**A Brief Tour of the Universe**

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This informal document is just a collection of images from the website given below with some interspersed text. I am not an astronomer and some numbers and claims may be quite incorrect.

Motivation: When I travel, I like to know a little about where I am. So I was looking for a good "3D star map" and found a simple one I liked, which is quoted below many times. It is here (but maybe read on first)

http://www.atlasoftheuniverse.com/universe.html

In these pictures, it is possible that the north pole of the earth is "up", but maybe not. The real check is to look at some object in the sky and see where it is on the 3D map, then you are "oriented".

The two tours below do not include the "dark matter" itinerary, only the "visible universe". Nor does the tour include other universes, parallel or otherwise (those cost extra).

These tours are a little more detailed than the classic 1968 powers of 10 movie which is here,

http://www.wimp.com/scaleuniverse/ // Charles and Ray Eames (IBM)

The numbers below concern the speed of light and this is something we think of as being "fast". Light moves 1 foot in a nanosecond which is $10^{-9}$ seconds. But oscilloscopes routinely view things on such a time scale, so perhaps it is not all *that* fast. In terms of the scale of the universe, the speed of light is painfully slow, causing information to move at a snail's pace at most. Just travelling to the edge of the Milky Way galaxy from the earth takes light (or us bound by that limit) something like 17,000 years (earth time). I would not be surprised to find that there are objects in the universe which can in effect go very much faster than the speed of light, but none have ever been truly detected (they would be called tachyons as a general class).

**Let's start with some numbers:** m = meter // numbers are not exact

| | | |
|---|---|---|
| speed of car going 224 mph | $1 \times 10^{2}$ m/sec | 100 m/s |
| speed of light | $3 \times 10^{8}$ m/sec | 300,000,000 m/sec |
| distance light travels in one second | $3 \times 10^{8}$ m | one light-second |
| distance light travels in one minute | $1.8 \times 10^{10}$ m | one light-minute |
| radius of the earth's orbit around sun | $1.5 \times 10^{11}$m = 8.3 light-minutes | ( = 1 au, "astronomical unit") |
| distance light travels in one year | $1 \times 10^{16}$ m = 1 $\ell$y | one light-year |
| distance of nearest star to the sun | 4.2 $\ell$y | it is called Proxima Centauri |
| distance earth radio signals have gone | ~ 100 $\ell$y | ball of this radius around the earth |
| response radius | ~ 50 $\ell$y | |

If someone received first earth-transmitted signals circa 1900 and responded, we would receive those response signals circa year 2000.

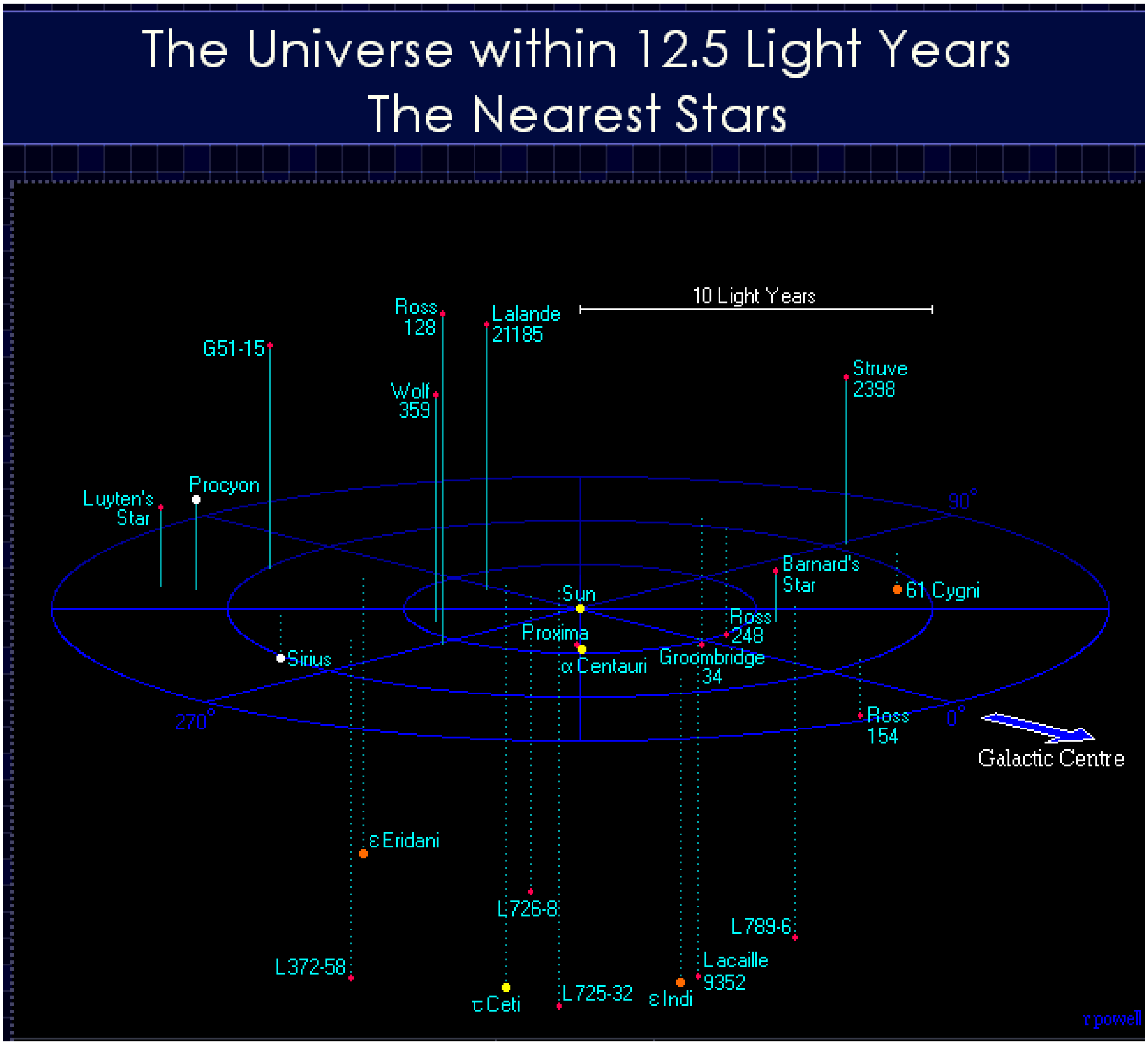
| | | |
|---|---|---|
| number of stars within 50 $\ell$y : | $1.4 \times 10^{3}$ | 1400; 133 are visible to the naked eye |
| number of stars in the visible universe: | $3 \times 10^{22}$ | see European summer tour below |

Often astronomical distances are measured in parsecs (pc) instead of light years:

1 pc = 3.26 $\ell$y $\approx$ $3.1 \times 10^{16}$ m

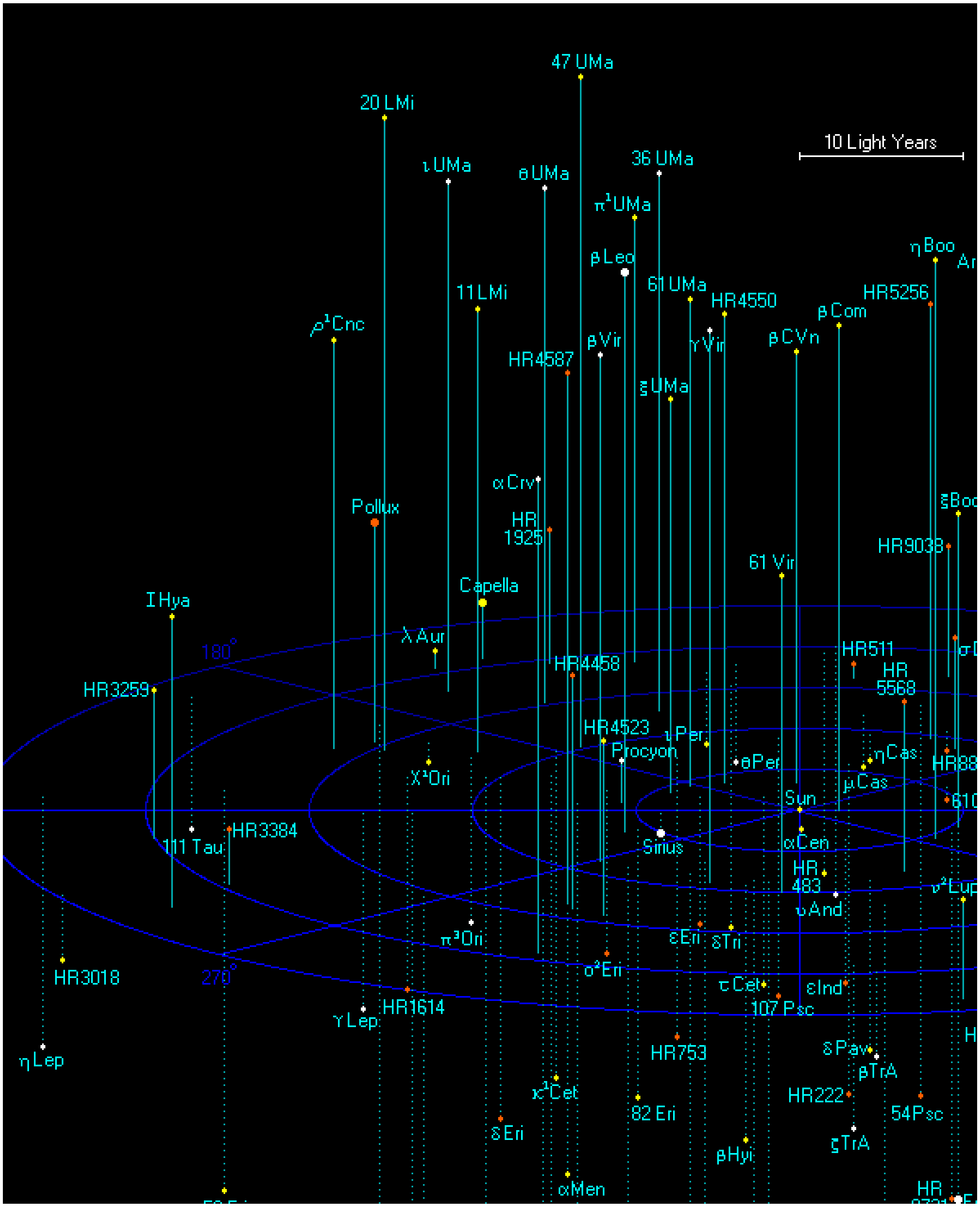
**Your Summer Tour of the Western United States (including Zion and Disneyland!)**

The solar system is only about 80 au = 11 light-hours in diameter out to Pluto ( = $10^{-3}$ of a light year) and so does not show in this picture; it is a dot at the word Sun :

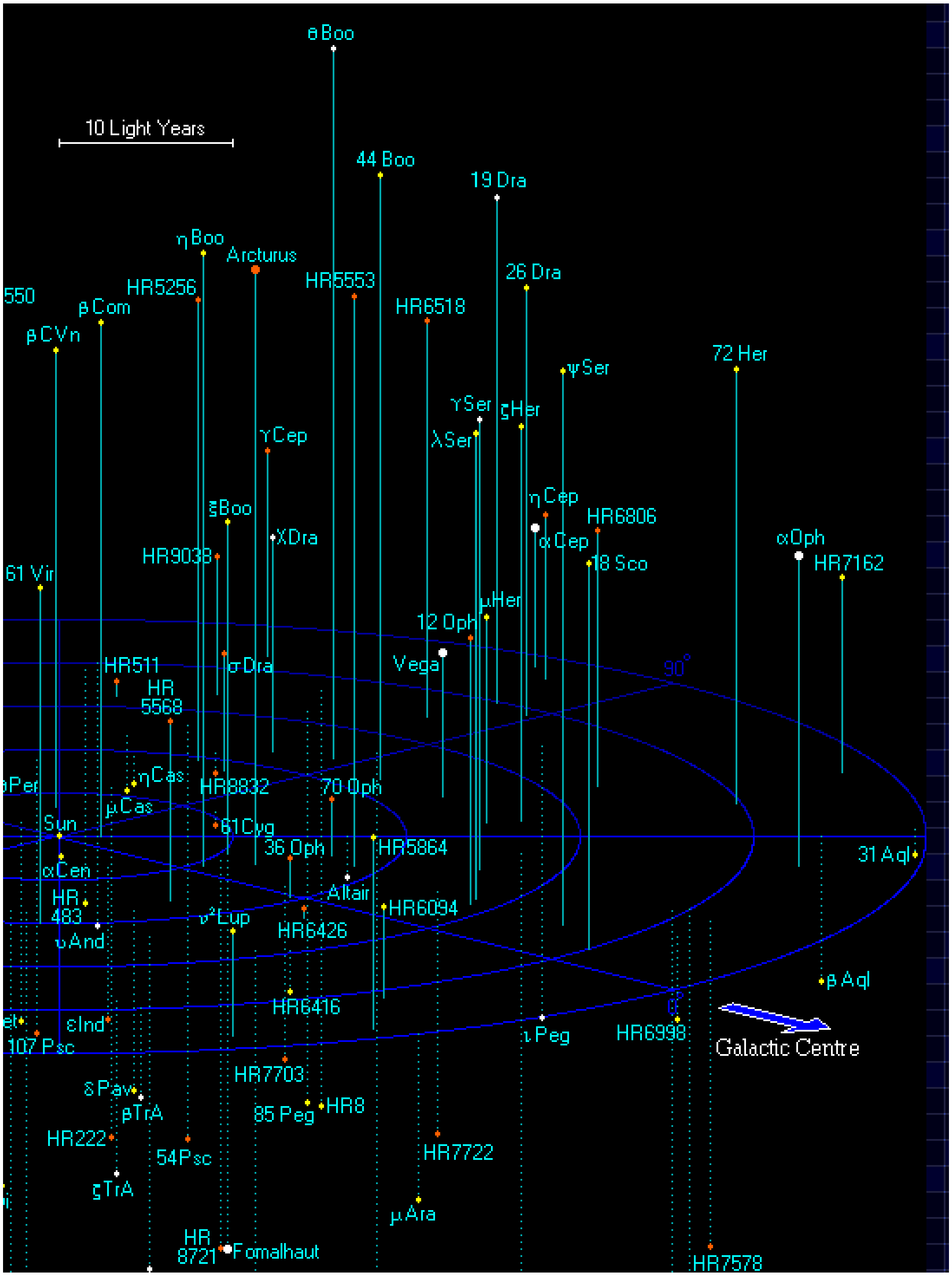



**Sirius** (8.6 *ℓ*y) is the brightest star in the sky, **Procyon** is also quite bright, both visible when Orion is visible. Notice your nearest neighbor **Proxima Centauri** near the center.

If you back the camera up so it is 4x farther way, there are more stars in the picture. The claim is that within 50 *ℓ*y there are 1400 star systems, of which the naked eye can see 133. Here are those 133 in two pictures. First the left half of the picture:

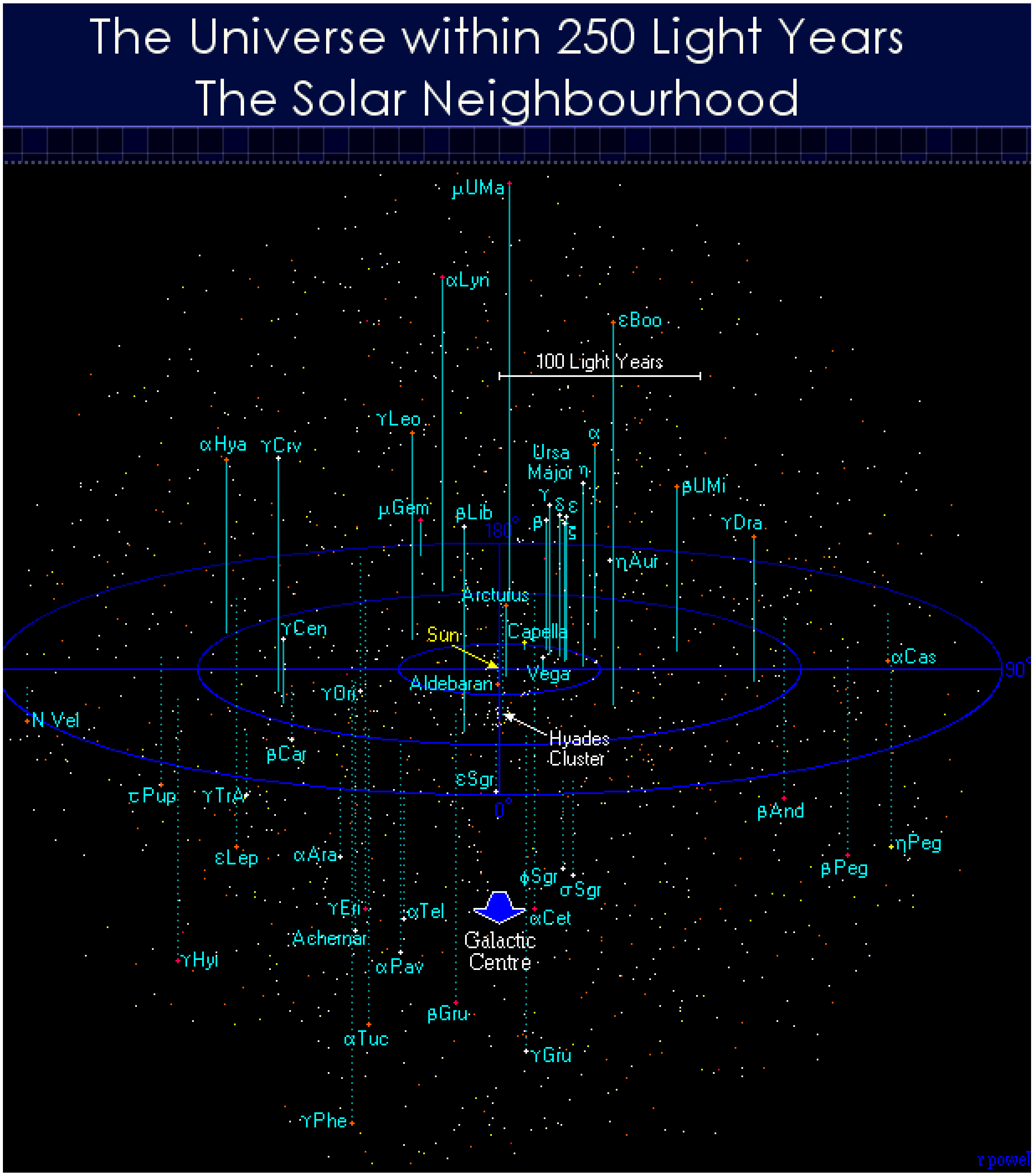



Now Sirius and Procyon are close to the center, **Pollux** and **Capella** are very visible as well in the Orion region of your sky. Unfortunately, Pollux's twin brother **Castor** is just off the left edge and did not make the 50 *ℓ*y cut. And now the right half,



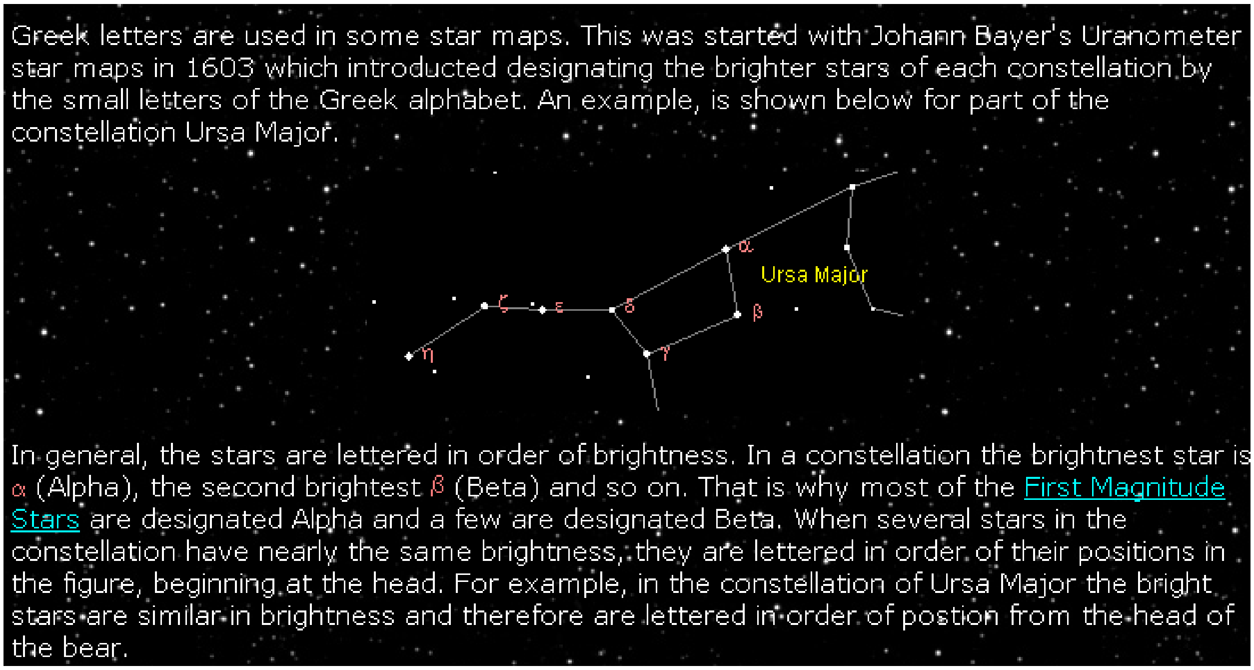

The four named stars here are **Vega** (where Jodie Foster goes in Contact), **Altair** (the Bellerophon crashed on Altair 4 and discovered the Krell civilization there in Forbidden Planet), **Formalhaut** and **Arcturus**.

Now we back out to show some of the brighter stars within a radius of 250 $\ell$y :

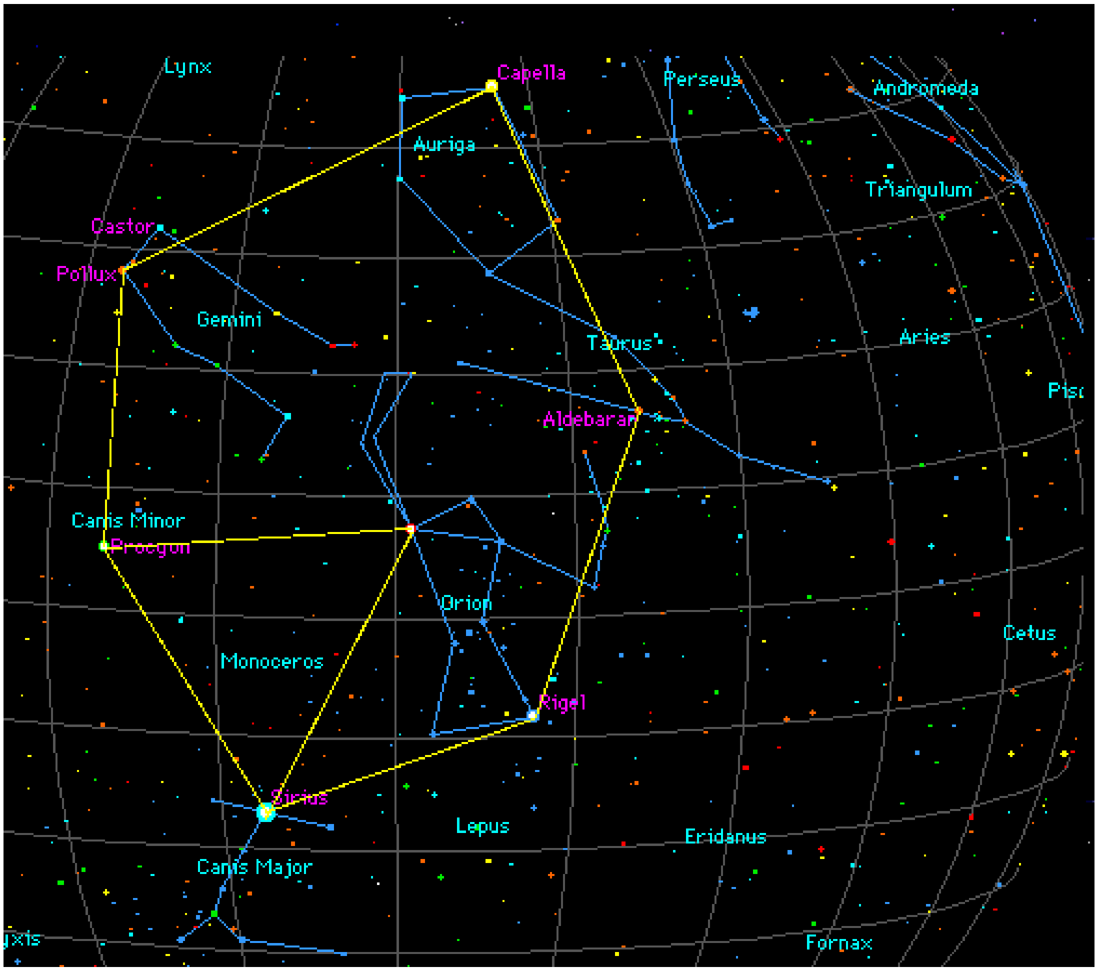



The only new named stars appearing here are **Achernar**, Aldebaran and a Big Dipper star **Ursa Major** γ. The **Hyades Cluster** is a star group like the **Pleiades** (which are farther out). **Aldebaran** (65 *ℓ*y), also known as **Alpha Tauri**, is close to the Pleiades in the sky. In fact, old Aldebaran is chasing those 7 sisters and his name means "the follower" in Arabic.

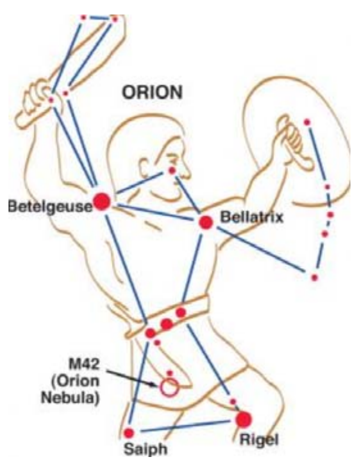
Regarding the names Ursa Major γ and Alpha Tauri:



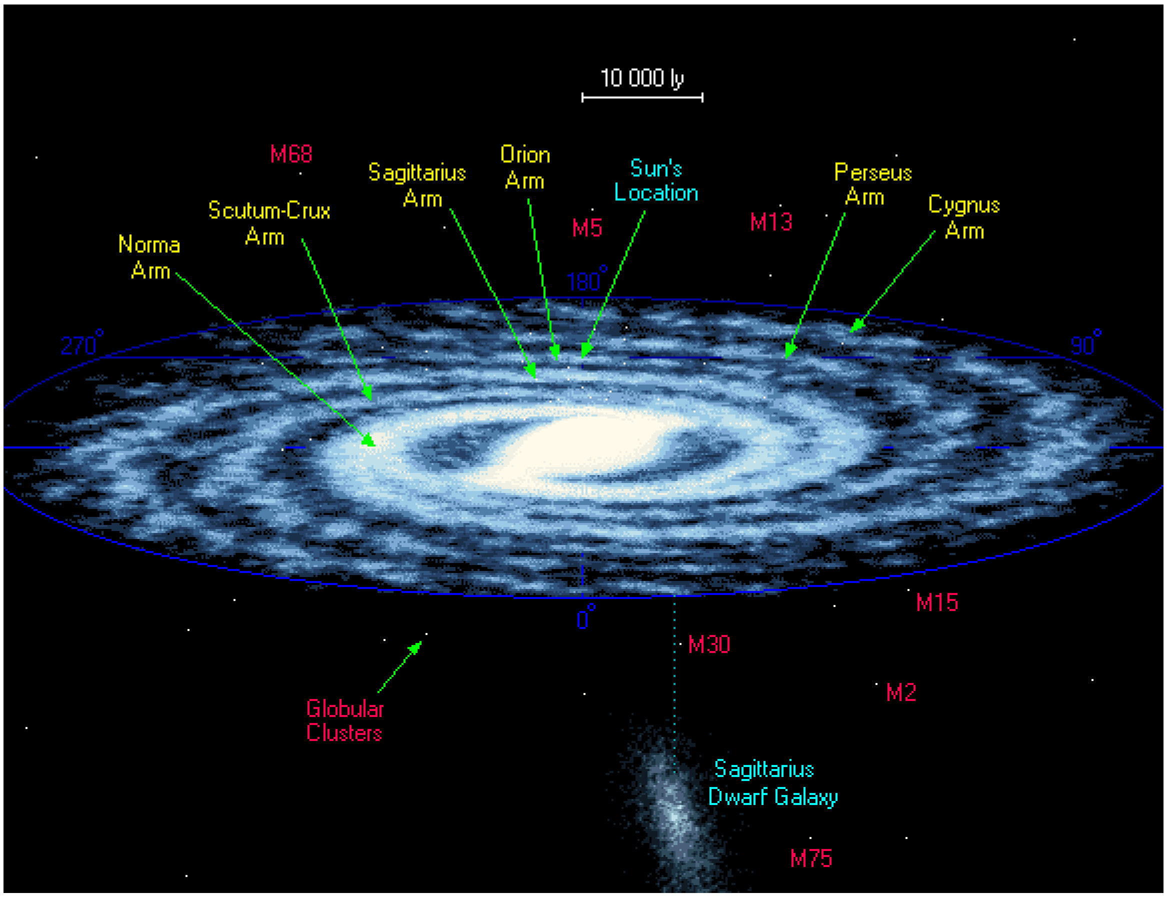

Moving the camera now *to your back yard*, here is a picture I am very familiar with when/if I get up before 5:30 AM and look southwest and up (early December, see Stellarium):




Orion's right shoulder (he is facing us) is Betelgeuse, unfortunately not labeled above but see below. This bright star forms the center of a VERY EASY TO SEE ring of 6 bright stars, all of which have been mentioned in the tour above. From Rigel go up to Aldebaran and the Pleiades nearby, then up to Capella which is in that pentagon thing called Auriga, then over to Castor and Pollux in Gemini, down to Procyon in the Smaller Dog, then way down to bright Sirius (the dog star) in the Bigger Dog. Lurking on the upper right are our two nearest neighbor large galaxies Triangulum and Andromeda (coming soon).

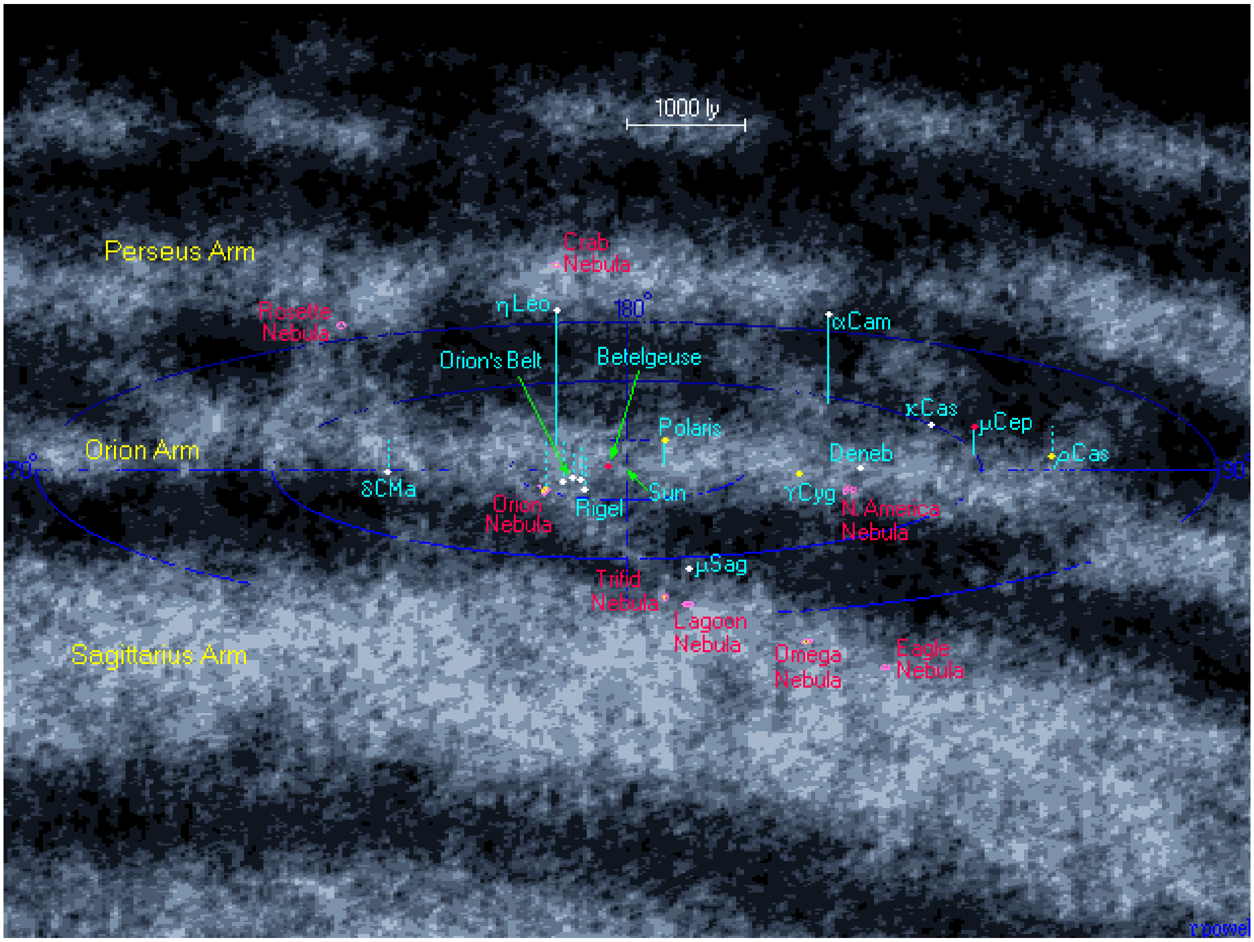


Now we back out a whole lot and look at the Milky Way galaxy :




Notice the scale of an inch being 10,000 *ℓ*y. The diameter of the Milky way is about 100,000 *ℓ*y. The swath you seen in the sky is all those $10^{11}$ stars seen edge on. The Milky Way is a spiral arm galaxy and all the arms have names: Norma (Norma?), Orion, Cygnus, etc. These spiral arms are a little like the rings around planets, and it makes you think there is probably something big at the center. We are located in the Orion Arm about 2/3 out from the center to the edge.

The camera now zooms in and looks down from the top at our location (now 1" = 1000 *ℓ*y )



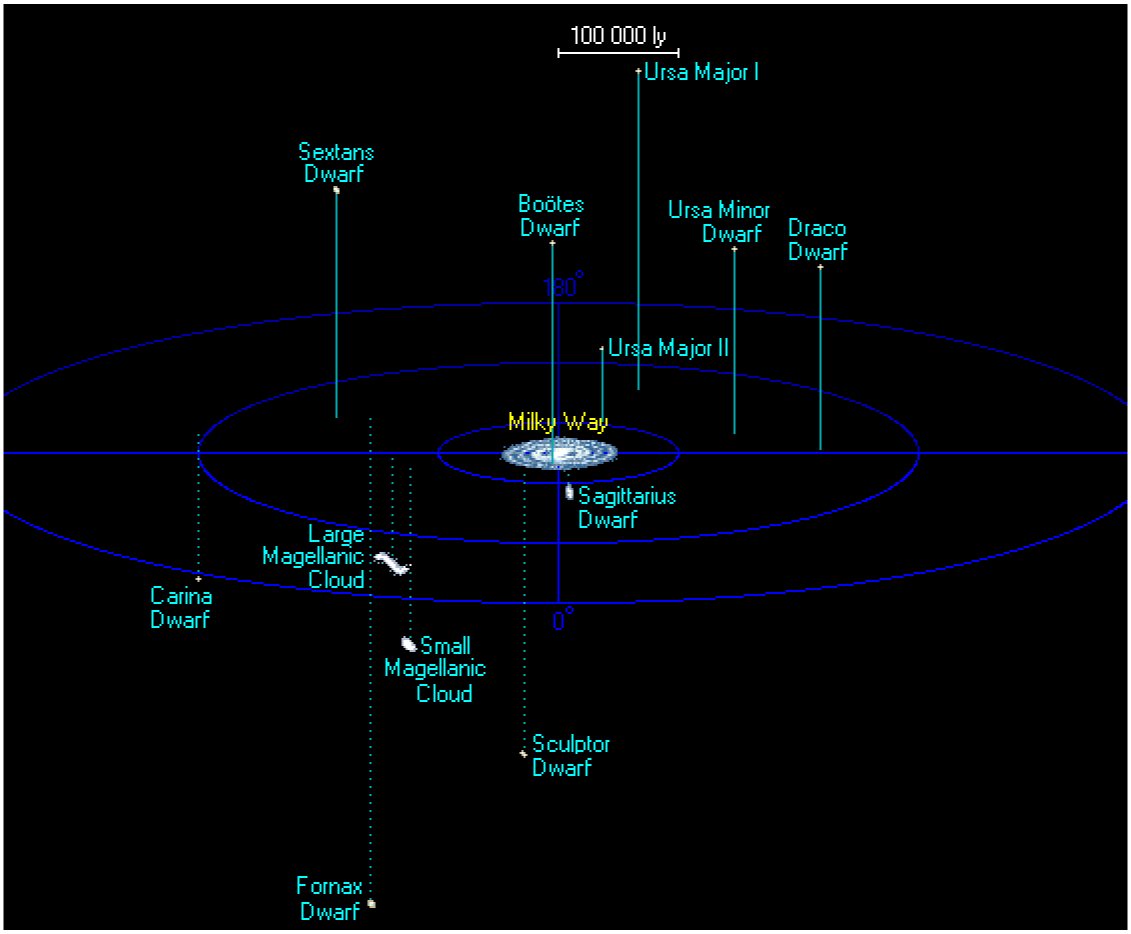

Now finally the Orion constellation stars come into the picture, most are about 800 ℓy from the sun. Polaris is 433 ℓy and it is The North Star. Deneb is the top of the Northern Cross (aka the Swan, Cygnus) and is 1400 ℓy away, yet it is clearly visible to the naked eye! That is pretty amazing. We pause for a few more numbers:

| | | |
|---|---|---|
| 100W light bulb | 100 watts | |
| power human generates riding bike hard uphill | 250 watts | |
| average electric power used in the state of Utah: | 2 GW | // gigawatts, 2 x $10^{9}$ watts |
| average electric power planet wide: | 1940 GW | // about 2x$10^{3}$ GW |
| total power output of the sun | 4 x $10^{17}$ GW | |
| total power output of Deneb | 60,000 times the output of the sun | |

That is no doubt why Deneb is visible to us from 1400 ℓy away.

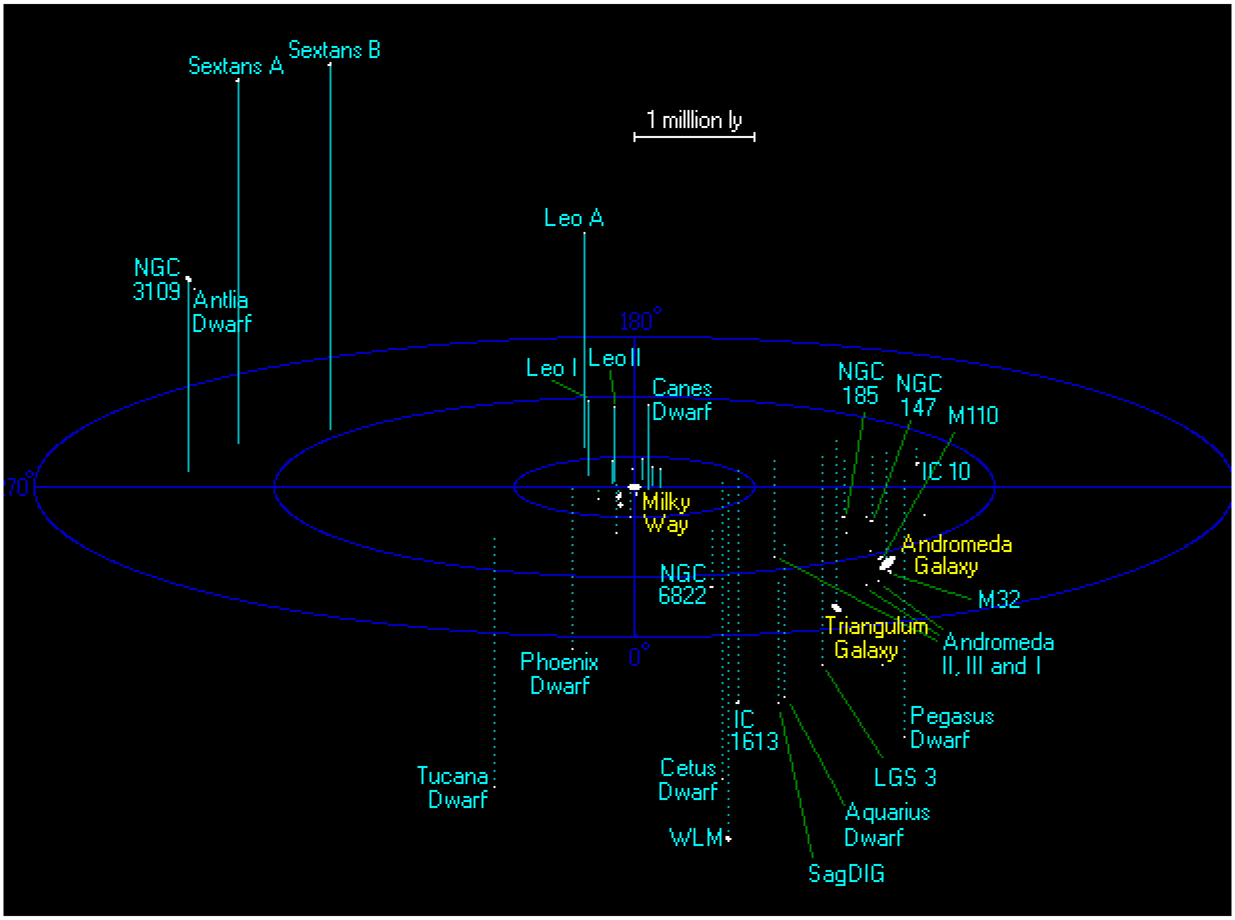
Notice also in the above picture various **"nebula"** objects in our Orion Arm and in the neighboring Perseus Arm and Sagittarius Arm. A famous one is the **Crab Nebula**.

The camera backs out again to a point where an inch is now a Milky Way diameter,




Things are pretty sparse here. Two smallish galaxies are called the Large and Small Magellanic Clouds, and maybe there are ten "dwarf galaxies". We need to back out some more to get more action.

Finally we get to what is called amusingly "**The Local Group**" which contains 56 galaxies (the M numbers below refer to the 1771 Messier catalog notation, while NGC numbers refer to the 1888 New General Catalog).



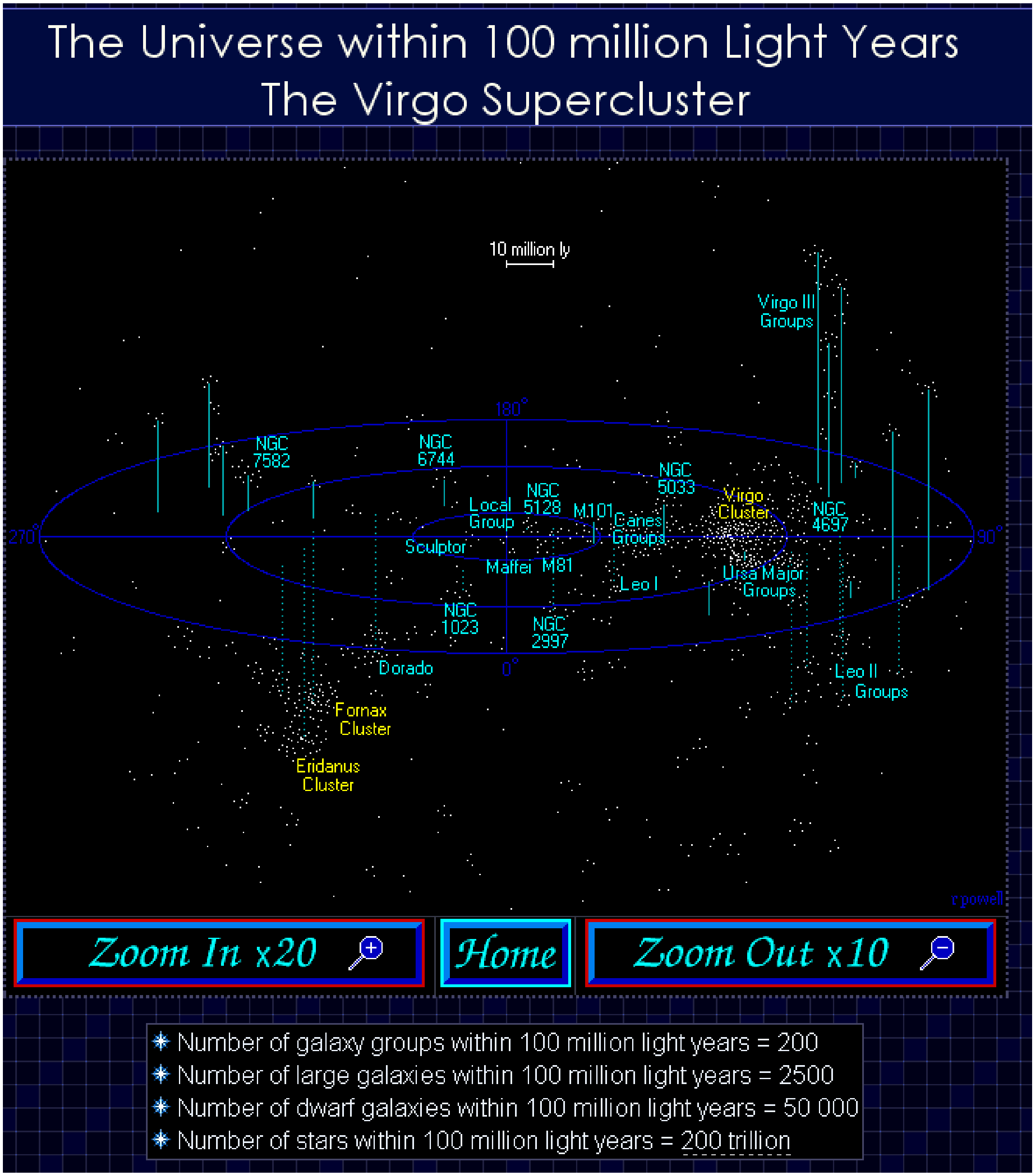

An inch is now $10^6$ *ℓ*y and you see some more Dwarf Galaxies and other objects, but the big news is that the Local Group contains two other large galaxies. **Andromeda** (M31) is about the same size as the Milky Way, and **Triangulum** (the Pinwheel, M33) is about 1/3 the size of the Milky Way. Both Triangulum and Andromeda are visible to the naked eye, even though they are about 3 million light years away. The reason Andromeda is visible is because it contains $10^{12}$ stars, and remember how bright Deneb was above, just one star. But most of Andromeda's stars are more like the sun in brightness or less, and in fact:

| | |
|---|---|
| Power output of the Andromeda galaxy | $2.6 \times 10^{10}$ times that of the sun |
| | $= 10^{28}$ GW |

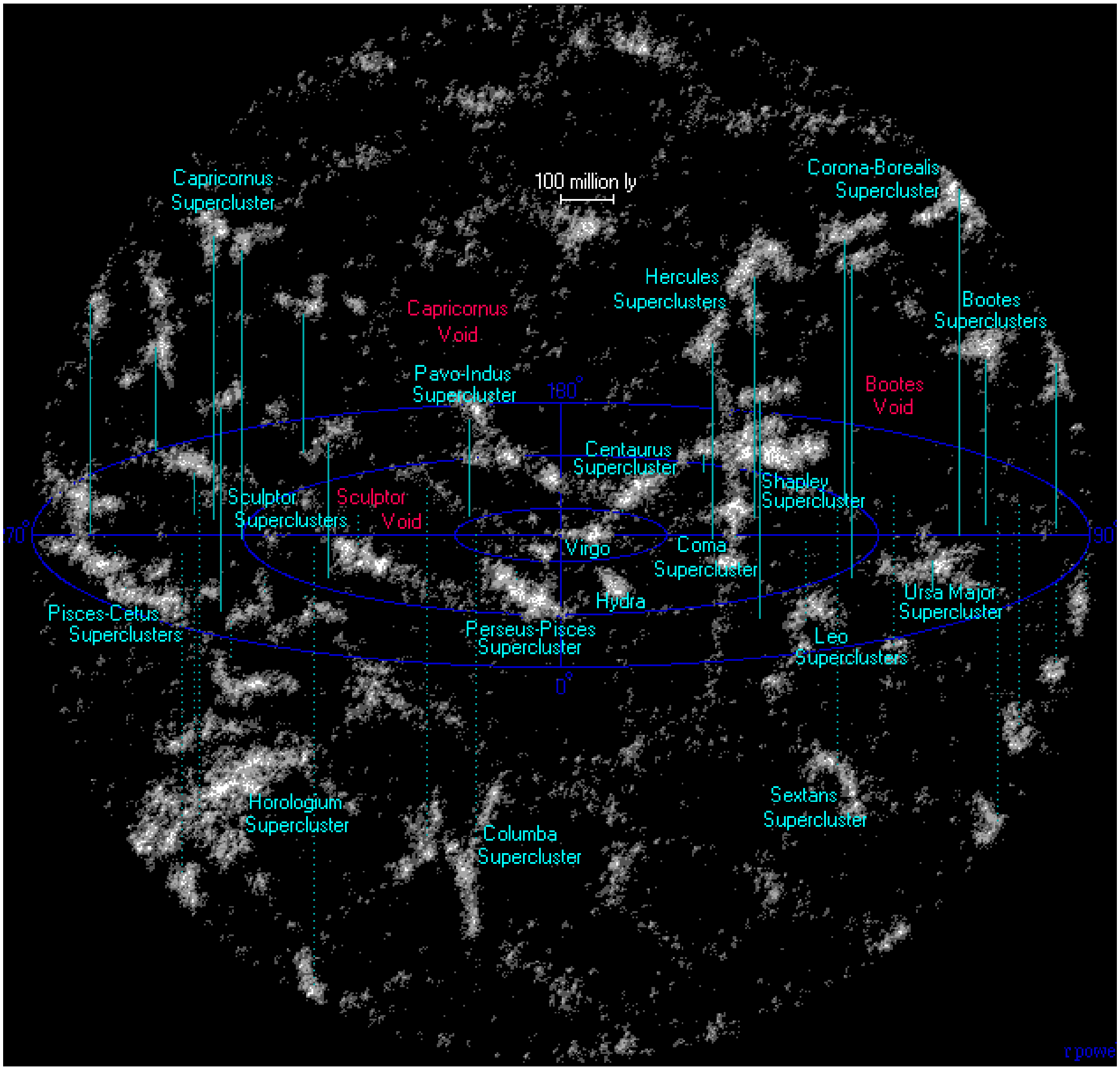
This concludes our tour of the immediate vicinity of the sun, and it is time for the European summer vacation tour to see what is a little farther from home than the Local Group.

**European Vacation Tour**

An inch is now 20 million $\ell$y , and it is seen that our Local Group is one of 200 such globs of galaxies within a radius of $10^8$ $\ell$y of the sun. Each dot in this picture probably represents 5 Milky Way size galaxies. Small collections with 50 or fewer galaxies are called "groups", but those with 50 to 1000 galaxies are called "clusters". This entire picture then forms a "supercluster", so yes, we are living near the middle of the Virgo Supercluster:

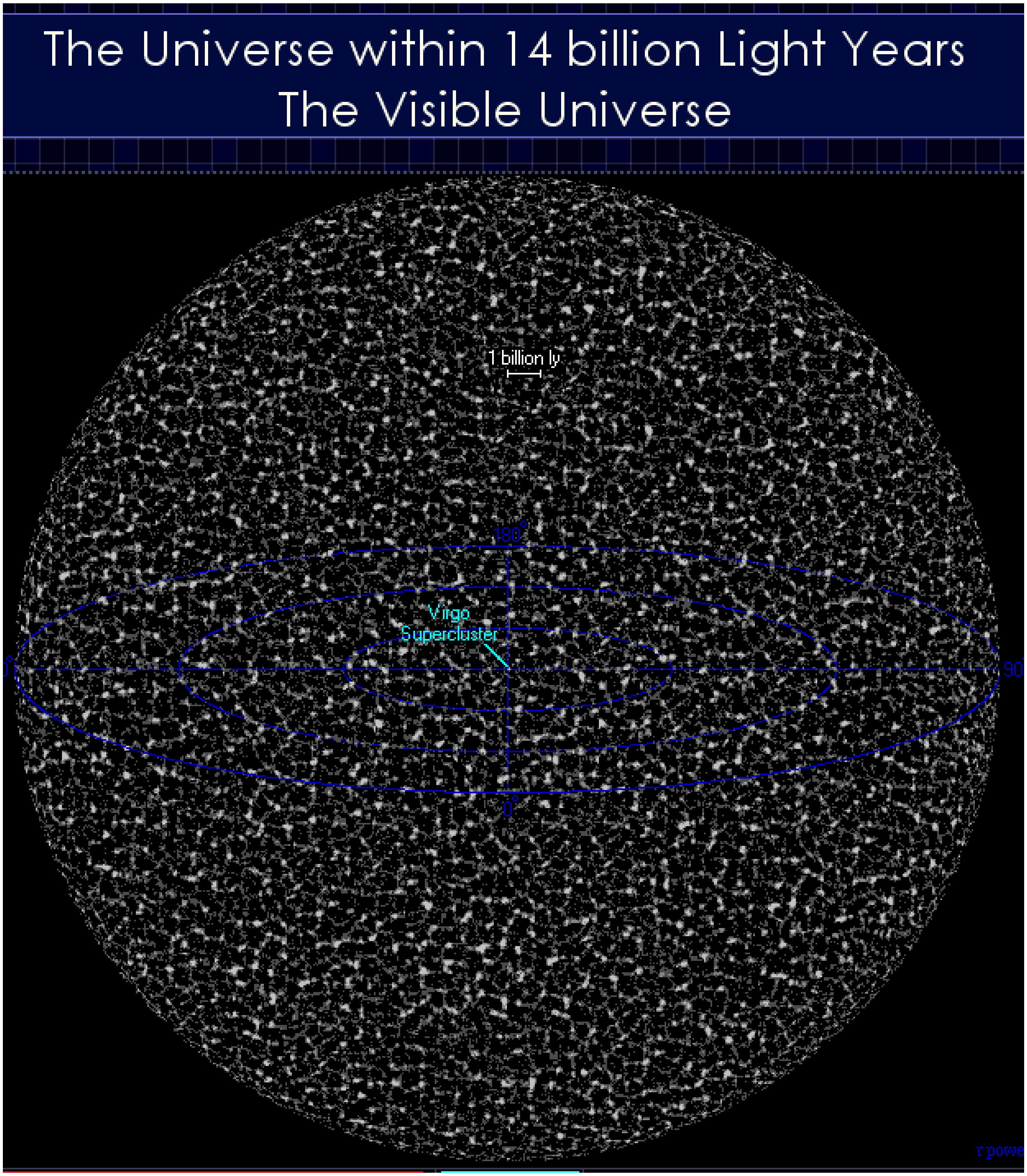


But of course this is just one of many superclusters, so we back out again




and the Virgo thing is near the center. The picture radius is now about $10^{9}$ light-years. These superclusters seem to be the largest scale objects there are, apart from filaments of same. The Horologium supercluster contains $10^{17}$ sun size stars and has a diameter of 550 x $10^{6}$ $\ell$y.

There is now only one final scenic view on the European Summer Vacation tour which shows that the Virgo supercluster is just one of 10 million similar superclusters in the known universe:




and here is some data to go with this picture

- Number of superclusters in the visible universe = 10 million
- Number of galaxy groups in the visible universe = 25 billion
- Number of large galaxies in the visible universe = 350 billion
- Number of dwarf galaxies in the visible universe = 7 trillion
- Number of stars in the visible universe = 30 billion trillion ($3 \times 10^{22}$)

The interesting last number says there are $3 \times 10^{22}$ stars in the visible universe, give or take a few.

If one star in each 3 million stars had a planet containing some form of life, there would be $10^{15}$ inhabited planets of which about 100,000 would be in the Milky Way (not counting dark matter and other "dimensions").

Stars have differing power output, but if we crudely imagine that each star is like our sun, we can estimate the total power output of all the floating nuclear reactors in the universe,

total universe power output $\sim 3 \times 10^{22} * 4 \times 10^{17} \sim 10^{40}$ GW

That is a lot of gigawatts.

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This PDF file can be found on the web by searching for "Phil Lucht Documents".