha Centauri would be 2.75 km (1.7 miles) away

So, who are our neighbors in space?



3D Map of Known Stellar Systems in the Solar Neighbourhood

ESO PR Photo 03c/03 (13 January 2003)

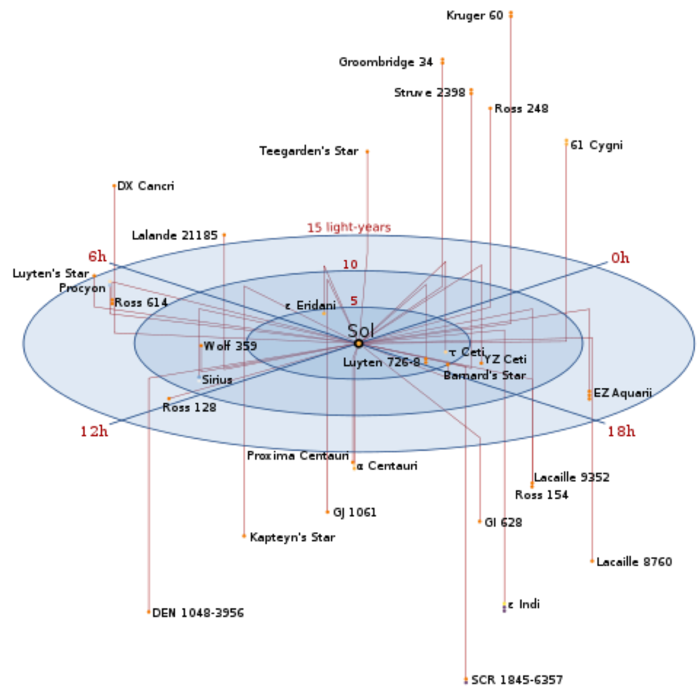


3D Map of Known Stellar Systems in the Solar Neighbourhood

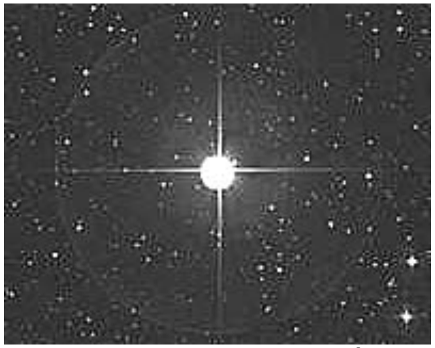
ESO PR Photo 03c/03 (13 January 2003)

The nearest stars

- 34 stars within 13 light years of the Sun
- The 34 stars are contained in 25 star systems
- Those visible to the naked eye are Alpha Centauri (A & B), Sirius, Epsilon Eridani, Epsilon Indi, Tau Ceti, and Procyon



Stars we can see with our eyes that are relatively close to the Sun



- Arcturus … 36 light years
- Vega … 26 light years
- Altair … 17 light years
- Beta Canum Venaticorum .. 27 light years (a star like the Sun)
- Lambda Serpentis … 38 light years (***)
- 72 Herculis … 47 light years (***)
- 18 Scorpii … 46 light years (the "Solar Twin")

Observed and Inferred Properties of Stars

- Observed properties
- Brightness (apparent magnitude)
- Distance
- Spectrum or color

- Inferred properties
- Luminosity (power output)
- Surface temperature
- What does “surface” of a star mean?

Some more words on the colors of stars…stellar spectra

“Sit up and pay attention; this is important!”

Starlight…application of spectroscopy to stars

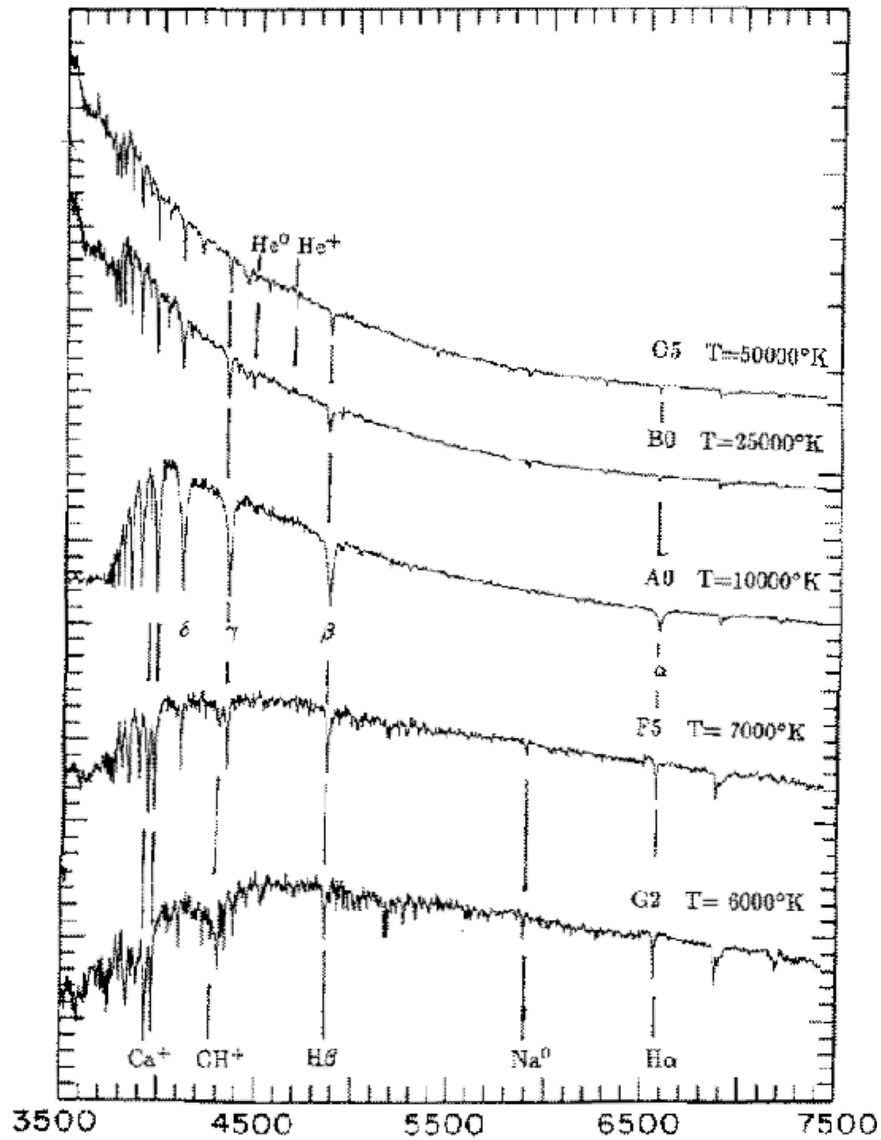
This is the spectrum of the Sun; what do other stars look like?

Examples of stellar spectra

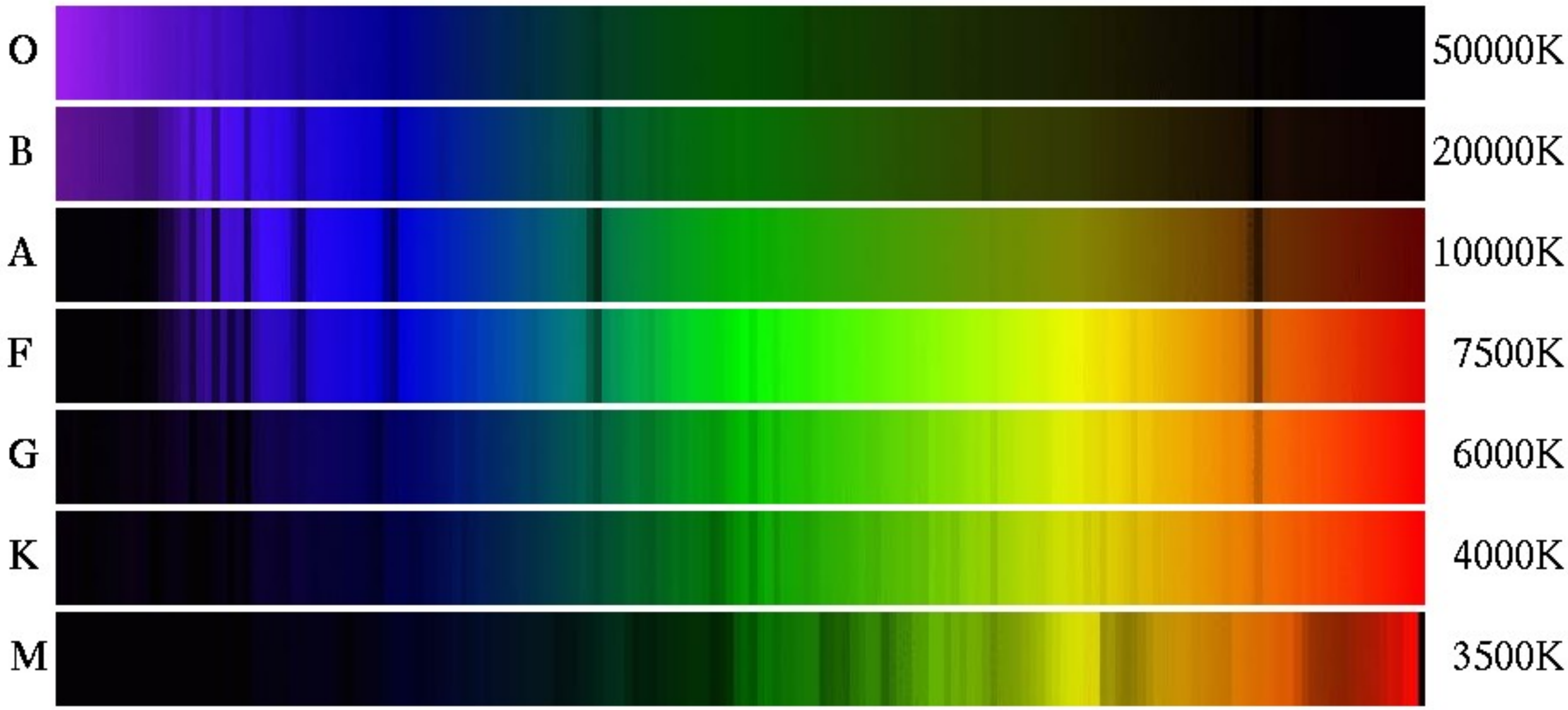
For different stars…

(1) Color changes (different amounts of blue and red light)
(2) Different spectral lines become prominent

This one is like the Sun



Classifying stars according to their spectra

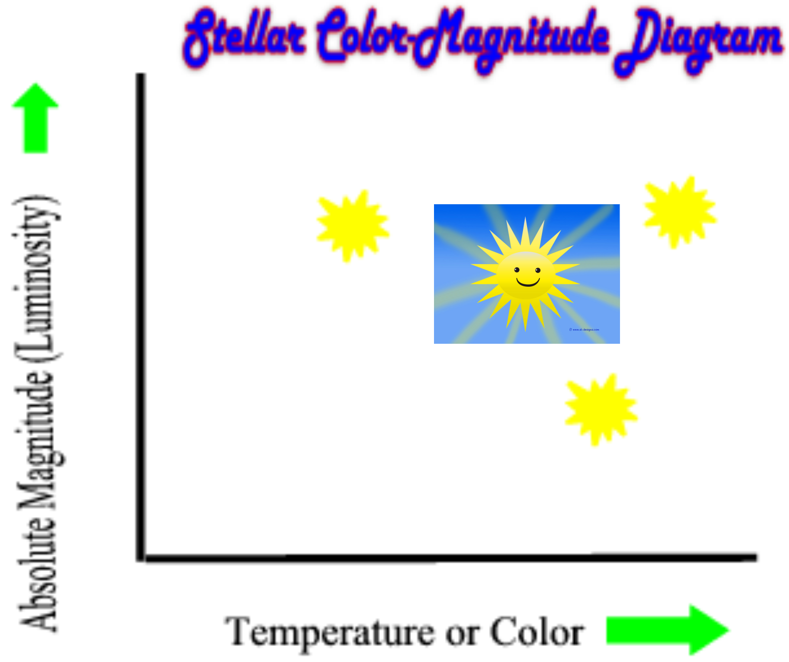


What do the spectra of stars tell us about stars (other than they are different)? Answer: lots

Cecilia Payne Gaposchkin
… first to apply emerging field of quantum mechanics to stellar spectra

The *recipe* for the Sun and stars, i.e. what elements from the Periodic Table of the Elements are present

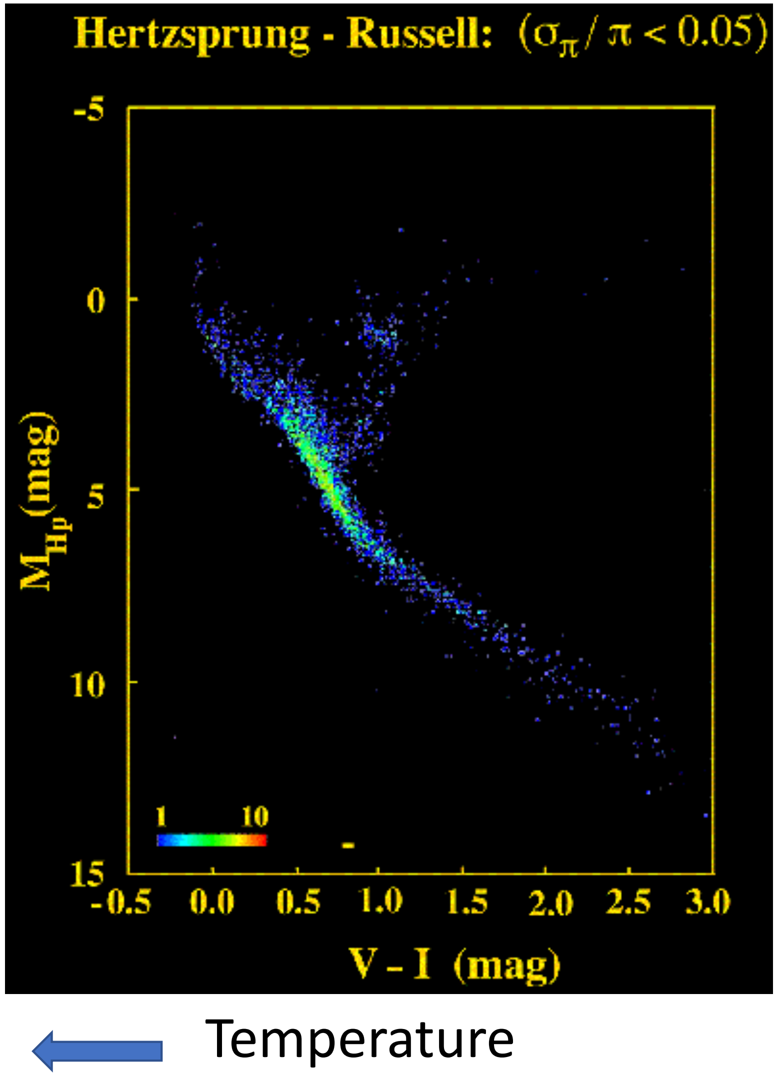
With information such as temperatures and luminosities, we can look for **patterns** in stellar properties



The Hertzsprung-Russell diagram and the nature of stars

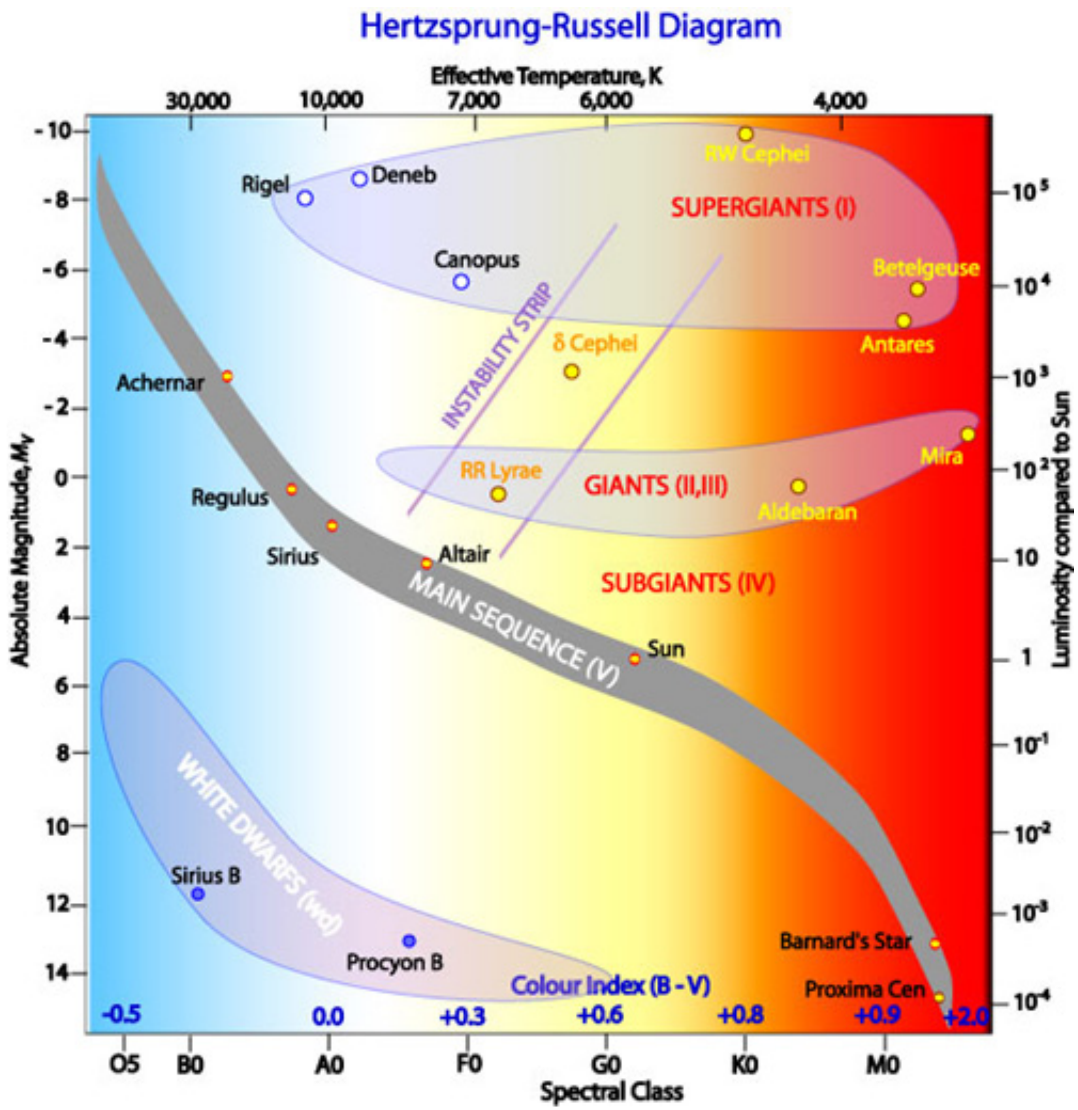
What the data show: the **Hertzsprung-Russell Diagram**

Highest quality data from the Hipparchus spacecraft



The HR Diagram with gaudy color

The Sun is *related to* most of (~80 %) stars; but most have different temperatures and luminosities than the Sun



The scientific classification scheme for the Sun

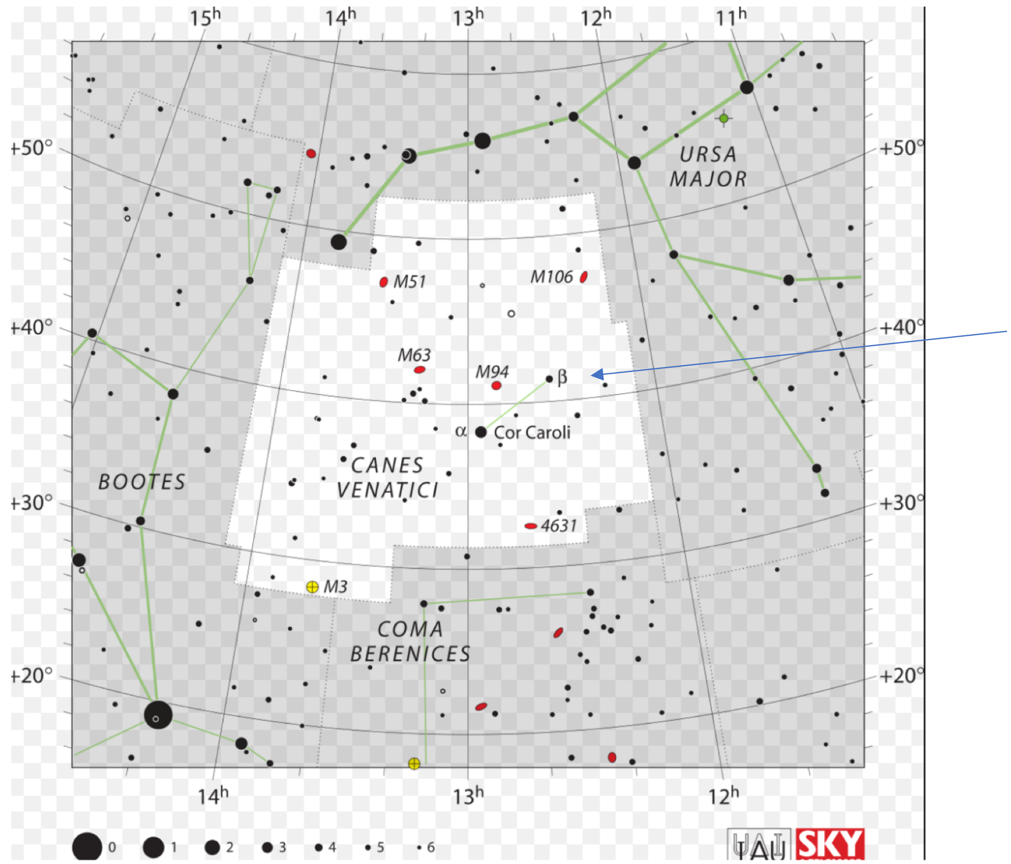
The Sun is a class G2V star…a main sequence, spectral class G star…the Galaxy probably has a billion of them

What are the stars we can see in the night sky?

- Sirius… A1 ... Main sequence
- Procyon... F5... Main sequence
- Aldebaran...K5 ... Giant (III)
- Capella ...G8... Giant (III)
- Betelgeuse... M2 ...Supergiant
- Rigel... B8... Supergiant
- Regulus...B7...Main sequence

In searching for planets outside the solar system, certainly the *Solar Type Stars*, or *Solar Analogs* would seem to be the most intriguing

- Beta Canum Venaticorum
- Spectral type G0V
- Apparent magnitude = 4.26
- Distance = 27.5 light years



A solar type star must have a spectrum like the Sun

Classes of Solar Type Stars (109 stars) Cayrel de Strobel, A&A Rev. 1996

- Solar Type Stars…roughly the same color, temperature, and brightness as the Sun
- Solar Analogs…rarer, more similar stars
- Solar Twins…if powerful aliens swapped them, you couldn't tell the difference!

And the winner is….18 Scorpii!!! (HR6060)

THE ASTROPHYSICAL JOURNAL, 482:L89–L92, 1997 June 10

HR 6060: THE CLOSEST EVER SOLAR TWIN?[1]

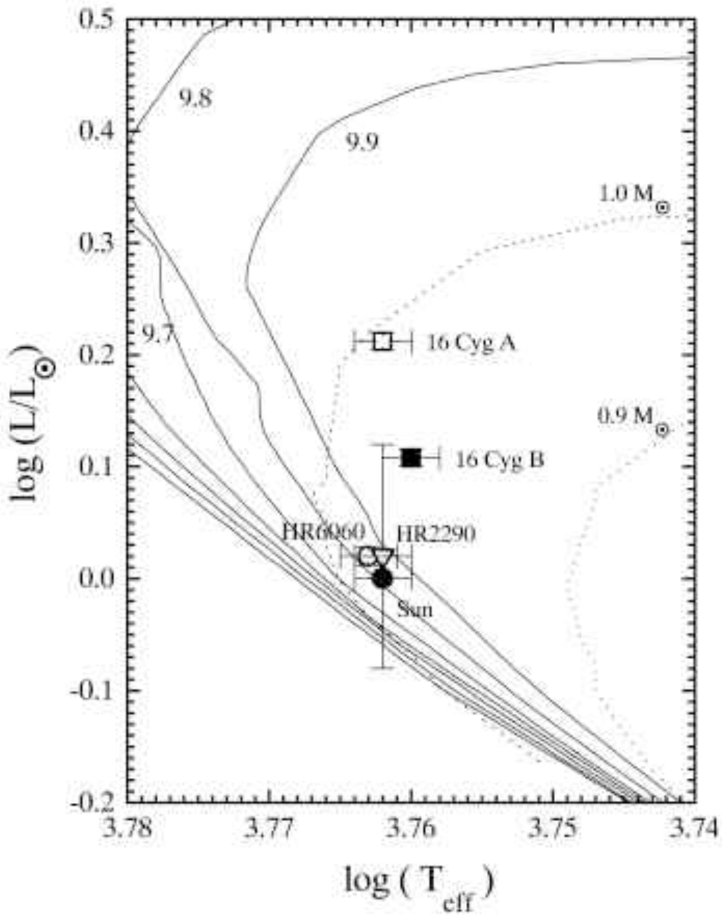
G. F. PORTO DE MELLO[2,3] AND L. DA SILVA[3]
Received 1996 November 22; accepted 1997 March 17

ABSTRACT

The detailed analysis of the optical spectrum and evolutionary state of the G2 Va star HR 6060 shows this object to have atmospheric parameters, mass, chromospheric activity, and *UBV* colors indistinguishable from the solar ones within the observational uncertainties. Only its luminosity and age are slightly higher than solar. Its abundance pattern is solar, with the exception of a slight excess of Sc, *V*, and the elements heavier than Sr. HR 6060 surpasses all previously claimed solar twins in likeness to the Sun, and we recommend that it be considered for strong priority in the ongoing planet-searching programs as well as in SETI surveys.

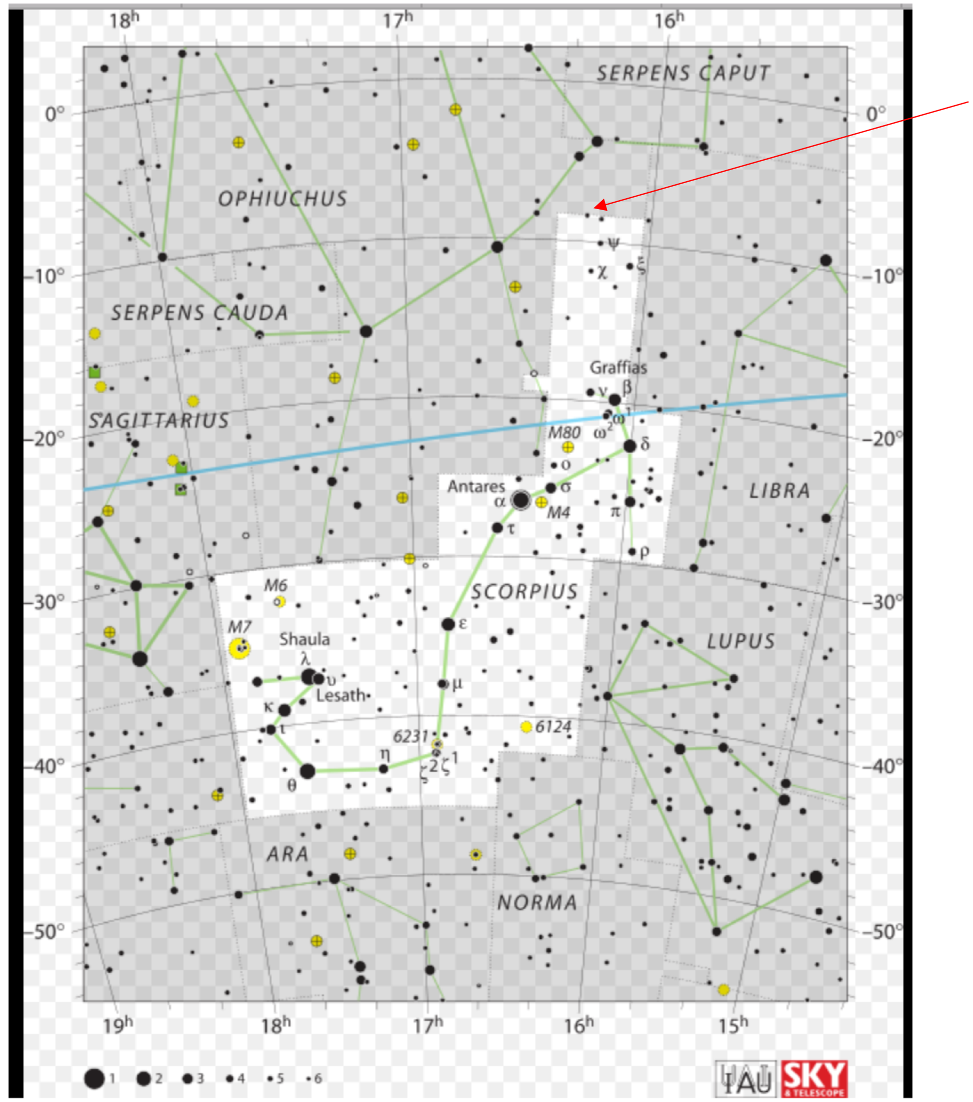
Subject headings: stars: fundamental parameters — stars: abundances — Sun: fundamental parameters

How 18 Sco & the Sun stack up



Where is 18 Scorpii
in the night sky?

In good position for evening viewing in late summer. Plan on going to a Cedar Astronomers public night and see it.



Next time: how we can detect planets around other stars, and what we have found