Reach for the Stars – Div. B

Help session:

Sunday afternoon: March 15, 2020

Properties and evolution of stars and galaxies as well as their observations using different portions of the electromagnetic spectrum.

Resources for test

“Two 8.5 x 11 inch two sided sheet”

“two non-programmable, non-graphing calculators

Test on March 28, 2020

Will need a red flashlight!!!

Test will include questions about a series of images projected onto the front of the room.

The room will be dimly lit (planetarium program is part of test)

***(red) flashlight strongly recommended*.**

REACH FOR THE STARS

See General Rules, Eye Protection & other Policies on www.soinc.org as they apply to every event.

1. **DESCRIPTION**: Students will demonstrate an understanding of the properties and evolution of stars and galaxies as well as their observation using different portions of the electromagnetic spectrum (e.g., Radio, Infrared, Visible, Ultraviolet, X-Ray, Gamma Ray).

   A TEAM OF UP TO: 2 **APPROXIMATE TIME**: 50 minutes

2. **EVENT PARAMETERS**:
   a. Each team may bring two 8.5" x 11" **sheets of paper, which may be in sheet protectors sealed by tape or laminated, that may contain information on both sides in any form and from any source without any annotations or labels affixed.**
   b. **Each team may bring two non-programmable, non-graphing calculators** as well as two clipboards and two red-filtered flashlights.

3. **THE COMPETITION:**

   This event is divided into two parts. Notes may be used during both parts.

   Part I: Written Exam

   a. Participants may be asked to identify the stars, constellations, and deep sky objects included in the lists below as they appear on star charts, H-R diagrams, portable star labs, photos, or planetariums, and must be knowledgeable about the evolutionary stages of all stars and deep sky objects on the list below. Note: Constellations are underlined; **Stars** are boldface; *Deep Sky Objects* are italicized.

   Andromeda: *M31 (Andromeda Galaxy)*
   Aquila: **Altair**
   Auriga: **Capella**
   Bootes: **Arcturus**
   Canis Major: **Sirius**
   Canis Minor: **Procyon**
   Centaurus: *NGC5128*
   Coma Berenices: *NGC4676, NGC4555*
   Corvus: *NGC4038/NGC4039*
   Crux: *Dragonfish Nebula*
   Cygnus: **Deneb**
   Dorado: *30 Doradus, LMC*
   Gemini: **Castor, Pollux**
   Lyra: **Vega**
   Ophiuchus: **Zeta Ophiuchi**, *Rho Ophiuchi cloud complex*
   Orion: **Betelgeuse**, **Rigel** & *M42 (Orion Nebula)*
   Perseus: **Algol,** *NGC1333*
   Sagittarius: *Sgr A**, *M8 (Lagoon Nebula)*
   Sextans: *Baby Boom Galaxy*
   Scorpius: **Antares**, *NGC6357, NGC6334*
   Taurus: **Aldebaran**, *T Tauri*
   Tucana: *SMC*
   Ursa Major: **Mizar, Alcor**, *GN-z11, M101*
   Ursa Minor: **Polaris**
   Virgo: **Spica,** *M60, M104*

   Part II: Hands-on or Interpretive Task

   a. Participants will be asked to complete one or more hands-on or interpretive tasks selected from the

Study points

- Download planetarium software, Stellarium (http://www.stellarium.org/) is good and free!!!
- Practice recognizing pattern of stars of constellations and stars listed on the rules sheet.
- Google the objects on the list and try to under stand how they fit into the birth and death of stars.
- Try to understand what a stars magnitude, luminosity and distance modulus means. Understand the inverse square law..

→Memorization and conceptual understanding is required.

Test is in 2 parts

- Part 1– planetarium program
  - Identical show repeated 3 times every hour
  - Timed power point presentation
  - Circles put around objects, constellations and stars → “name this”
  - Planets and the moon are “off”
- Part 2 – Normal test, multiple choice, fill in blanks. Pictures shown as part of a timed power point presentation

What you may need to know

Constellation and object in it	
Andromeda	M31 Andromeda galaxy
Aquila (the eagle)	Altair (star)
Auriga	Capella (star)
Bootes	Arcturus (star)
Canis Major	Sirius (star)
Canis Minor	Procyon (star)
Centaurus	NGC5128 (a galaxy)
Coma Berenices	NGC4676 (Mice galaxies) NGC4555 (galaxy with dark matter)
Corvus	NGC4038, NGC4039 (colliding galaxies)
Crux	Dragonfish Nebula,
Cygnus	Deneb
Dorado*	30 Doradus, LMC
Gemini	Castor & Pollux (two stars in Gemini),
Lyra	Vega (star) ,
Ophiuchus	Zeta Ophiuchi (young massive star), Rho Ophiuchi cloud complex
Orion	Betelgeuse, Rigel (stars) & M42 (Orion Nebula star forming region)
Perseus	Algol (variable star), NGC1333
Sagittarius	Sgr A*– Sagittarius A – a radio source that is a massive black hole and center of our Milky way Galaxy M8 Lagoon Nebulae
Sextans	Baby Boom Galaxy
Scorpius	Antares (red giant star), NGC6357 (lobster nedula) NGC6334 (cat's paw nebula)
Taurus	Aldebaran (star), T Tauri – typically of a new born star
Tucana	Small Magellanic cloud (SMC)
Ursa Minor	Polaris (North Star)
Ursa Major	Mizar & Alcor (second star(s) in the handle – a binary) GN-z11 (oldest and most distant galaxy yet found) M101(Pin wheel galaxy)
Virgo	Spica (star), M60 (elliptical galaxy), M104(Sombrero Galaxy)

Part II

Part II: Hands-on or Interpretive Task

a. Participants will be asked to complete one or more hands-on or interpretive tasks selected from the following topics:
   i. Stellar and galactic evolution
   ii. Spectral classification of stars
   iii. Hubble classification of galaxies
   iv. Observation using multiple portions of the electromagnetic spectrum
   v. The relationship between stellar temperature, radius, and luminosity
   vi. Magnitude and luminosity scales, distance modulus, inverse square law

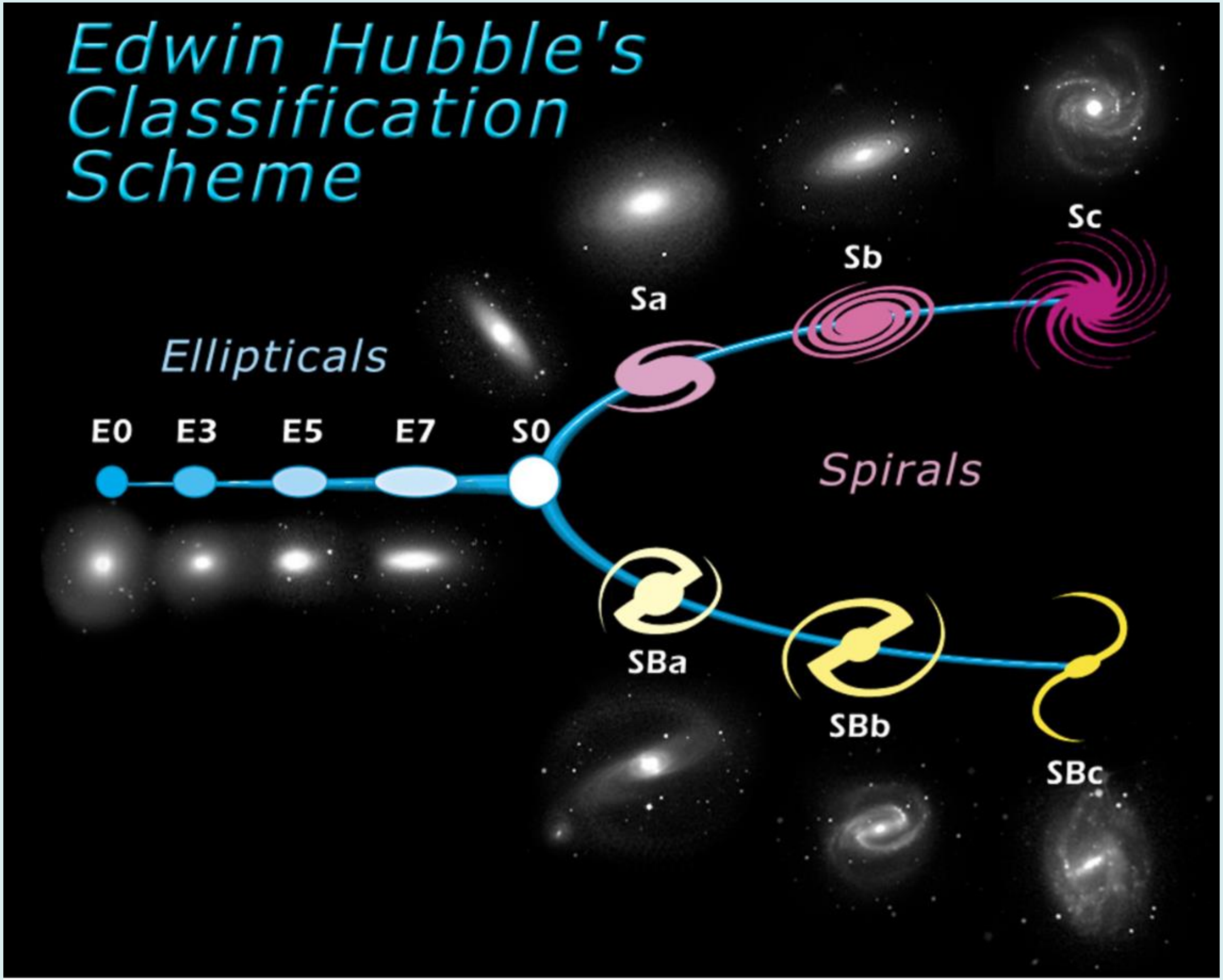
Stellar Evolution

- Most stars are born in open clusters
  - Dragonfish Nebula, M42, 30 Doradus (Tarantula Nebula), NGC635, NGC6334 are examples have clusters in the making,
  - There are many molecular clouds that are forming new stars as open clusters. Rho Ophiuchi, NGC1333 and Lagoon Nebula (M8) has these molecular clouds
  - **T Tauri stars** are a class of stars that are just being born
  - Open clusters don’t stay as open clusters very long → torn apart by tidal forces in our galaxy.
- Other ways:
  - Star burst galaxies – very early in life of universe Baby Boom Galaxy,
  - Galaxy collisions (NGC4676, NGC4038/4039), active galaxies (NGC5128
- Stars that are less than ~4x the mass of our sun die as planetary nebulae and leaving a white dwarf (Sirius B)
- High mass stars die as supernovas with remnants (Type II supernovae remnants leaving pulsars or black holes)
- White dwarf dentonation– Type 1a supernovae
  - Type 1a are important measuring sticks of the universe

Galactic evolution

- Earliest galaxies condensed into Very massive stars and blackholes.
- The very massive stars went supernovae within a few million years → spreading metals (iron and less in the periodic table) in the interstellar media. These metals were picked up by a new generation of longer lived stars that included planets made from those metals around them.
- The blackholes merge and become supermassive gobbling up matter near them. This generated very large and energetic radiation – Active Galactic Nuclei (AGN) or Quasars -- These are at the edge of the observable universe.
- All galaxies have supermassive black holes at their core including our Milky Way (Sgr A*) and M31 – these black holes are not now "active" – not sucking much material and hence do not generate much radiation.
- Galaxies DO NOT evolve based on the Hubble's classification scheme.
- Galaxies collide and become disrupted. Colliding spiral galaxies become giant elliptical galaxies.
- Fresh star formation is caused by shockwaves caused by colliding galaxies and by supernovae.
- The lowest mass stars (M type) will live for trillions of years.
- The ultimate fate of galaxies is unclear

Hubble's classification of galaxies does not represent galactic evolution



Our galaxy is a Barred spiral → most likely a SBb or a Sba

Andromeda galaxy is a Sa or Sb

Molecular clouds

- The radiation from new hot stars embedded in molecular gas and dust clouds will ionized the gas – that is, an electron will be stripped from the atom of the gas. Much of that gas is hydrogen. The region of the gas cloud where hydrogen becomes ionized is called an "emission nebulae" -- ***Dragonfish nebulae, 30 Doradus***
- These molecular clouds with emission nebula show very characteristic emission lines in a spectroscope.

Brightness of Stars

- **Needed to understand the Hertzsprung-Russell diagrams (H-R diagrams)**
- **Brightness measured as luminosity or magnitude**
  - **Luminosity is the total energy output of a star**
    - **Depends on size and surface temperature**
  - **A star's magnitude is the logarithm of its luminosity**
  - **Apparent magnitude (m) – four factors**

    what we appear to see
    - **Its temperature or color (wattage of a light bulb)**
    - **Its size**
    - **How far away it is**
    - **If it is obscured by dust**
  - **Absolute magnitude (M)**
    - **Magnitude of a star when viewed from a fixed distance and without any dust in the way.**

Luminosity, L

- Total amount of energy emitted by the star,
- Depends on the surface temperature (same as color)
  - Hot (Blue)
  - Yellow
  - Orange
  - Cool (red)
- Depends on the size
  - The larger the star, the more surface area to emit the energy and the brighter the star
- Measured relative to our sun (sun =1)
  - L>1 for Stars emitting more energy than our sun
  - L<1 for Stars emitting less energy than our sun

A star’s magnitude as brightness

- Magnitude is more often used to describe an objects brightness.
- The higher the magnitude the dimmer the object.
  - The apparent magnitude (lower case m) of our sun is -26.7
  - The apparent magnitude of a full moon is -12.6
  - The apparent magnitude of the Sirius is -1
  - Dimmest star you see (in Wilmington) +3.5
  - Dimmest star you see in a dark sky sight +5.5
- The absolute magnitude (capital M) is the magnitude of the star / object if it was place a fixed distance away (10 parsecs = 32.6 light years).
- Our sun’s absolute magnitude is 4.8

Distance Modulus

- It is a way that astronomers measure large distances
  - it is the apparent magnitude less the absolute magnitude or = m – M
  - The higher the number the more distant the object
  - Our Sun’s distance modulus is

    -26.7-4.8 = -31.5 this is a very low number meaning that the sun is very close to us!!

Distance Modulus - 2

- Examples of some common stars

Star	Apparent magnitude “m”	Absolute magnitude “M”	Distance Modulus	Distance in light years
Sirius	-1.47	1.41	-2.88	8.65
Vega	0.04	0.5	-0.46	26
Polaris	1.99	-3.2	5.19 (more distant)	360
Betelgeuse	0.41	-5.6	6.01 (most distant)	520

Inverse square law

- The brightness of an object (star) decreases by the square of the distance between the observer and the object.
  - if a light bulb looks like a 100 watt bulb at 10 feet,
  - then at 100 feet it will look like a 1 watt bulb.

Brightness (at distance b)

= brightness (at distance a) x (a/b)x(a/b)

Or = brightness (at distance a) x $(a/b)^2$

Categorizing stars by their spectra

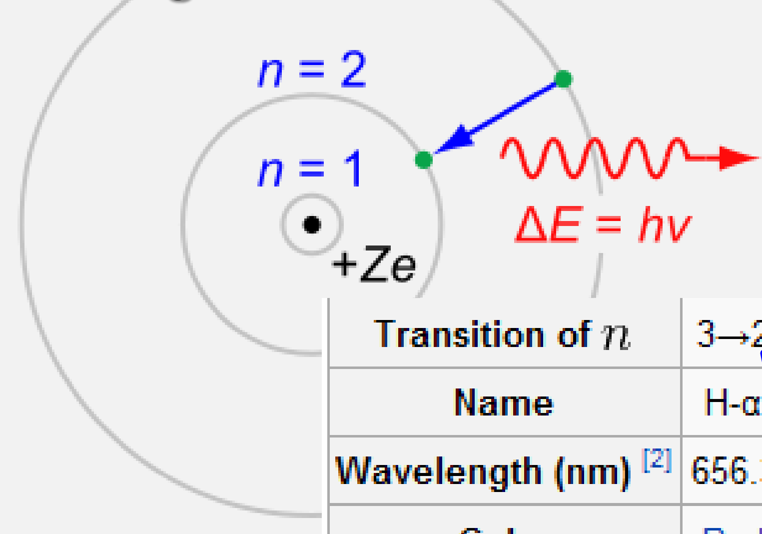
1. Spectra can tell you the stars approximate temperature (blackbody radiation)

2. Absorption (dark) lines in a star's spectra give a finger print of elements that are seen in that spectral class of stars

BUT emission spectra (bright lines against a dark background) are given off by nebulae – glowing gas clouds like the emission nebula described above.

Dark (absorption) lines in emission spectra (of stars) or bright lines in nebulae

- **Electron transition from a lower energy state to a higher energy state → receiving energy → adsorption line**
- **Electron transition from a higher energy state to a lower energy state → giving off energy → emission line**
- **Below is the Balmer series of lines associated with electron transition in the hydrogen atom to and from the second lowest energy level**
- **H-α (“hydrogen alpha”) is an important line in both emission and absorption spectra. It has a wavelength of 656.3 nm or 6563 Angstroms**

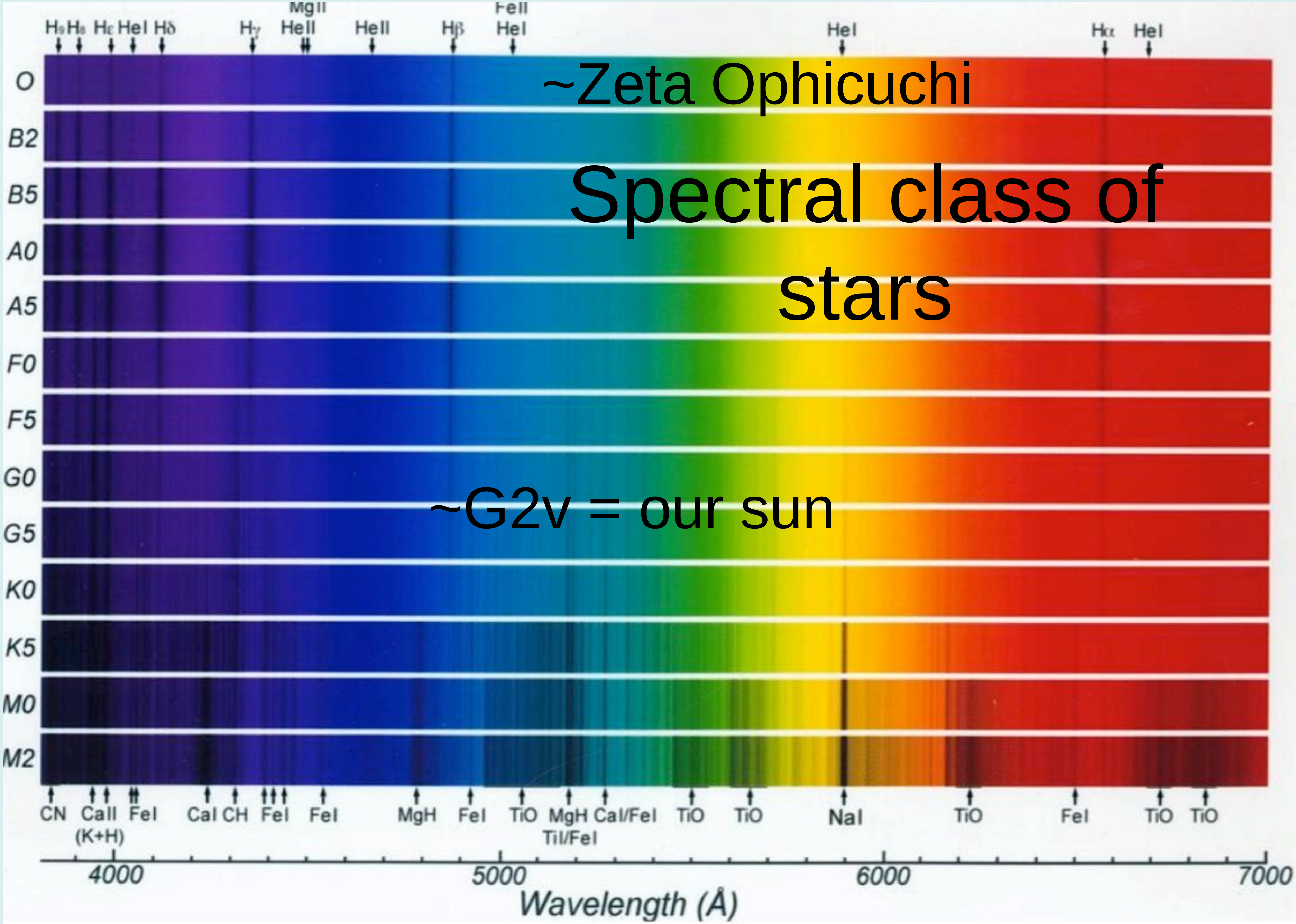


Emission regions show the 656.3 nm line

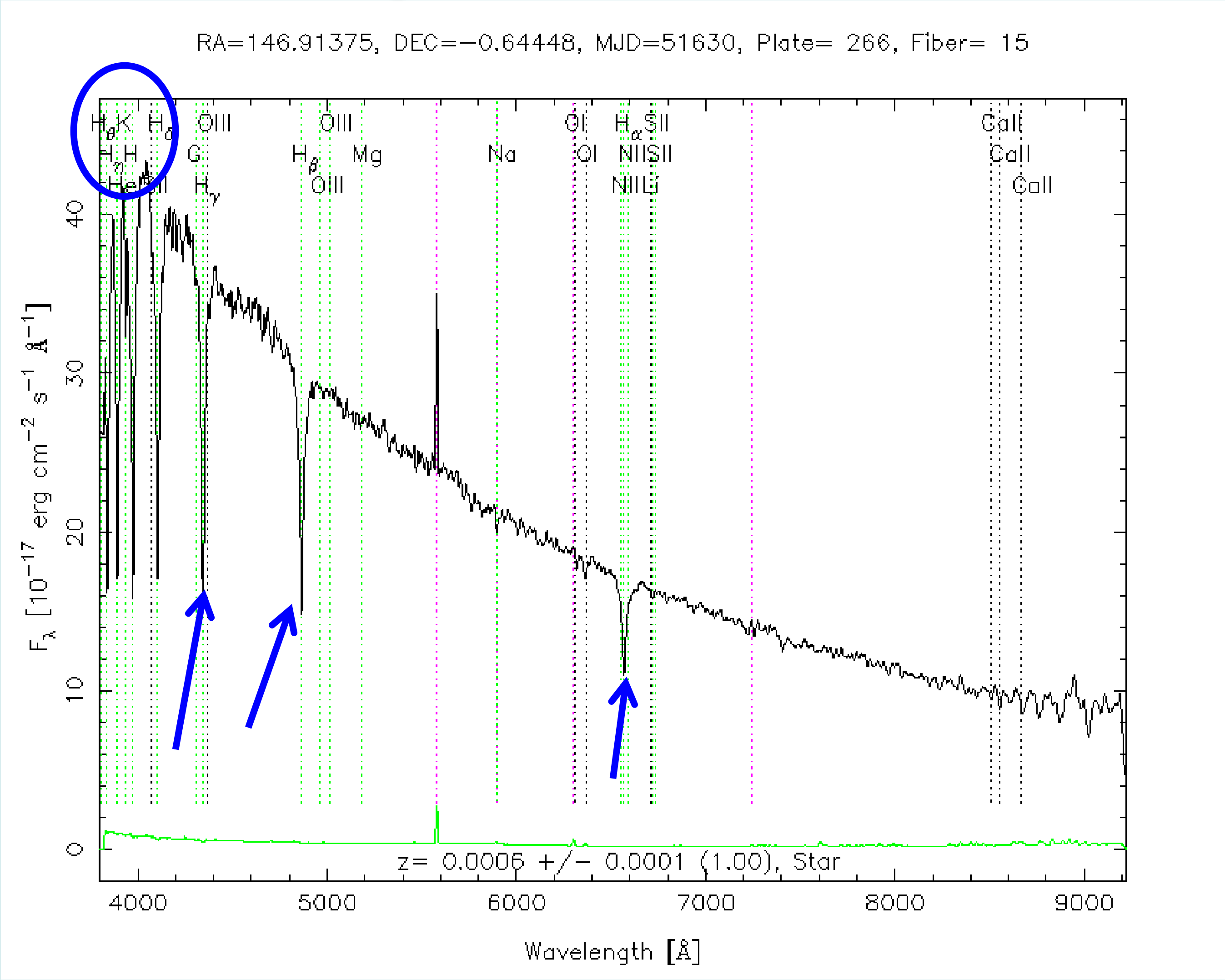
Absorption line seen in stars are used to classify them
Other elements → next slide

Transition of n	3→2	4→2	5→2	6→2	7→2	8→2	9→2	∞→2
Name	H-α	H-β	H-γ	H-δ	H-ε	H-ζ	H-η	
Wavelength (nm) [2]	656.3	486.1	434.1	410.2	397.0	388.9	383.5	364.6
Color	Red	Cyan	Blue	Violet	(Ultraviolet)	(Ultraviolet)	(Ultraviolet)	(Ultraviolet)

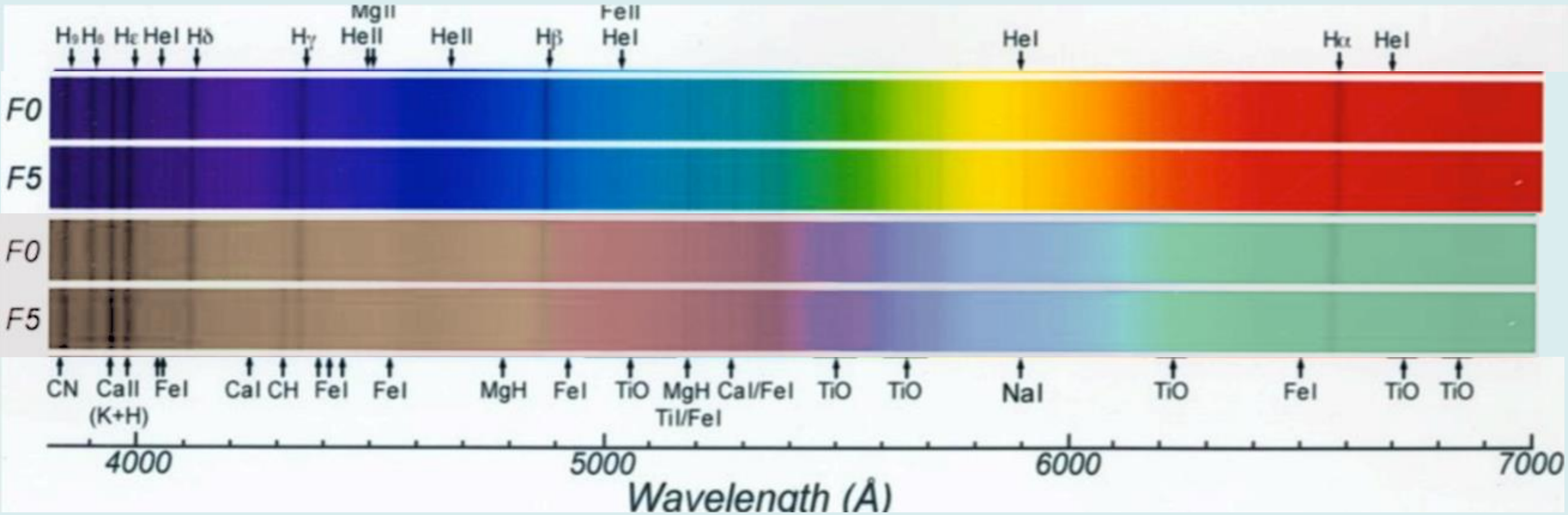
Spectral class of stars



Example of a star's spectra

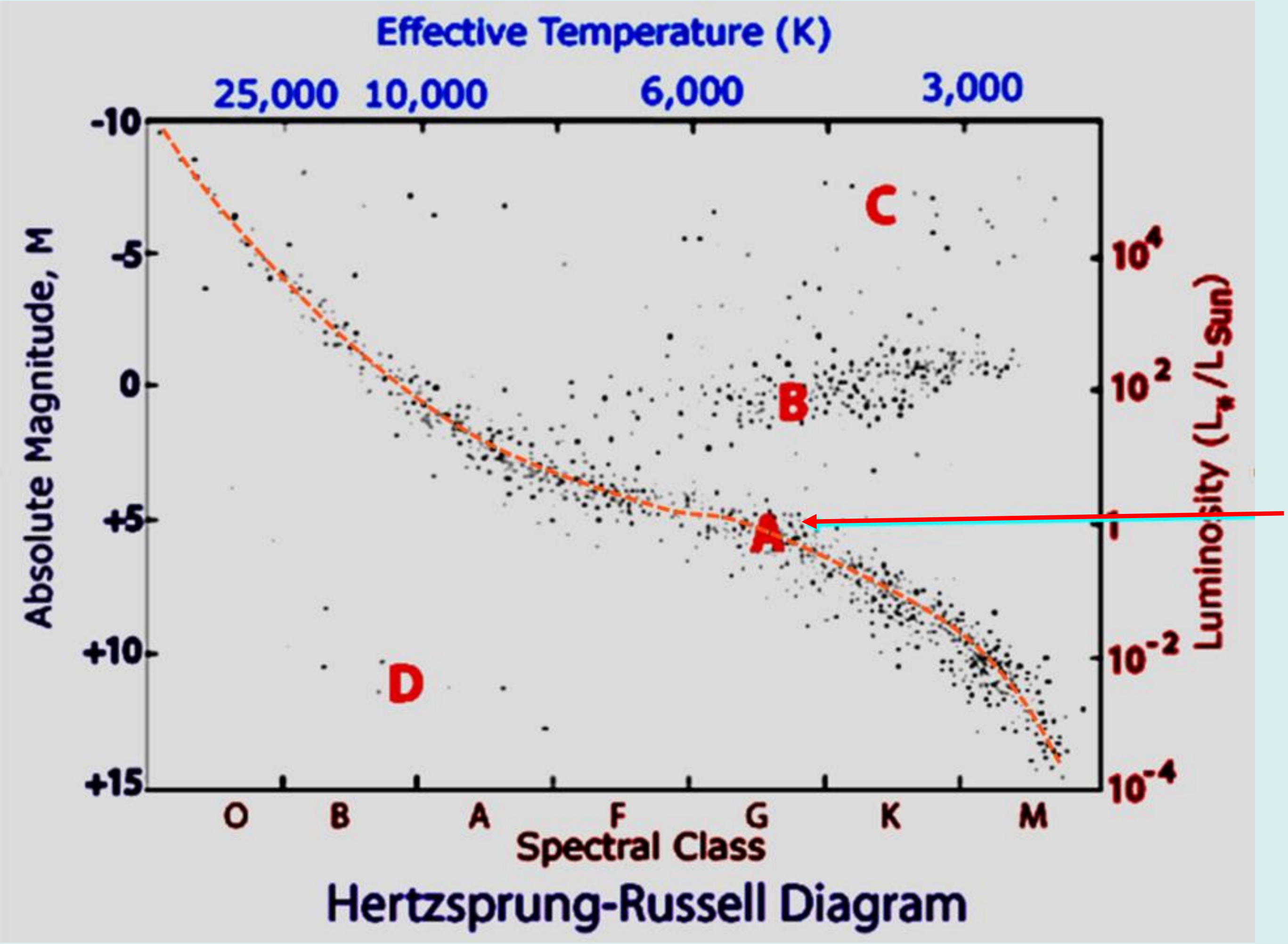


- Strong hydrogen lines, →B, A, and F type star
- No helium lines not a B star.
- ionized calcium (the H and K lines),
- **→This is an F type star**



Mg II
Fe II
H9 H8 Hε He I Hδ
Hγ
He II
He II
Hβ
He I
He I
Hα He I
F0
F5
F0
F5
CN
Ca II
(K+H)
Fe I
Ca I CH
Fe I
Fe I
MgH
Fe I
TiO
MgH
Ti I/Fe I
Ca I/Fe I
TiO
TiO
Na I
TiO
Fe I
TiO TiO
4000
5000
6000
7000
Wavelength (Å)

Hertzsprung-Russell Diagram
-- Each dot is a star



Y axis is always brightness or relative luminosity

X axis is always temperature, color or spectral class

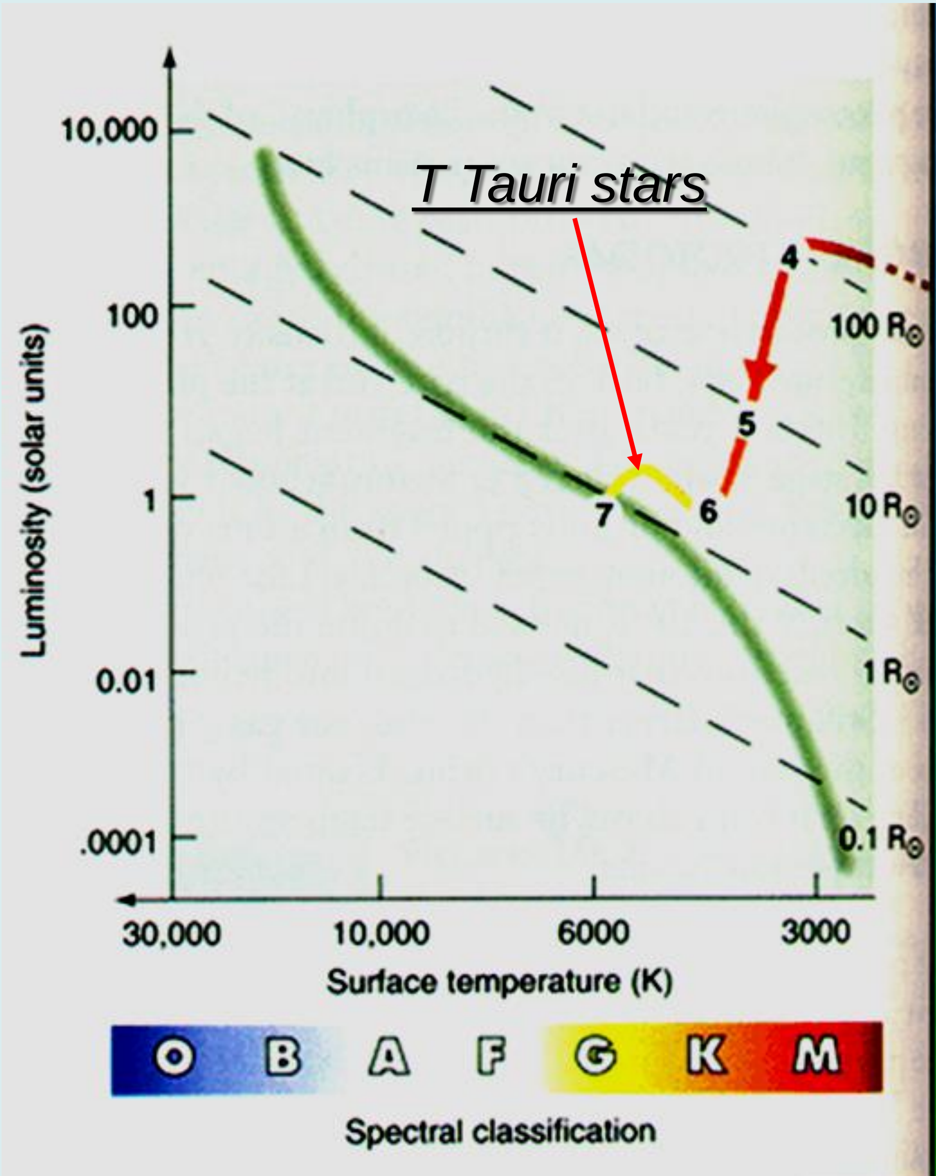
A is main sequence

B is horizontal branch

C are supergiants

D are white dwarfs

- http://outreach.atnf.csiro.au/education/senior/cosmicengine/stars_hrdiagram.html



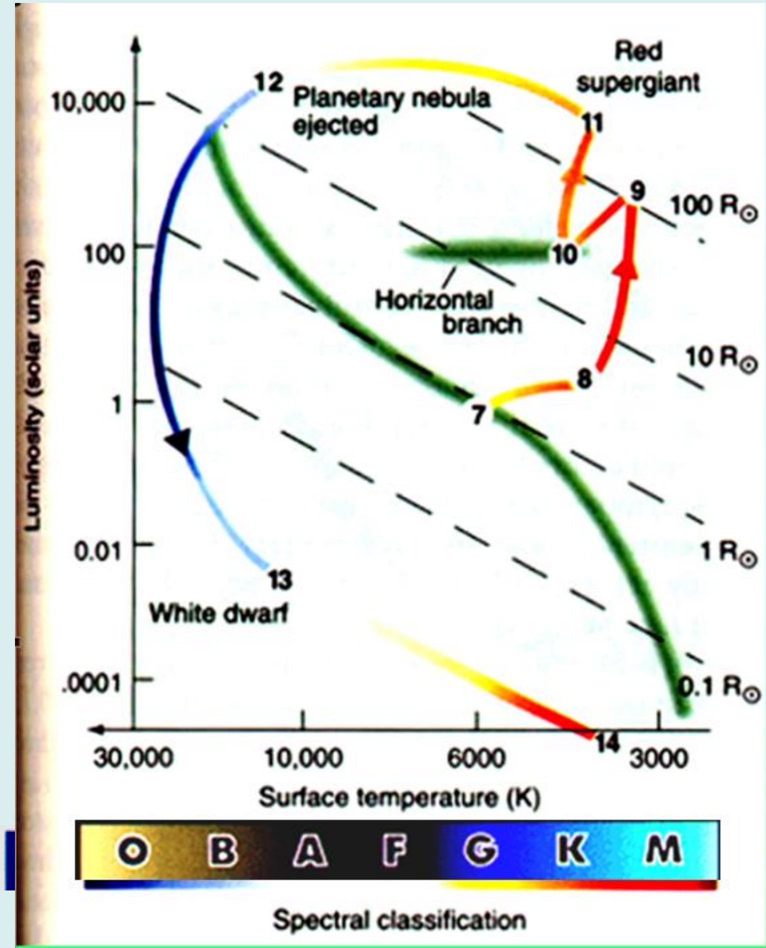
The birth of a 1 solar mass star going onto the main sequence.

Before point 4, contraction of intersteller gas cloud. The cloud heats up as it contracts, causing its luminosity to increase -- we don't see it because the protostar at this star is hidden in dust.

From point 4 to 6, -- The cloud contracts more and its luminosity drops.

Point 6, hydrogen starts to fuse to helium in the stars core. The *heat generated from fusion* balances *gravity*. The star's surface heats up slightly. *T Tauri stars*

Point 7. The star has reached a long lived equilibrium where the heat from fusing hydrogen to helium balances gravity. The star resides on the **main sequence** for most of its life (~10 billion years for a 1 solar mass star).



The death of a 1 solar mass star

7. Star on main sequence Hydrogen fusion in core

8. Hydrogen fusion around core of (non-fusing) Helium Star becoming a red giant.

9. Core has reach temperature to cause He to start fusing in the core (He flash)

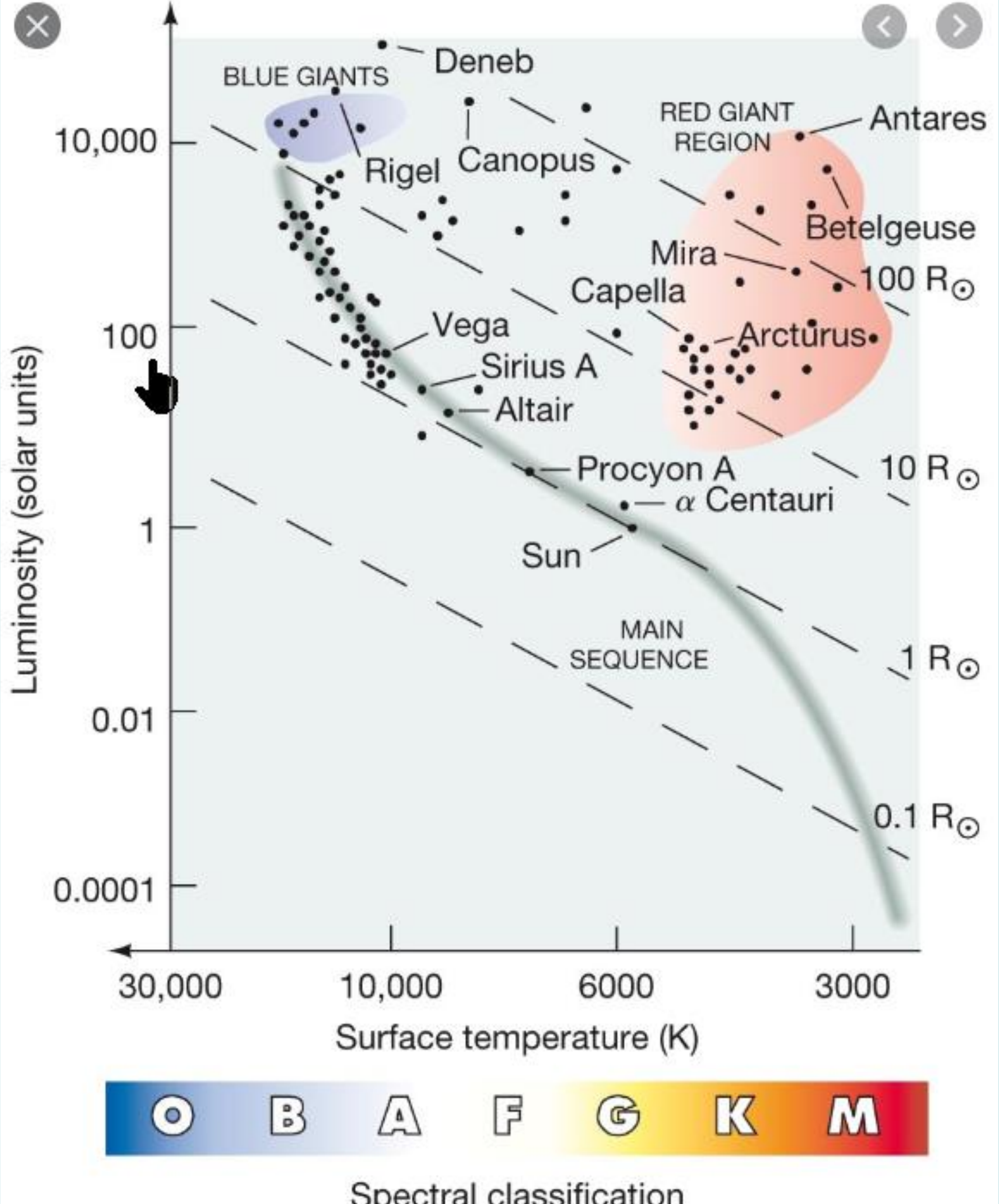
10. Helium burning core. Star is at a another short term equilibrium.

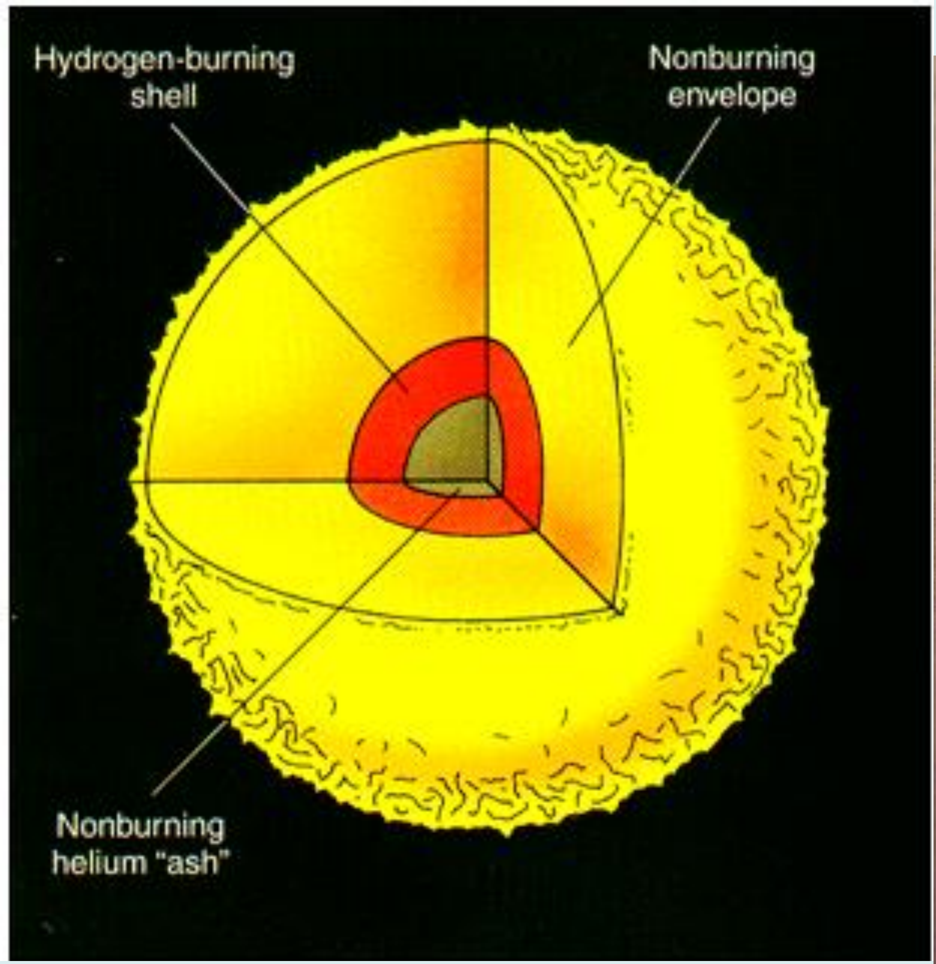
After 10 He fusion stops but continues in a shell around a carbon core

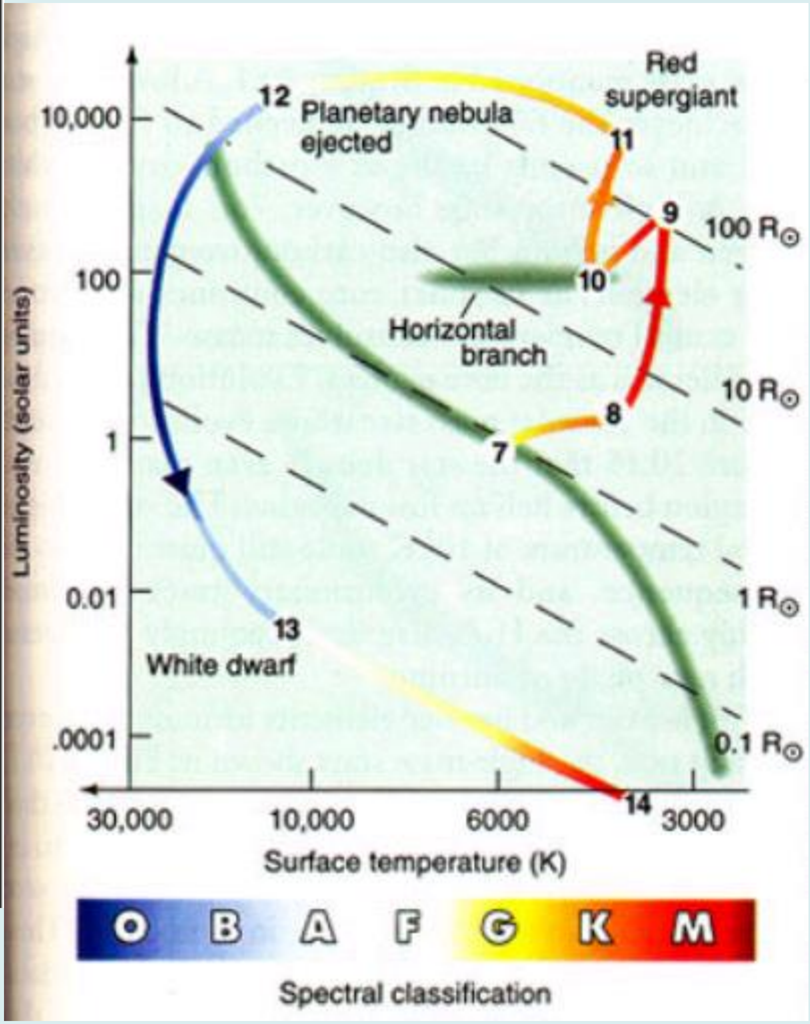
11. He fusion and hydrogen fusion stops, carbon core continues to collapse

12. He and hydrogen blown off to make planetary nebulae. "dead" but hot carbon core left

13. Very hot carbon core star is a white dwarf -- continues to cool to a brown dwarf star (14)


Deneb
BLUE GIANTS
Rigel
Canopus
RED GIANT REGION
Antares
Betelgeuse
Mira
100 R☉
Capella
Arcturus
Vega
Sirius A
Altair
Procyon A
α Centauri
Sun
10 R☉
MAIN SEQUENCE
1 R☉
0.1 R☉
10,000
100
1
0.01
0.0001
Luminosity (solar units)
30,000
10,000
6000
3000
Surface temperature (K)
O
B
A
F
G
K
M
Spectral classification





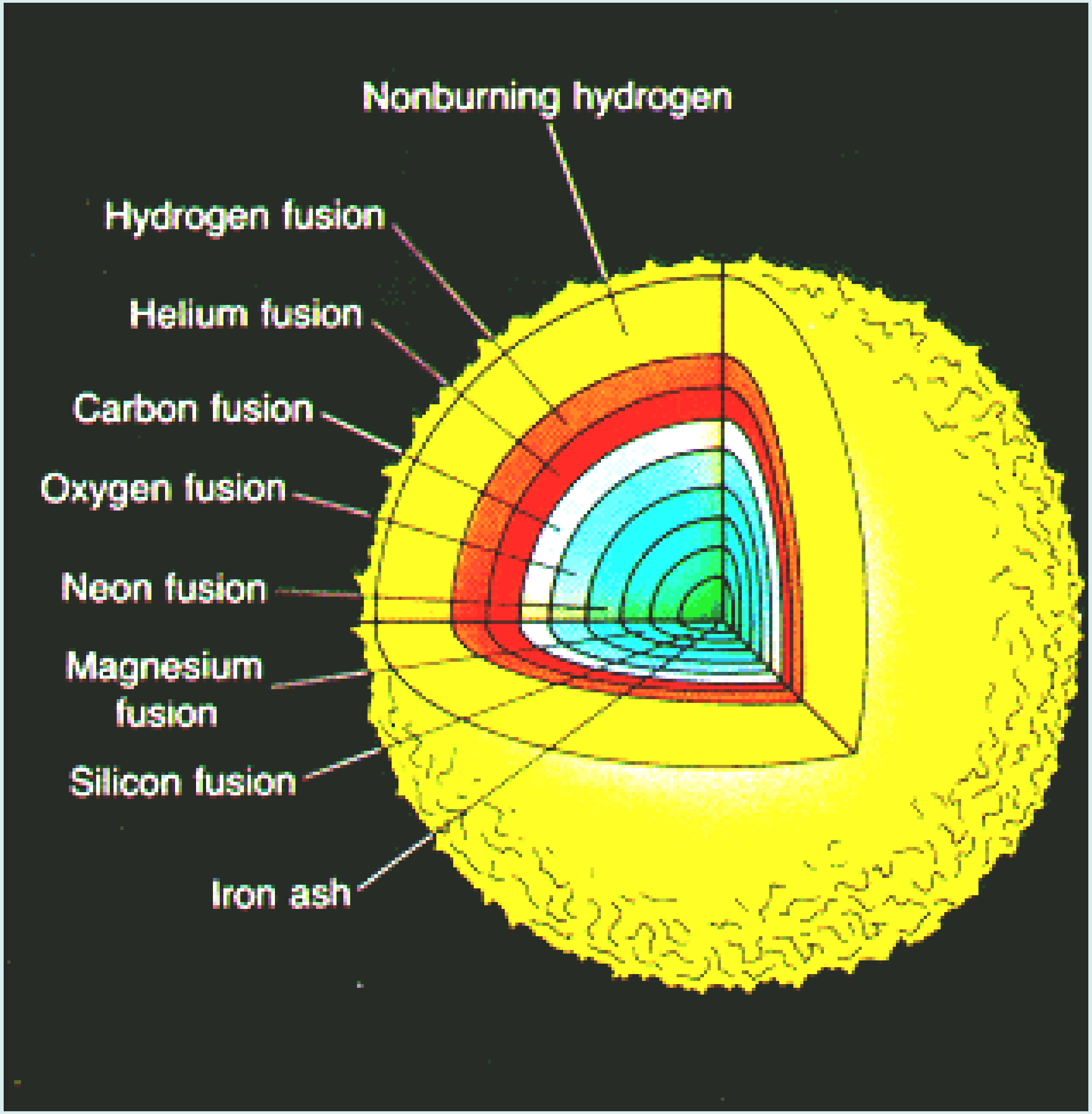
Low mass star like our sun stops at carbon formation....

And fluffs off its outer layers to make a planetary nebula and a white dwarf star. ....

NGC 7293,Helix nebula

M57, the ring nebula

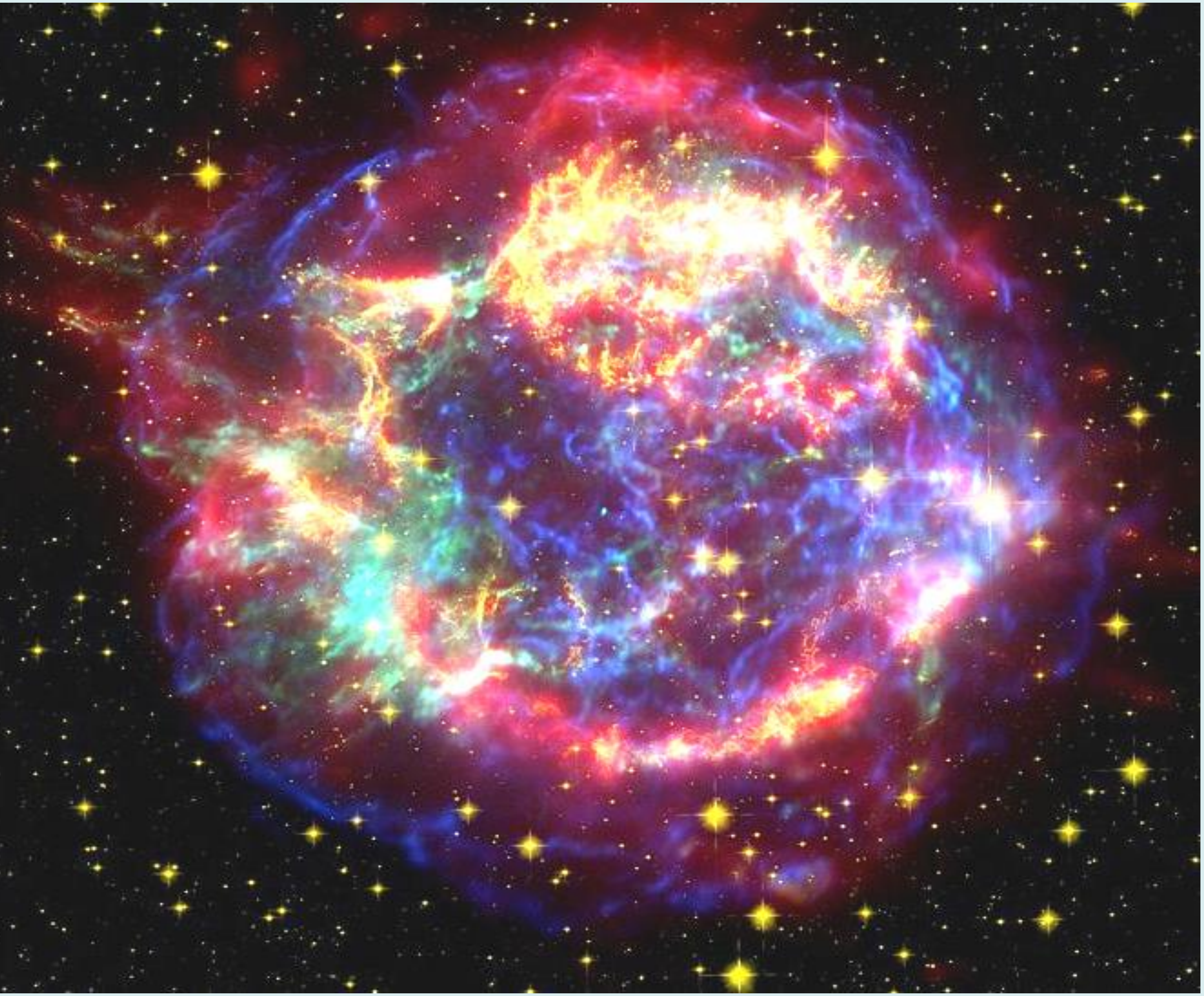
But a high mass star, has enough mass to fuse nuclear material all the way to iron. However, once iron accumulates in its core no net energy generation can be done by fusion of iron, gravity takes over and.....



It goes boom!!!!... A supernovae!!!
Electrons are pushed into protons to produce neutron and a flood of neutrinos

(this is the M1, the Crab Nebulae)

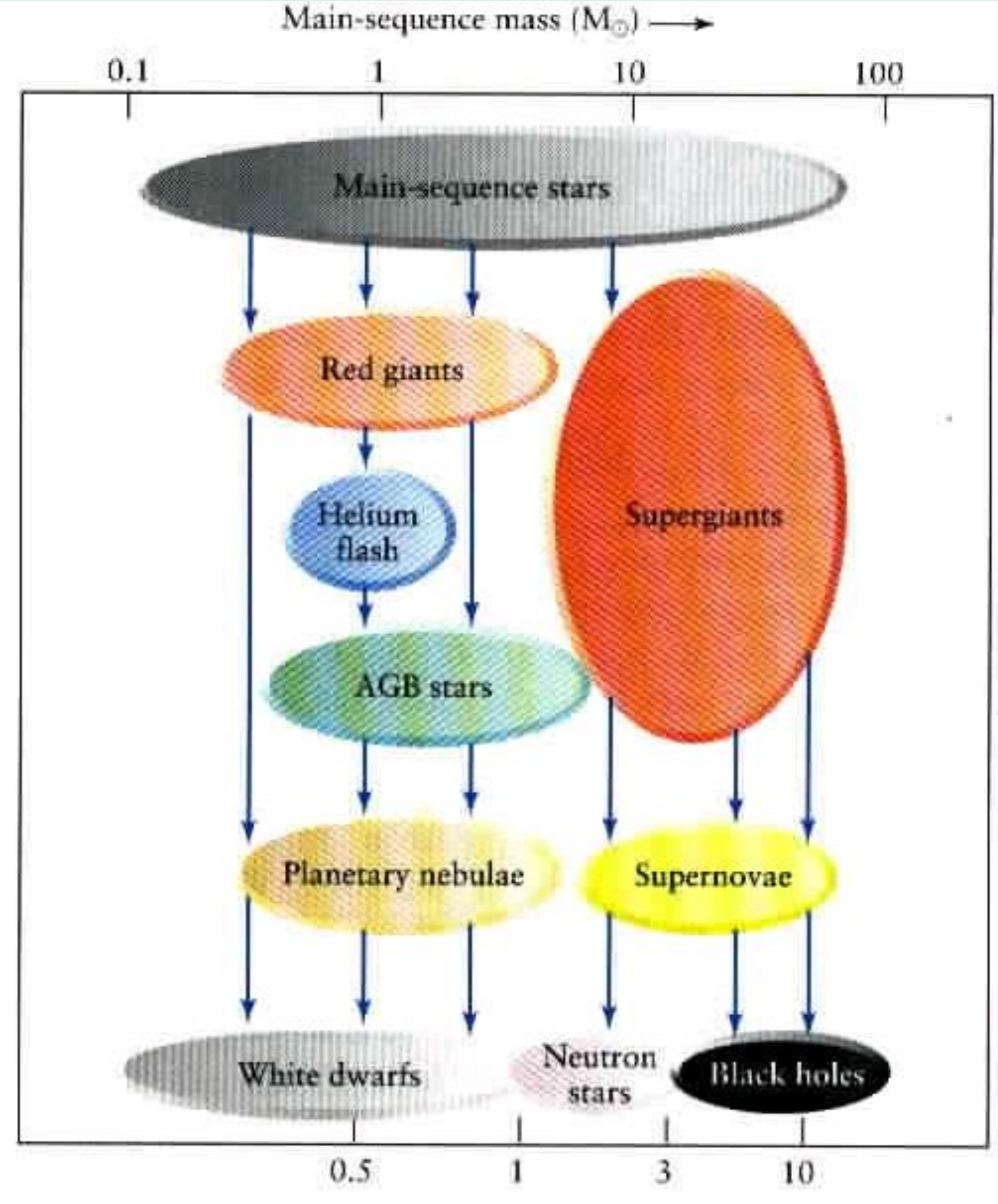
A spinning neutron star is inside this nebulae – called a pulsar.



- Cas A

(Cassiopeia A)

Type II Super Nova remnant



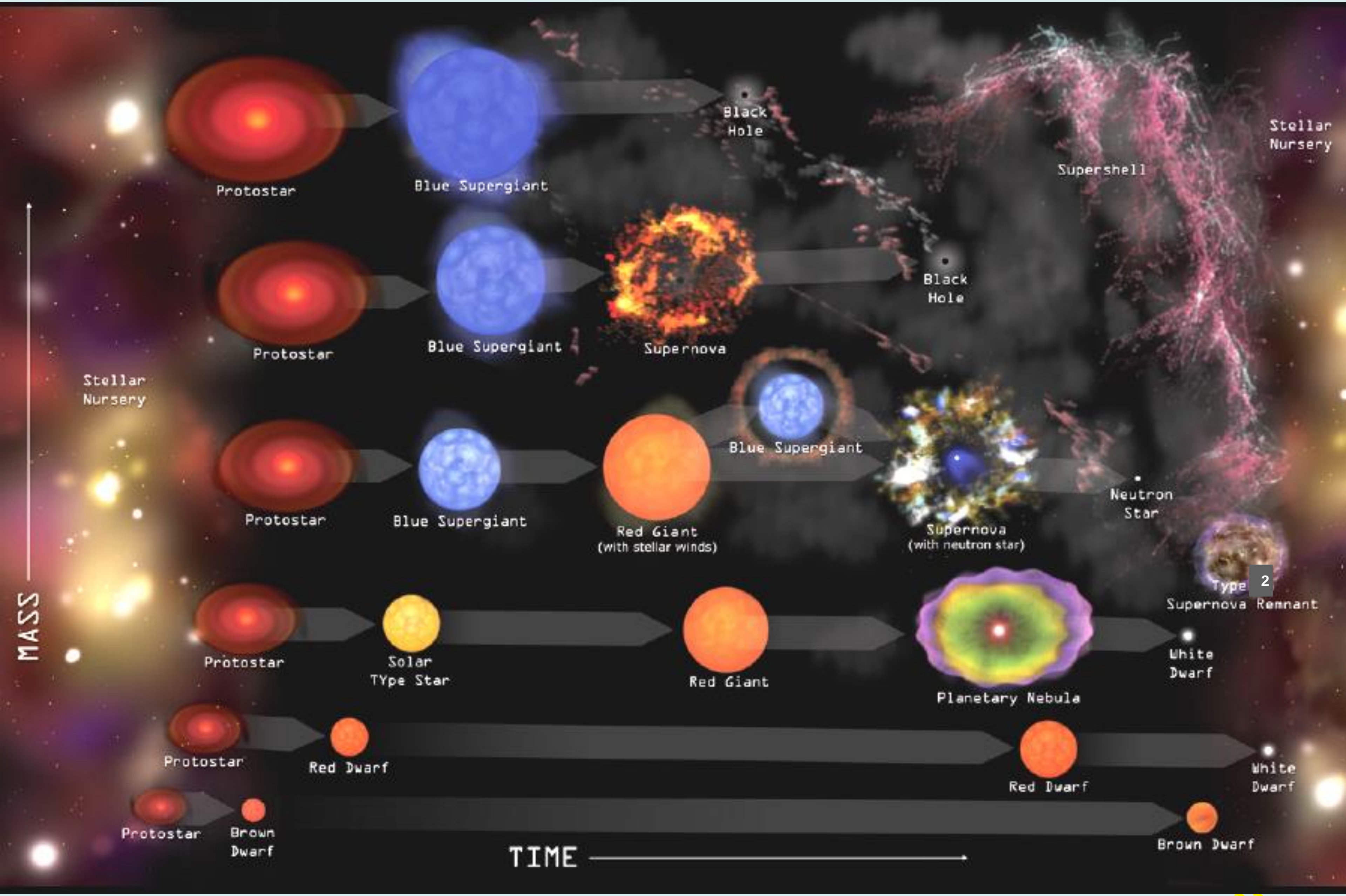
The ultimate fate of a star is dictated by one property: its mass

Low mass stars fuse hydrogen to helium very slowly and live for a long time on the main sequence.

High mass stars consume their fuel very rapidly and are on the main sequence for a short time

Low mass stars end up as white dwarf,

High mass stars as neutron stars or black holes after blowing up as type II or 2 supernovae


Protostar
Blue Supergiant
Black Hole
Stellar Nursery
Supershell
Protostar
Blue Supergiant
Supernova
Black Hole
Stellar Nursery
Protostar
Blue Supergiant
Red Giant
(with stellar winds)
Blue Supergiant
Supernova
(with neutron star)
Neutron Star
Type 2
Supernova Remnant
Protostar
Solar TYpe Star
Red Giant
Planetary Nebula
White Dwarf
Protostar
Red Dwarf
Red Dwarf
White Dwarf
Protostar
Brown Dwarf
Brown Dwarf
MASS
TIME

Recap

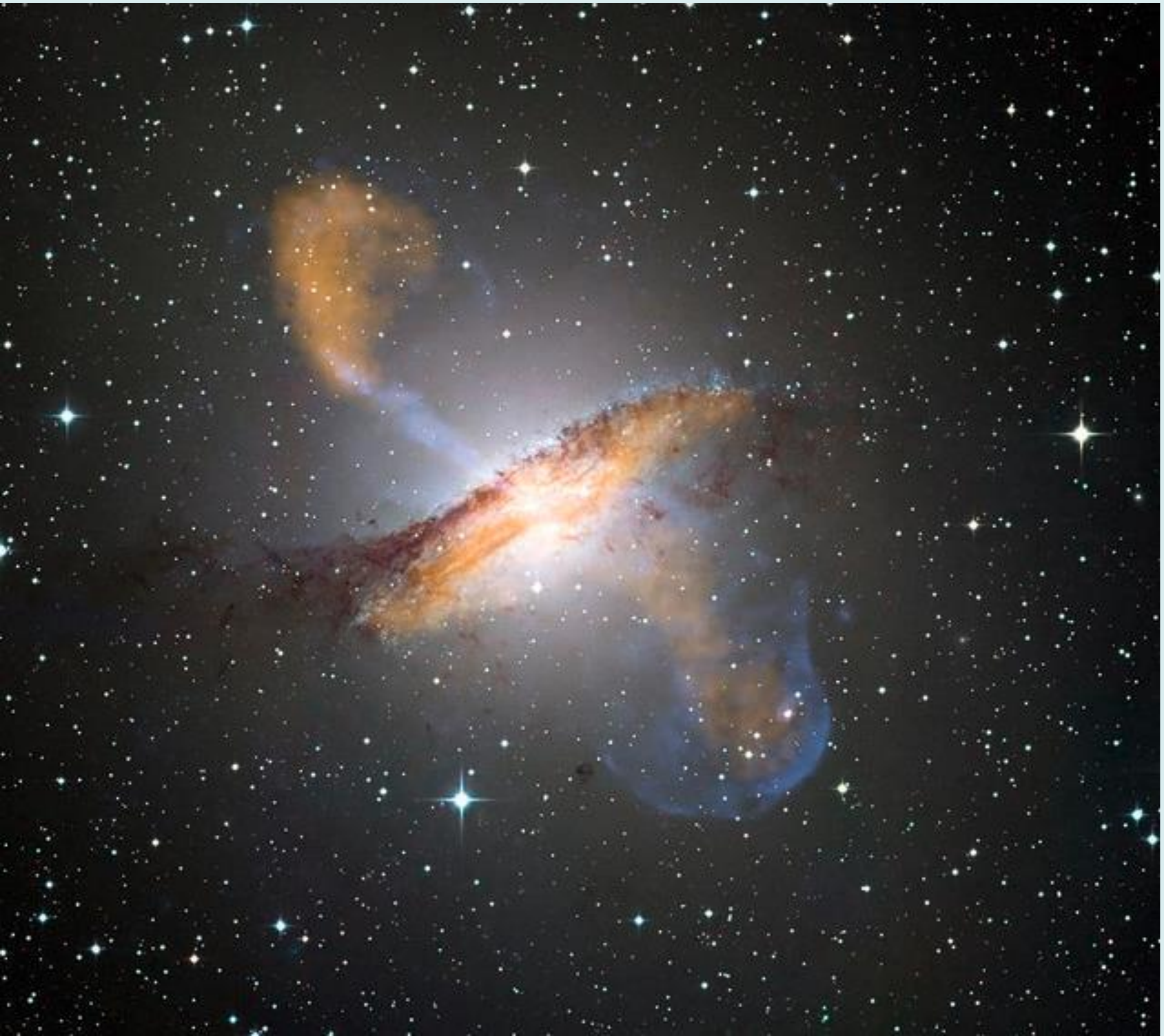
1a. Stars are categorized by their spectral class
1b. Hertzsprung-Russell (H-R) diagram is a way to represent the evolution of stars
2. The Main sequence is the location of stars on the H-R diagram where stars spend most of their lives: Hydrogen fusing to Helium in the star's ***<u>core</u>***
3. Stars remain stable for long periods (on the main sequence) by <u>balancing</u> the force of <u>gravity</u> with the energy generated by <u>nuclear fusion of hydrogen</u> to helium in the <u>star's core</u>.
4. Red giant stars are caused by nuclear fusion in the shell as well as the core. These stars on not on the main sequence.
4a. For the heaviest stars, fusion will continue in the core until iron builds up in the core of these heaviest stars. Gravity takes over and they will dye as type II supernovae
4b. For lighter red giant stars, fusion will stop at helium or oxygen / carbon and they will fluff off their outer layers as planetary nebulae. A white dwarf is left behind.
5. Mass is the single most important property of a star that dictates its ultimate fate.
6. A more massive star has a shorter lifetime
7. Stars in a single cluster are all "born" at the same time
8. An old star cluster will show stars in many stages of life as a result of the different masses of the stars formed in the cluster.

Objects on your list and how they are related to stellar / galactic evolution

M31 Andromeda Galaxy

- NGC5128 (Centaurus A)

- Active Galactic Nucleus (AGN) – super massive black hole consuming material.
- Strong radio emission.



Jets coming out at the poles

Star burst in its belly band.

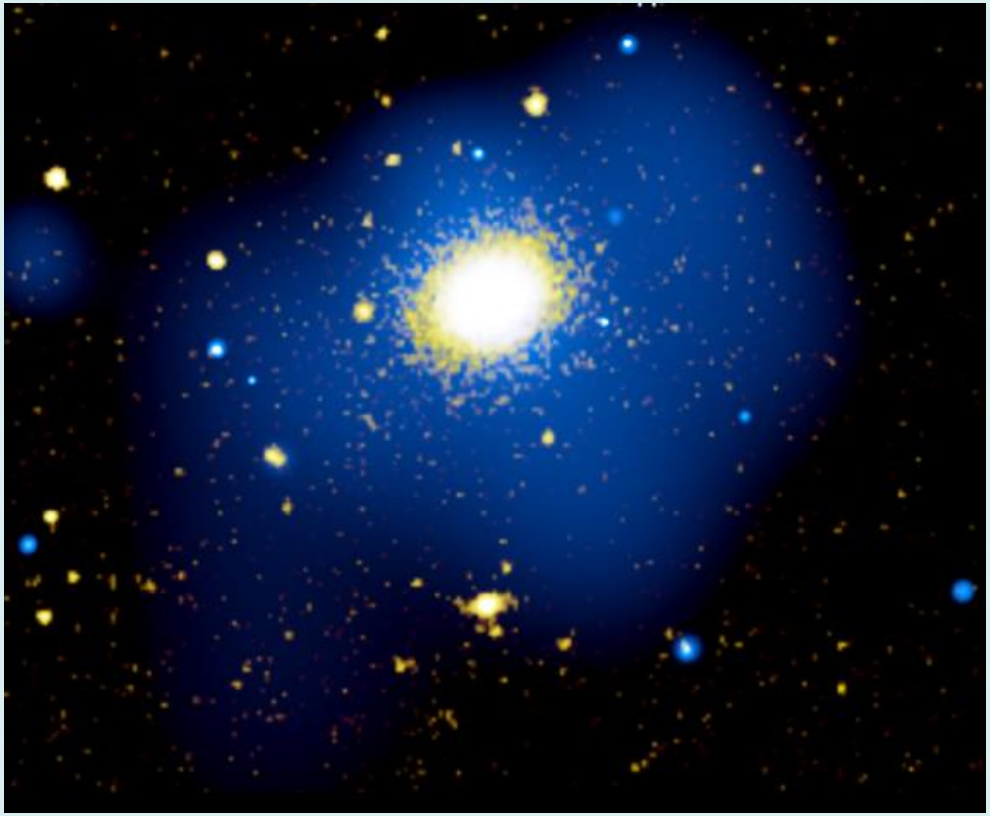
Dust lane in visible Blue colors are X-ray

Infrared in orange

Mice nebulae, NGC 4676, two galaxies in the process of colliding and merging. “Tails” are from tidal / gravitational forces pulling parts of the galaxies away from the core

NGC 4555

- Giant elliptical galaxy
- A pool of hot gases (so hot that it is giving off radiation as X-rays) surrounds the galaxy
- The hot gases should have dissipated long ago
- Dark matter is believed to be keeping these hot gases in place. There is not enough regular matter in the galaxy to do this.

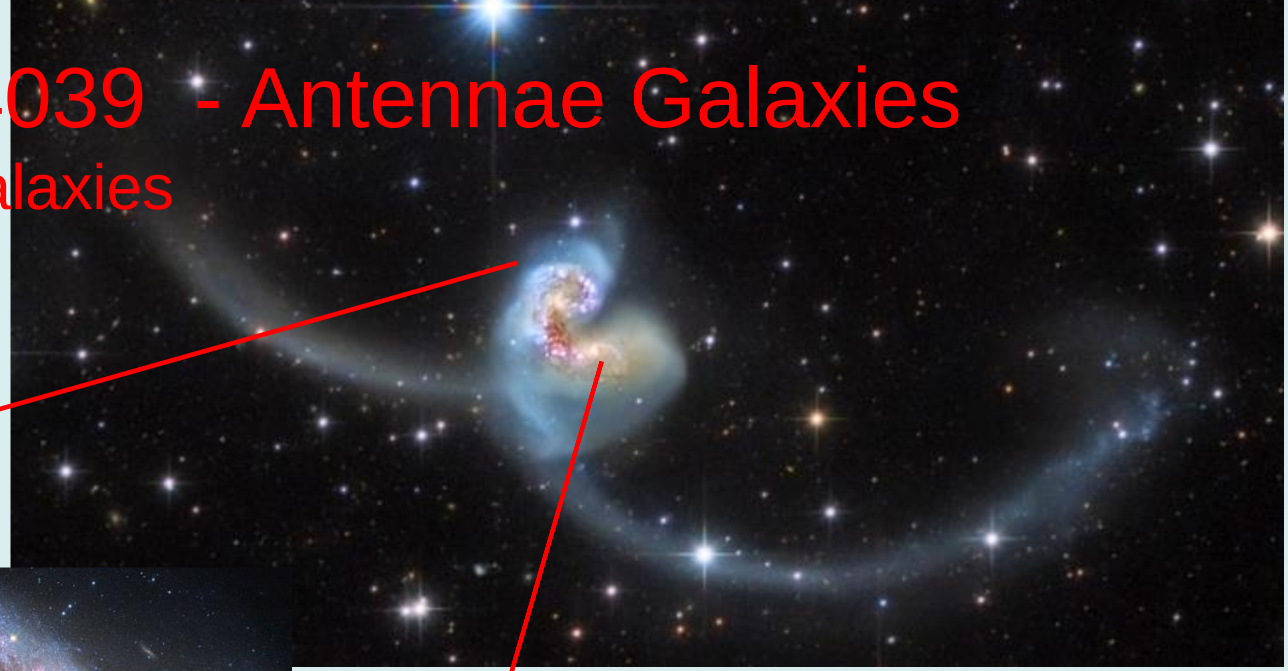


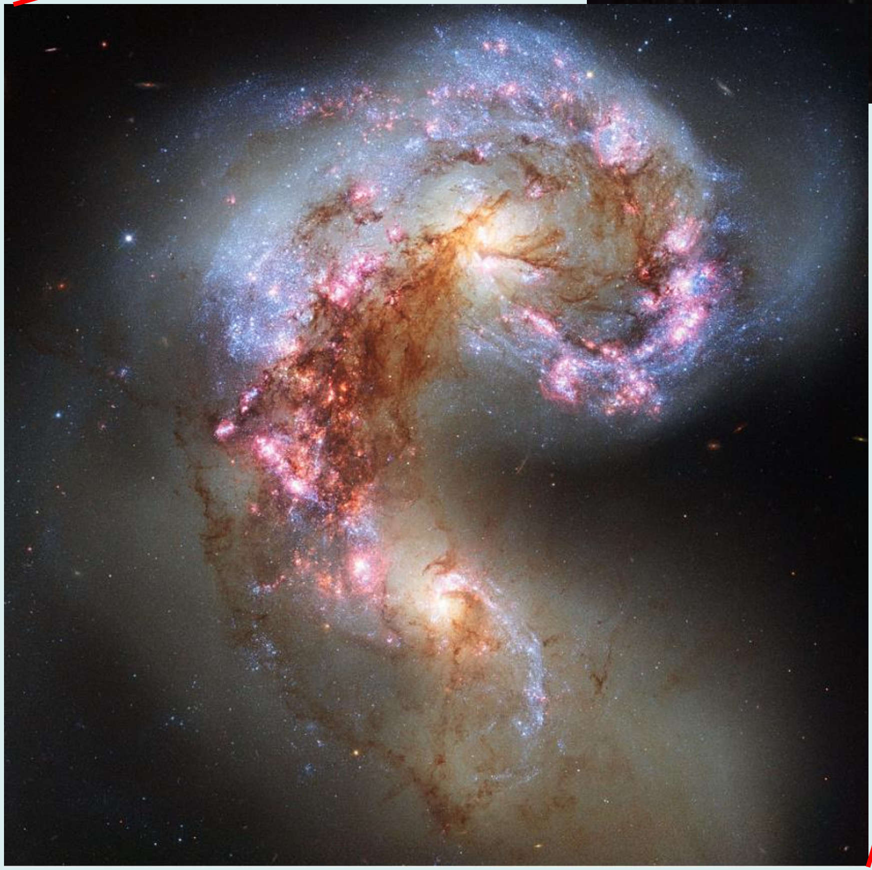
X rays in blue

Visible in white

NGC 4038 / 4039 - Antennae Galaxies

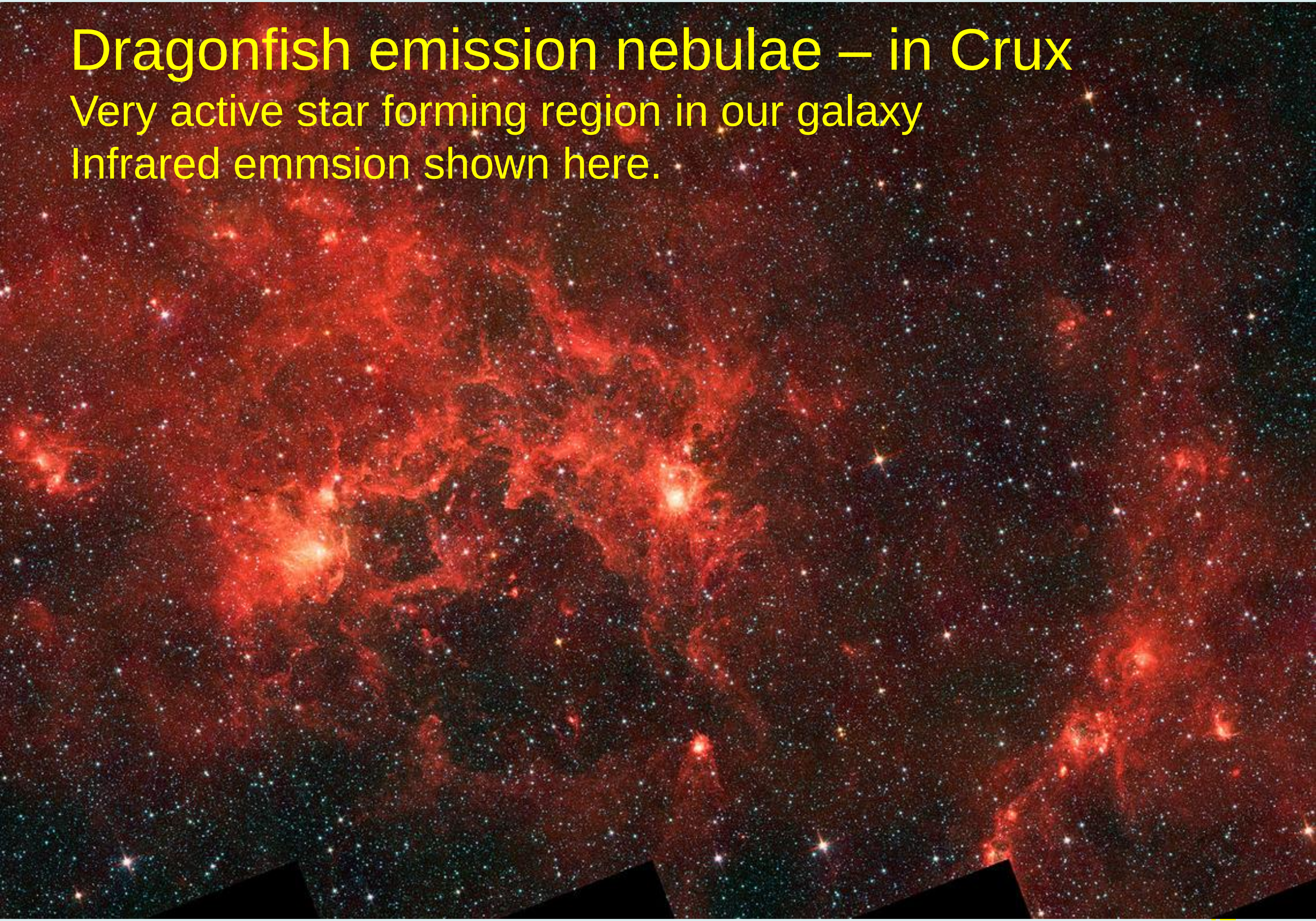
- Two colliding galaxies





NGC4038 top
NGC 4039 bottom

Pink are new and very active star forming regions

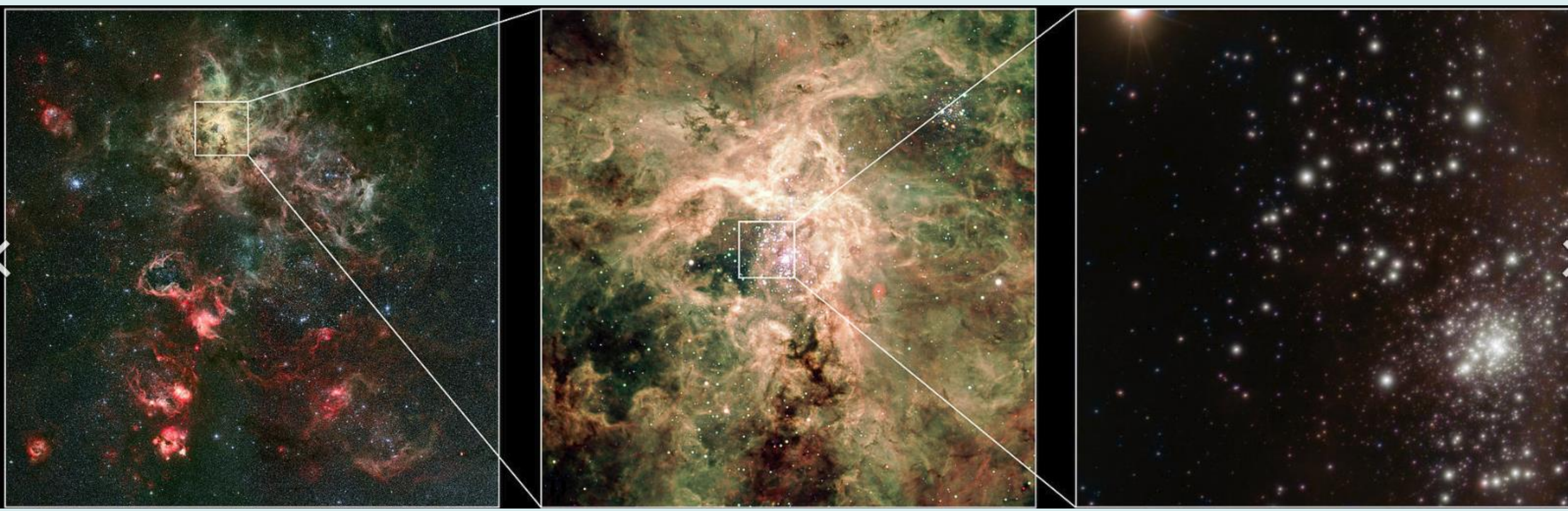

Dragonfish emission nebulae – in Crux
Very active star forming region in our galaxy
Infrared emmsion shown here.

30 Doradus – Tarantula nebula in large Magellanic cloud

Area of new star formation with supernovae remnants

Embedded in the nebula

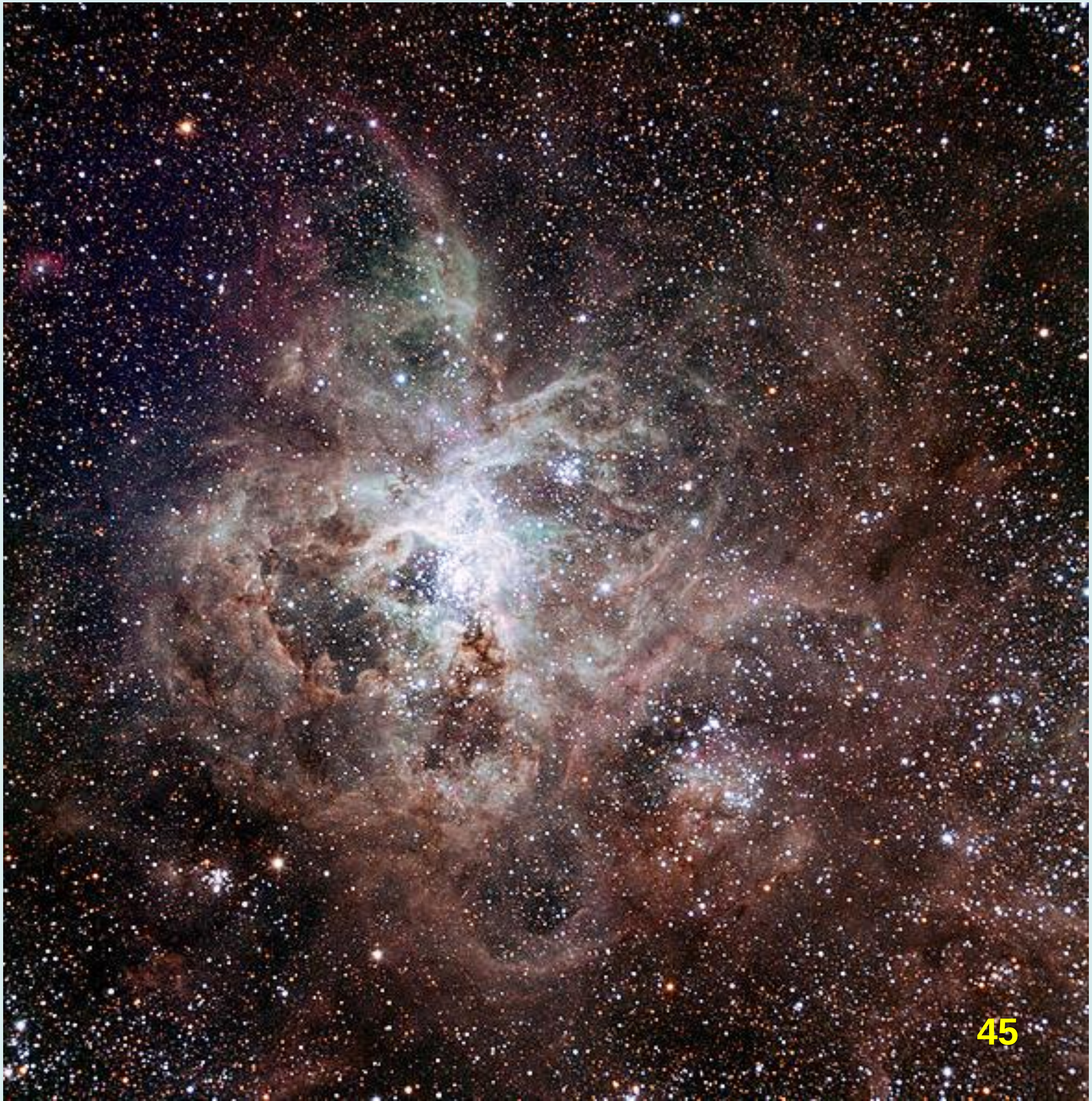
New star clusters being formed



The Tarantula Nebula (also known as 30 Doradus, or NGC 2070) in the Large Magellanic Cloud (LMC).
The Tarantula Nebula has an apparent magnitude of 8. Its distance is about 49 kpc or 160,000 light years. Its absolute brightness is so great that if it were as close to Earth as the Orion Nebula, the Tarantula Nebula would cast shadows. It is the most active and largest starburst region known in the Local Group of galaxies. It has an estimated diameter of 200 pc or 650 light years. The nebula resides in the Large Magellanic Cloud.

Objects

- 30 Doradus (Tarantula Nebulae)



Rho Ophiuchi

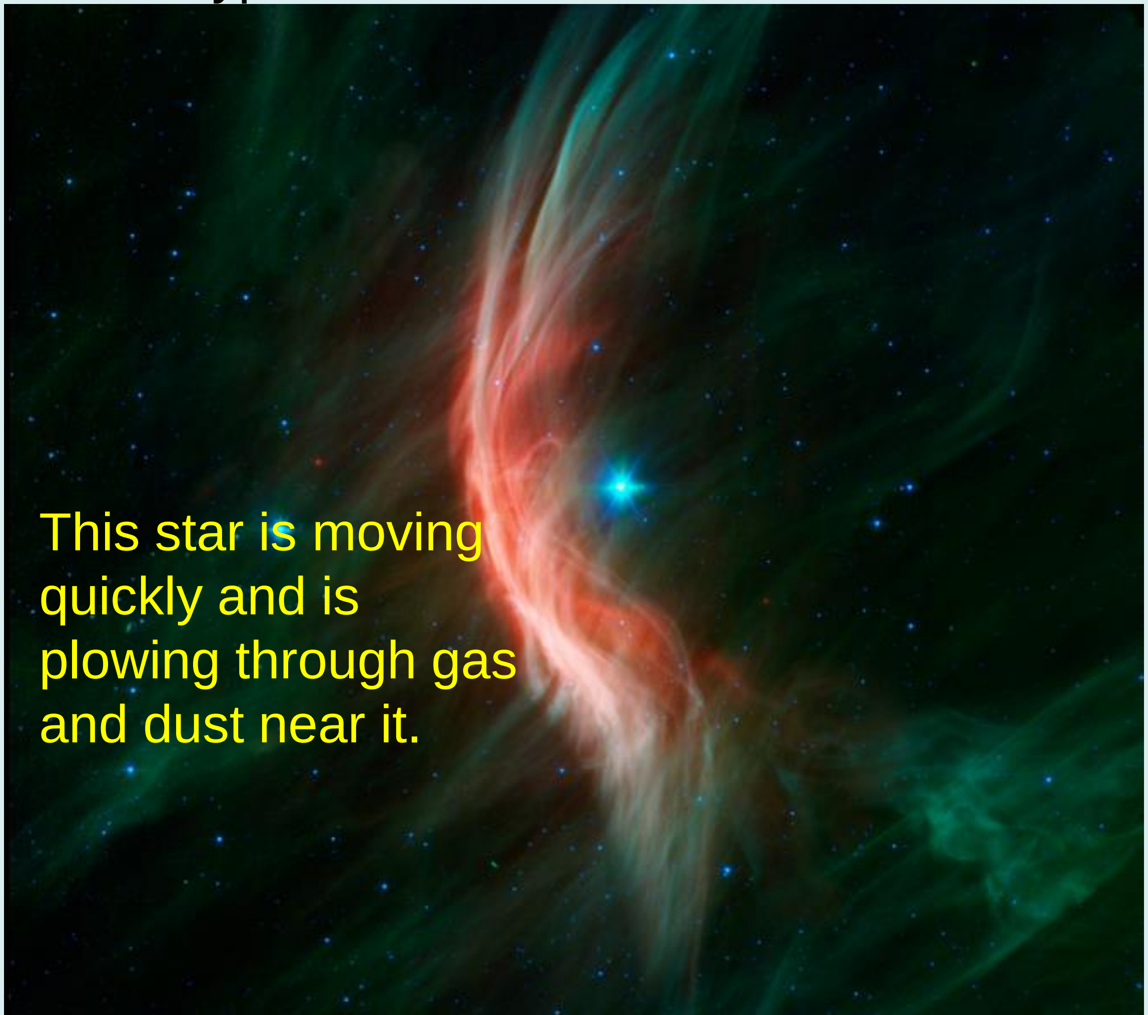
Cloud complex with multiple star system.

First brown dwarf found in this complex.

New stars being born in this complex.

One of the closest star forming regions to us

Zeta Ophiuchi is an enormous star with more than 19 times the Sun's mass and eight times its radius. The stellar classification of this star is O9.5 V, with the luminosity class of V indicating that it is generating energy in its core by the nuclear fusion of hydrogen. This energy is being emitted from the outer envelope at an effective temperature of 34,000K, giving the star the blue hue of an O-type star.



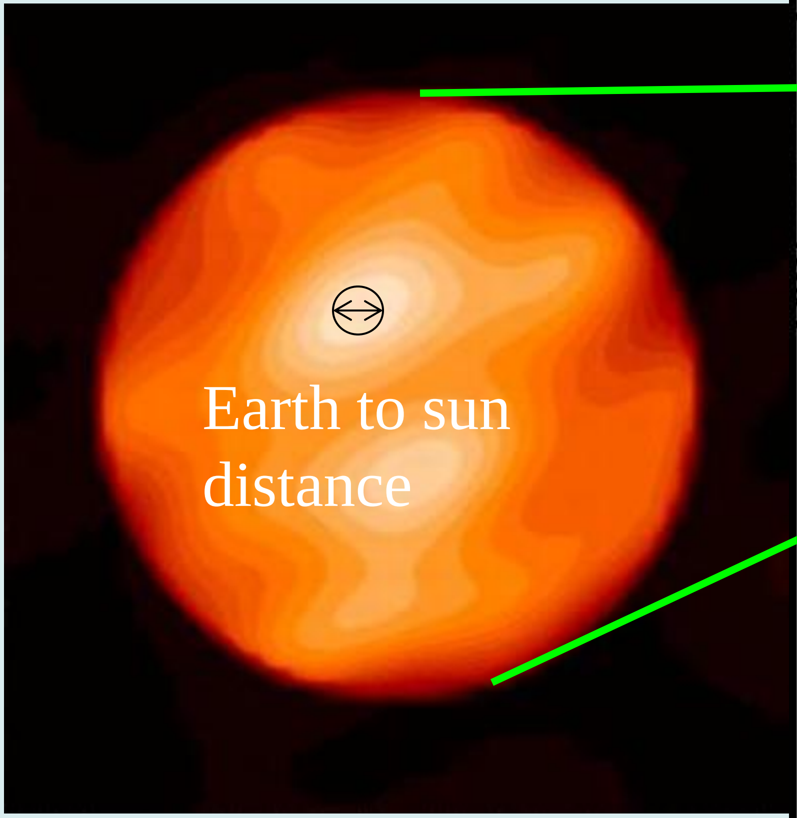
Zeta Ophicuchi

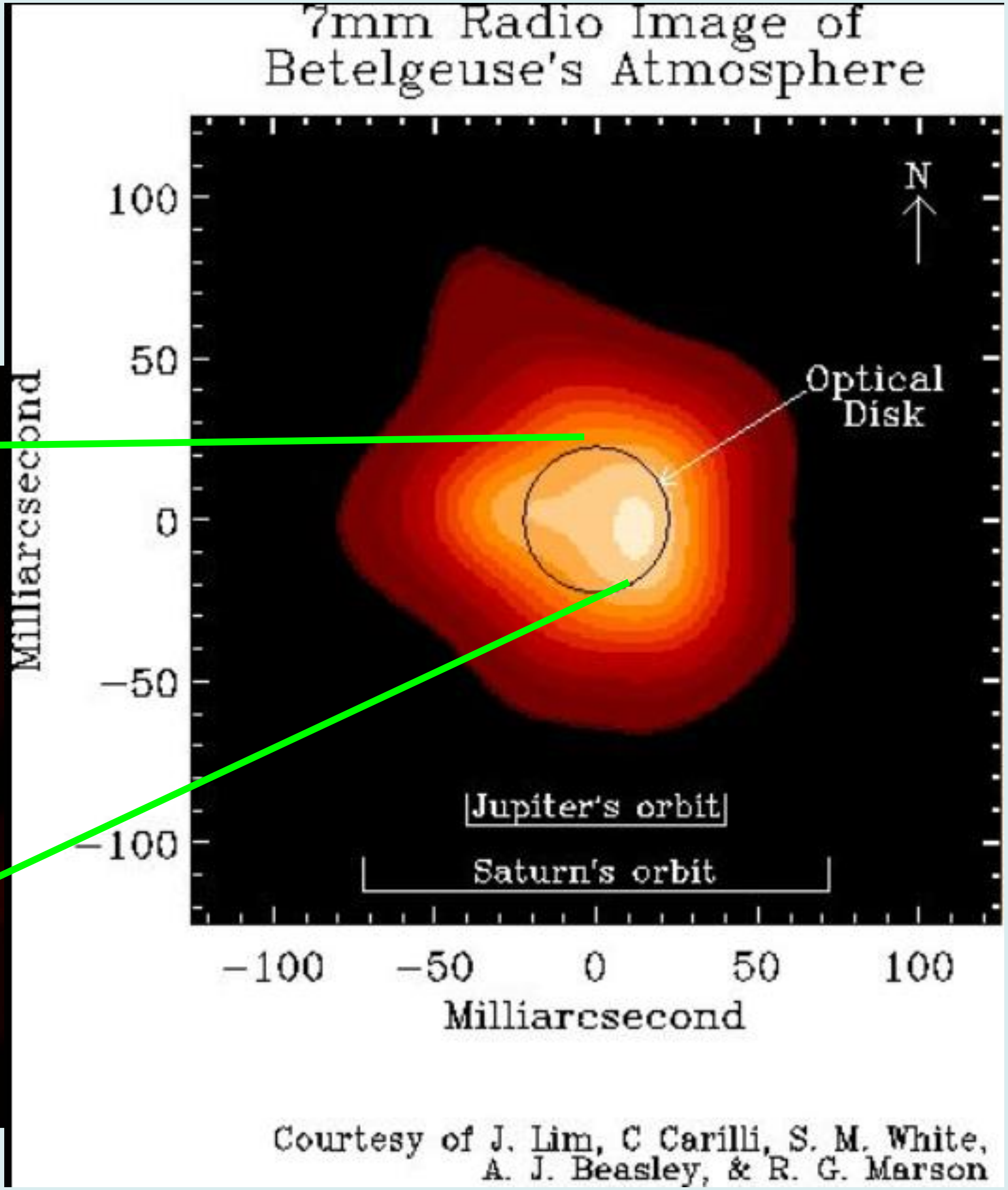
Run away star in Ophiuchus
Very large star (~19 x our sun)
Very young Type O star
Moving through dust pushing the dust out of its way by its strong stellar wind

Mid way through its (short life) as a main sequence star.

Dust obscures the star. Without dust it would be one of the brightest stars in our sky.

Betelgeuse is a red supergiant star

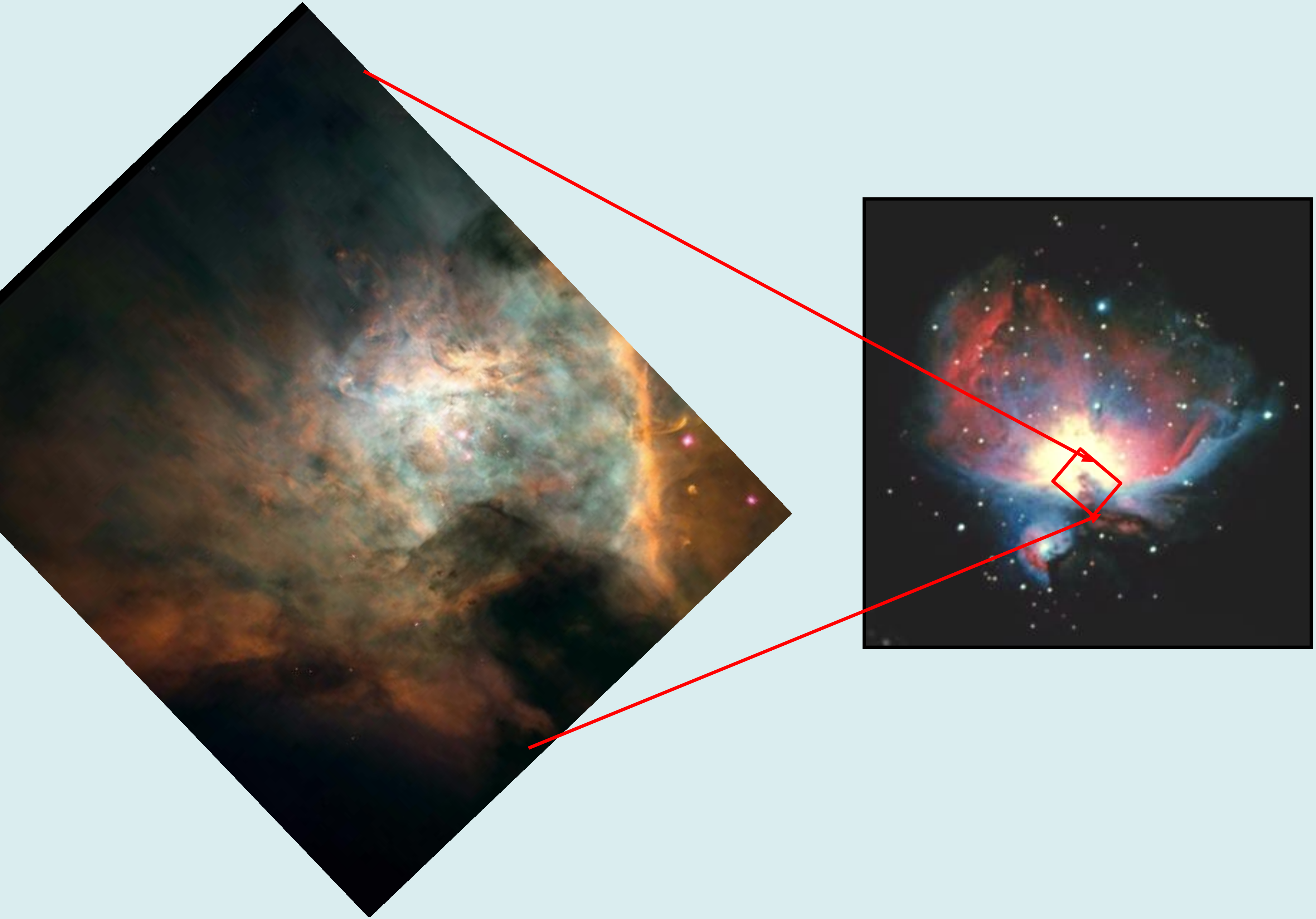




M42 Orion Nebulae star forming region

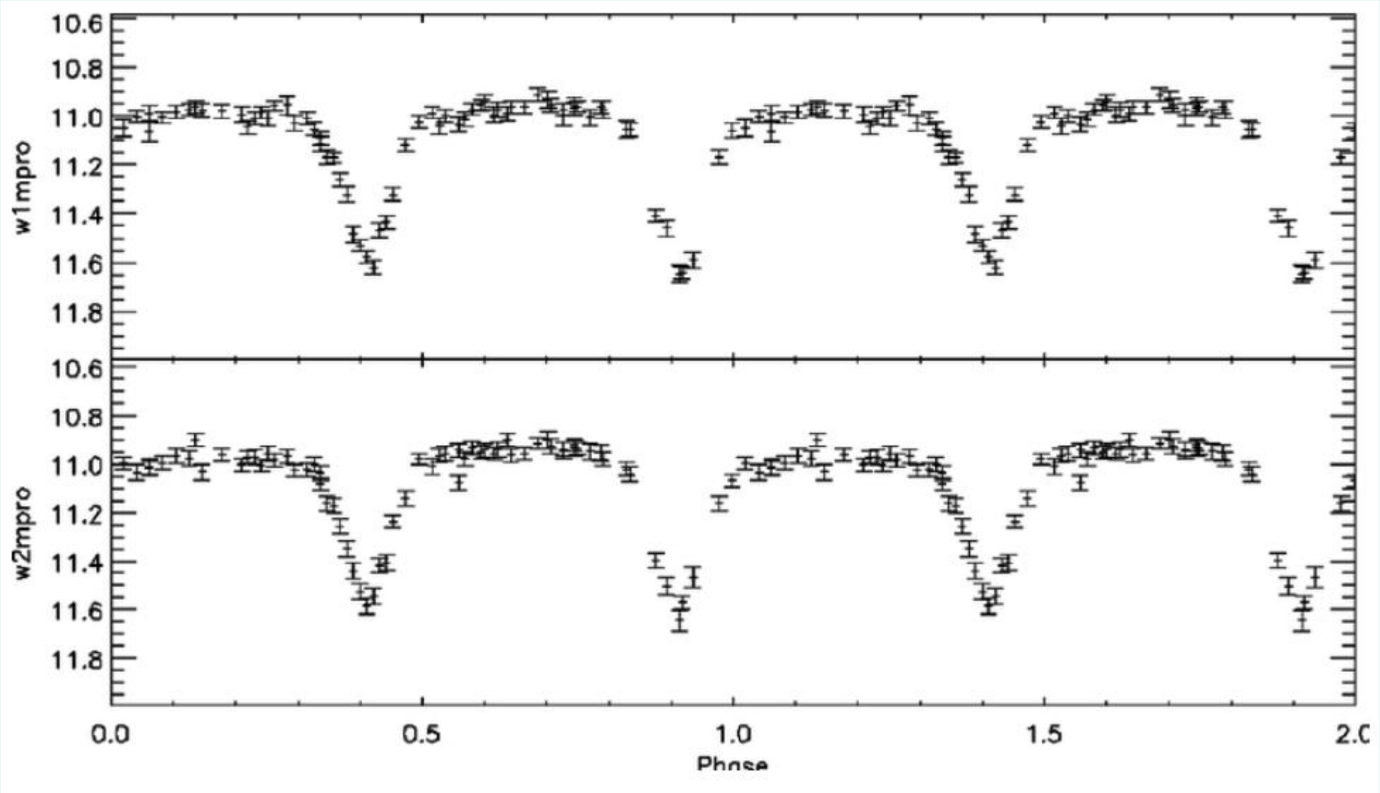
Large star forming region in Orion

Emission nebula regions glow from the radiation from the new young stars in the core of the nebulae.



Algol in Perseus

- The demon star
- First star that was recognized as a variable
- Eclipsing binary (one star goes in front of the other and partially blocks it)

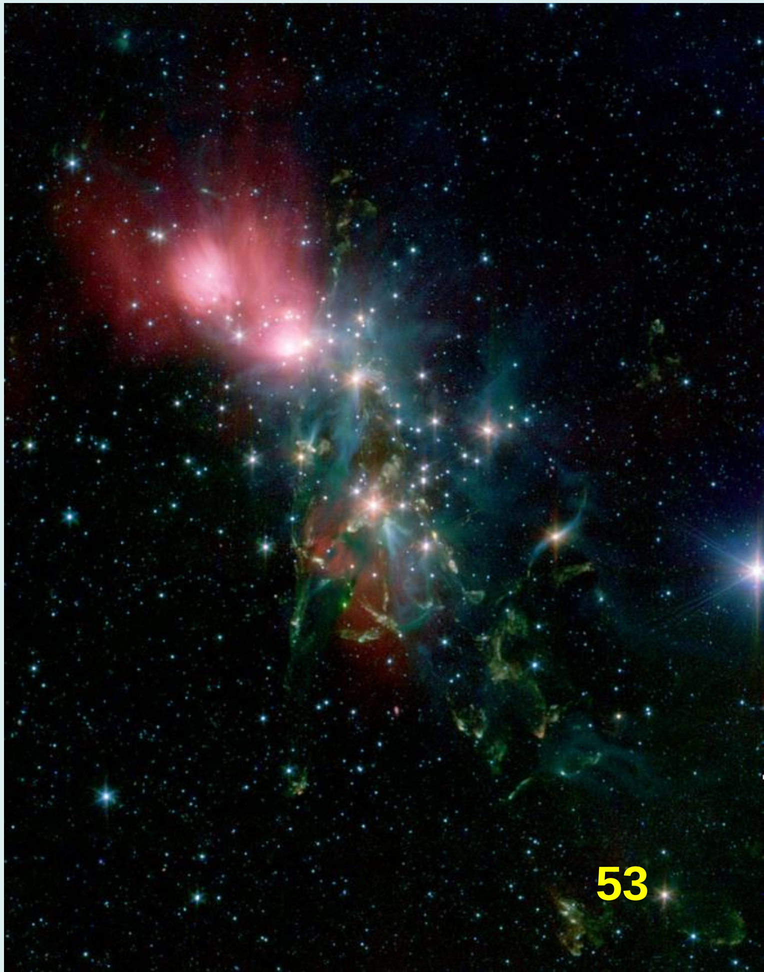


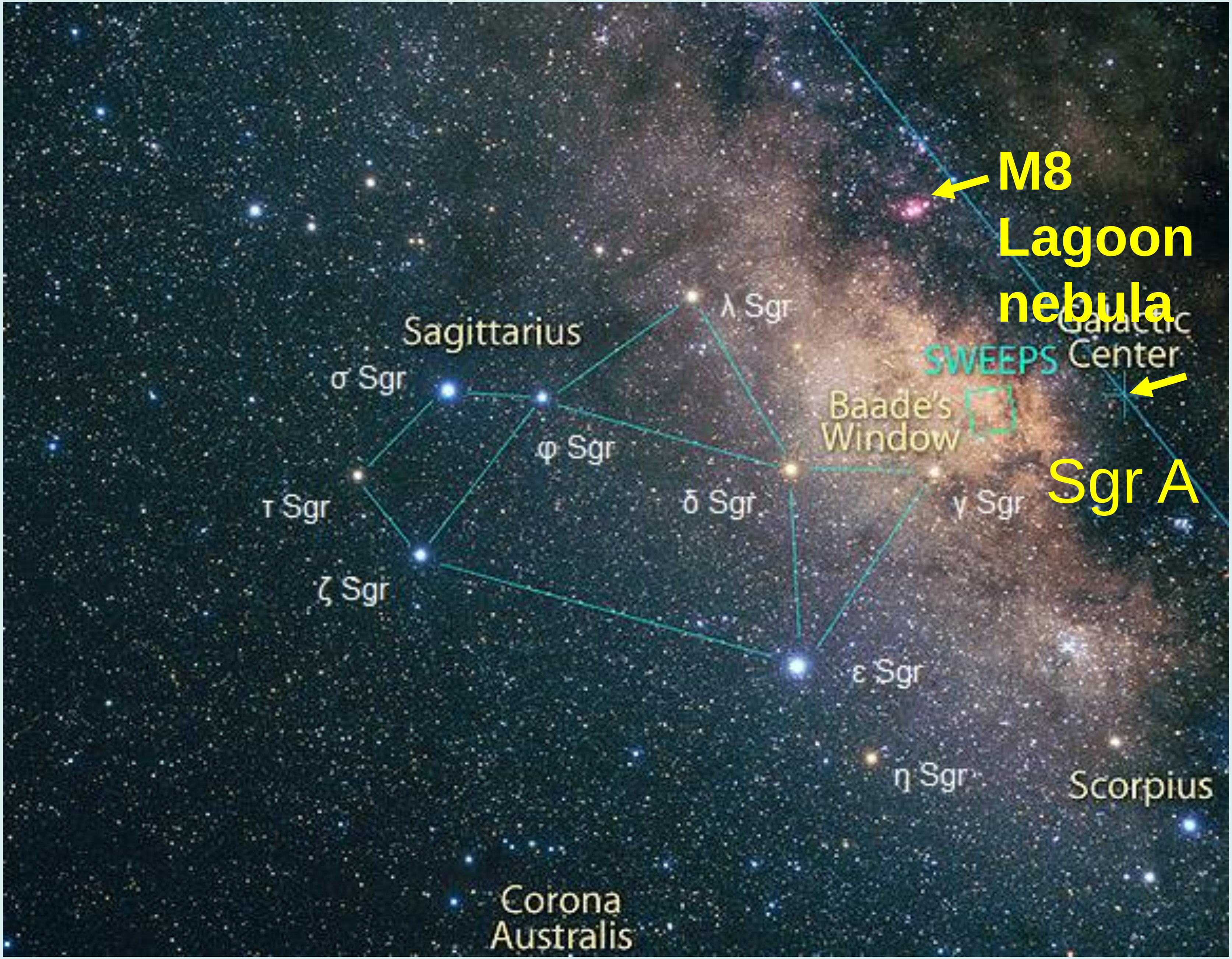
NGC1333

A nebula or dust cloud that is seen by reflected light and not by the glow of gas the is emitting light. New stars being formed but hidden by the dust.

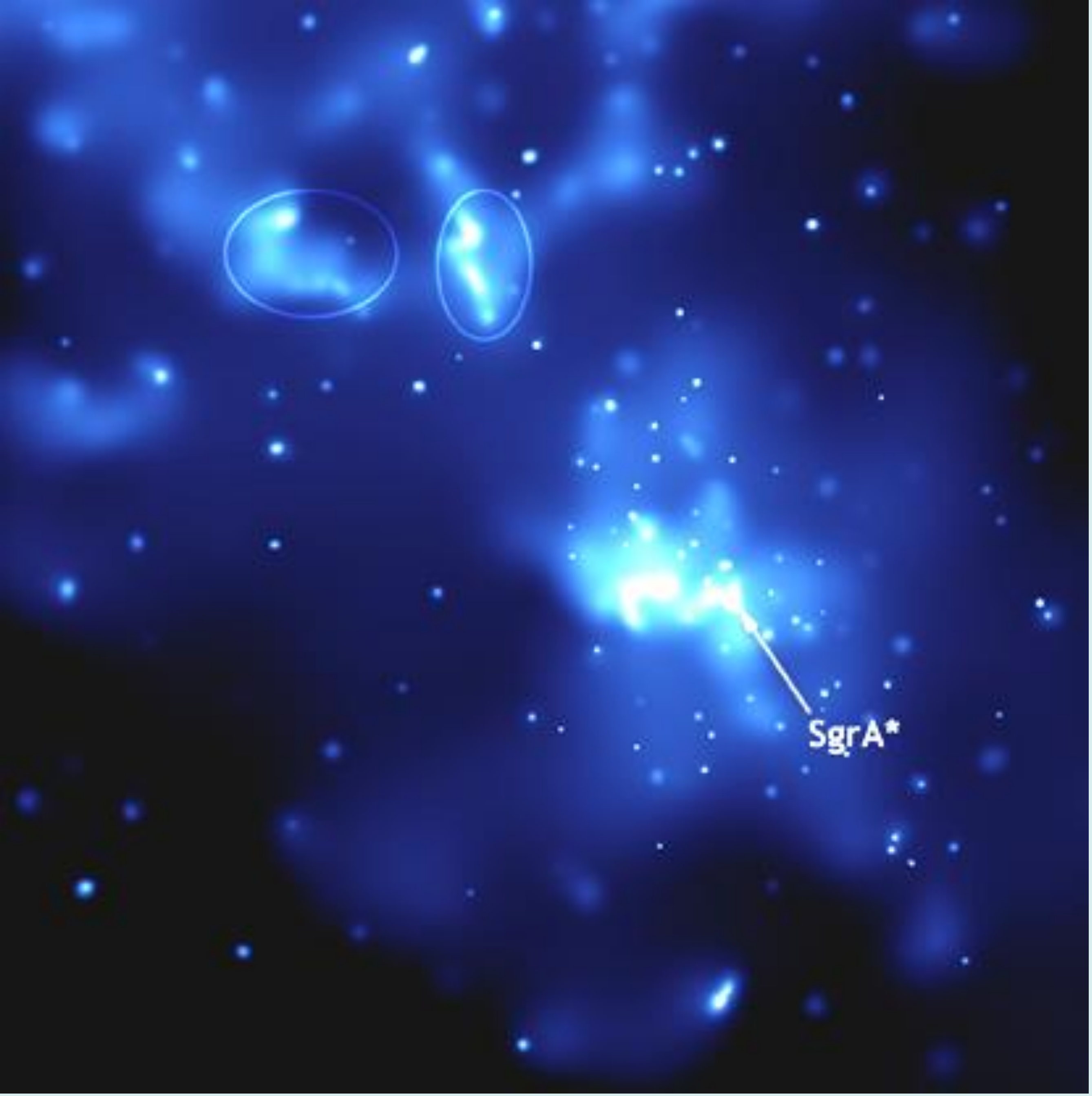
← Visible light

Inside it as seen in Infrared → (Spitzer space telescope)




M8
Lagoon
nebula
Galactic
Center
SWEEPS
Baade's
Window
Sgr A
Sagittarius
λ Sgr
σ Sgr
φ Sgr
τ Sgr
δ Sgr
γ Sgr
ζ Sgr
ε Sgr
η Sgr
Scorpius
Corona
Australis

- Lagoon Nebula(catalogued as Messier 8 or M8, and as NGC 6523) is a giant interstellar cloud in the constellation Sagittarius. It is classified as an emission nebula .
- The Lagoon Nebula was discovered by Giovanni Hodierna before 1654 and is one of only two star-forming nebulae faintly visible to the naked eye from mid-northern latitudes. Seen with binoculars, it appears as a distinct oval cloudlike patch with a definite core.



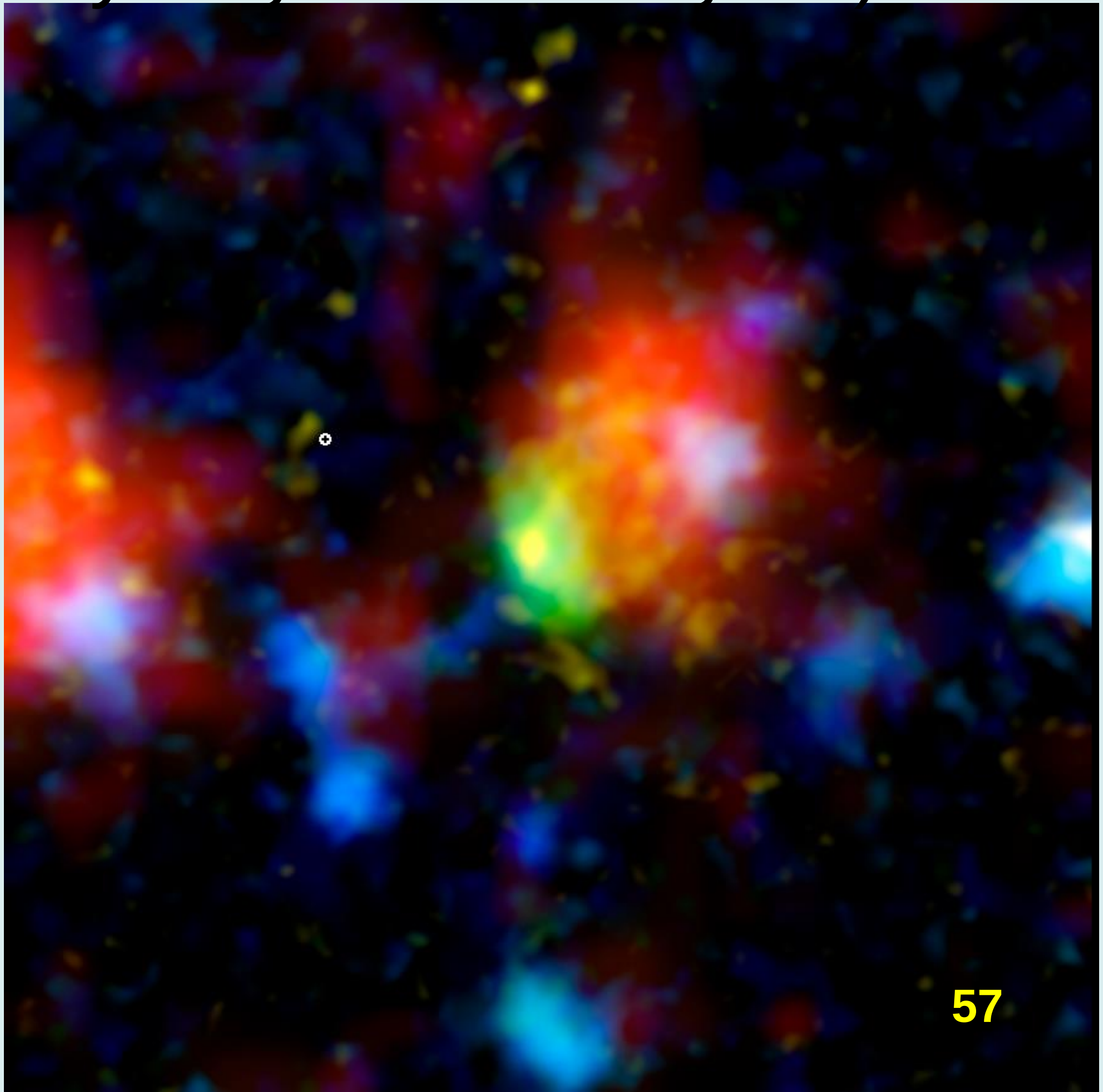
- Sgr A Sagittarius A – X-ray source (black hole) at center of our galaxy

Objects

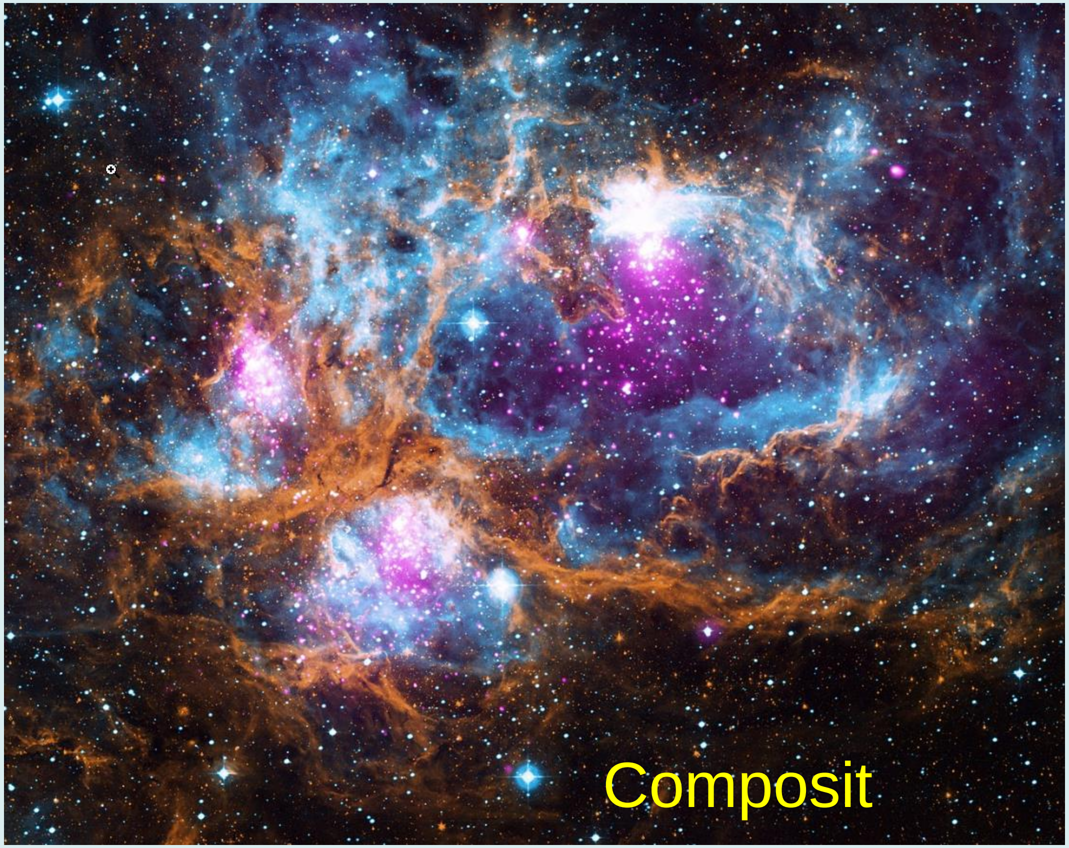
Baby Boom Galaxy- starburst galaxy ~12.2 billion light years away

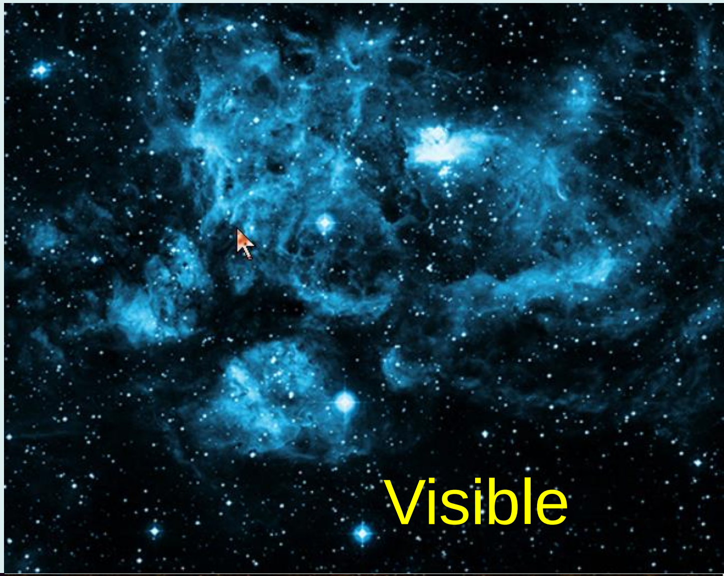
4000 stars/year (Milky way ~10 stars/year)

Astronomers do not know why this star burst galaxy star formation rate is so much faster than the Milky Way

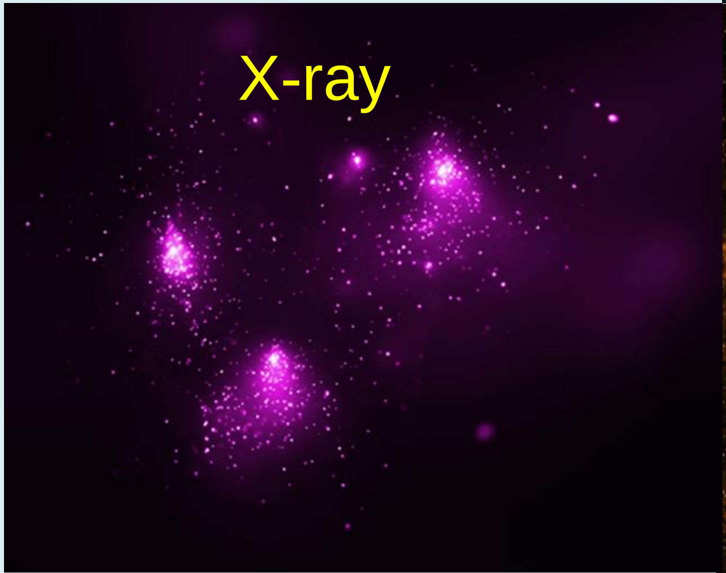


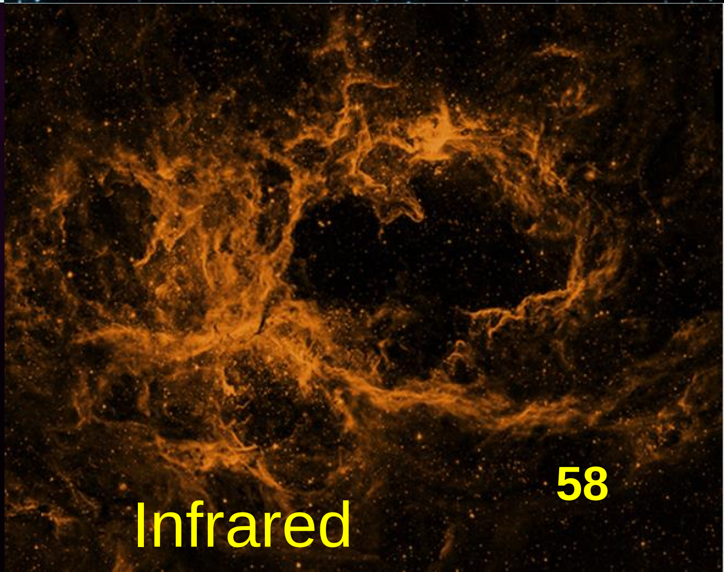
NGC635
emission nebulae in
Scorpius





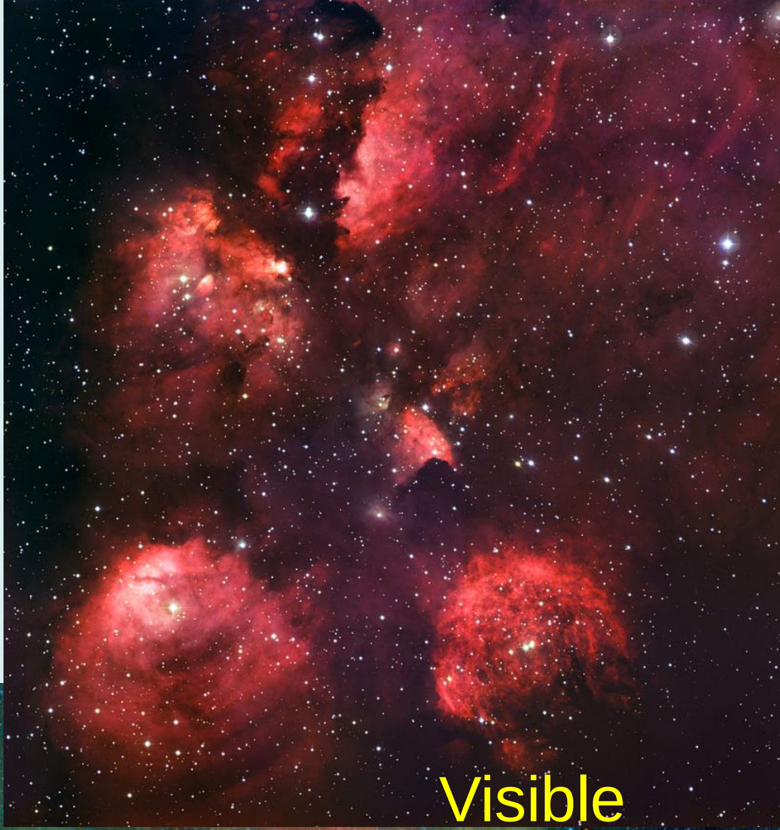
Hot new stars
Formed in
clusters
Heating up
Gas and dust
In the nebula

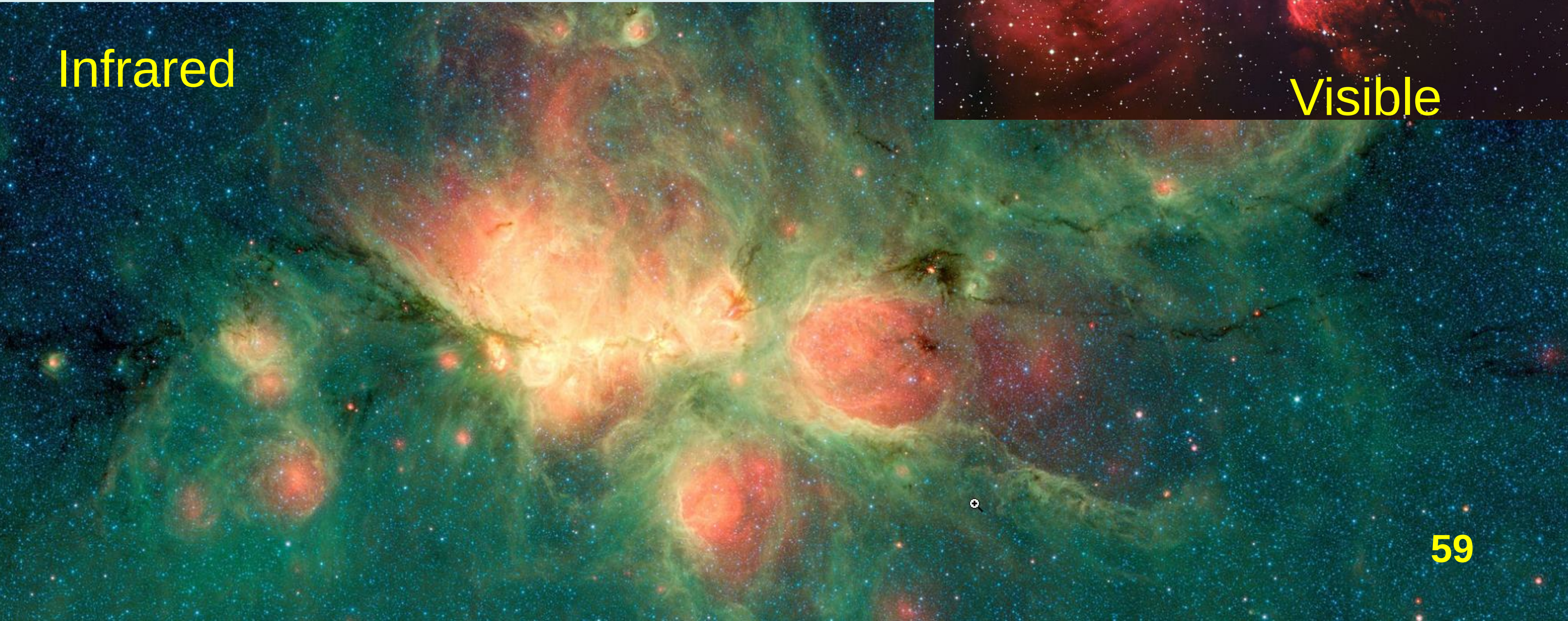




NGC6334 in Scorpius Cat's paw nebula

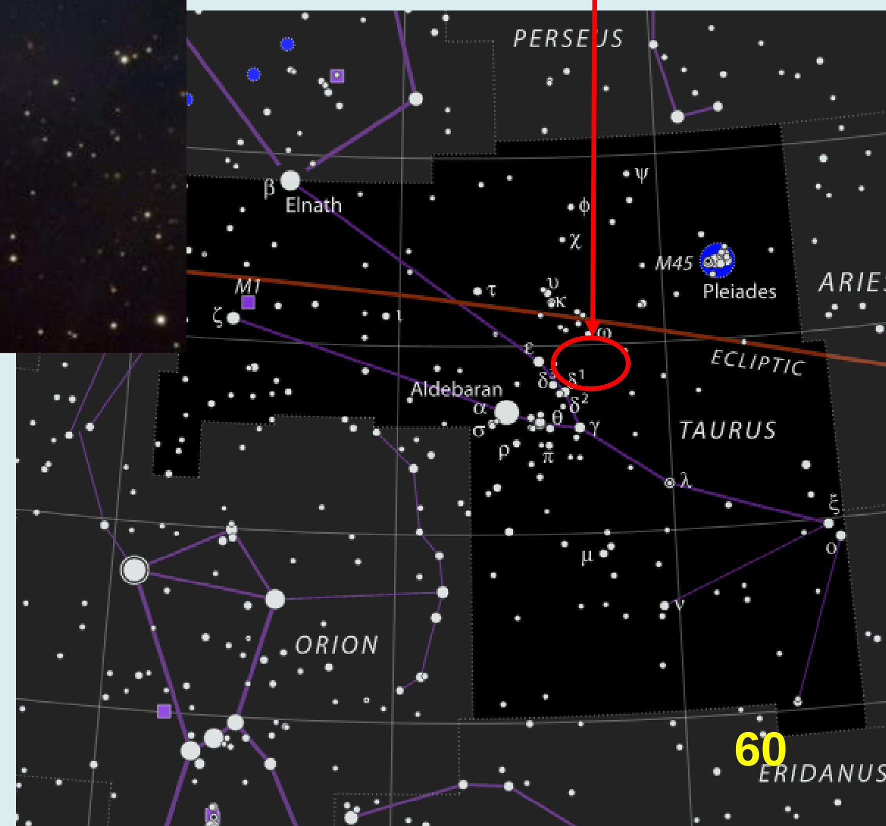
Emission nebula star forming region,





T Tauri

Brand new star that is still pushing gas and dust out of the way using its stellar wind – just started fusing Hydrogen to Helium in its core. Represents a class of young stars.



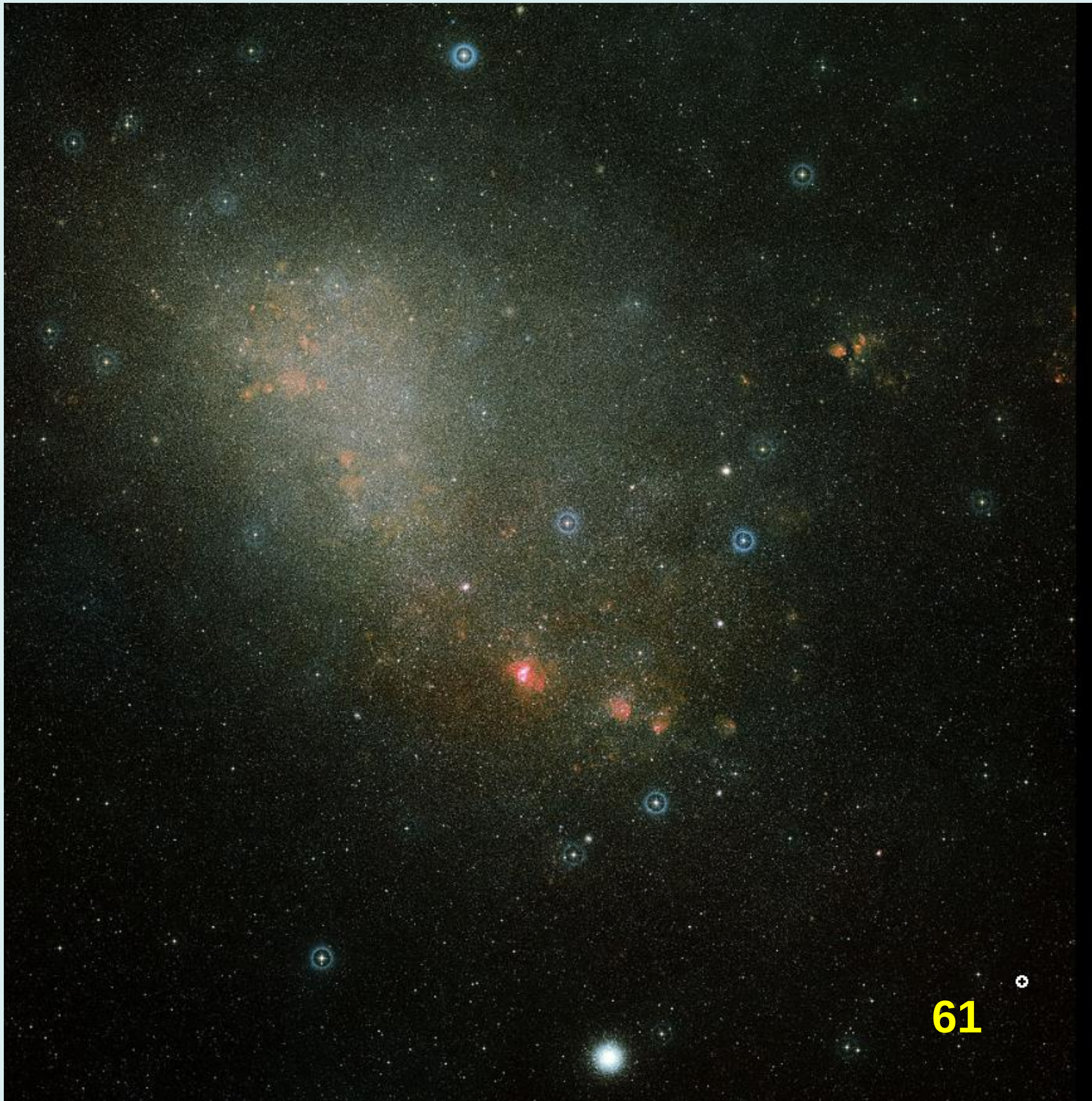
Small Magellanic cloud (SMC)

Satellite galaxy “orbiting” the Milky way.

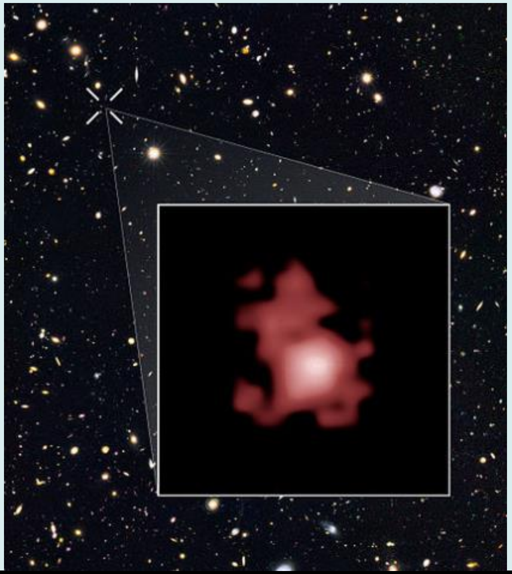
Captured long time ago. What we see here is the core of the captured galaxy.

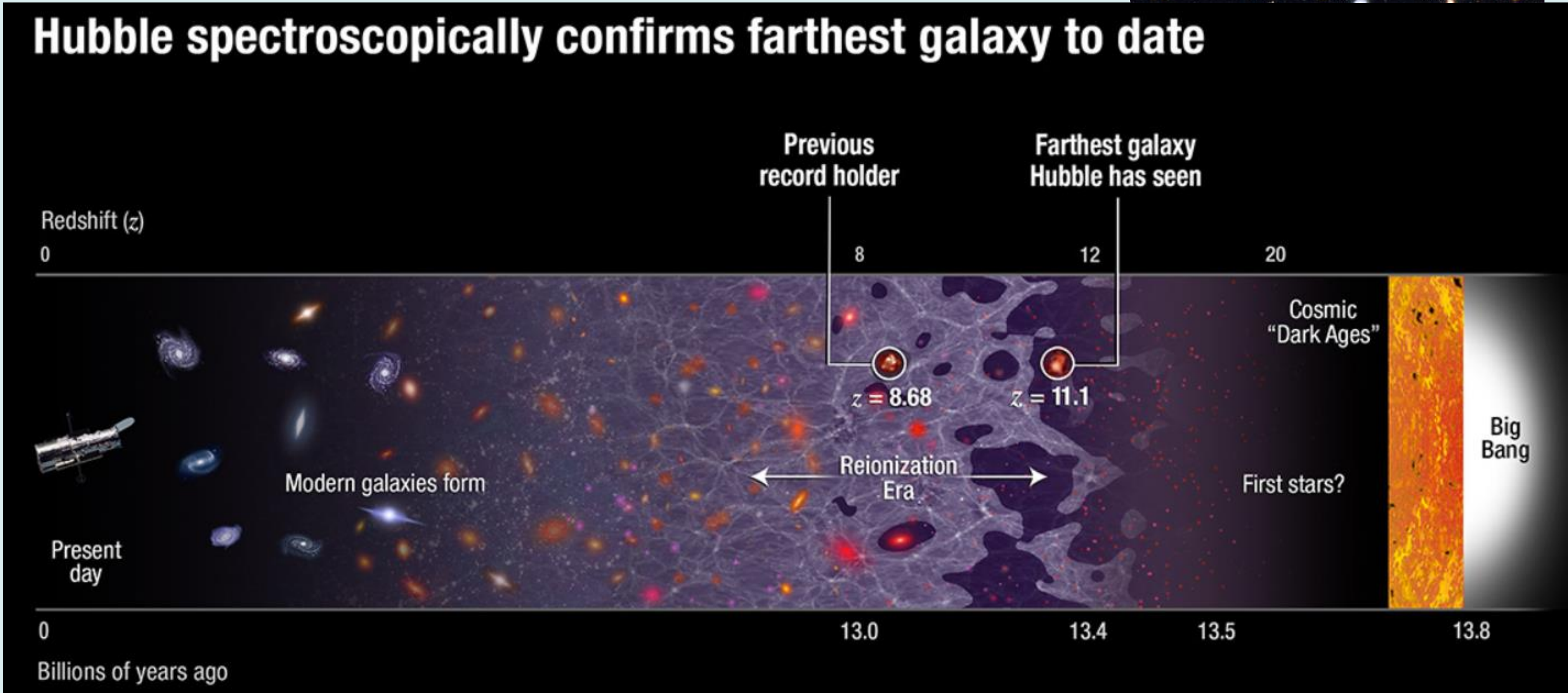
Streams of stars from this cannibalized galaxy encircles the Milky Way

Is classified as a dwarf irregular galaxy. It may have once been a barred spiral galaxy.



GN-z11   The Z refers to redshift – very high and very distance galaxy ~ 13.4 billion light years old
Generating stars 20X that of Milky Way but it is much smaller ~1% of the Milky Way mass





M101 The pinwheel galaxy

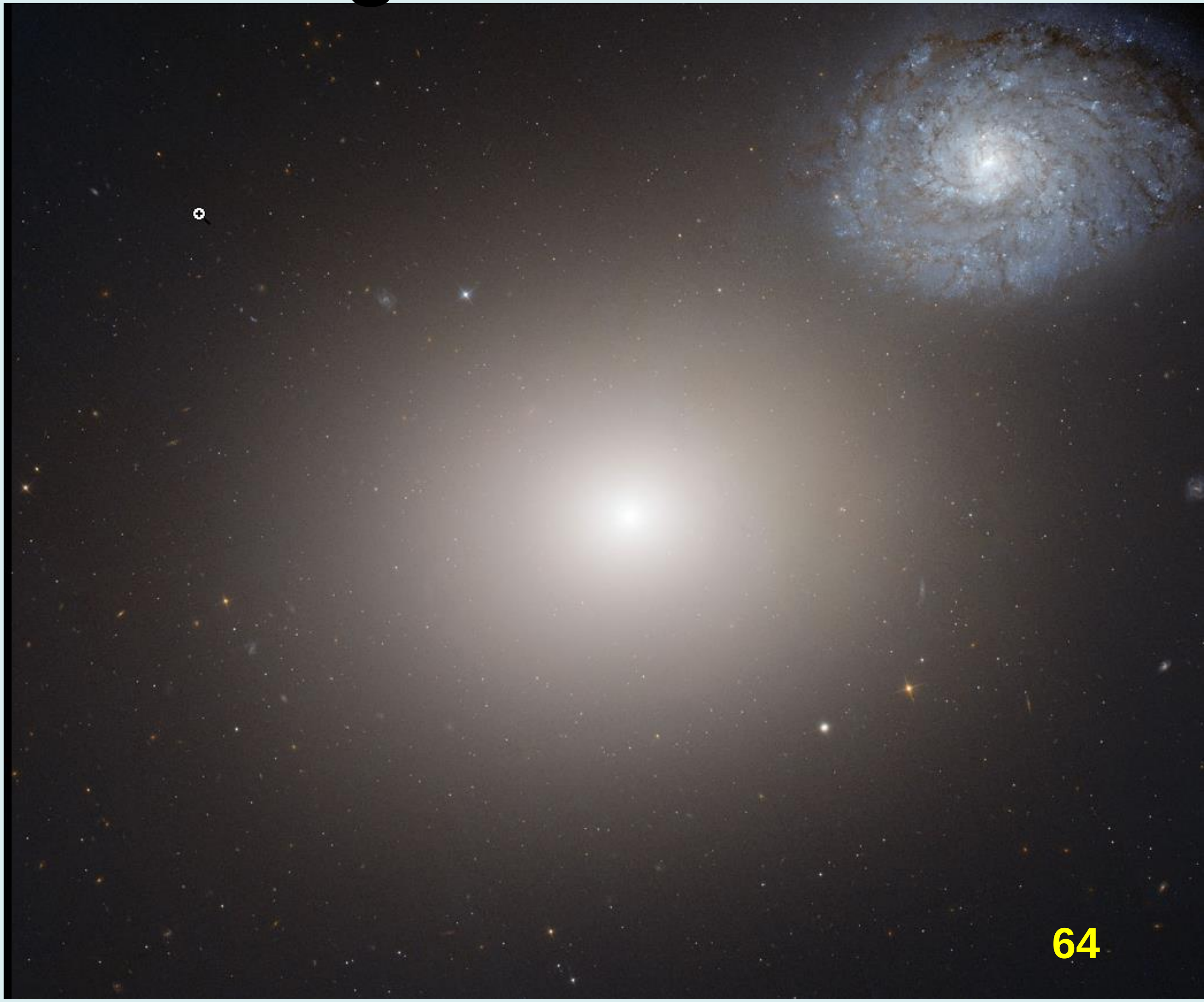
visible image (right)

Xray, infrared and visible light below

Grand spiral galaxy
In Ursa Major
Star production along spine of spiral arms

M60 Giant elliptical galaxy in Virgo

- No structure, no spiral arms
- Nearly circular in shape
- Supermassive black hole at center



M104 Sombrero Galaxy in Virgo

- Lenticular galaxy, prominent dust lane, supermassive black hole

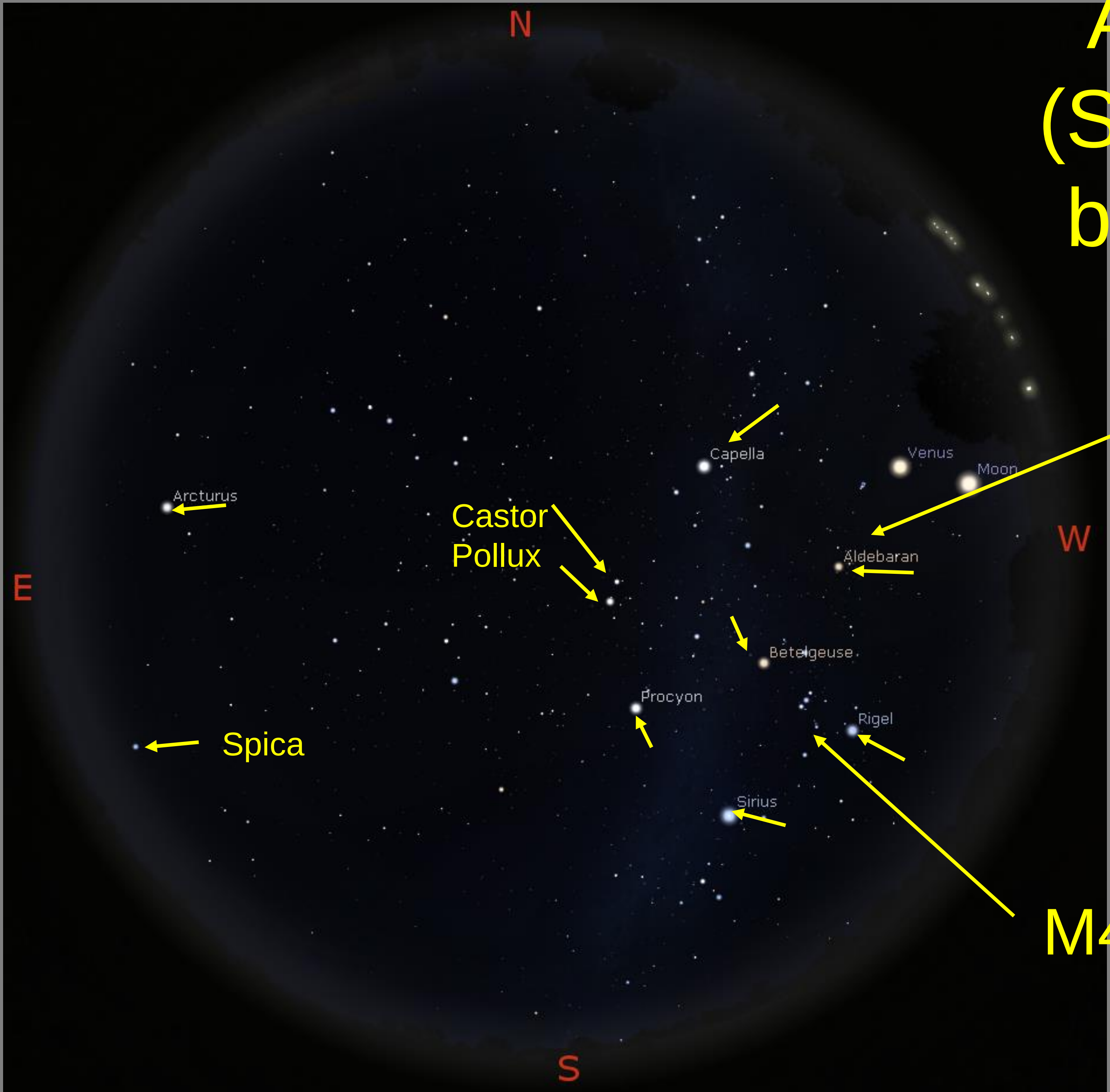
M104 Sombrero Galaxy in Virgo

- Infrared image shows dust ring.

Star Charts

~8:00 pm in the evening before the day of the competition in Dover Delaware

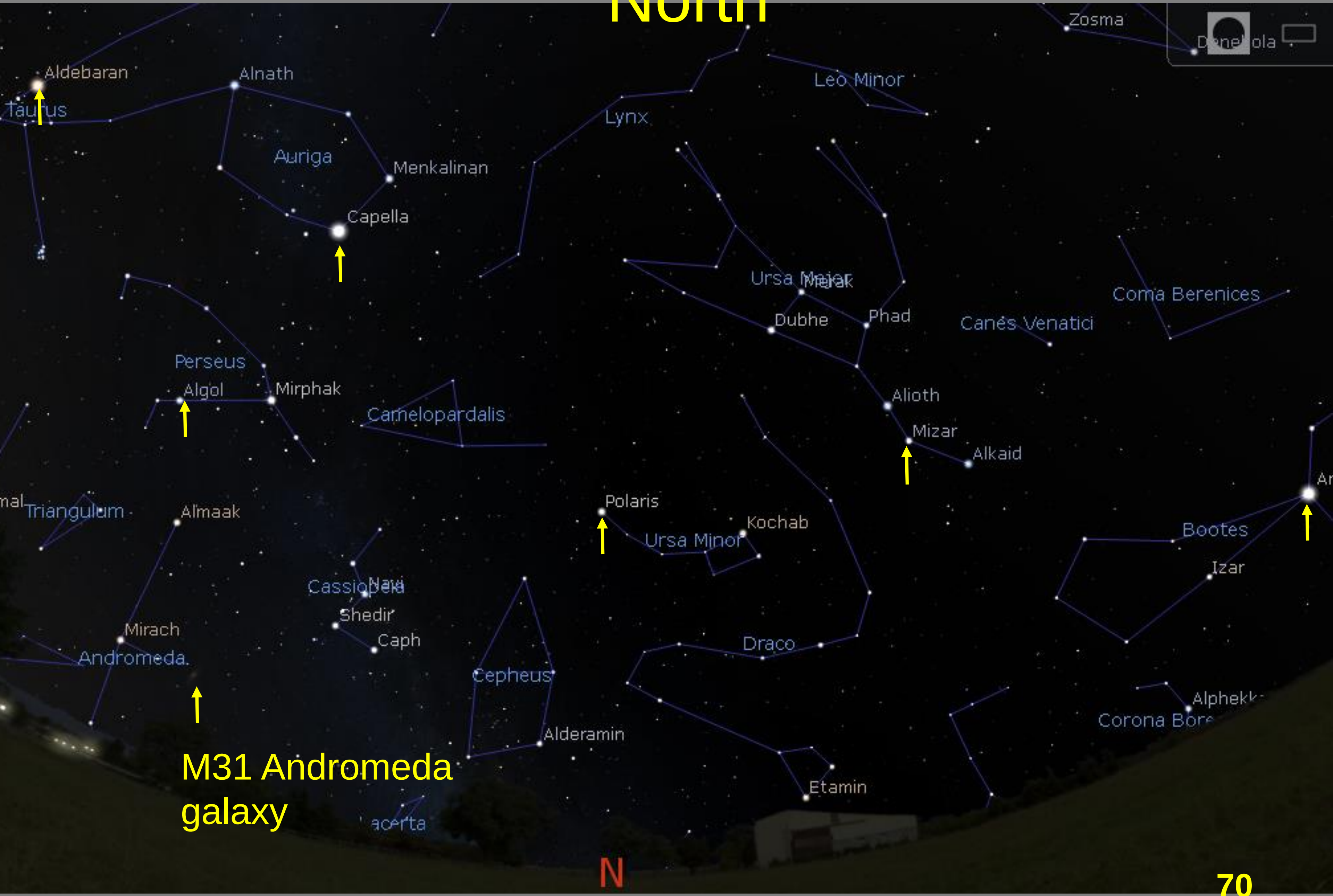
All sky (South at bottom)



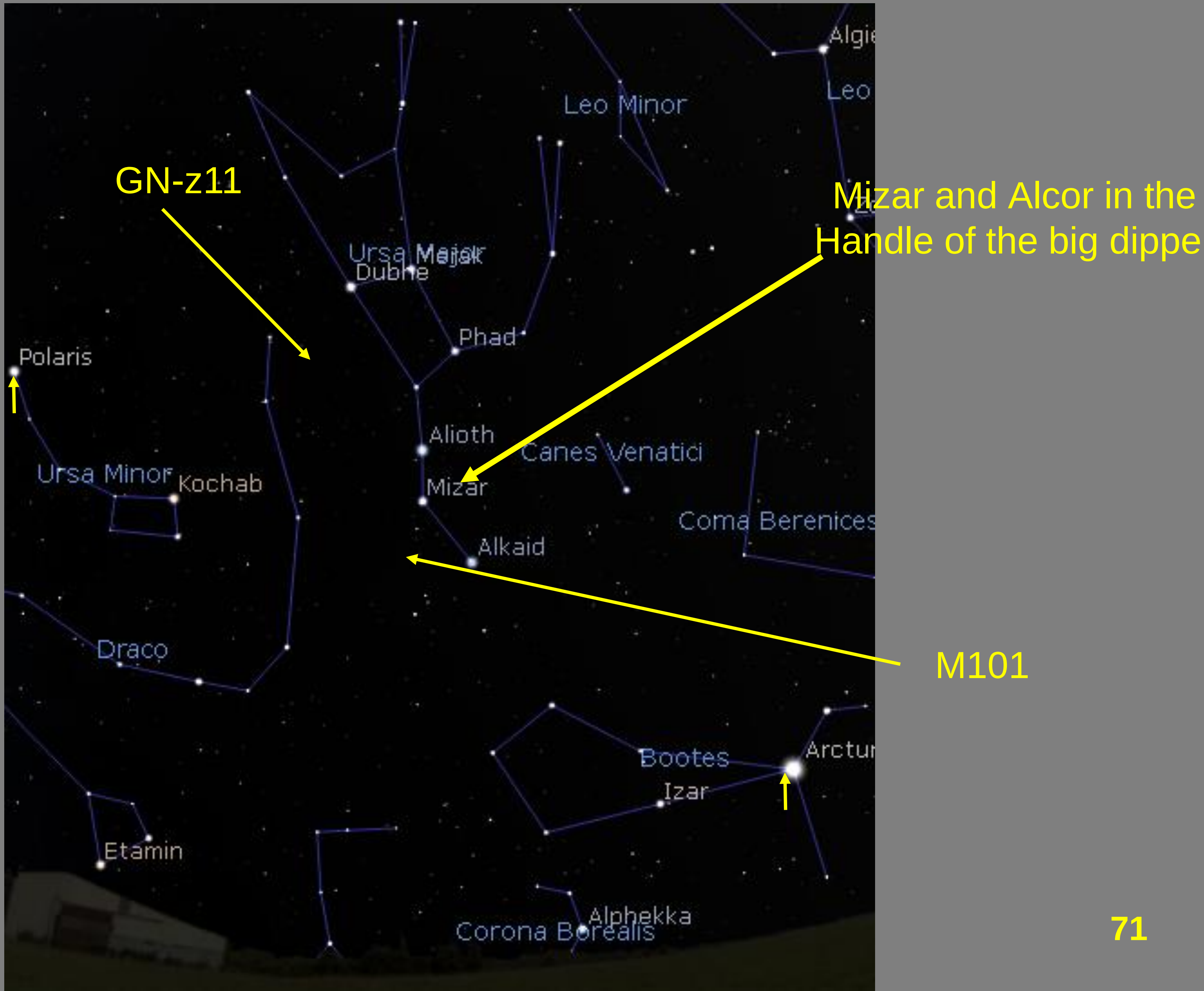
All sky (South at bottom)

Constellations now shown

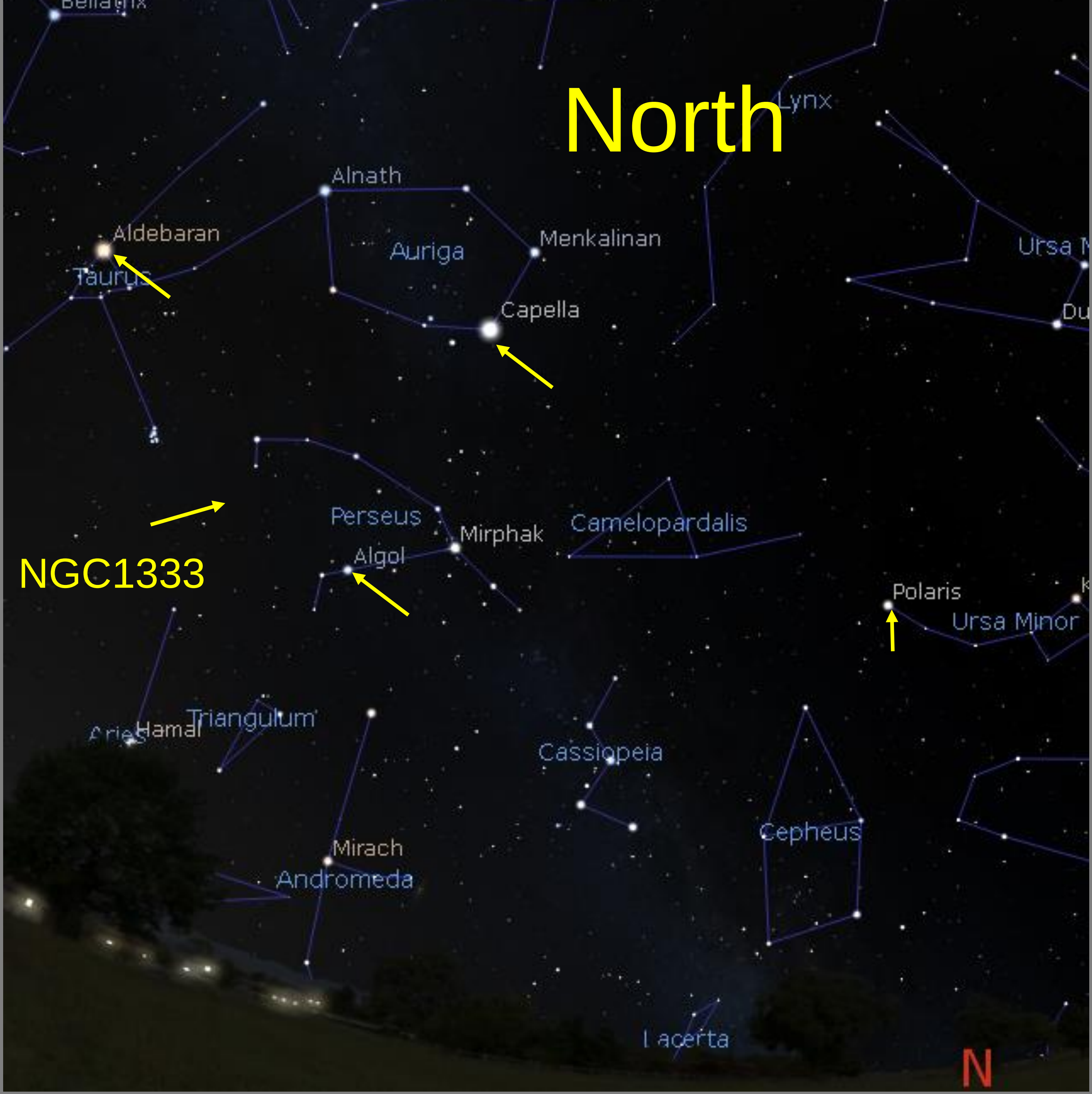
North



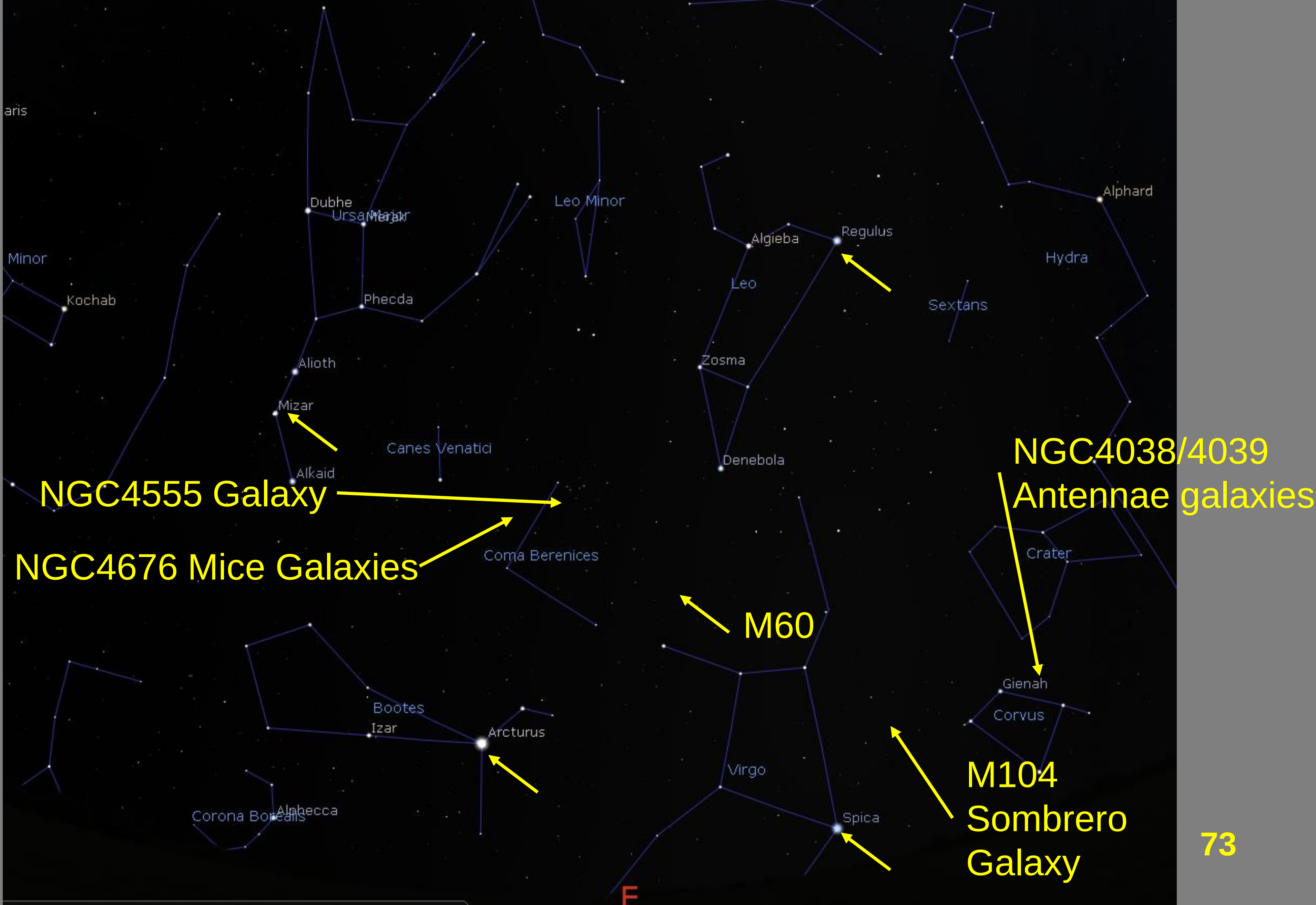
Aldebaran
Taurus
Alnath
Auriga
Menkalinan
Capella
Lynx
Leo Minor
Zosma
Denebola
Ursa Major
Merak
Dubhe
Phad
Coma Berenices
Canes Venatici
Perseus
Algol
Mirphak
Camelopardalis
Alioth
Mizar
Alkaid
Triangulum
Almaak
Polaris
Kochab
Ursa Minor
Bootes
Izar
Cassiopeia
Navi
Shedir
Caph
Mirach
Andromeda
Draco
Cepheus
Alderamin
Alphekka
Corona Borealis
Etamin
Lacerta
N
M31 Andromeda galaxy



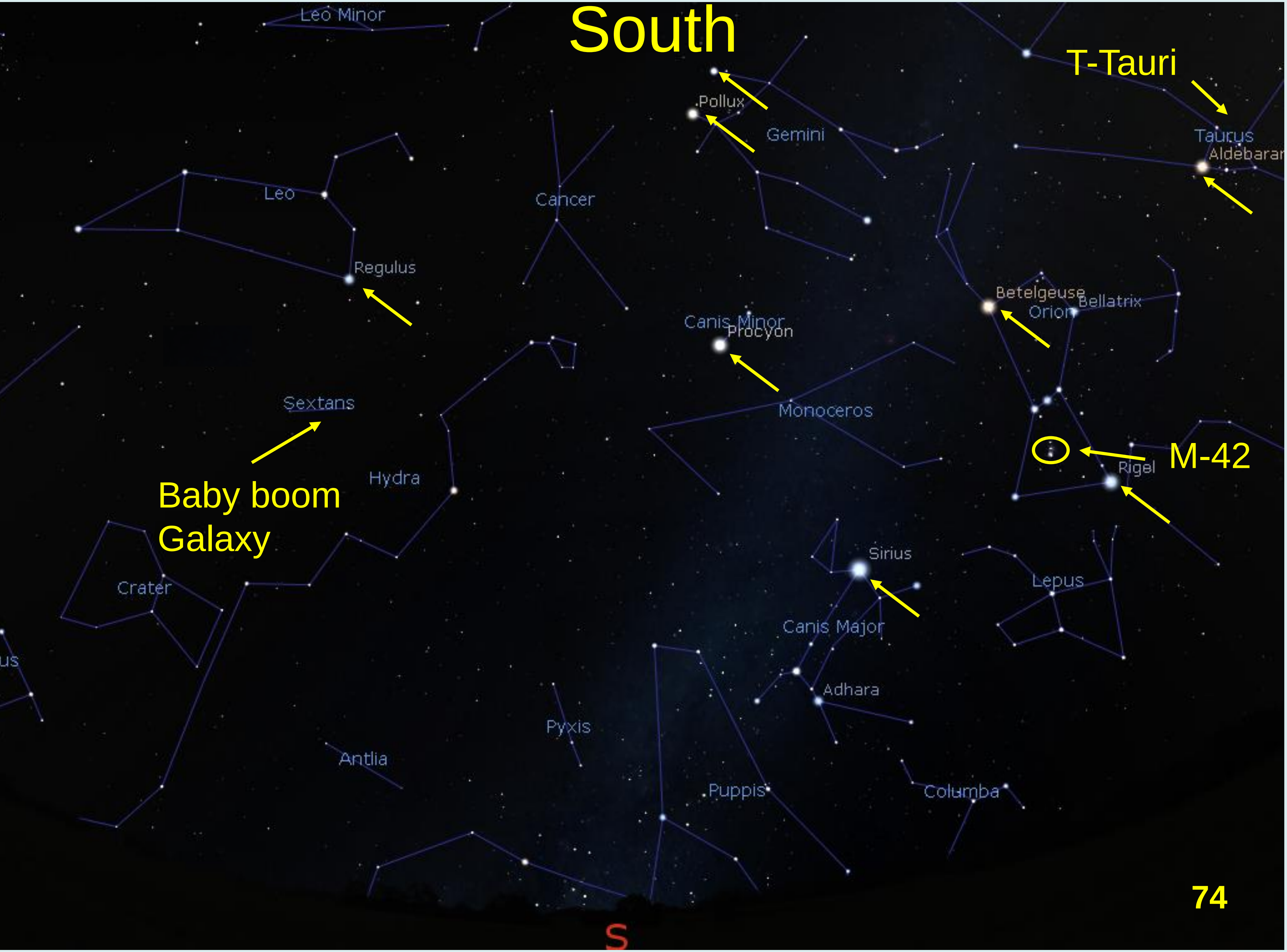
GN-z11
Mizar and Alcor in the Handle of the big dipper
M101
Leo Minor
Leo
Ursa Major
Dubhe
Merak
Phad
Polaris
Alioth
Canes Venatici
Mizar
Ursa Minor
Kochab
Coma Berenices
Alkaid
Draco
Bootes
Izar
Etamin
Alphekka
Corona Borealis


North
Lynx
Alnath
Aldebaran
Taurus
Auriga
Menkalinan
Capella
Ursa M
Du
Perseus
Mirphak
Camelopardalis
Algol
NGC1333
Polaris
Ursa Minor
Triangulum
Aries
Hamal
Cassiopeia
Cepheus
Mirach
Andromeda
Lacerta
N

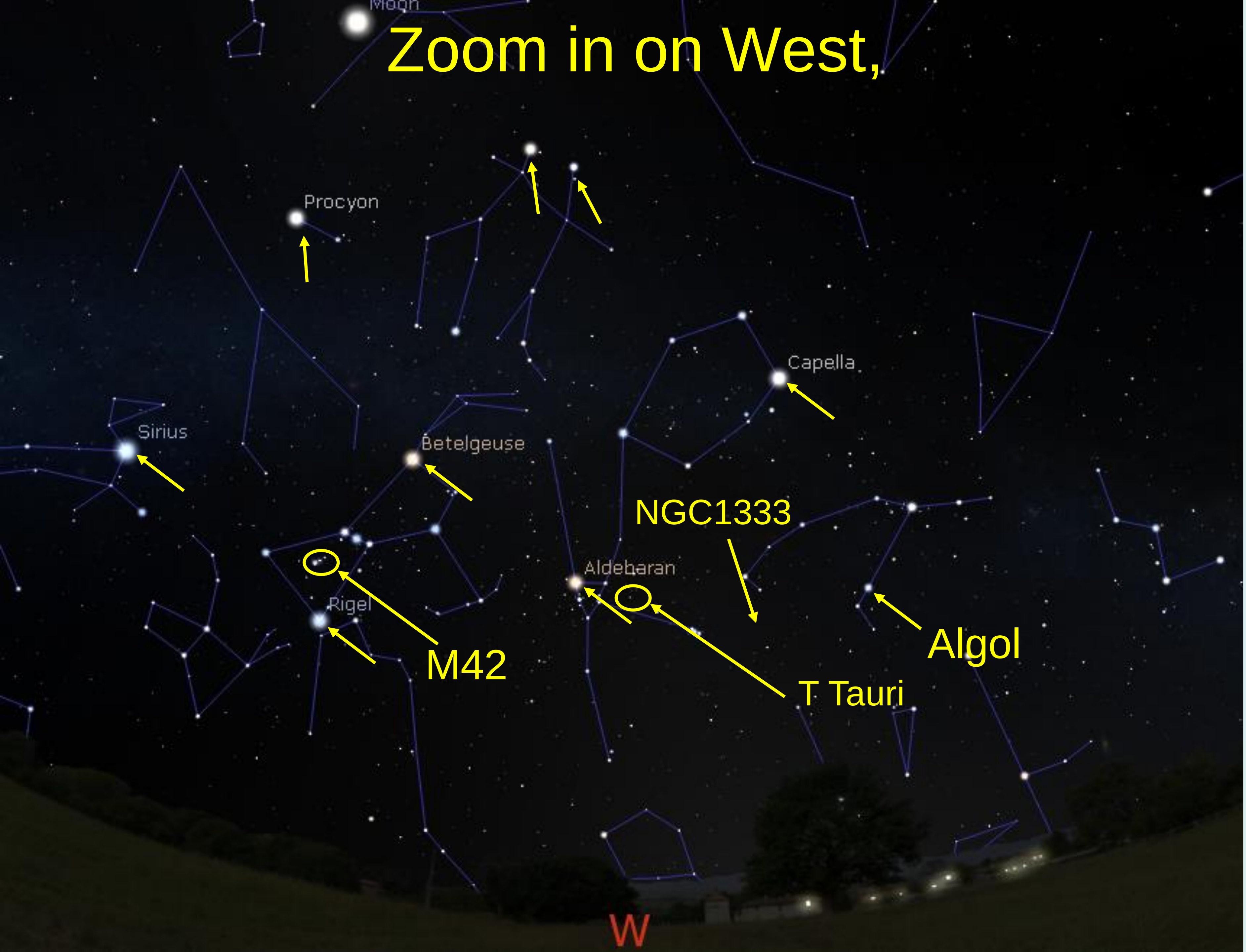
East


Lynx
Cancer
aris
Dubhe
Ursa Major
Merak
Leo Minor
Algieba
Regulus
Alphard
Minor
Kochab
Phecda
Leo
Hydra
Sextans
Alioth
Zosma
Mizar
Canes Venatici
Denebola
NGC4038/4039
Antennae galaxies
Alkaid
NGC4555 Galaxy
NGC4676 Mice Galaxies
Coma Berenices
Crater
M60
Gienah
Bootes
Corvus
Izar
Arcturus
M104
Sombrero
Galaxy
Virgo
Corona Borealis
Alphecca
Spica
E

South


Leo Minor
Pollux
Gemini
T-Tauri
Taurus
Aldebaran
Leo
Cancer
Regulus
Betelgeuse
Bellatrix
Orion
Canis Minor
Procyon
Monoceros
Sextans
M-42
Rigel
Hydra
Baby boom
Galaxy
Sirius
Lepus
Crater
Canis Major
Adhara
Pyxis
Antlia
Puppis
Columba
S

Zoom in on West,



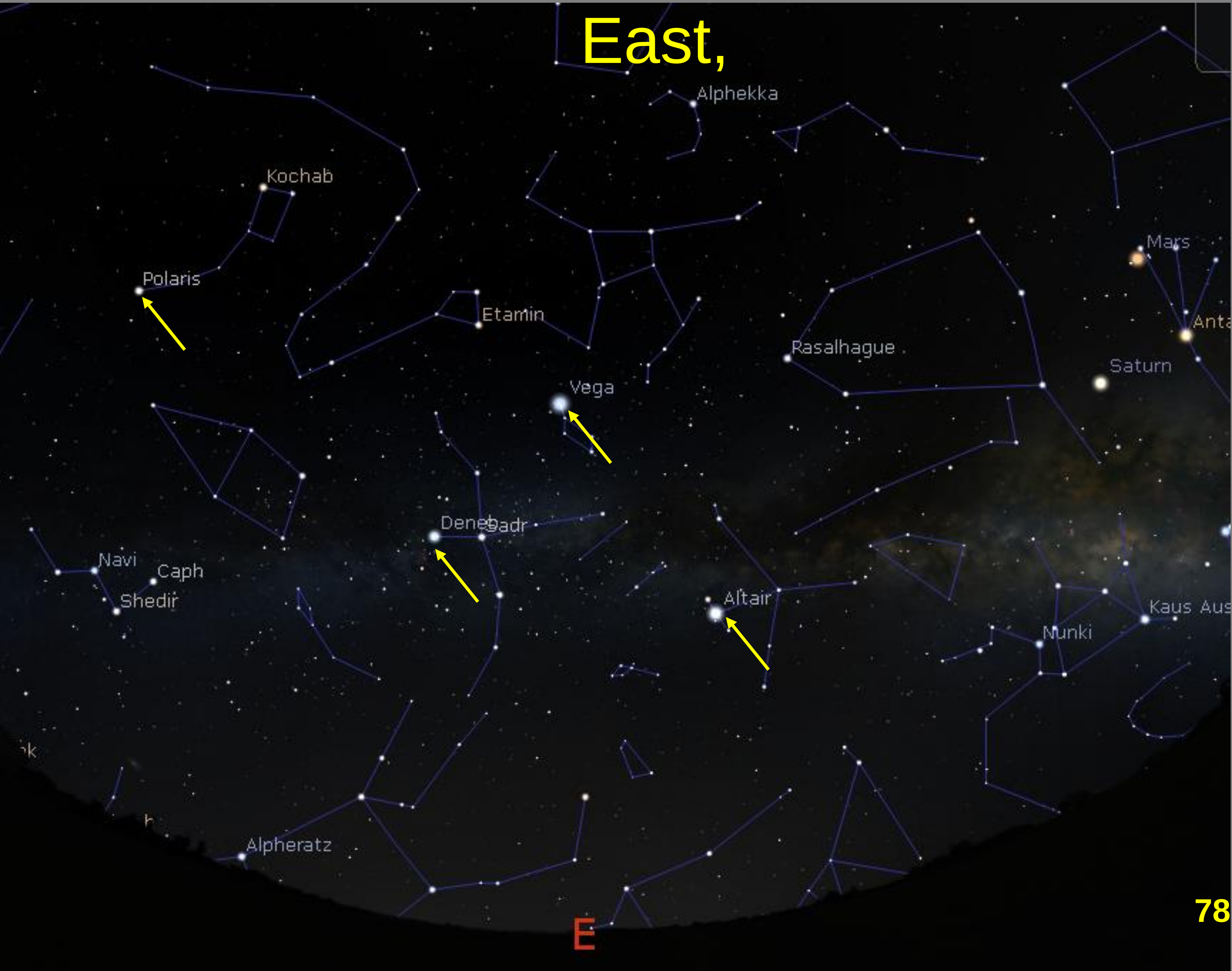
Star Charts

~5:00 am in the morning of the day before the competition in Dover Delaware

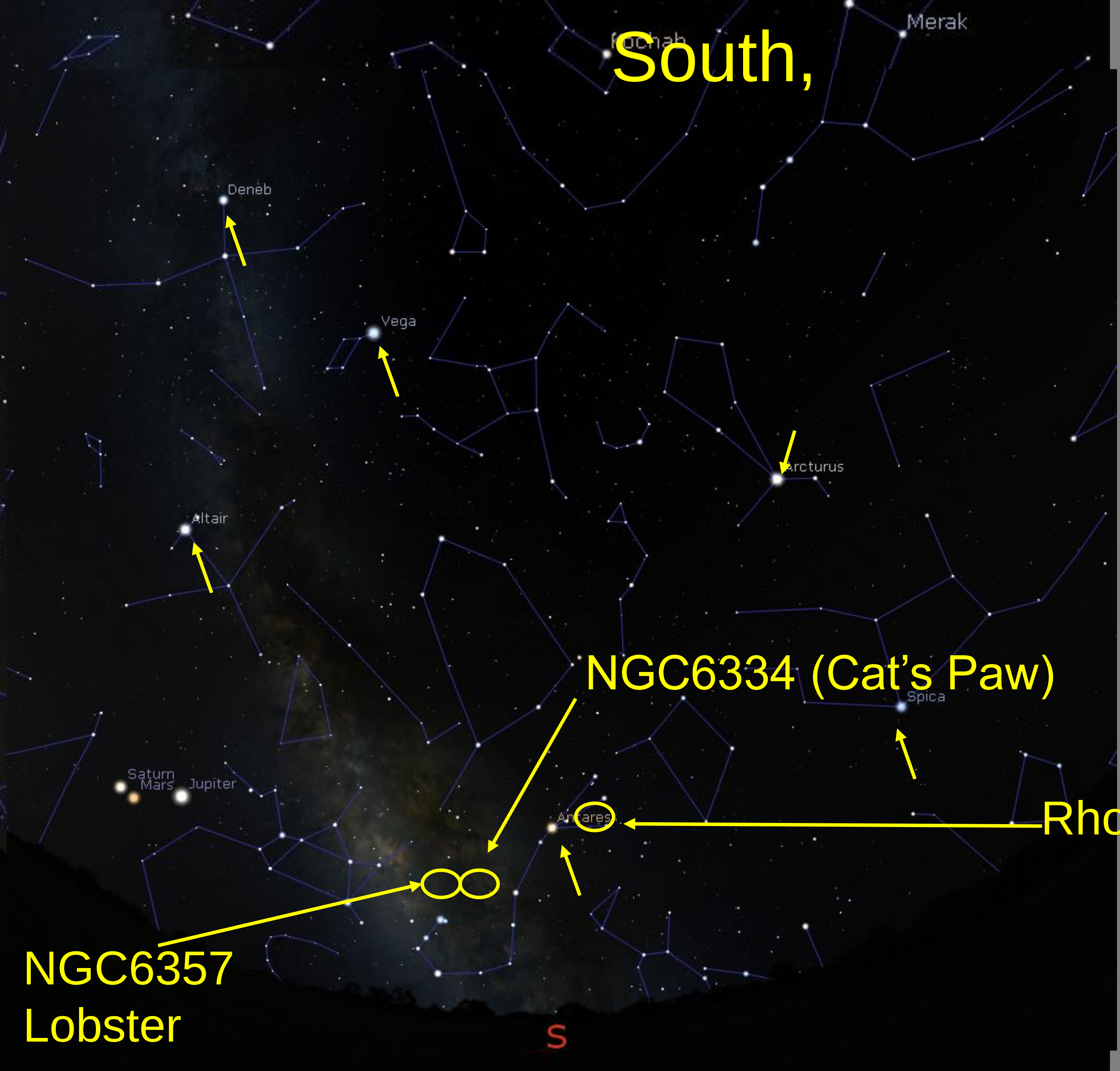
North,


Vega
Etamin
Sadr
Alkaid
Mizar
Deneb
Alioth
Kochab
Merak
Dubhe
Polaris
Caph
Navi
Shedir
N

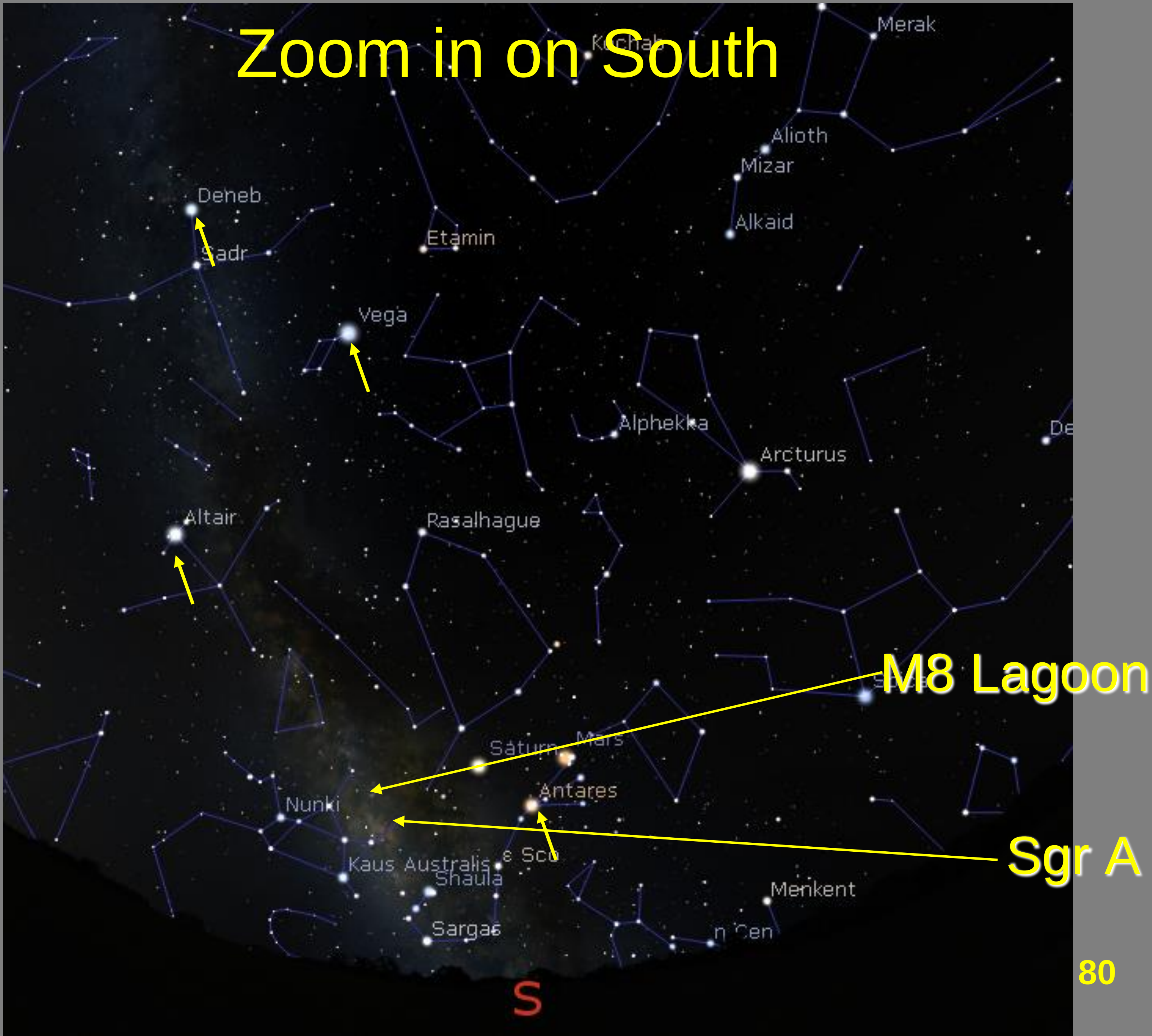
East,


Alphekka
Kochab
Polaris
Etamin
Mars
Rasalhague
Saturn
Vega
Deneb
Sadr
Navi
Caph
Shedir
Altair
Nunki
Alpheratz
E

South,


Merak
Deneb
Vega
Arcturus
Altair
NGC6334 (Cat's Paw)
Spica
Saturn
Mars
Jupiter
Antares
Rho Ophiuchi
NGC6357
Lobster
S

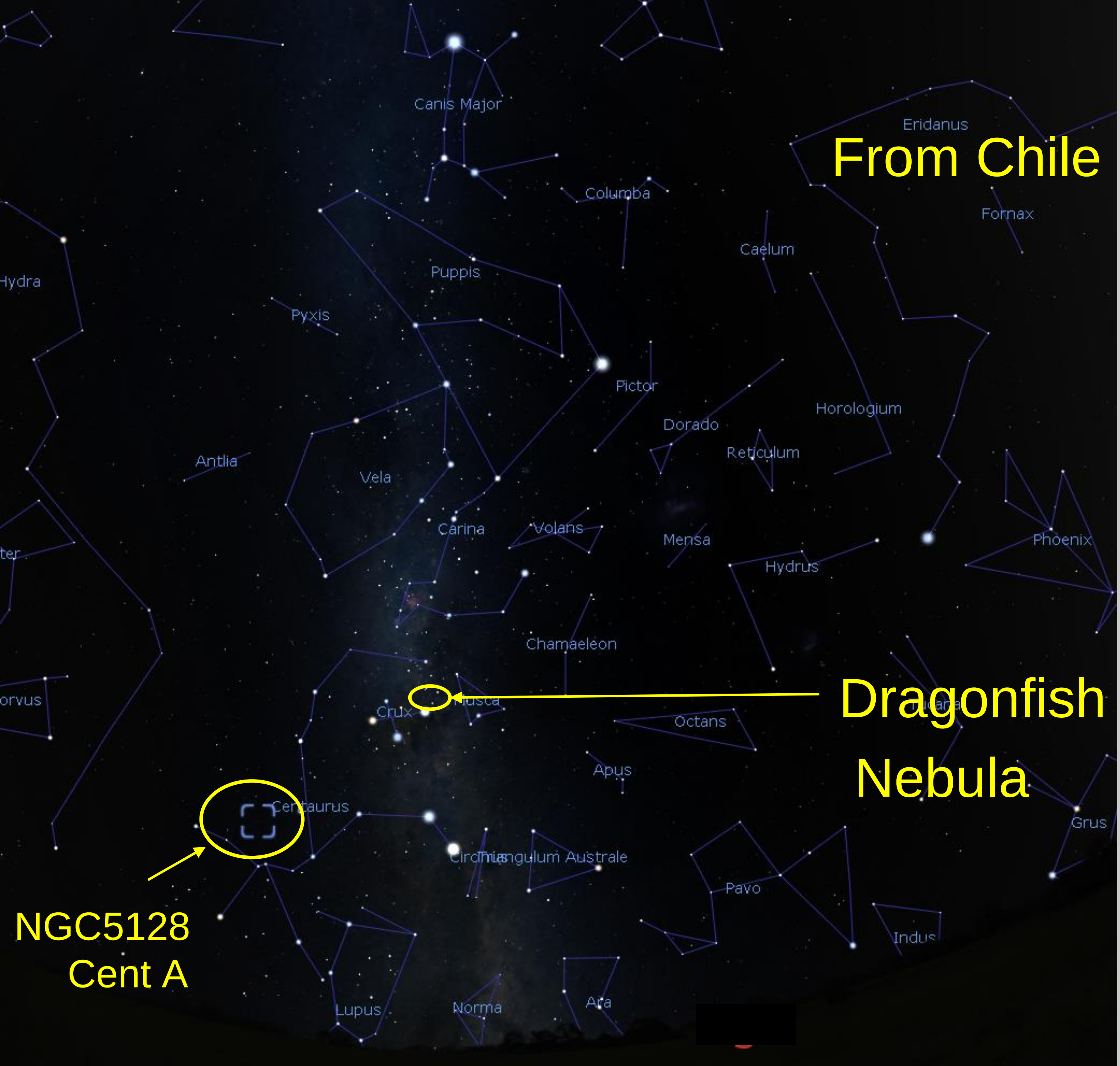
Zoom in on South



From Chile

Large Magellanic cloud (LMC) with 30 Doradus

Small Magellanic cloud (SMC)


From Chile
Dragonfish
Nebula
NGC5128
Cent A
Canis Major
Eridanus
Columba
Fornax
Caelum
Hydra
Puppis
Pyxis
Pictor
Horologium
Dorado
Reticulum
Antlia
Vela
Carina
Volans
Mensa
Phoenix
Hydrus
Chamaeleon
Crux
Octans
Apus
Centaurus
Grus
Triangulum Australe
Pavo
Indus
Lupus
Norma
Ara