

## EZStars Messier Table, Astrophysics, Aids

Galaxies:	Star Forming Nebula:	Clusters:	Exoplanets,
M31 Andromeda 4"	M8 Lagoon 4"	M4 Cat's Eye 4"	Kepler Space Craft
M51 Whirlpool, 4"	M16 Eagle 4" (dim)	M13 Hercules 4"	
M74 Phantom 4" (dim)	M17 Omega, Swan 4"	M15 Pegasus 4"	Supernova:
M77 Barred Spiral 4"	M20 Trifid 4"	M45 Pleiades 4"	M1 Crab 4"
M81 Bode's 4"	M42 Orion 4"	Info Double 4"	Info SN1987a*
M82 Cigar 4"	Planetary Nebula:	Info Coathanger	Info SN1006* Rib
M104 Sombrero 4"	RSG Antares	Double Stars:	*X-ray or Hubble
NGC4565 Needle (dim)	RG M57 Ring 4" (dim)	Mizar-Alcor info	images
Hubble Deep Field	WD M97 Owl 4"	Albireo	

The middle column emphasizes astrophysics with five star forming nurseries, the list being three red giants and two white dwarfs blowing off nebula. The bottom right supernova include a type II remnant with both a neutron pulsar at the center and an expanding nebula of blown off gasses. With some effort a beginner should be able to find M1 in Taurus. The other two you can't see but are fundamentally interesting and discussed below. The Sombrero and Needle galaxies are included in the left column because they are so striking spooky to contemplate that one ought to know where they are even though you can't see them with a minimal telescope. The 33 Messier objects used in this table are either on the Sky & Telescope 11" star wheel or are rated as easy to find by Ken Graun in his book ("The Next Step: Finding and Viewing Messier's Objects") The two digits preceding M are his ranking for find and identify: 1=easy, 5=difficult. Twelve non-Messier locations are included as well. Clicking on M# in the table gives information about the object, including which "The Next Step" star chart to use. Clicking on the object's name gives Hubble-class imagery. Clicking on "4" gives Ken's small scope images. With 4"-8" telescope aperture you have portability and capability to "detect" objects. 12" and above is needed to begin to resolve and "observe" objects, and with the larger amateur sizes 18"-24", non-turbulent atmosphere and 2" wide-field eyepieces, the sensation of being in space with what you are observing can be breathtaking.

A new form of amateur astronomy is to learn where in the sky impressive Hubble-class imagery has come from and some of the modern astrophysics of what you are looking at in these objects. And particularly interesting for me has been learning the life events of stars with examples in this subset of Messier objects.

One way to classify these star life events is in the five steps shown below. The physics of the first three isn't hard to understand, basically just gravity pulling together "dust" clouds until regions become so dense and pressure heated that thermonuclear reactions begin and a star is born. The "Pillars of Creation" photograph is one of Hubble's most convincing and spooky displays. And to see beautiful other-world galaxies like Andromeda, Sombrero and Needle is also humbling.

Tantalizing but harder to understand are steps 4 and 5 at the end of star life when they blow off gases. Explosions seem like a strange way to burn out. It happens two ways: first "relatively gently" in ejection nebula as the star first runs out of hydrogen in its core, and then at the end in a supernova explosion after completion of heavier fuels as well. Lighter stars with less than .3 solar mass can be different in a couple ways.

### 1) Gravitational merging of large amounts of "dust"

"Metal rich" refers to elements heavier than helium. Our sun is 98.66% H and He by weight, so has "metallicity" = .0134. Some of the elements are heavier than iron and from supernova explosions

### 2) Star Nursery Nebula:

M42: Orion Nebula M8: Lagoon Nebula, with center "Hourglass" M16: Eagle Nebula with center "Pillars of Creation" M20: Trifid Nebula, with center "stellar jets"

### 3) Formation of Galaxies and Star Clusters within them

(Gravity tends to form spinning disk with bar in center.) 14 Milky Way Clusters in table, M45 Pleiades easy to see 14 Galaxies in table, M31 Andromeda the easiest to find/see Diameters: Andromeda (220kly), Milky Way (160kly), Sombrero (49kly)

4) Star Ejection Nebula (called "Planetary" but have nothing to do with planets)—Red Giants v. White Dwarfs: Betelgeuse Nebula around red giant Antares Nebula, around red giant M57: Ring Nebula, around red giant (2.6 ly) M27: Dumbbell Nebula, around white dwarf (2.9 ly) M97: Owl Nebula, around forming white dwarf (0.9 ly)

### 5) Supernovas—Degeneracy & Core Collapse v. Type Ia:

SN1987a Type II, shock ring but no nebula found, neutrinos first (.7 ly) SN1054 M1 Crab nebula, second brightest, Type II so left neutron quasar inside (11 ly) SN1006 Type Ia so no remnant star, brightest ever, now very dim (65ly) (1006 & 1987a not visible in a small telescope)

### Star Ejection Nebula called "Planetary"—Red Giants versus White Dwarfs

(These have nothing to do with planets.) Examples listed are for three red giants and two white dwarfs. I didn't find any similar imagery for the other prominent red giant, Aldebaran. Apparently all stars large and small eject outer shell gasses after they run out of hydrogen fuel in their core. With gravity no longer opposed by thermonuclear heating pressure, the core contracts. If the star is 0.3 solar masses or larger, this gravitational compression causes the core to heat up to even higher temperature than before so that thermonuclear fusion of helium can occur. For large stars this process of increased gravitational compression heating goes through a series for successive fusionings of heavier elements. These are red giants or red supergiants. Small stars, though, can't generate enough gravitational compression heating to reignite even helium fusion and end up with collapse prevented by quantum mechanical electron degeneracy. These are white dwarfs. When its core contracts, the star's outer shell expands and ejects gasses. This seems counterintuitive at first, and many descriptions on the web give confused answers. Two basic principles of physics are involved.

First, the geometry of "core" needs to be clarified. Stars are formed by gravitational attraction pulling together a huge clump of helium and other debris and squeezing it until temperature rises to the point that fusion of hydrogen nuclei can occur. But the star ball of gas is not uniform in temperature. The center gets squeezed the hardest, so nuclear reactions occur only in a limited central region—until this region much later runs out of hydrogen fuel and contracts. With contraction heating two things happen. The center core heats up as described. But everything else compression heats as well, and if the star is massive enough, hydrogen fusion will commence in a shell around the central core. This hydrogen fusion shell has larger diameter and so can actually be of larger volume than the original core, so there is an increase in thermonuclear heating in two ways—hydrogen

burning in a shell around core that is more extensive than when the star first formed, plus helium burning in the central core. And this is still inside much of the cooler outer shell of hydrogen. The structure becomes: contracted core switching to next heavier fuel, an energetic hydrogen fusion shell and then outer shell of hydrogen not yet hot enough to react.

Second, the way energy gets from the inside to the outside of a star is rather complicated. It takes about 170,000 years for energy generated in the core of our sun to get to the outside and be radiated as heat and light. Most of this time is spent in what is called the "radiative zone" out to about 70% of the radius of the sun. The outer 30% thickness of the sun is cool enough for hydrogen atoms to form with electrons (even if in very highly excited levels) staying attached to protons, and these atoms can absorb radiation, heat, and mix in turbulent convection. That transports energy relatively quickly to the surface—but only through that last 30% of distance to the surface. In the nuclear reacting central region of the star, electrons and nuclei are totally disassociated. In the outer convection region they are bound. In the transition "radiative zone" electrons stick only fleetingly to protons before being banged off again. This temporary bond species cause radiation to essentially just bounce in random directions with no relation to temperature gradient. This makes net energy flow toward the exterior very slow.

A star always has this heat-transport-resistive region just outside the fusion region. But when core hydrogen burns out and the star transitions to helium core + hydrogen shell burning, it begins to exert much more radiation pressure on this radiation resistive region. It is this radiation pressure that expands the outside gasses without heating them very much. And since these outer gasses are expanding, they cool forming a red giant likely to expel gasses.

A white dwarf apparently shares fundamentals but doesn't push out and cool such a large volume of outer gasses and so remains white.

The examples of these nebula, again, are Antares, Betelgeuse and M57 Ring Nebula for red giants versus M27, Dumbbell and M97 Owl Nebula for white dwarfs.

Supernovas—Degeneracy & Core Collapse v. Type Ia:

SNFeOnionProgenator.png In core collapse the star has transitioned several times through burning heavier and heavier nuclei until, with iron, there is no more energy to be had from fusion. As with the red giant transitioning to burning helium in its core, each stage involves gravitational contraction and heating to a still higher temperature at which the next heavier nuclear fuel can undergo thermonuclear fusion. But fusion of iron nuclei would consume rather than release energy, so after silicon is fused to iron in the core, something else has to prevent gravitational collapse. Electron degeneracy comes into play and can prevent collapse of stars smaller than about eight solar masses. This is due to three features of quantum mechanics: 1) particles have to be described by a probability distribution wave function, 2) this function has a wavelength  $\lambda$  and the particle momentum  $p$  is inversely proportional to this wavelength,  $p = h/\lambda$  where  $h$  is the Planck constant, and 3) no two particles can be in the same quantum mechanical state. Their spin can be up or down, so there can be two particles in each, what you might call a "geometry" state described by the probability distribution function. Counting these geometry states is a boundary value problem similar to the zero-motion condition at the ends of a guitar string. Electrons in the core of a star must have zero probability of being present at the core boundary. To simplify we approximate the core as being a cube with length of each side being  $L$ , where  $L$  is a little smaller than the spherical diameter of the core. Then along each direction the component of wavelength of the electron probability distribution must be an integral fraction of  $L/2$ . The allowed wavelengths are restricted to the same formula as for a guitar string,  $\lambda = L/2n$  with  $n$  an integer,  $n=1,2,3,\dots$ . In the stellar core problem, though the maximum value that  $n$  can have is

$n_{\max} = .5 N^{1/3}$ , where  $N$  is the number of electrons, a very large number. Now figure out the energy of each electron and also the sum of all their energies. For each coordinate direction and

wavelength  $L/2n$ , momentum is proportional to  $n/2L$  and kinetic energy is proportional to  $(n/2L)^2/m$  where  $m$  is the electron mass. The sum of all these terms is  $(n_{\max})^3/(4L)^2m = .354 N / mL^2$ . And with all three axis directions included, the total kinetic energy of electrons in the stellar core is proportional to  $N / mL^2$ . Electron degeneracy is the state where gravity has collapsed  $L$  as much as it can but is stopped by not being able to provide enough energy to further increase  $N / mL^2$ . It's because  $N$  is such a huge number. And note that because electrons have smaller mass than neutrons, electron degeneracy occurs before neutron degeneracy. The Chandrasekhar limit is the breakdown of this condition when the mass of the iron core exceeds 1.4 times the mass of the sun. I think it's because of a relativistic effect with electron mass  $m$  increasing as much as  $N$  as more iron is added to the core. This increase in iron nuclei and accompanying electrons is from silicon fusion reactions in the shell around the core. Then in the core the electron energy states are so high and their velocities so very near the speed of light that their mass increases as  $L$  decreases, and  $N / mL^2$  can no longer impede gravitational contraction. The iron nuclei until this point have been careening past and into each other with long mean free path compared to their size. But with unremitting gravitational compression they are forced to fuse, which disrupts the nuclear forces that hold them together and causes the protons to decay to neutrons. This releases positrons and electron neutrinos. The positrons annihilate with electrons releasing much radiation energy, but according to modeling, 99% of the supernova explosion energy is radiated as neutrinos. What forms at the center is usually or maybe temporarily a very compact neutron star that resists further gravitational collapse both by strong nuclear force neutron-neutron repulsion and by neutron degeneracy. Meantime the outer layers of the star contract, too, very rapidly until they rebound in a tremendous shock wave after hitting the hard size limit of the neutron star core. There is also increase in their own thermonuclear fusion reactions. It is this outward shock wave that blows the exterior of the star apart and causes the supernova explosion. There are two remnants after core collapse—a central remaining neutron star or maybe black hole if the star had been very massive, plus a large amount of material in an expanding ball of nebula gasses. Size, brightness and chemical composition spectra can vary considerably, so there are several classes of core-collapse supernova with designations Type Ib, Type Ic, and Type II.

SN1987a was the first supernova observed with neutrino detectors. A "shower" was observed on earth from three locations with a total of 25 neutrinos in two 2-3 second bursts. Visible light from SN1987a was not observed until three hours later. This difference is because neutrinos pass through the outer layers of the core-collapsing star almost unimpeded, but it takes a long time for the shock wave to reach the stellar surface for stimulating light emission. That modeling fits very well, but there are two significant problems. No remnant neutron star has been found for SN1087a, and there is no significant expanding ball nebula. See Sky & Telescope. Instead, SN1987a now shows an impressive set of three rings around a small center of gasses. Interpretation given is that the outer two rings were from a progenitor star known as Sanduleak probably going through its red supergiant ejection phase, and that the inner brighter ring is being formed by shock wave collision of the more recently expelled supernova materials hitting gasses out some distance from the supernova origin. This has been monitored for the 40 years since the explosion, and the motion videos of the inner shock wave ring expansion are available on line.

SN1054 was the second largest ever supernova in recorded history with a peak magnitude of +6 and visible with the unaided eye for two years. It was a Type II supernova that gave birth to the Crab Nebula, M1, that by now has expanded to 11 light years in diameter. It does have a remnant neutron star at its center, a very energetic quasar with large magnetic field, spinning at 30 rpm, and interacting with its vicinity with strong solar wind. The neutron star has been observed both optically and by radio telescope. The Crab Nebula images show fine filamentary structure. This is synchrotron radiation. Strong magnetic field from the spinning neutron star forces the path of charged particles to bend, and charge moving on a curved path emits electromagnetic radiation.

SN1006 was the largest ever supernova in recorded history with a peak magnitude of +7.5, about the brightness of the moon three days past new, visible with the unaided eye for three years, and now expanded to 65 light years in diameter. It was a Type Ia supernova, though, which spews out much less material. The available images of it now all seem to be x-ray, one of just a ribbon of shock wave at the very edge being particularly impressive. But there is no value given for present apparent magnitude. It is optically very dim.

Tycho's supernova SN1572 and Kepler's supernova SN1604 were also Type Ia. More recently in 1998, measurement of large numbers of Type Ia supernova used as "standard candles" lead to the discovery that expansion of the universe changed about 7.5 billion years ago from slowing down to speeding up.

### Type Ia:

With core collapse supernova the power that expels material is a shock wave caused by neutron degeneracy suddenly stopping gravitational collapse of what had been a burned out iron core of the star. This ejects material from around the core, leaving the core to form either a neutron star, or if massive enough, a black hole. This remaining remnant star is in the center of the expelled gasses that were thrown outward and form the remnant nebula. In a Type Ia supernova the explosion spontaneously involves all the material of the star, so that there is no remnant star and all that remains afterward is the outward expanding of gasses that form the nebula. The way this happens starts with a star that is too small to have the gravity compression temperatures needed to complete nuclear "burning" to iron, but massive enough for gravitational compression to be stopped by quantum mechanical electron degeneracy. A white dwarf forms with fading nuclear heating and few elements heavier than helium. This is a common end state of thermal cool down, except sometimes there is a neighboring binary star from which the white dwarf draws material. The increasing gravitational compression can then eventually overpower the electron degeneracy restraint pressure at the Chandrasekhar limit of about 1.4 times the mass of the sun. At that point gravitational collapse heats up almost all the material in the star to high nuclear fission rates, the sudden nuclear heating then overpowering gravity and causing all the mass of the star to explode. Because this happens at the precise Chandrasekhar mass limit, the emissions brightness is always the same, so apparent brightness compared to theoretically known absolute brightness gives a measure of distance.

### The 20 brightest stars in the north:

Aldebaran	al DEB uh ran	$\alpha$ Taurus	follower of Pleiades (A)	orange giant with burning H shell
Algieba	al JEE buh	$\gamma$ Leo	the forehead (A)	
Altair	as TAIR	$\alpha$ Aquila	the flying one (A)	main sequence
Antares	al TAIR ees	$\alpha$ Scorpius	rival of Mars (G)	red supergiant
Arcturus	ark TOUR us	$\alpha$ Boötes	bear guard (G)	red giant
Betelgeuse	BET el jews	$\alpha$ Orion	armpit of mighty one (A)	red supergiant
Capella	kah PELL ah	$\alpha$ Auriga	the she goat (L)	4 stars*
Castor	KAS ter	$\alpha$ Gemini	the beaver (G)	3 binaries**
Denab	DEN eb	$\alpha$ Cygnus	tail of the hen (A)	
Denebola	duh NEB oh lag	$\beta$ Leo	tail of the Lion (A)	
Mirphak	$\alpha$ Perseus		supergiant	
Mizar	$\zeta$ UMa			
Polaris	$\alpha$ Umi		orange evolved giant star, has planet	

Pollux	β Gemini	
Procyon	α CMa	white sub giant + dim white dwarf
Regulus	α Leo	4 stars***
Rigel	β Orion	A blue-white supergiant + 4 smaller
Sirus	α CMa	main sequence + faint white dwarf, only 8.6 ly
Spica	α Virgo	massive tight binary****
Vega	α Lyra	1/10 age of sun but 2x mass and both mid age *Capella is 4 stars in 2 binary pairs: Aa&b both red giants w He core; Ba&b small **Castor is 3 binaries; A & B main sequence each >Msun, C is two red dwarfs ***Regulus is 4 stars in 2 groups; Aa blue white main sequence 3.8Msun, Ab white dwarf, Bs small ****Spica is early main sequence, massive tight binary 11+7Msun, 4day period

## Aids For Finding Stars

Most people will long ago have picked their favorite star finding aids, but in case there are a few coming to AHSP who are just starting out, here's a partial list.

The modern winner is the one that fits in your pocket and does not require a flashlight. The free App Stellarium can be put in red display night view mode to preserve eye dark adaption. But start with setting your display brightness and turning off your screen's auto-lock setting so that you won't have to look at a bright screen to wake up your device. Laminated foldouts will also fit in a (large) pocket. They're 4.5"x8.5" folded, opening to 4.5"x19.25".

- Stellarium Mobile, for hand helds: App Store or Google Play
- Stellarium for computers: stellarium.org
- Monthly sky charts: KenPress.com
- Seasonal sky charts: Ch. 4, NightWatch by Terence Dickinson
- Star Wheels, Planispheres, Foldouts: (do search for "star wheel," not "star wheels")

TypeBy	Size	Bkgd	Material	Objects?
star wheel	Sky & Tel	7½x7½	black	tough paper no
star wheel	Sky & Tel	10¾x10¾	black	tough paper many
star wheel	Graun 16x16	white	plastic	many
star wheel	Chandler	8½/x10	white	plastic some
foldout	of stars	4x8.5/19	white	plastic some
foldout	of Messier	4x8.5/19	white	plastic Messier

- Tables or Books such as: Celestron Sky Maps\*
- Wikipedia cartesian display of celestial sphere.
- A version more like foldouts is given here as First 16 Stars To Learn
- Telrad finder, Rigel finder, Red Dot finder, finder scope
- Go-To for telescopes is better if it uses encoders to measure gimbal angle. That allows you to intermix manual and powered pointing so as to learn the sky rather than totally depend on the software. Stellarium can direct Go-To, but many prefer other control software.

- Red night vision flashlights: fixed, adjustable1, adjustable2 \*If you get sleepy or hungry when using Celestron Sky Maps, it's because the glossy ink is not dry and is outgassing. The only solution is to expose every page to direct sunlight for 15-30 min.

### Ranking of Star Wheels and Charts:

Get and use Stellarium first, both versions, and do some web browsing. Part of modern amateur astronomy is just appreciating the awesome photography and astrophysics from Hubble class telescopes and maybe also learning where in the heavens these pictures came from.

It takes a year of occasionally going out in the evening to watch the stars go by and maybe two years to build a solid memory for how the celestial sphere fits together. We assume here that you are located at a northern latitude as in the US. Then there are two regions of the celestial sphere to keep in mind - 1) the northern view which is circular and rotates around Polaris, and 2) the southern view which is essentially a cylinder. It's the celestial sphere less cones around the polar directions and extends from a little north of your zenith down to Scorpio and Sagittarius. The mental map you build of time progression is essentially an x-y plot of this cylinder as in the next link.

Foldouts display these two views as distinctly separate. Star wheels and planispheres blend the two views together making a little confusion about how to hold the device. It's instructive to eventually learn how to use these wheels with the periphery cut off to make them smaller. The outer half of a trimmed-off wheel is similar to the x-y plot of a foldout, both giving the time progression of constellations and stars during the year.

Black background is better than white for maintaining eye dark adaption. Plastic or well laminated is needed for withstanding dew. Big can show more detail with some deep-space objects. You can write in and erase your own with felt pen on white plastic but not on the black star wheels.

After Stellarium, start with a red flashlight and the smaller Sky & Telescope star wheel, a KenPress monthly sky chart or maybe the foldout of stars. If you are beginning to use a telescope, you'll need to put things down on the wet grass, so though it opens to large size, the foldout that fits in a hip pocket is convenient.

To trim the size of a star wheel or planisphere start by using pliers to crimp shrink the central ring rivet so that it comes out without tearing anything. Then use scissors to trim off the outer periphery of month-day indicators on the star wheel. Get the hang of it, and you can throw away the holder part that bounds what you can see on the star wheel. Just look at the starry sky. The horizon boundary of what you can see is already there, and your star wheel is smaller without the cover.

### Initialization of Stellarium on Computers:

The two most desirable settings are to make Stellarium come up using your location and to make it show the evening sky for, say 10:30 pm, even if you are booting in the daytime. The user interface for saving your settings for these is very different and potentially confusing.

To set the default time use the "Configuration window," go to subwindow "Navigation" and set "System Date" to 10:30 pm. Then to save this setting you must also go back to the "Main" subwindow and click "Save settings."

To set the default location use the "Location window." A very long list of locations is displayed. One and only one of them can have the check box selected to be "Use current location as default." (Better wording would be "Use this location as default.") You can scroll through the list or do a text search to find the location nearest to you. Then check the box for "Use current location as default." Now closing the window saves your setting. This won't be exactly your location, but it's good enough, especially in suburbs where you can't see much near the horizon anyhow.

You can get into trouble if you choose to enter your location more exactly. If you make a mistake, which is easy when entering degree, minutes and seconds, you may find that the "Delete from list" button does not work. This is because the list of locations displayed in Stellarium's "Location window" is a combination of what is in two files - your entries and Stellarium's built-in list of locations. The delete button can be applied only to your entries.

If you want to have your own custom location or a short list of just your locations, you don't want Stellarium to find its built-in file. It's a compressed file called `base_locations.bin.gz` and changing the name to something like `base_locations.binX.gz` will work. For PC's versus Mac's the file is located at `C:\Program Files\Stellarium\data\` or `Applications/Stellarium/Contents/Resources/data/` (On Mac use `Cmc-Shift-A` to open the Applications folder and then Control mouse click the Stellarium application icon to open it and see its contents.)

And if you make a mistake entering all those degrees, minutes and seconds, it may be easier not to use the Stellarium "Location" window to fix it. Your user account file has `az el` entered as decimal degrees, and it's just a tab-delimited text file. On mac it's located at `~/Library/Application Support/Stellarium/data/user_locations.txt`.

(To open the Library folder in Mac, hold down `Opt` while pulling down the Go menu.)

#### Stellarium Plug-Ins, Oculars and Angle Measure:

You don't have to set up anything to display Telrad  $.5^\circ, 2^\circ, 4^\circ$  rings. Just click the Telrad icon on the top right of the Stellarium display. The rings are put at the center of the display, and then you have to move your target of interest to that position and set the zoom you want. It's a bit jumpy. Another, in some ways more convenient method, is to use the angular separation icon plug-in at the bottom of the Stellarium display.

But a convenient use for the Telrad rings is for making yourself a star chart to print out and use at night when attempting to star hop to an object of interest. For instance, after clicking and displaying the Telrad rings, go to the Andromeda galaxy, set zoom to a convenient amount, and then use screen capture (`Cmd-Shift-4` on Mac) to get a star chart file to print.

To change the Stellarium display to what you should see through your telescope click the Oculars plug-in icon at the top right of the display. It's the white square containing a black circle. You can toggle through eyepieces for your telescope.



But you need to have already put in the focal lengths for your eyepieces and for your telescope. The easiest way to get to the settings panel for the Oculars plug-in is by clicking the wrench icon at the top right of the Stellarium screen. There are panels for Eyepieces, Lenses and Telescopes. The Sensors panel is for the rectangular icon at the top right of the Stellarium display, which for now let's assume you will not be using.

Eyepieces—Enter the following, or your variants:		Name	aFOV(deg)	focal
length(mm)	field stop	26 mm Plossl	50	26
50	17	0	9 mm Plossl	50
(to go with eyepieces)—Enter the following, or your variants:		Name	multiplier	none
Eyepieces—Enter the following, or your variants:		Name	focal length(mm)	1
Diameter(mm)	Celestron 90GT	900	anything	

### Representing the Celestial Sphere:

A star wheel for use at northern latitudes like the US is made by opening up and flattening the celestial sphere less a 40° cone in the southern direction that can not be seen.

StarWheelFlattening.jpg

A planisphere is formed similarly but by doing less flattening, twice. The northern celestial hemisphere plus 20° below the equator is flattened and put on the front side of the wheel. The southern celestial hemisphere plus 20° above the equator is flattened and put on the back side of the wheel. This reduces distortion at the price of the user having to get used to flipping the planisphere when viewing stars below the equator.

A monthly sky chart uses the least flattening - of just the half of the celestial sphere that is overhead at about 10:30 in the evening.

Simplest in principle is the Cartesian x-y display for a foldout. This leaves out two cones, around both the northern and southern directions, flattens the remaining part of the celestial sphere onto a cylinder and then displays that with latitude for the y axis and right ascension for the x axis. Unlike a star wheel, the foldout does not attempt to cover up the part of the sky that you can't see at a particular time.

The display given in the next link for "First 16 Stars To Learn" is a version of Cartesian x-y display - with a shift in the y axis. The zero of elevation is set to the zenith that you see from a location 38.6° north of the equator, such as for AHSP.

### Missing Products:

Accurate Star Umbrella: Star and constellation umbrellas are available, but not like the one depicted above for amateur astronomers. It would be nice to have stars and constellations depicted fairly accurately on the inside of the umbrella for declinations down to 50° below the equator. The products available cost about \$23 and emphasize the 12 zodiac constellations, which are not the main ones you can pick out in the sky. This Black Tape Sunshade doesn't even have good pattern

matching at the sewn seams. The 2017 Creative Automatic [here](#) or [here](#) looks better, but requires you to join and give your credit card information to an overseas web site.

Accurate Smart Phone for Go-To: Stellarium Mobile displayed on a smart phone mechanically attached and software aligned on an aluminum telescope would in principle be both an instructive and a convenient way for manually directing the telescope to point at deep space objects without depending on batteries or slow motors. But the compass and elevation sensors in today's smart phones apparently aren't good enough.

more stuff at [EdsStuff.info](http://EdsStuff.info)