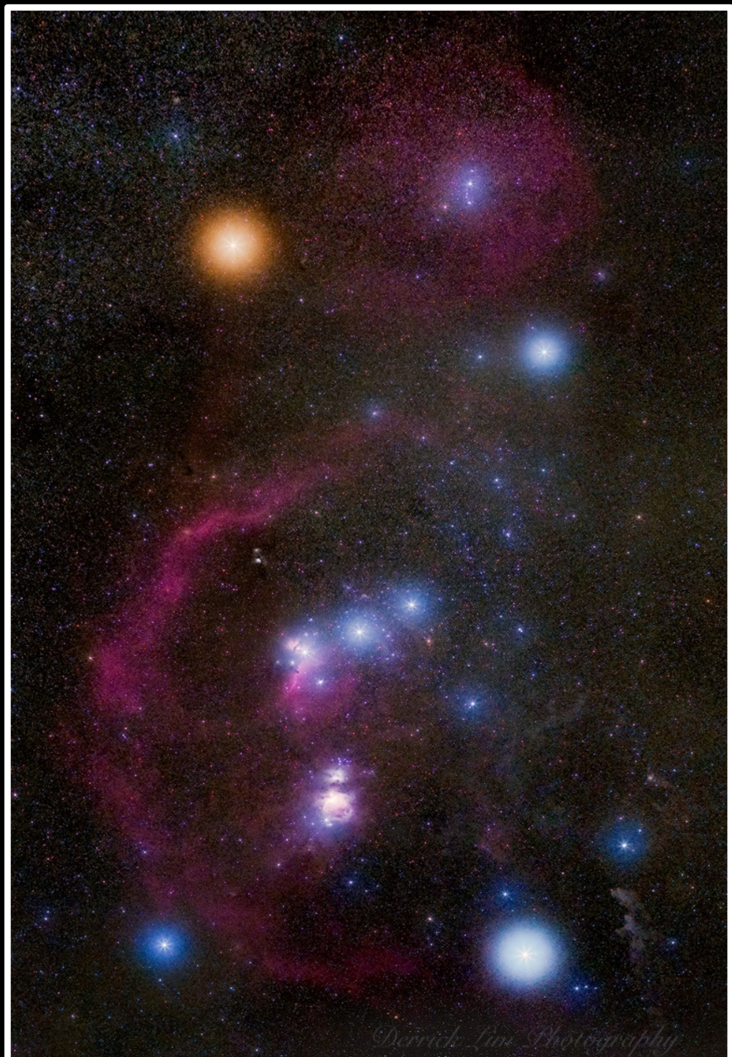
National Science Olympiad

Reach for the Stars B Event 2020

Properties and Evolution of Stars & Galaxies



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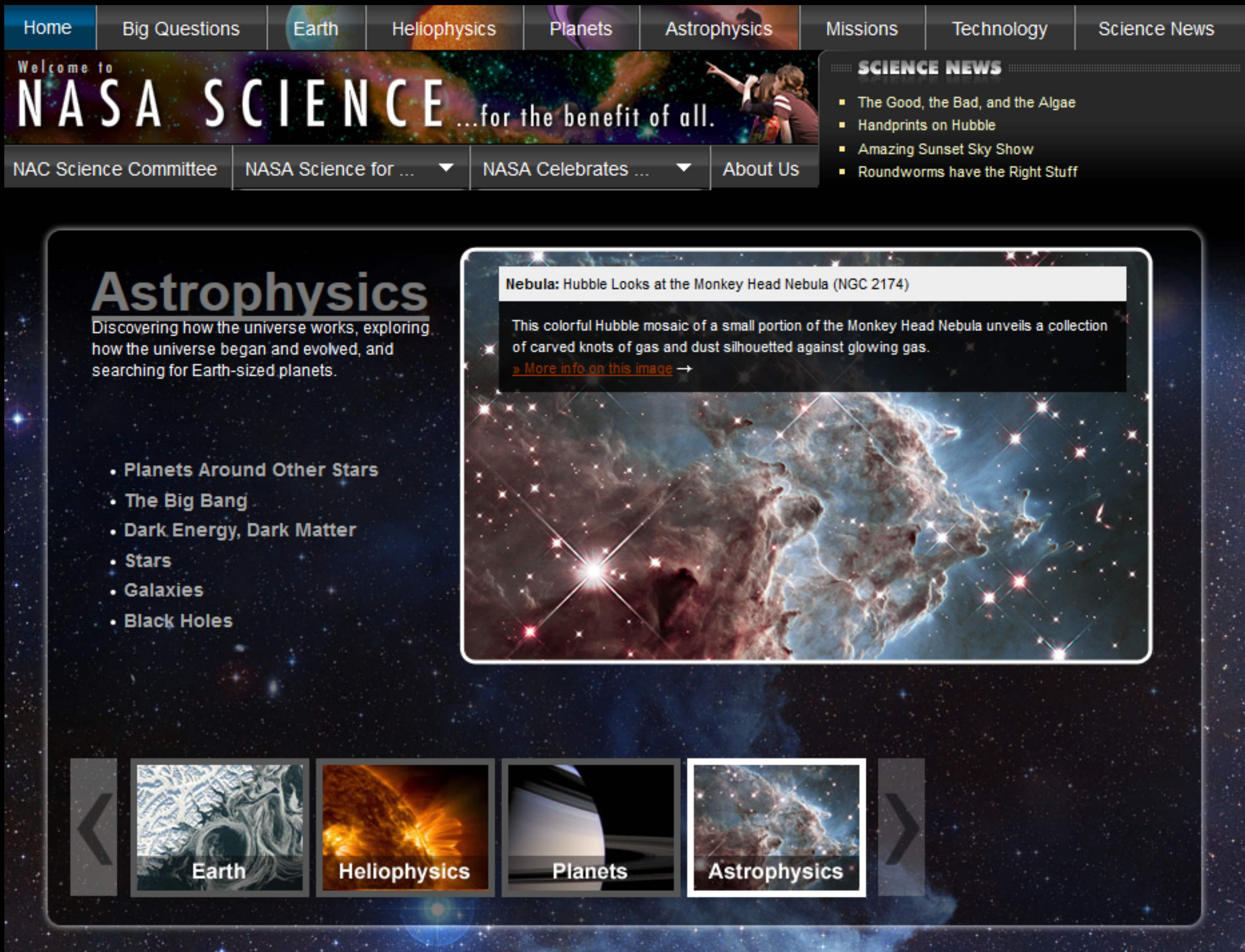
NASA Astrophysics Division/Chandra/NSO

Supported by the NASA Universe of Learning STEM Literacy Network



Chandra X-Ray Observatory

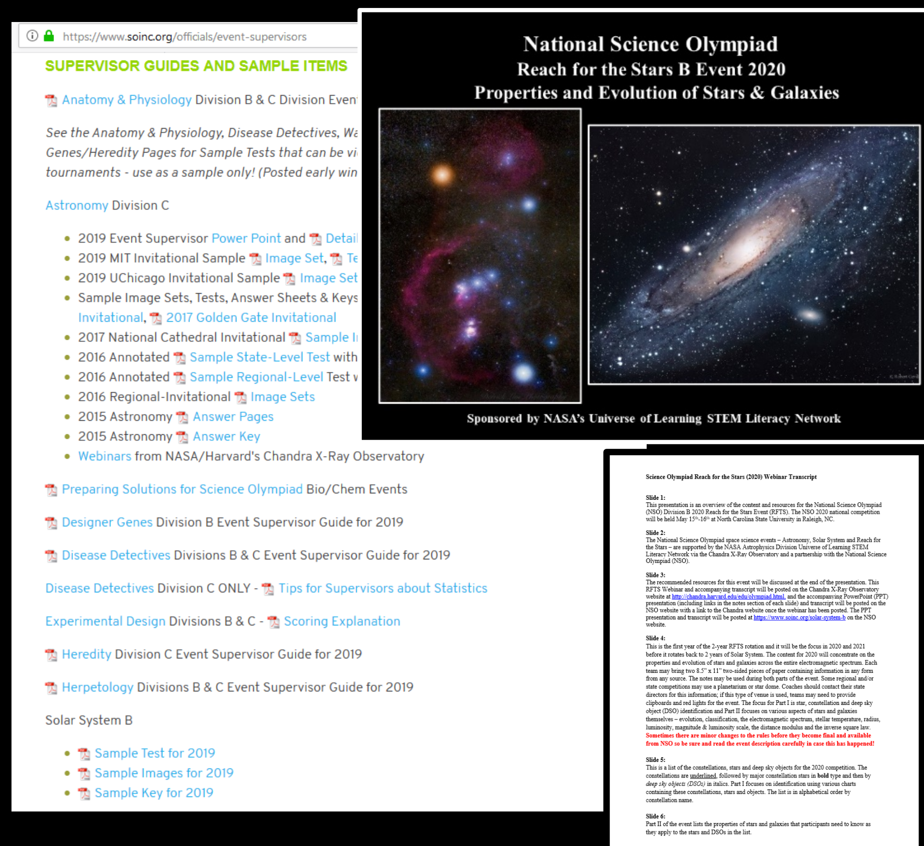
chandra.si.edu/edu/olympiad.html

Astronomy Event Supervisor 2019

Stellar Evolution 101 for National Science Olympiad Coaches and Teams Webinar.

National Science Olympiad Astronomy Event - 2019.

National Science Olympiad Solar System Event - 2019.



The "A-Team"

A group of 35 (and counting) Science Olympiad alumni & educators that work with the NASA Universe of Learning team to develop events

We attend and write events for invitationals, regionals, states, and national competitions for both Astronomy and Reach for the Stars

If you need help with space events for your competition, please contact me (tkomacek@uchicago.edu) and I'll see what the A-team can do!

REACH FOR THE STARS, Division B

DESCRIPTION: Students will demonstrate an understanding of the properties and evolution of stars and galaxies, and their observation with different portions of the electromagnetic spectrum: Radio, Infrared, Visible, Ultraviolet, X-Ray & Gamma Ray.

EVENT PARAMETERS: Each team may bring only two 8.5"x11" two-sided pages of information in any form from any source and **may be asked** to provide clipboards and red-filtered flashlights.

THE COMPETITION: This event is divided into two parts. **Notes may be used** during both parts.

Part I: Constellation, Star, and Deep Sky Object Identification
Participants **may** be asked to identify the stars, constellations, and deep sky objects (DSOs) included in the list below as they appear on star chars, H-R diagrams, portable star labs, photos, or planetariums, and **must** be knowledgeable about the evolutionary states of all stars and deep sky objects on the list below. Note: Constellations are underlined; **Stars** are boldface; *Deep Sky Objects (DSOs)* are italicized

Part I: Constellations, Stars, and Deep Sky Objects

<u>Andromeda</u>: *M31(Andromeda Galaxy)*
<u>Aquila</u>: **Altair**
<u>Auriga</u>: **Capella**
<u>Bootes</u>: **Arcturus**
<u>Canis Major</u>: **Sirius**
<u>Canis Minor</u>: **Procyon**
<u>Centaurus</u>: *NGC 5128 (Cen A)*
<u>Coma Berenices</u>: *NGC 4555, NGC 4676 (The Mice)*
<u>Corvus</u>: *NGC 4038 & 4039 (Antennae)*
<u>Crux</u>: *Dragonfish Nebula*
<u>Cygnus</u>: **Deneb**
<u>Dorado</u>: *30 Doradus (Tarantula Nebula), Large Magellanic Cloud (LMC)*
<u>Gemini</u>: **Castor, Pollux**
<u>Lyra</u>: **Vega**
<u>Ophiuchus</u>: **Zeta Ophiuchi** *Rho Ophiuchi Cloud Complex*
<u>Orion</u>: **Betelgeuse, Rigel** *M42 (Orion Nebula)*
<u>Perseus</u>: **Algol** *NGC 1333*
<u>Sagittarius</u>: *SgrA*, M8 (Lagoon Nebula)*
<u>Sextans</u>: *J100054+023436 (Baby Boom)*
<u>Scorpius</u>: **Antares** *NGC 6357 (Lobster Nebula), NGC 6334 (Cat's Paw Nebula)*
<u>Taurus</u>: **Aldebaran** *T Tauri*
<u>Tucana</u>: *Small Magellanic Cloud (SMC)*
<u>Ursa Major</u>: **Mizar, Alcor** *GN-z11, M101 (Pinwheel Galaxy)*
<u>Ursa Minor</u>: **Polaris**
<u>Virgo</u>: **Spica** *M60, M104 (Sombrero Galaxy)*

REACH FOR THE STARS, Division B

DESCRIPTION: Students will demonstrate an understanding of the properties and evolution of stars and galaxies, and their observation with different portions of the electromagnetic spectrum: Radio, Infrared, Visible, Ultraviolet, X-Ray & Gamma Ray.

Part II:

- **i:** Stellar and galactic evolution
- **ii:** Spectral classification of stars
- **iii:** Hubble classification of galaxies
- **iv:** Observations using multiple portions of the electromagnetic spectrum
- **v:** The relationship between stellar temperature, radius, and luminosity
- **vi.** Magnitude & luminosity scales, distance modulus, inverse square law

Deep Sky Objects by Type

Stars (19):

Altair, Capella, Arcturus, Sirius, Procyon, Deneb, Castor, Pollux, Vega, Zeta Ophiuchi, Betelgeuse, Rigel, Algol, Antares, Aldebaran, Mizar, Alcor, Polaris, Spica

Galaxies (12):

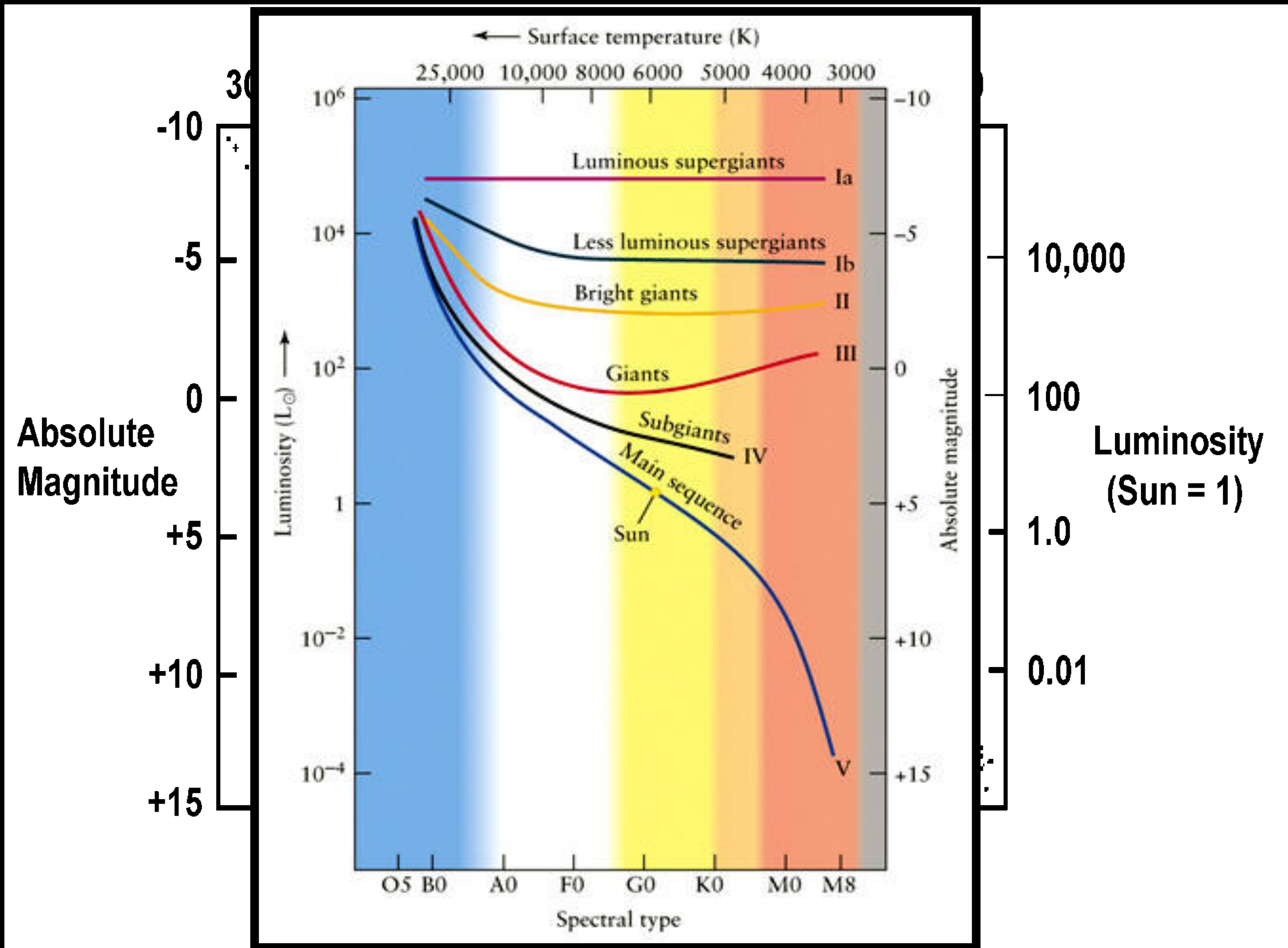
M31 (Andromeda), NGC 5128 (Cen A), GN-z11, M101 (Pinwheel), M104 (Sombrero), LMC, SMC, M60, NGC 4555, NGC 4676 (The Mice), NGC 4038-4039 (Antennae), J100054+023436 (Baby Boom)

Star Formation Nebulas/Regions (8):

30 Doradus, Dragonfish Nebula, rho Ophiuchi Cloud Complex, M42 (Orion Nebula), NGC 1333 (star cluster), M8 (Lagoon Nebula), NGC 6357 The Lobster Nebula, NGC 6334 (Cat's Paw Nebula)

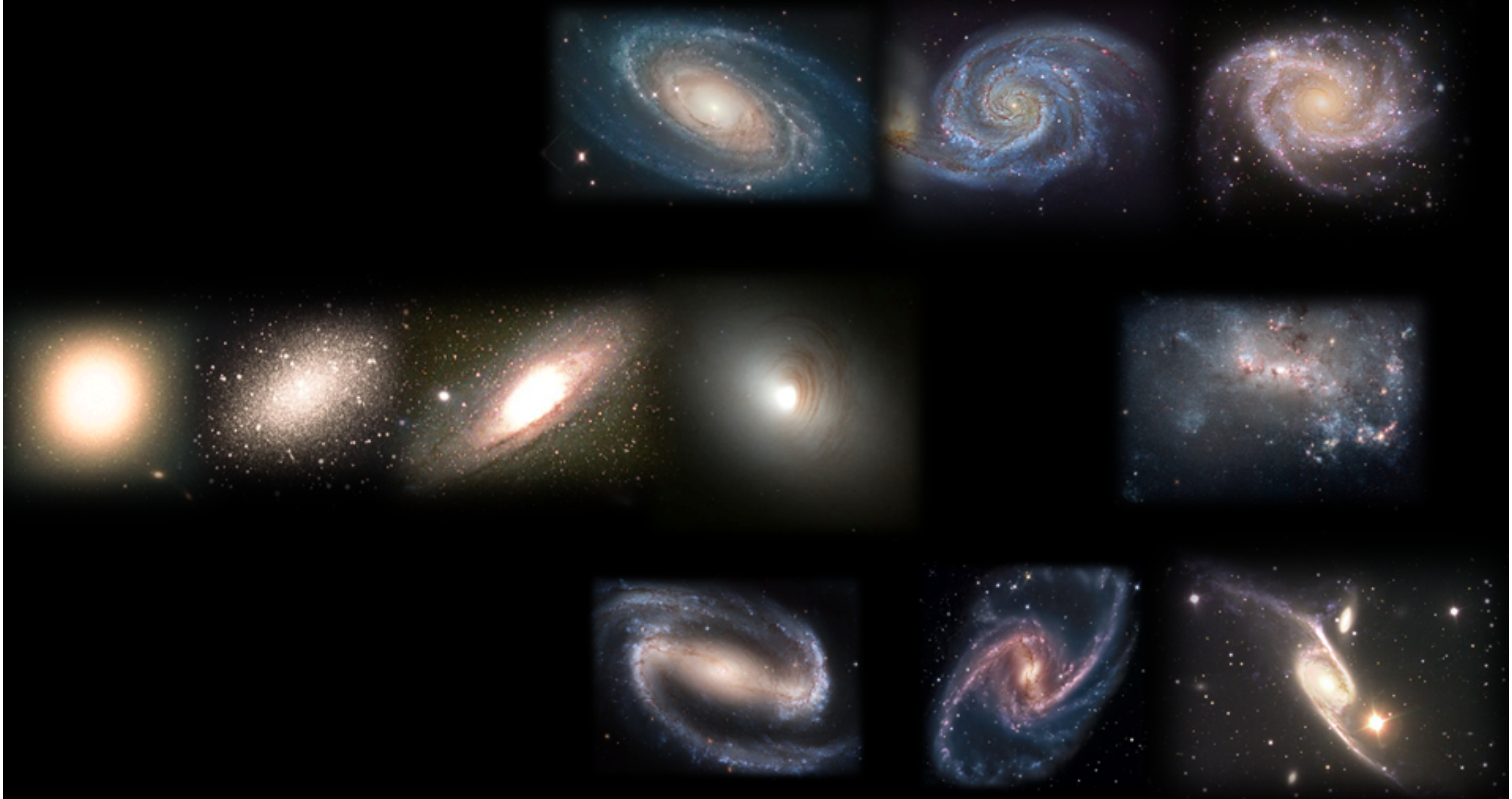
Others: Sgr A*: black hole at center of Milky Way Galaxy (MWG)
T Tauri: protostar

Stellar Evolution & H-R Diagram Overview

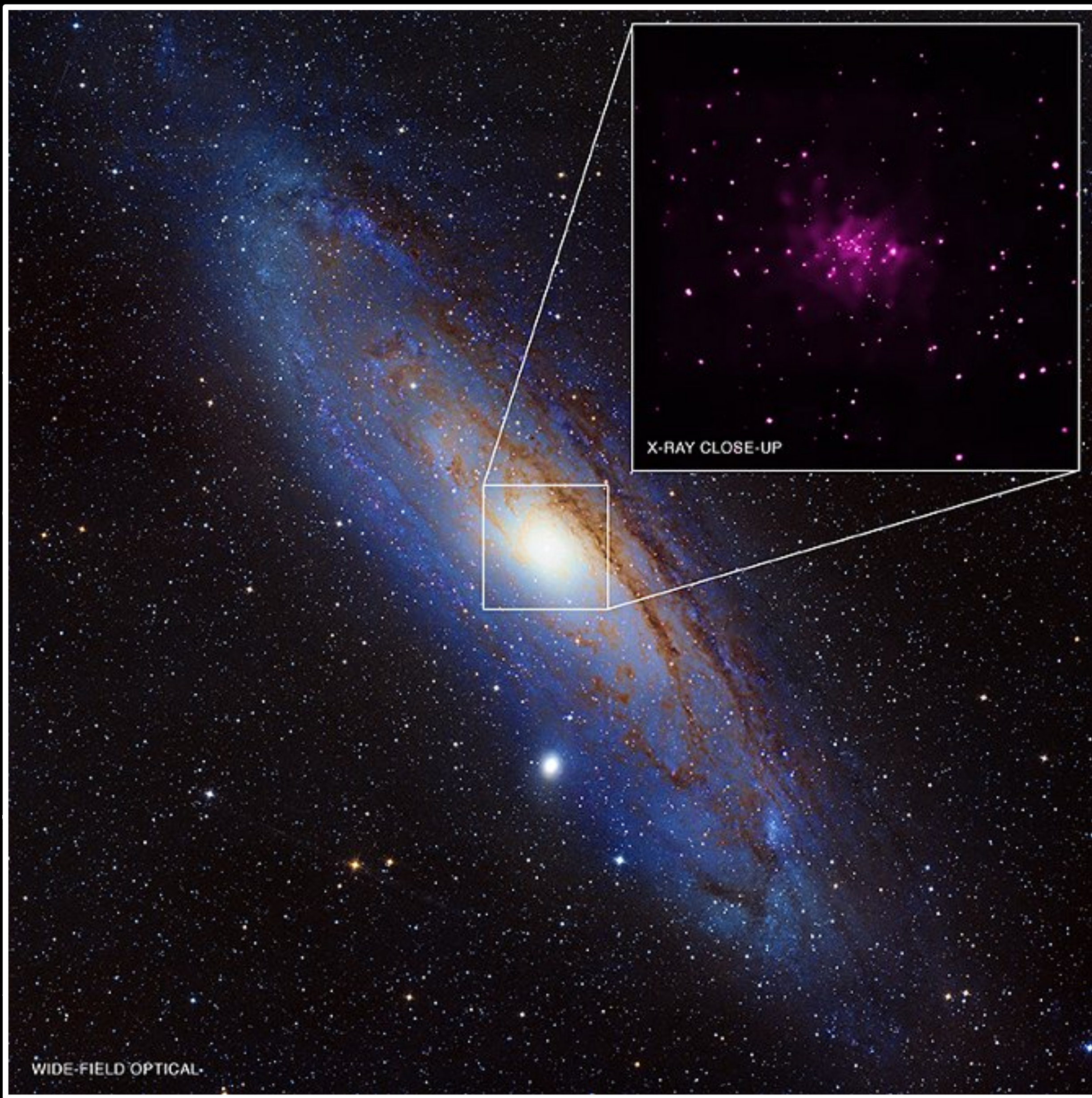


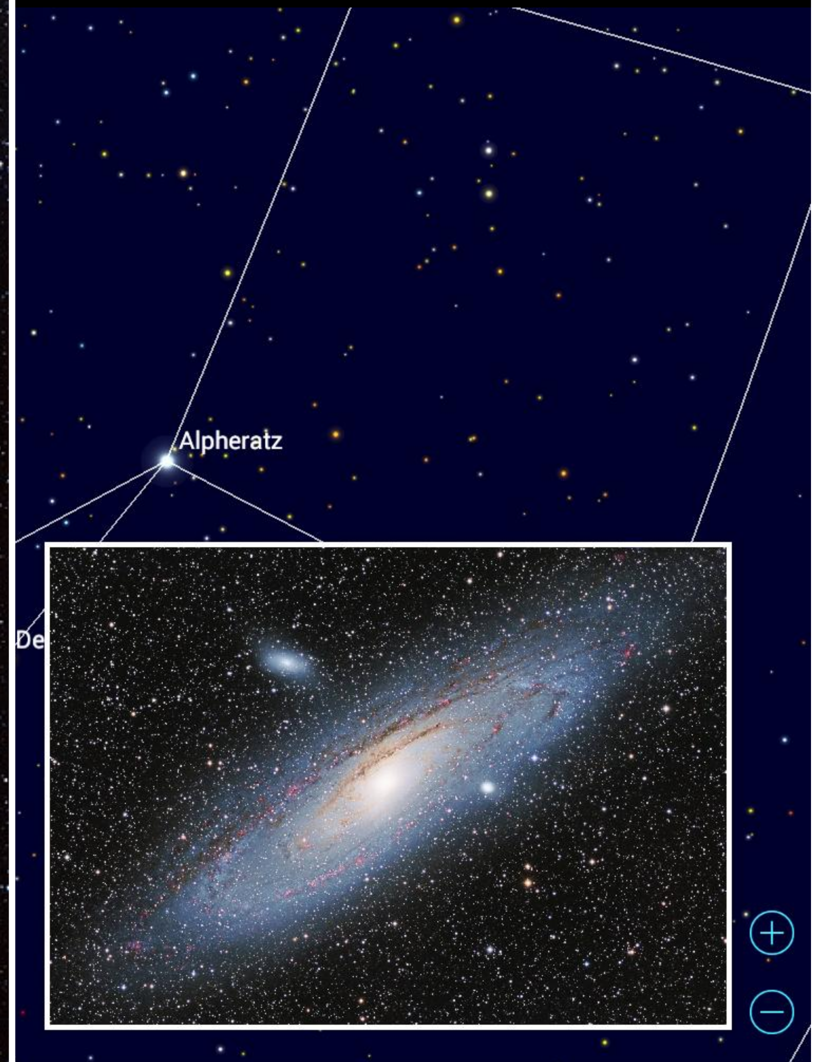
The Hubble Classification of Galaxies

Spirals, Ellipticals, Lenticular and Irregular

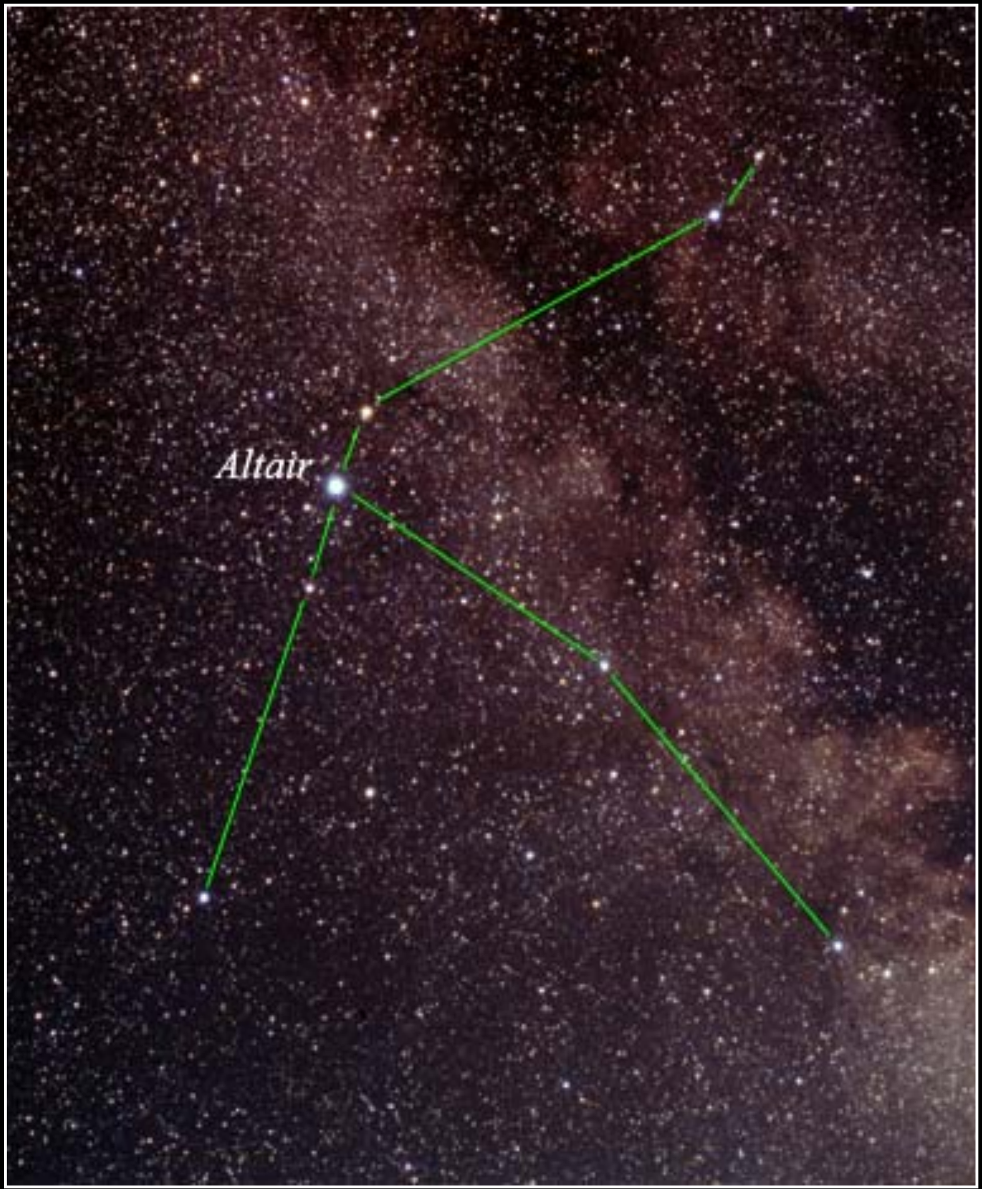


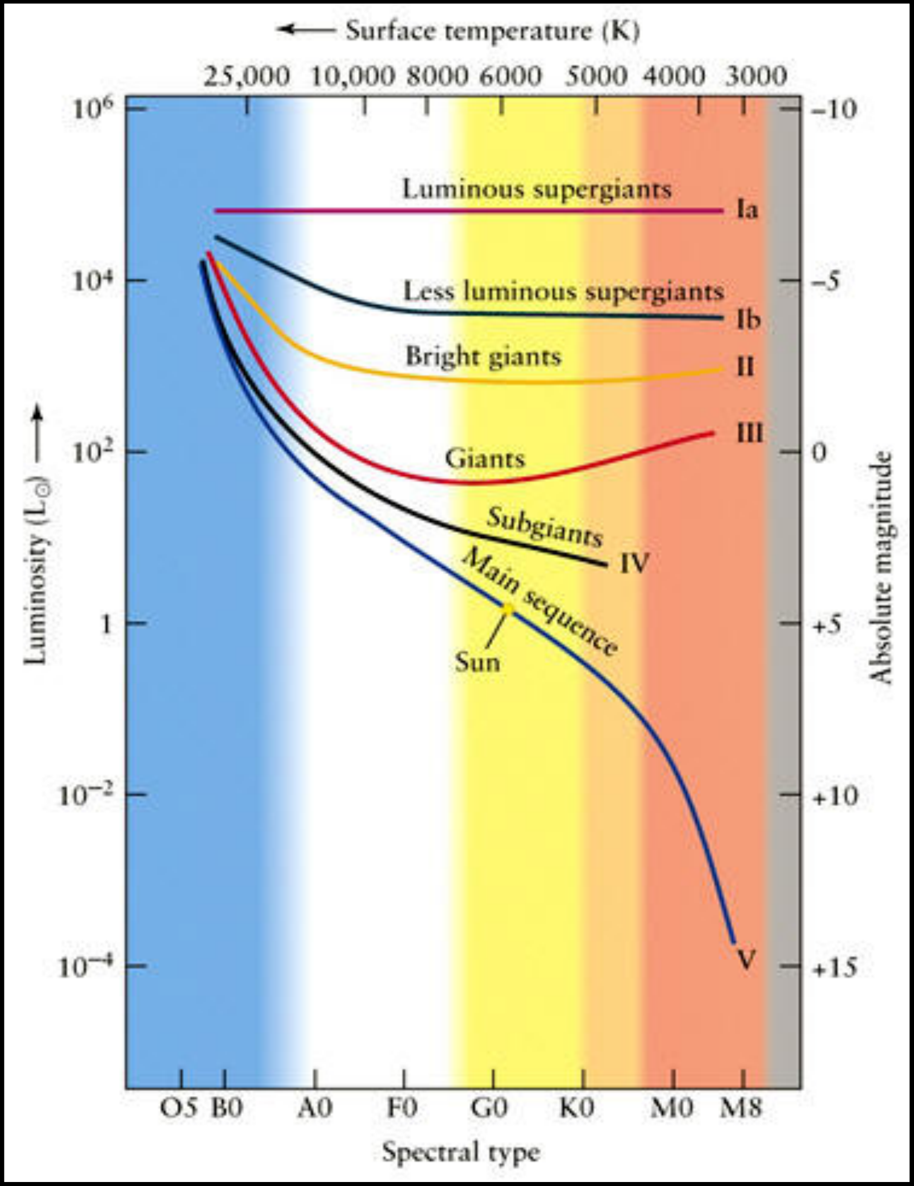
The Andromeda Constellation & Galaxy (M31)



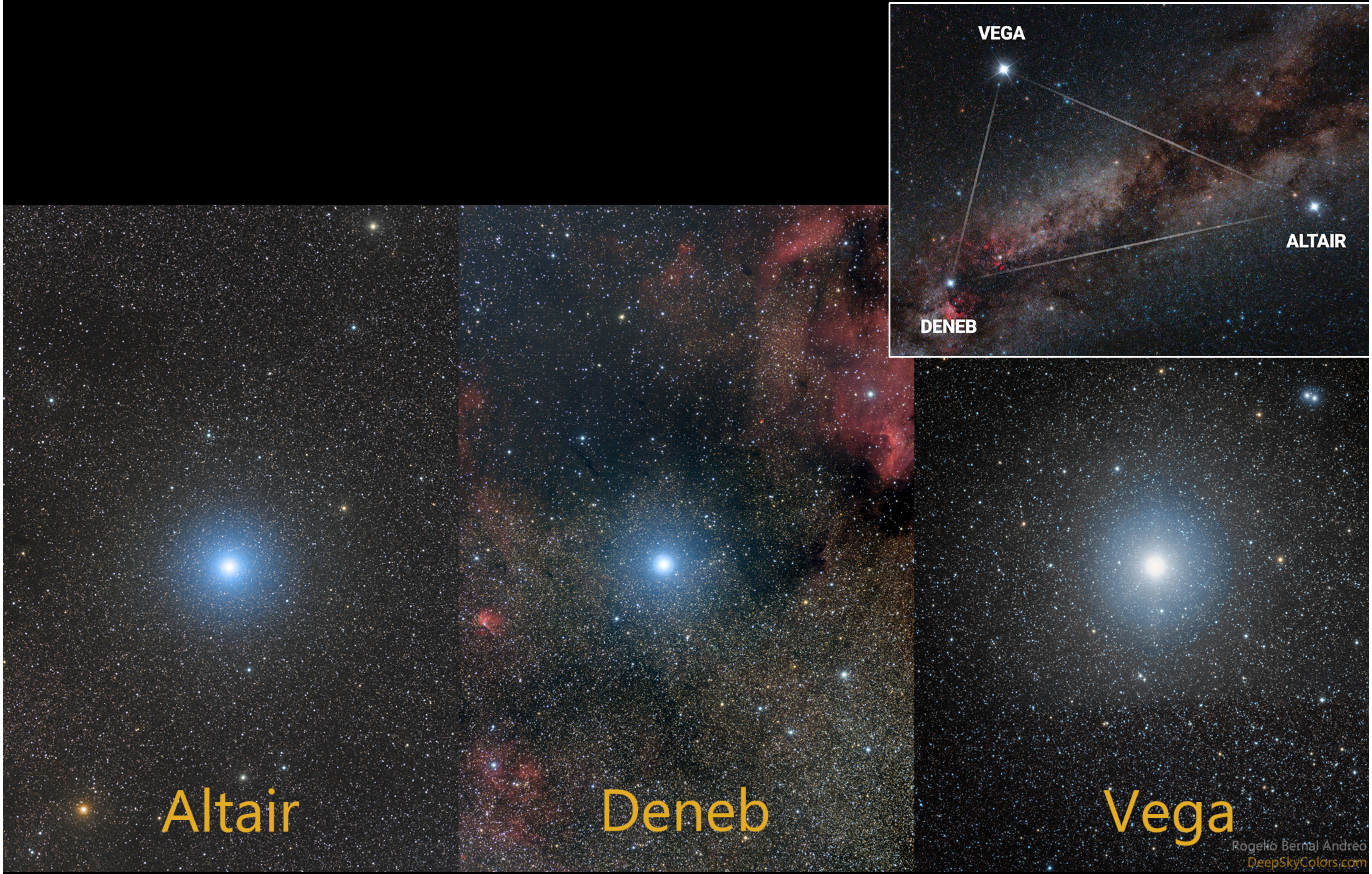


Aquila: Altair (A7IV/V)

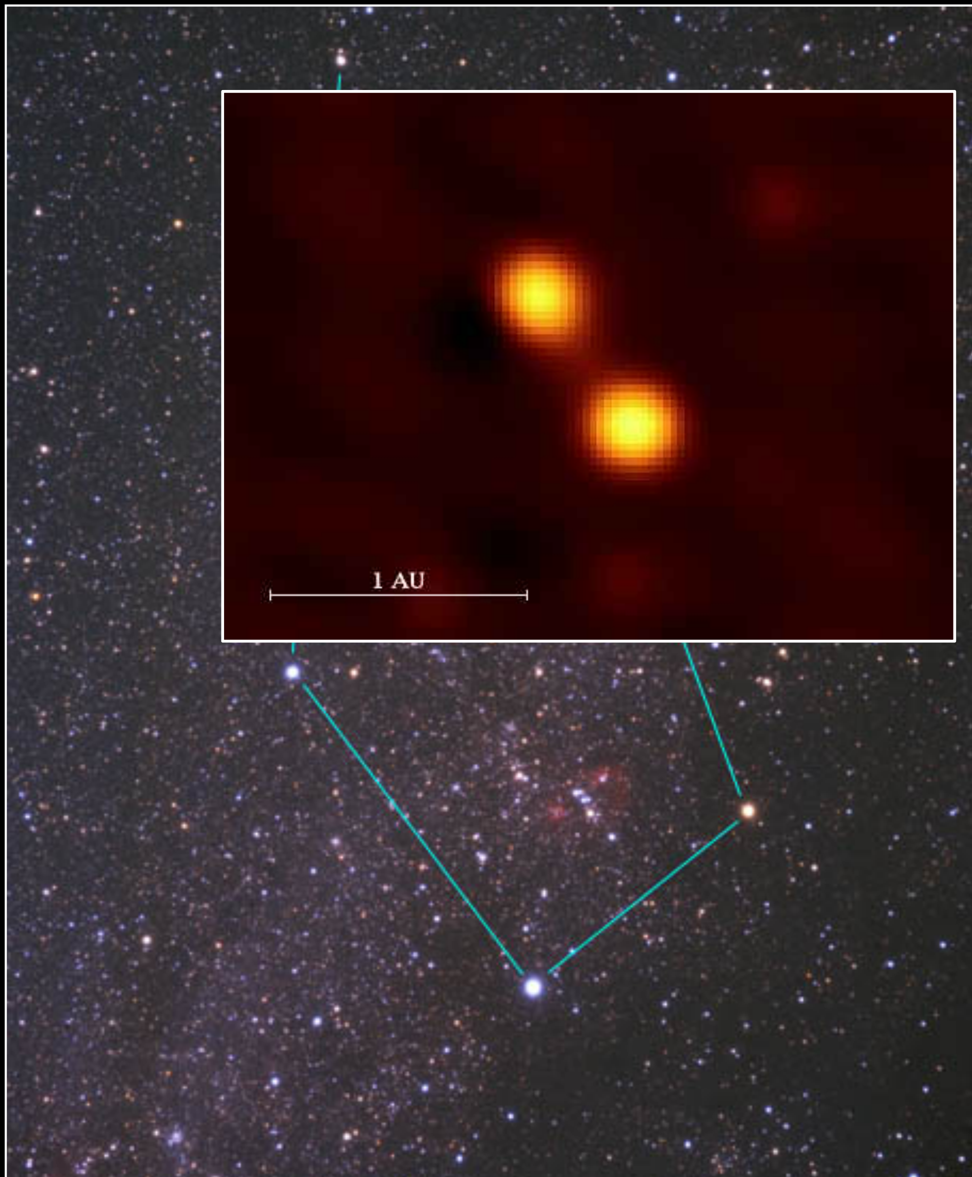


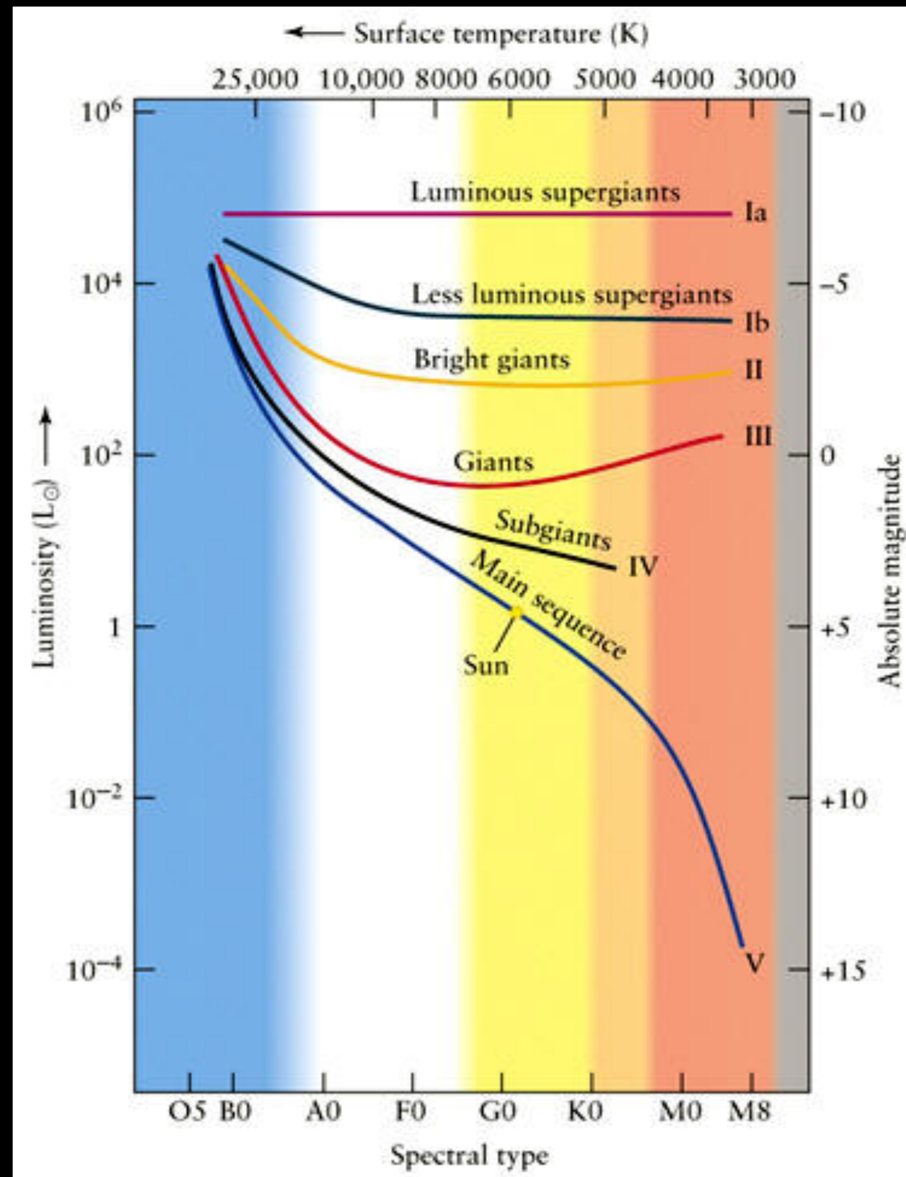


The Summer Triangle

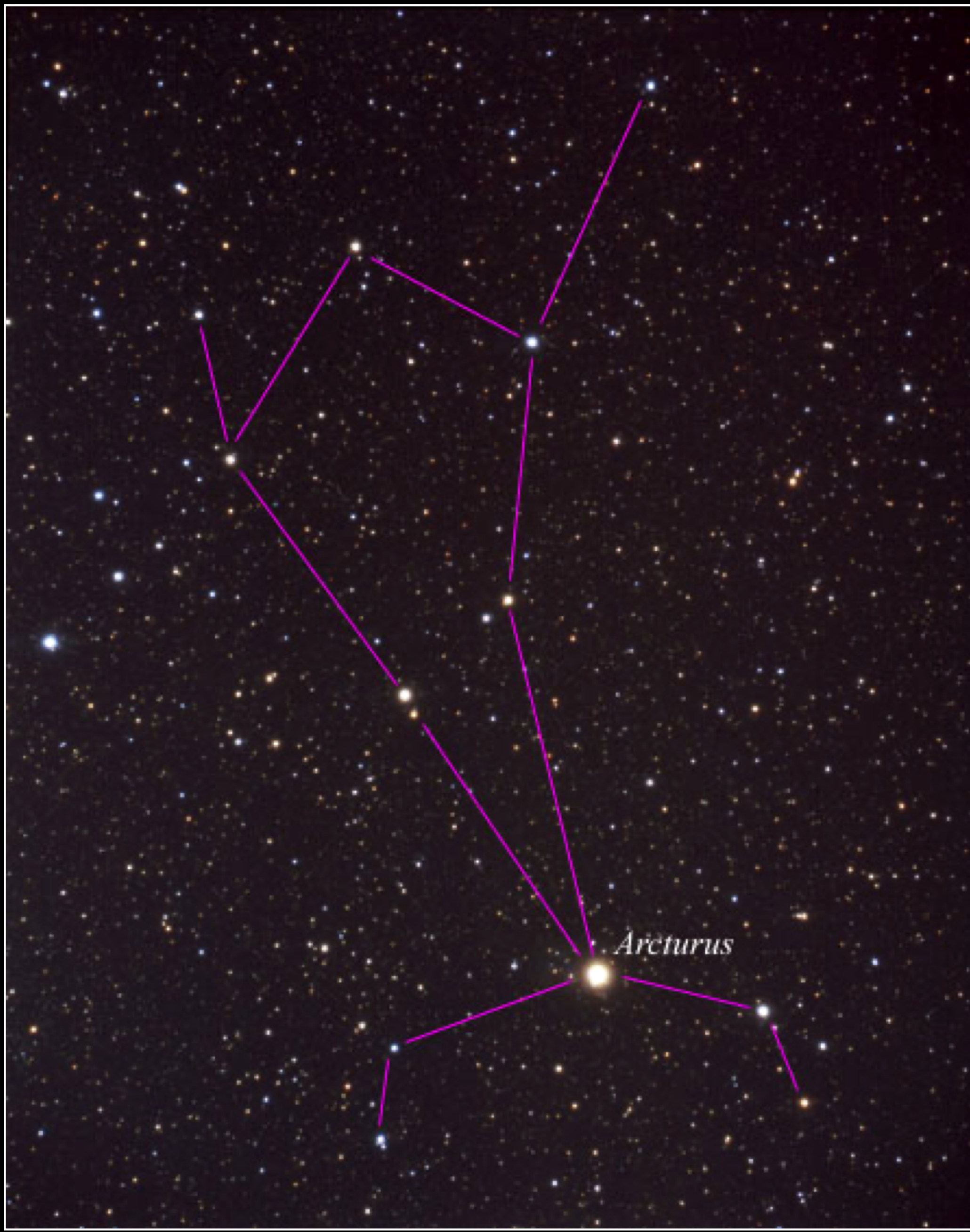


Auriga: Capella A & B(K0/G1III)



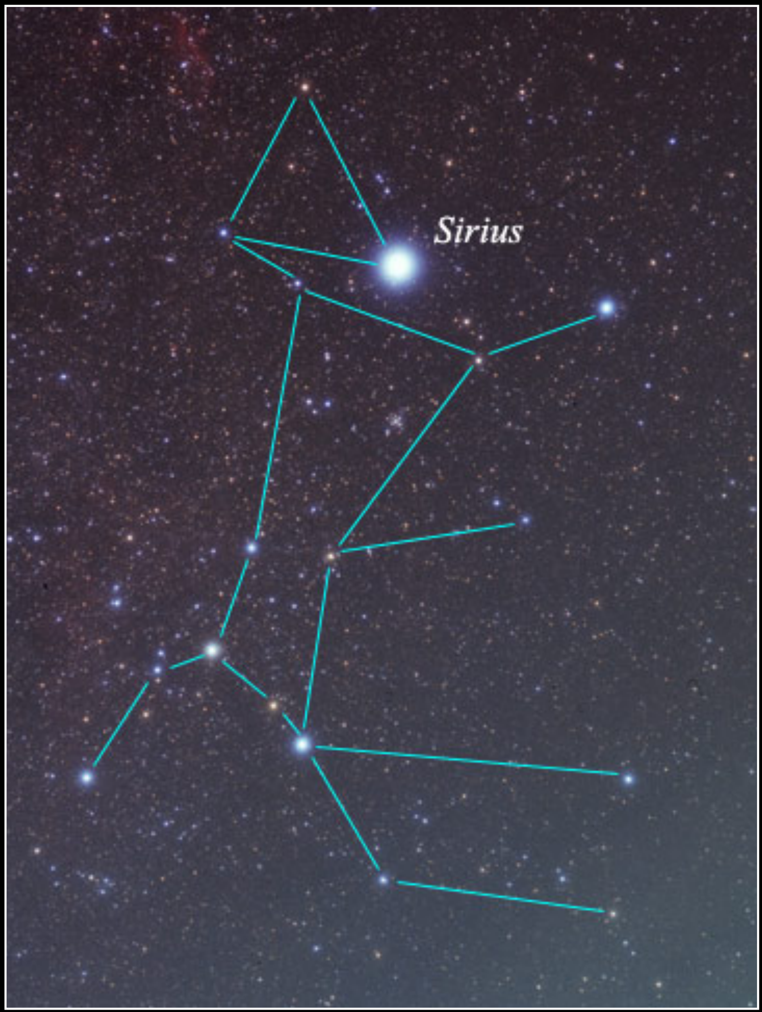


Bootes: Arcturus (K0III)



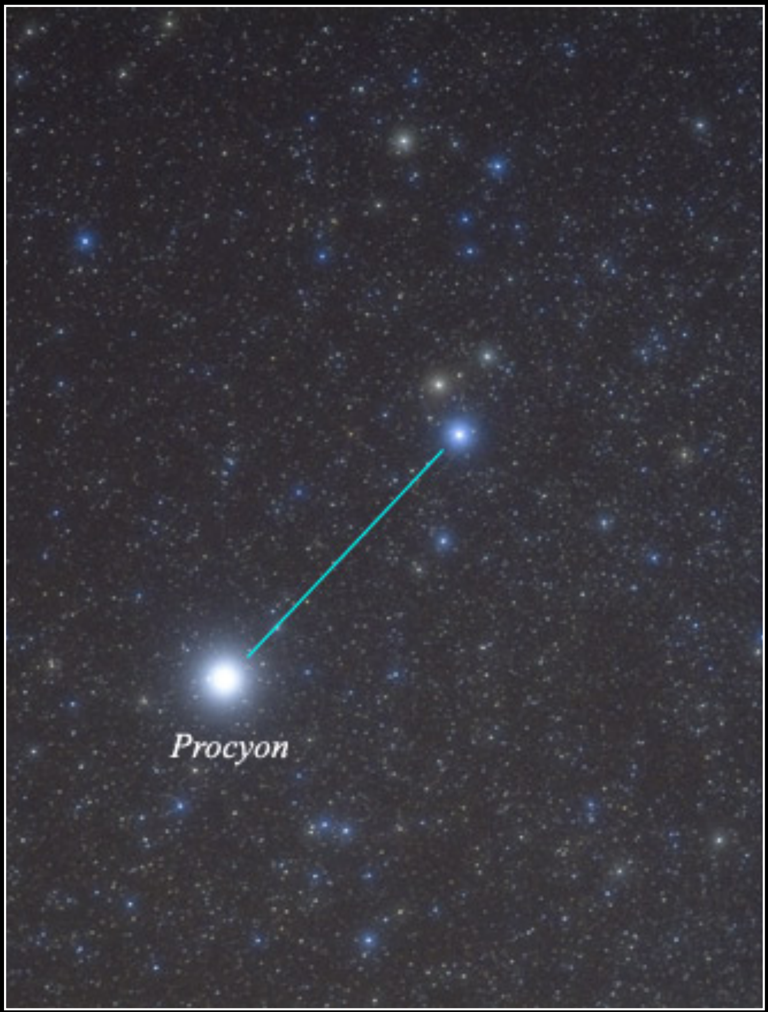
Sirius A & B

Canis Major: Sirius (A1V) & white dwarf companion



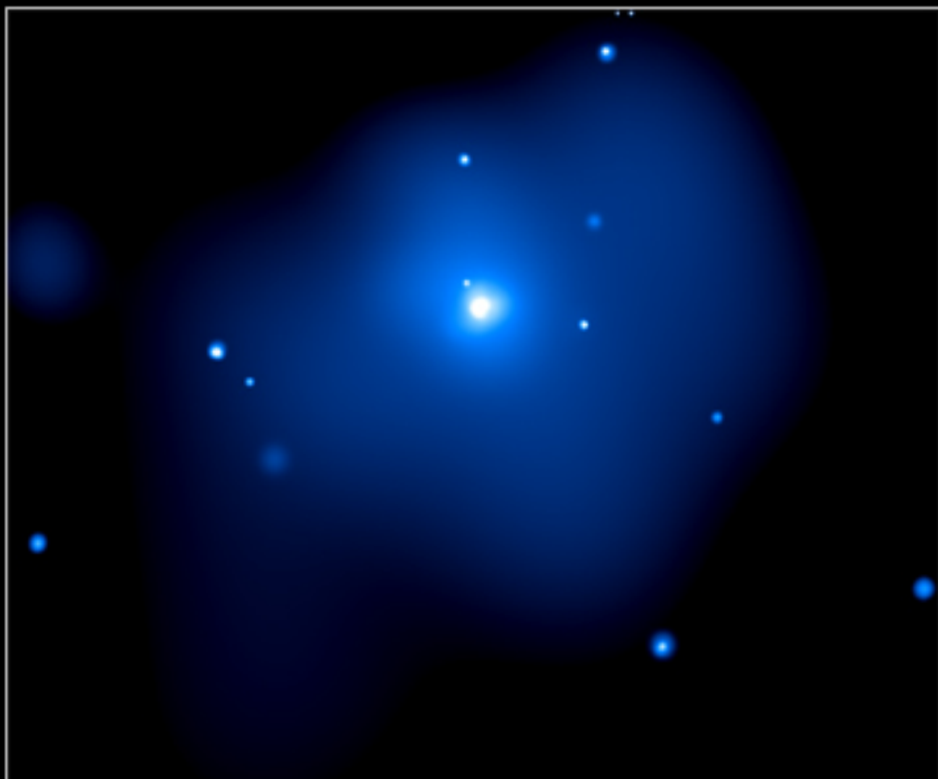
Procyon A & B

Canis Minor: Procyon (F5IV) & white dwarf companion

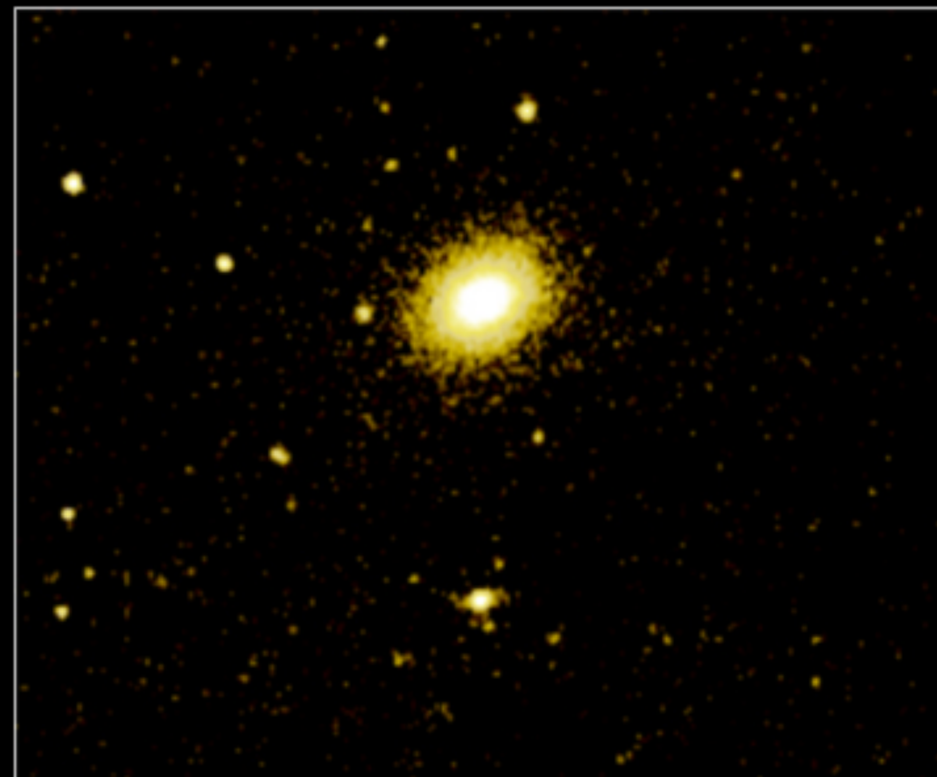


Centaurus A (NGC 5128) Active Starburst Galaxy

Coma Berenices & Galaxy NGC 4555



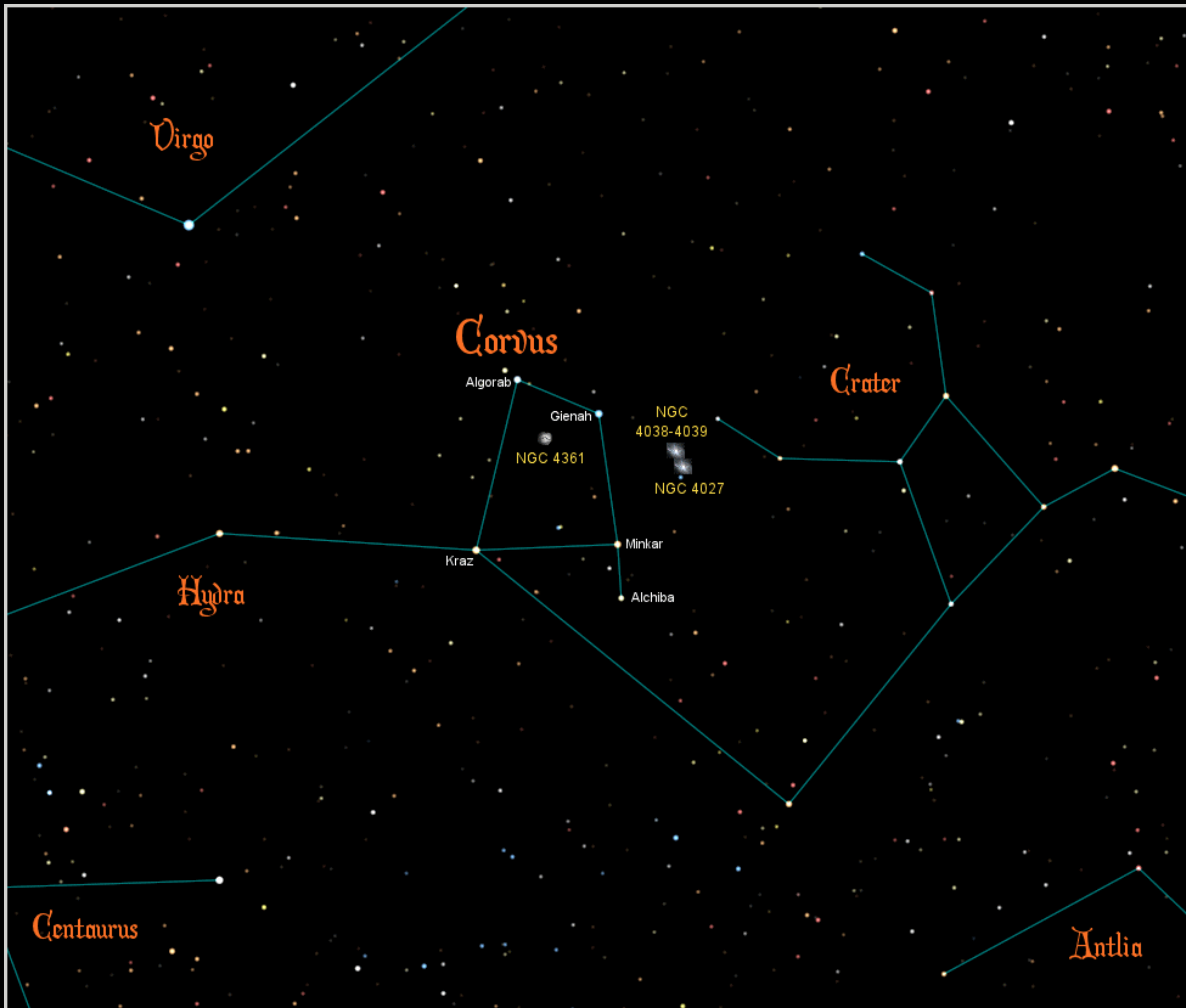
CHANDRA X-RAY



DSS OPTICAL

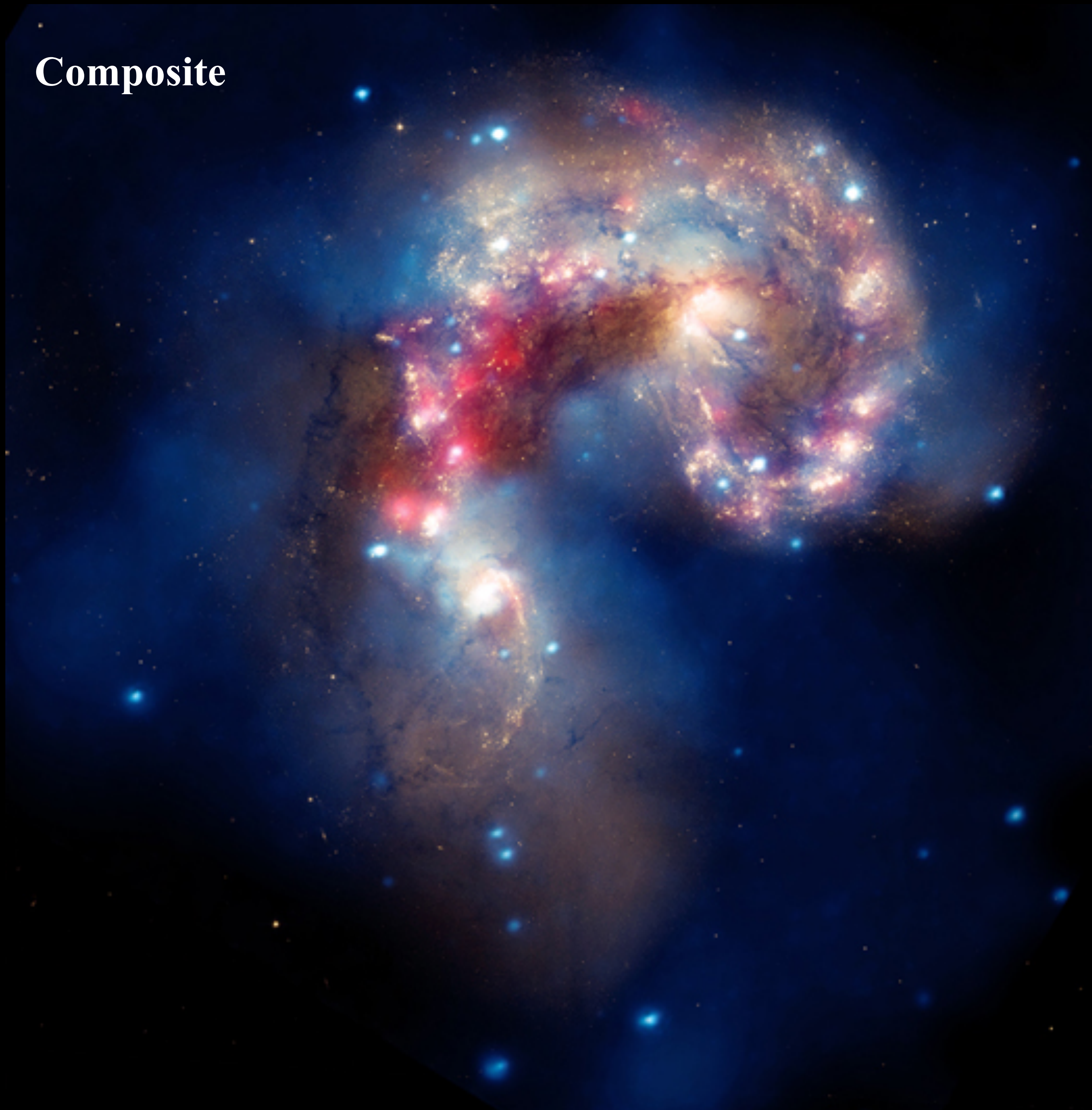
Coma Berenices & Galaxy NGC 4676
A.K.A. The Mice

Corvus the Crow

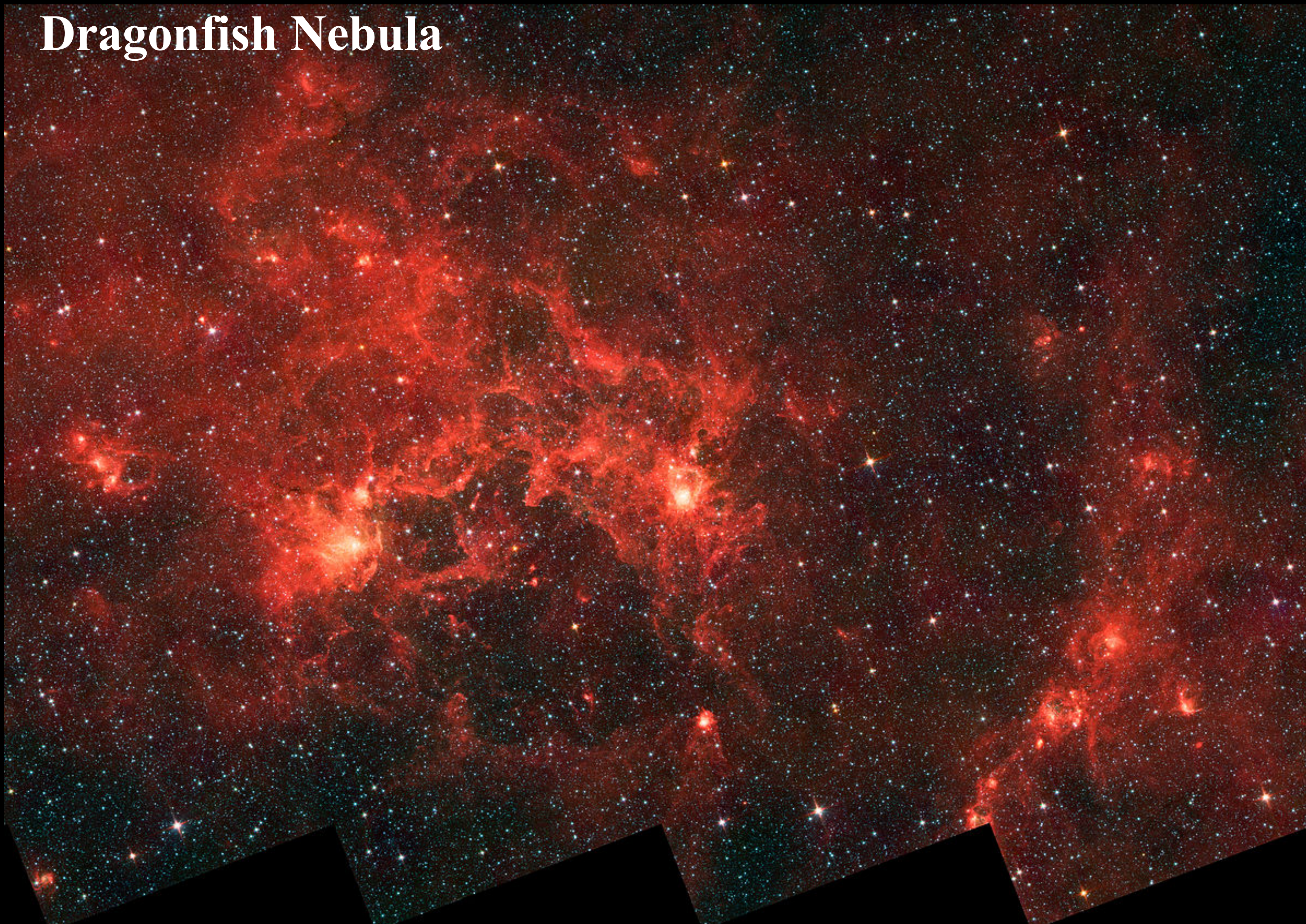


Corvus and Interacting Galaxies NGC 4038 & 4039
A.K.A The Antennae

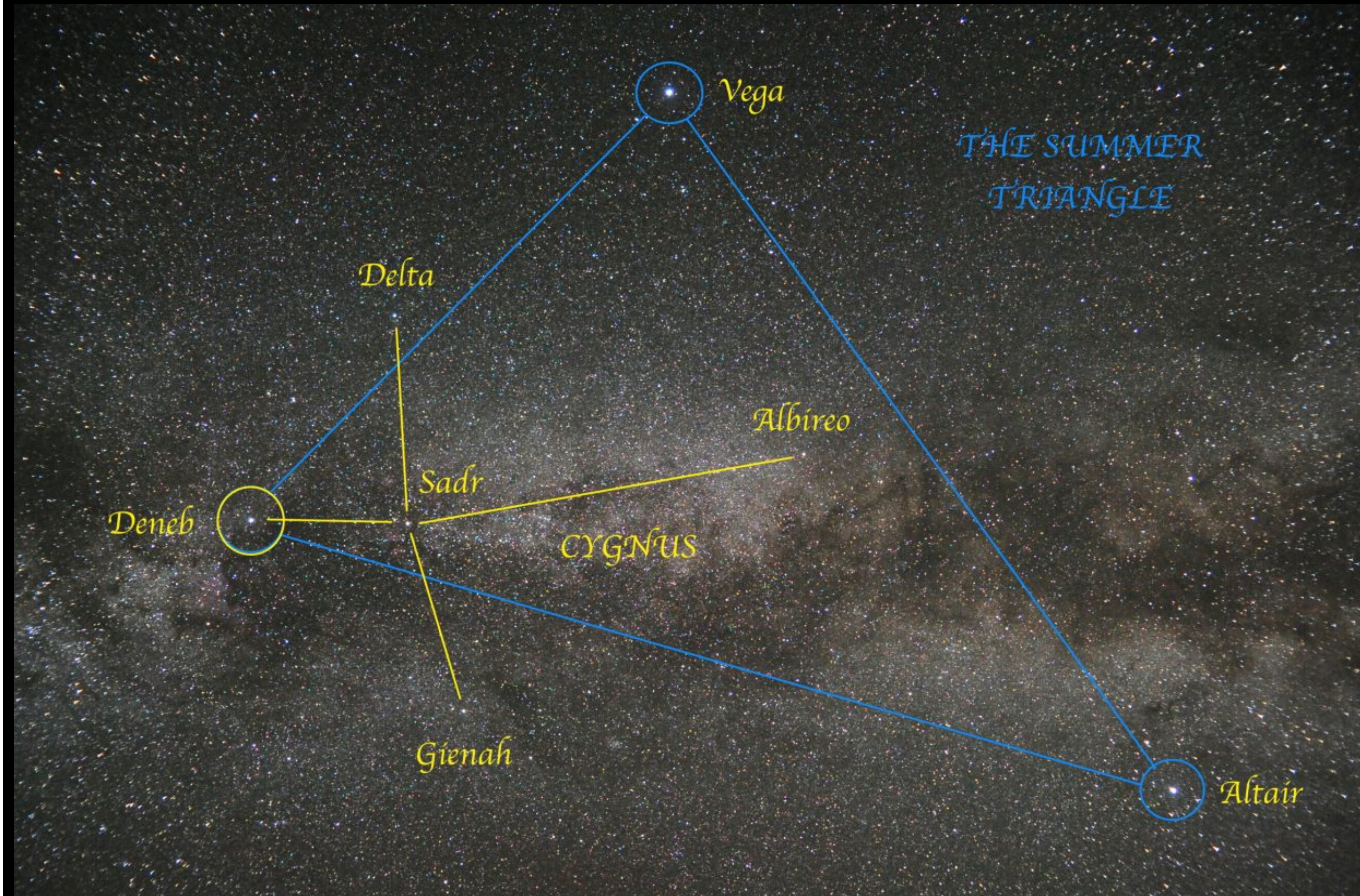
Antennae Interacting Galaxies – Optical, IR, X-Ray, Composite



Crux – The Southern Cross



Cygnus The Northern Cross & Deneb (A2I)



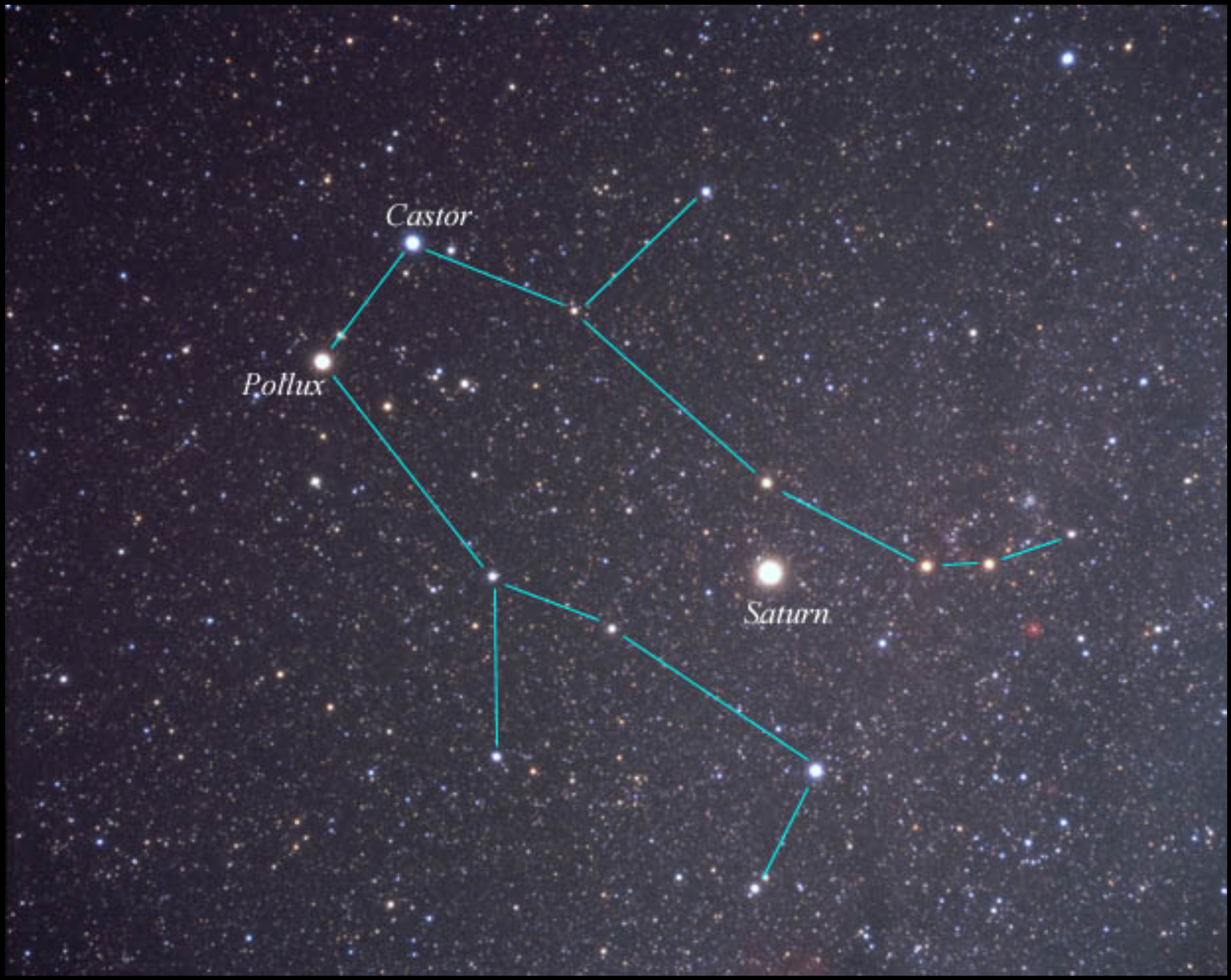
Doradus: Large Magellanic Cloud (LMC)

Doradus: 30 Doradus (Tarantula Nebula)

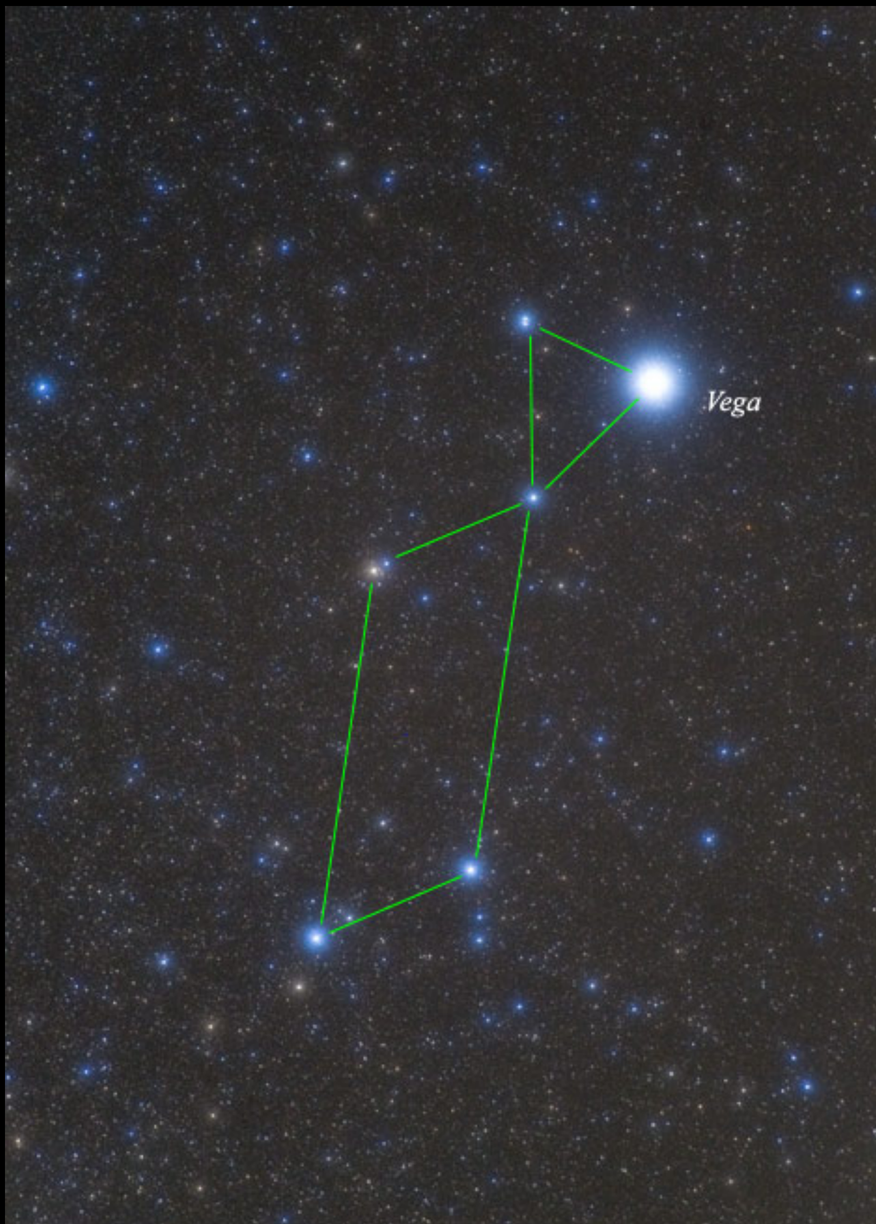
MCELS, University of Michigan

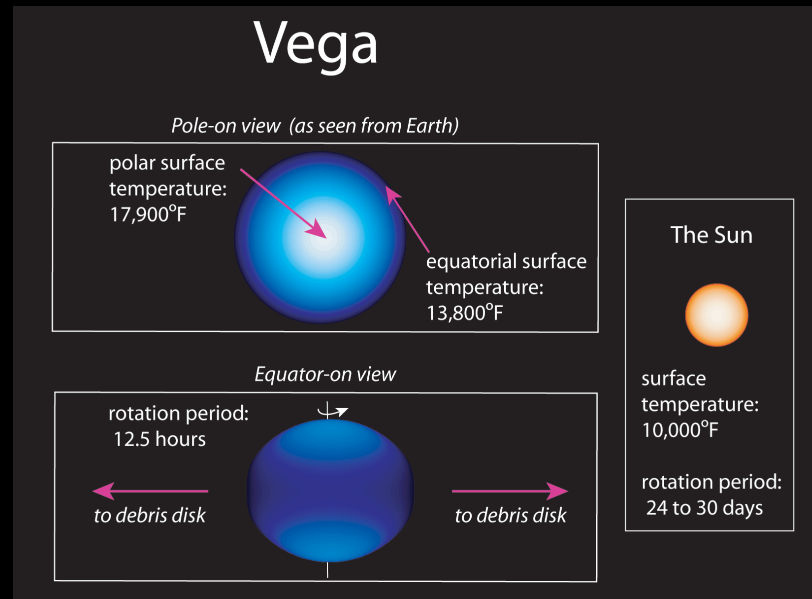
30 Doradus
Star Formation Region

Gemini: Castor (A1V) & Pollux (K0III)



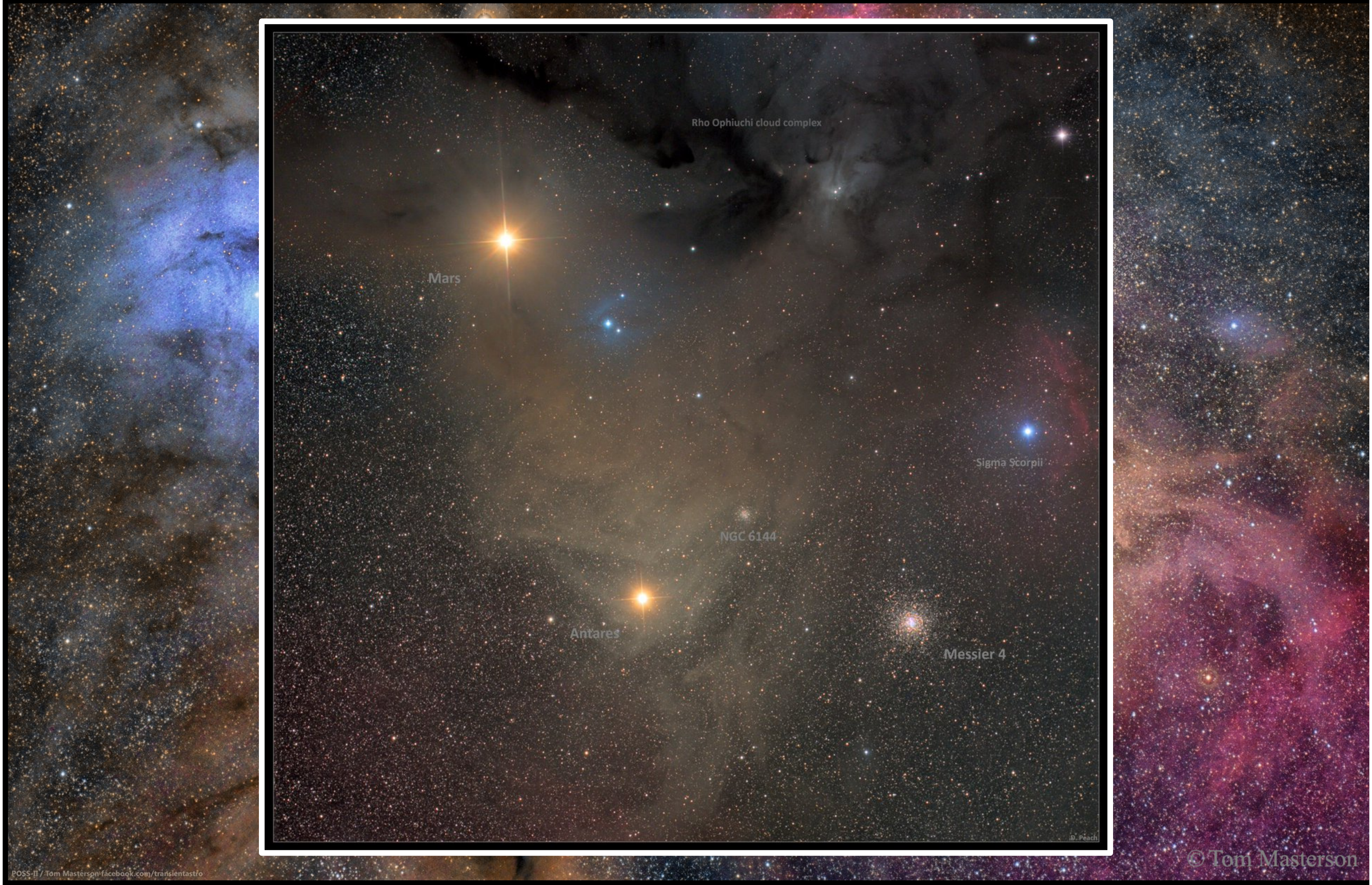
Lyra: Vega (A0V)



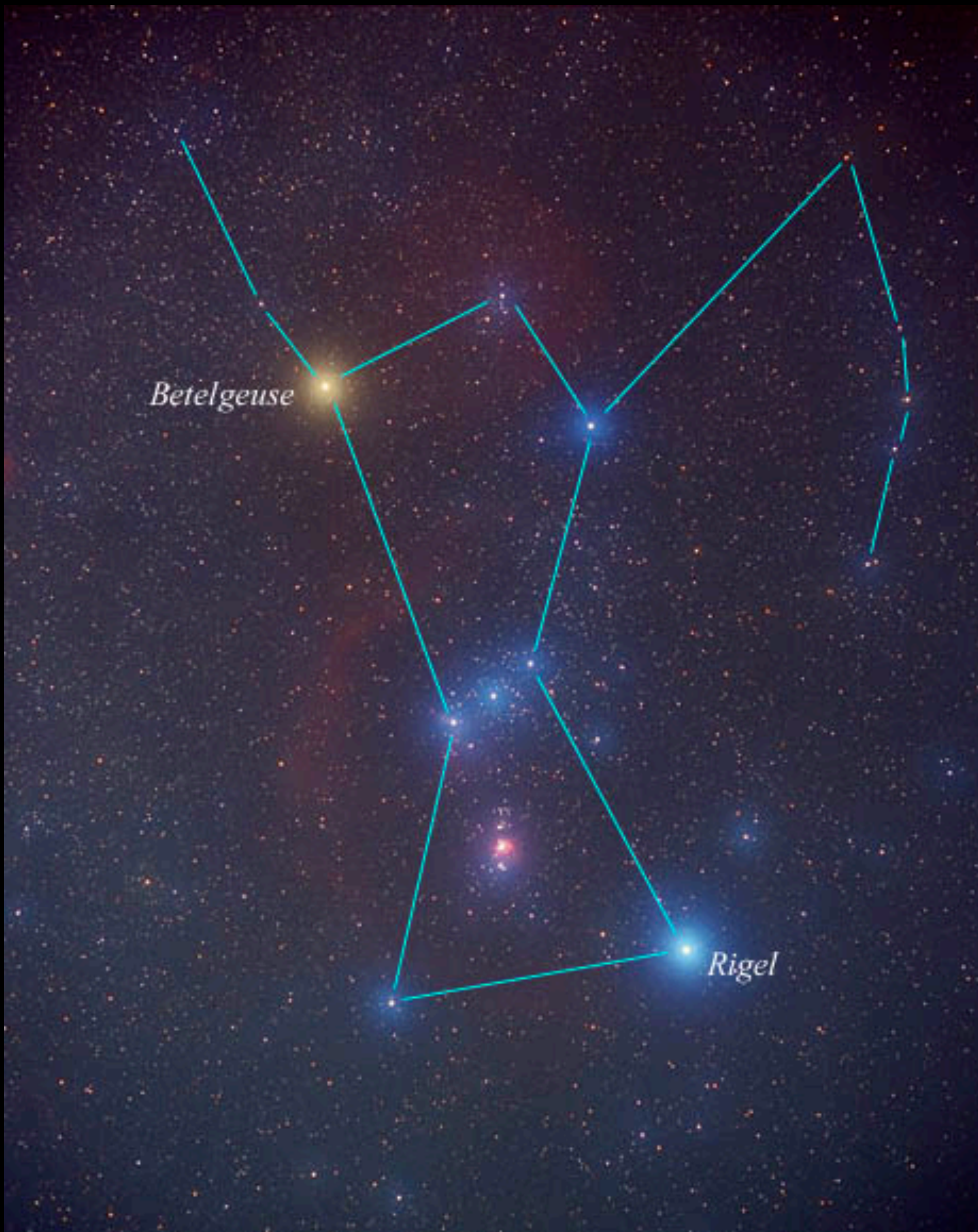


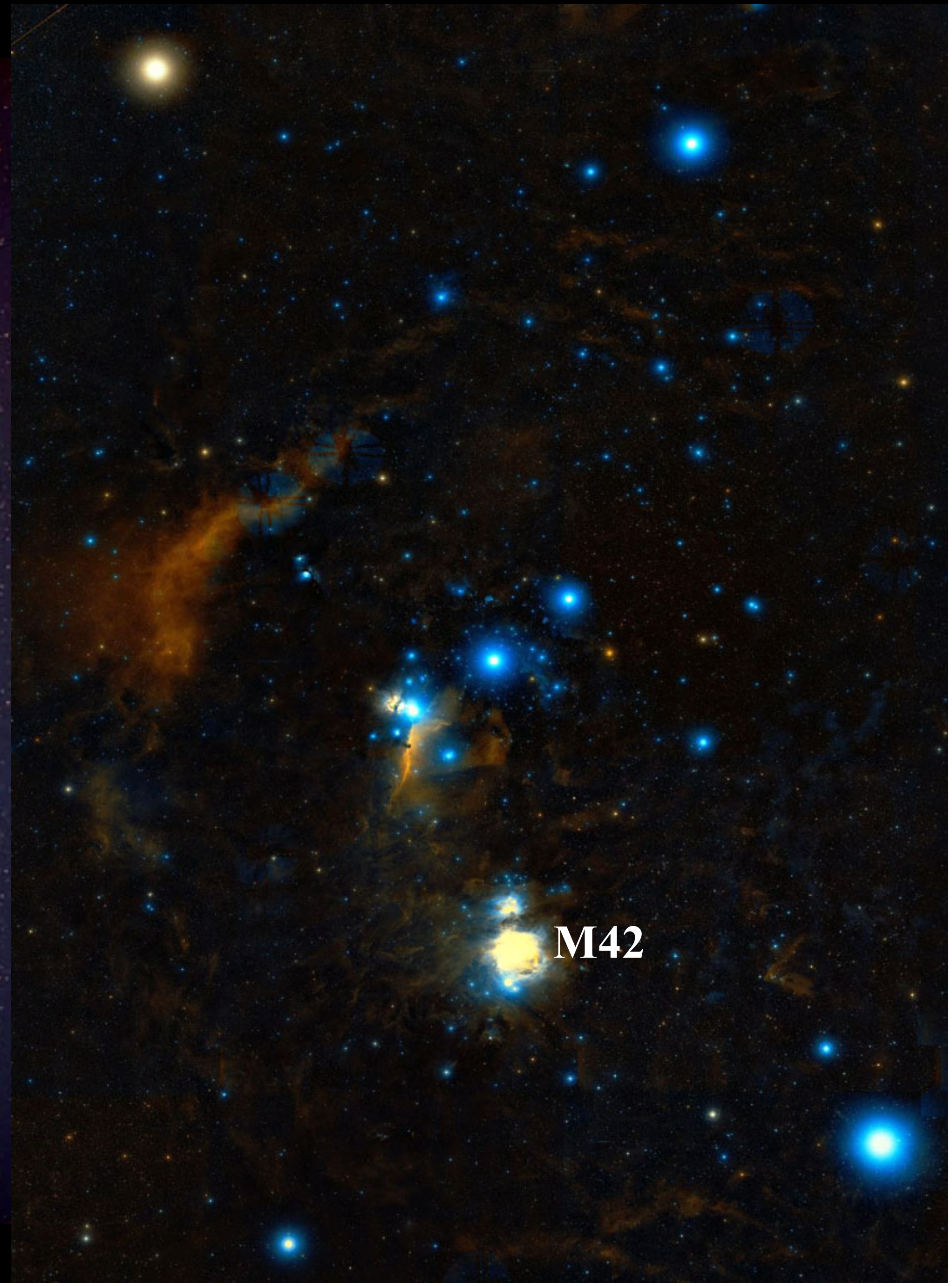
Ophiuchus: Zeta Ophiuchi – 09.5V

The rho Ophiuchi Cloud Complex

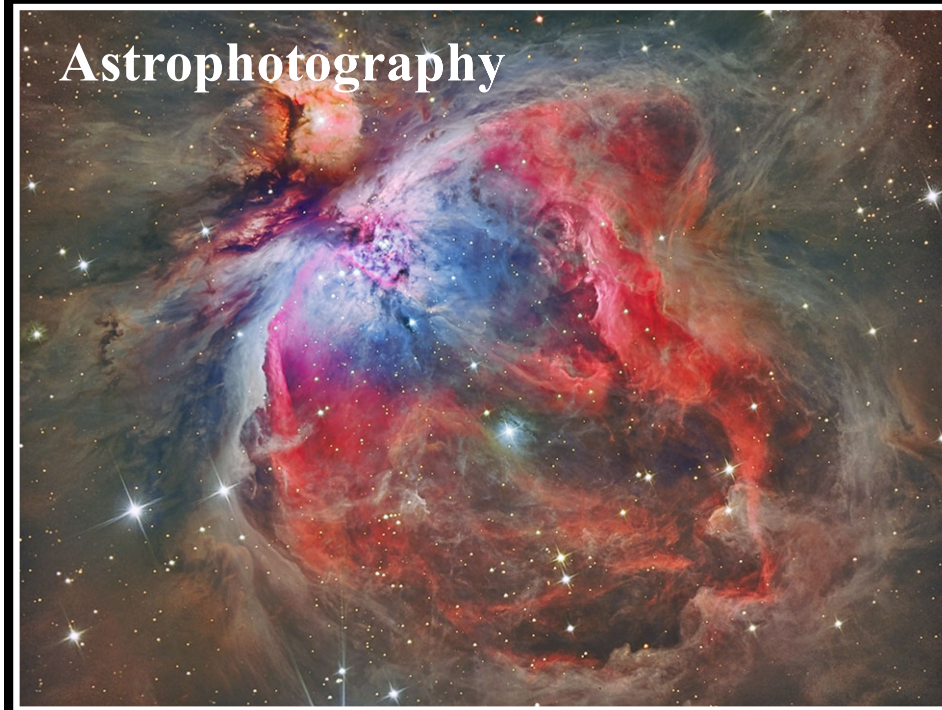


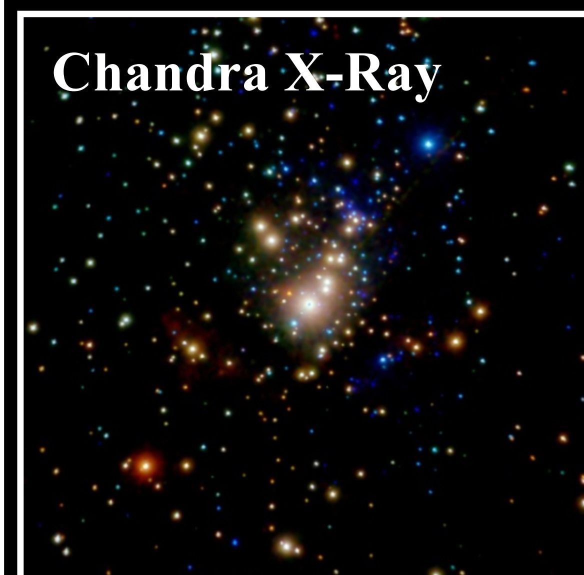
Orion: Betelgeuse (M2I), Rigel (B8I)



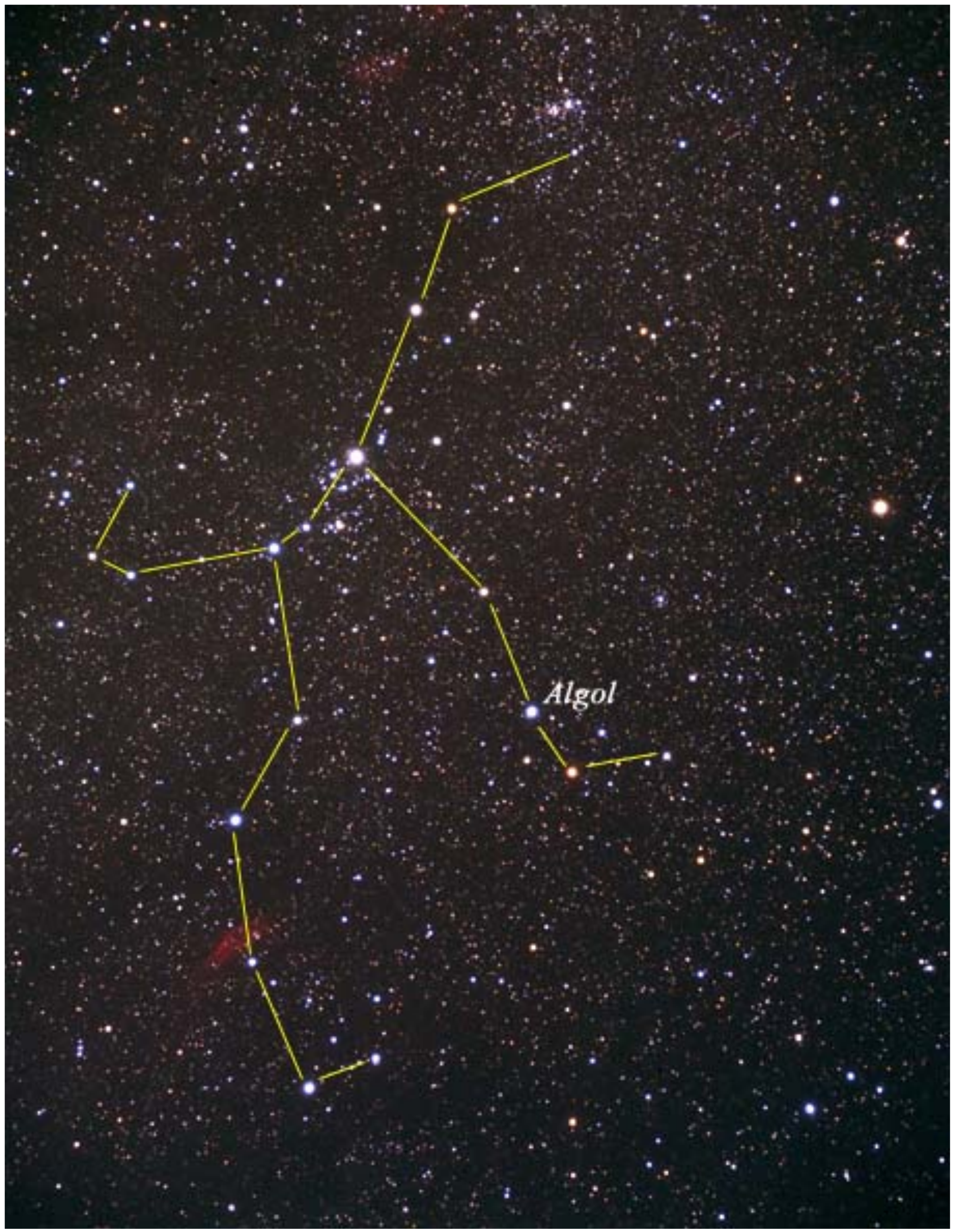


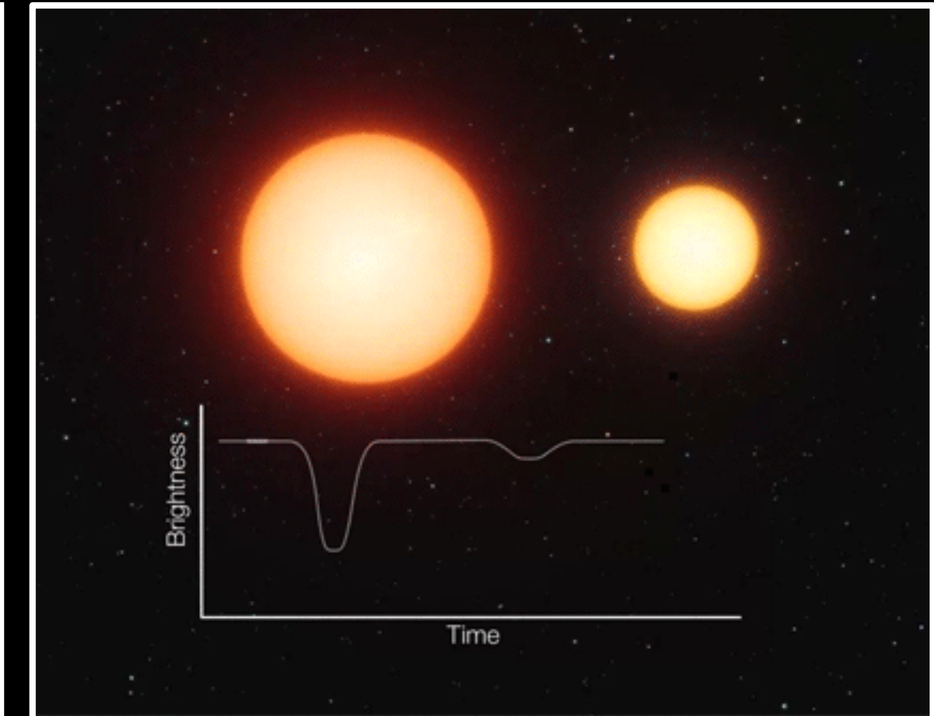
M42 (Great Orion Nebula) – Star Formation Region

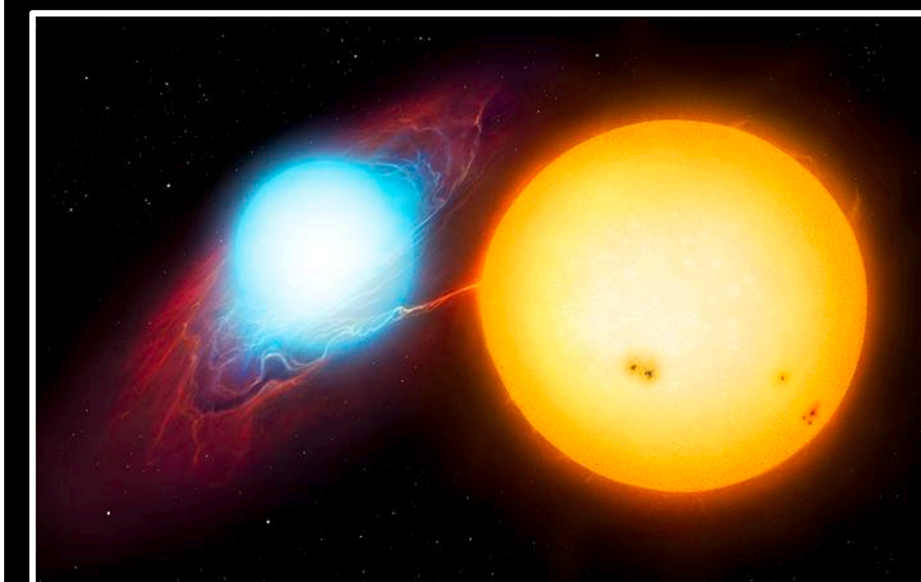




Perseus: Algol (B8V)

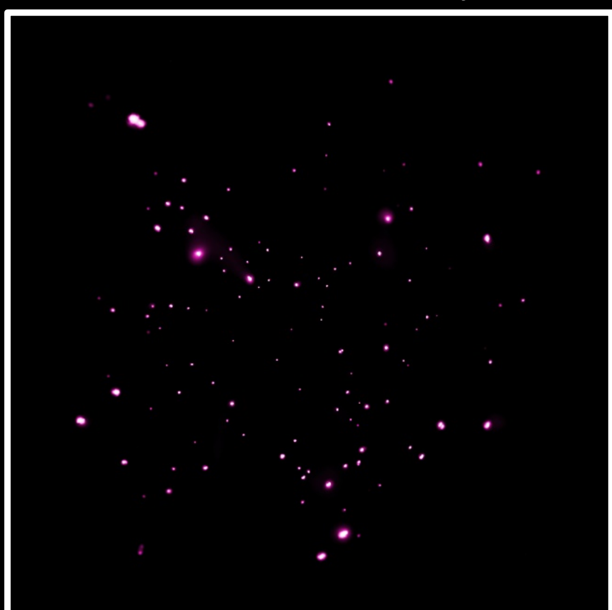




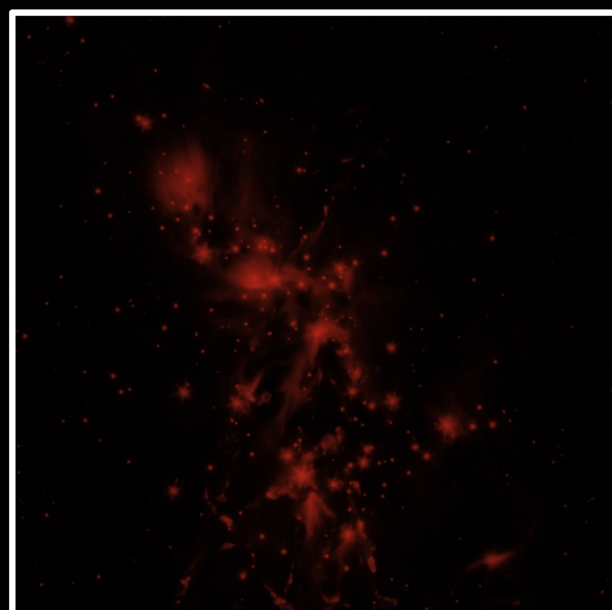


Perseus and the Stellar Cluster in NGC 1333

Chandra X-Ray

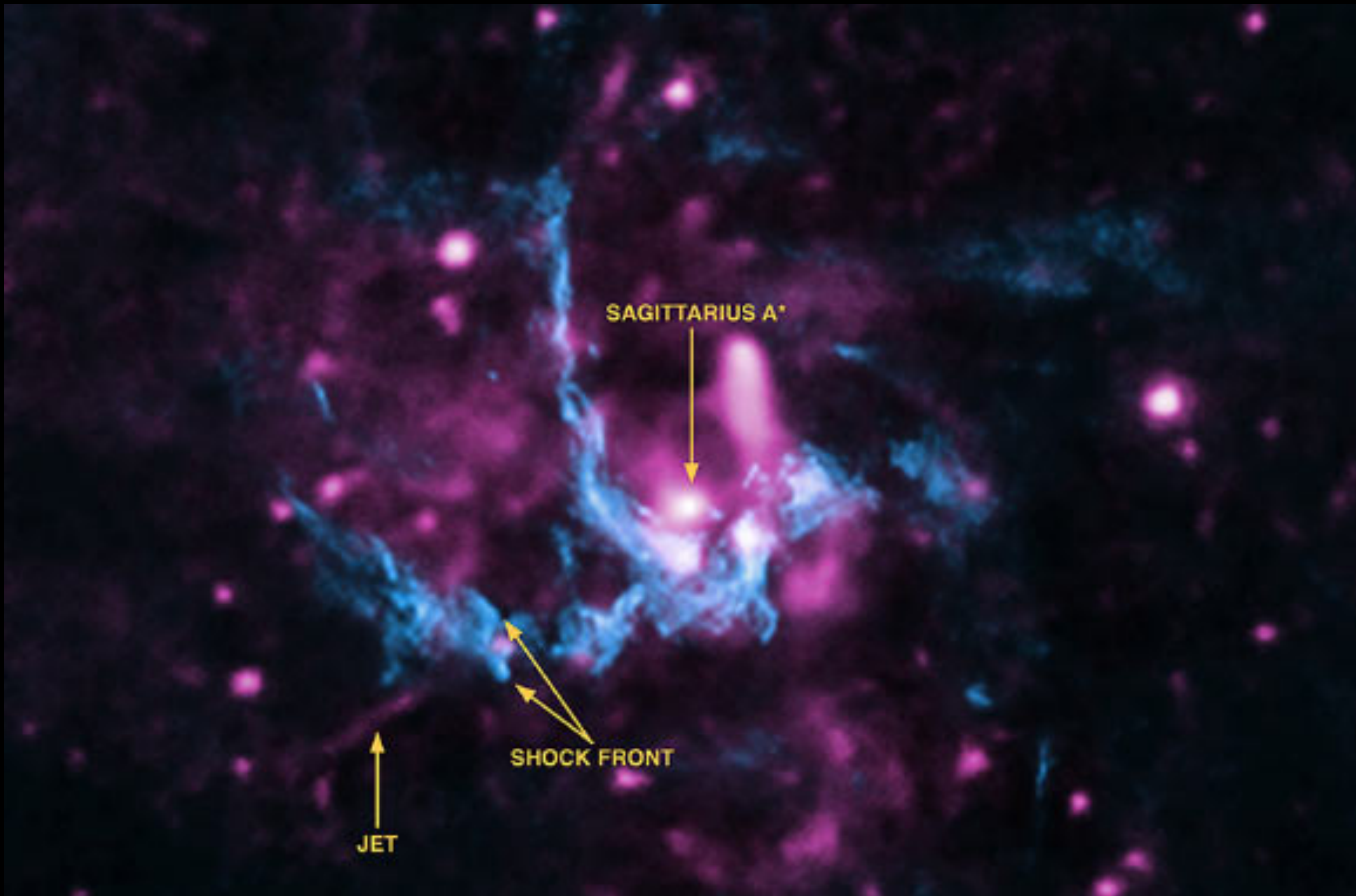


Spitzer IR

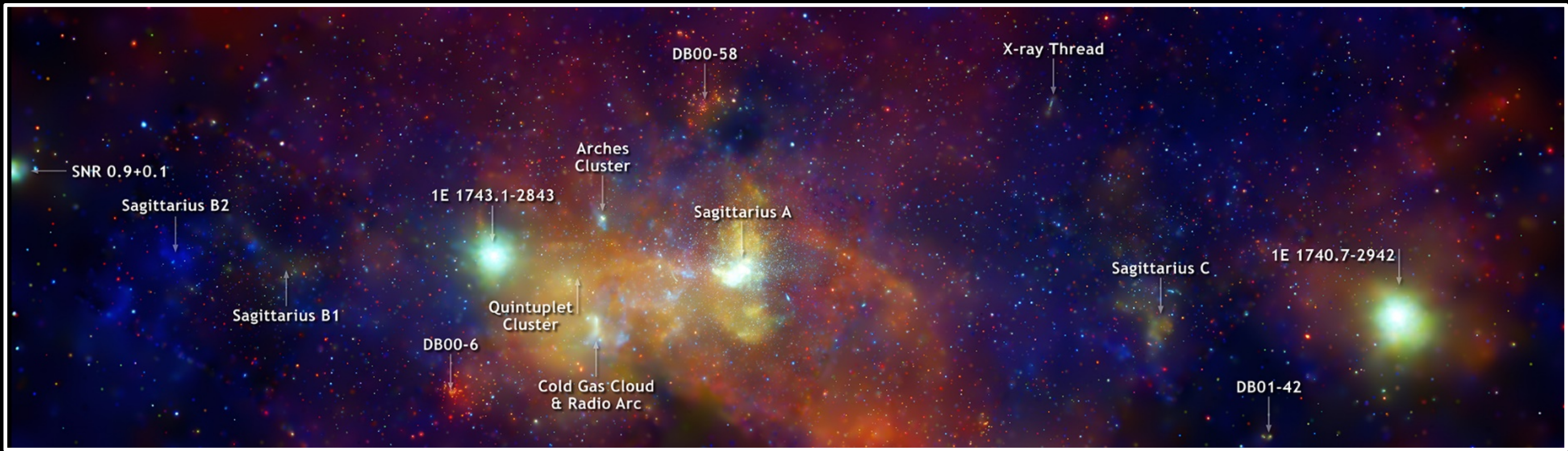


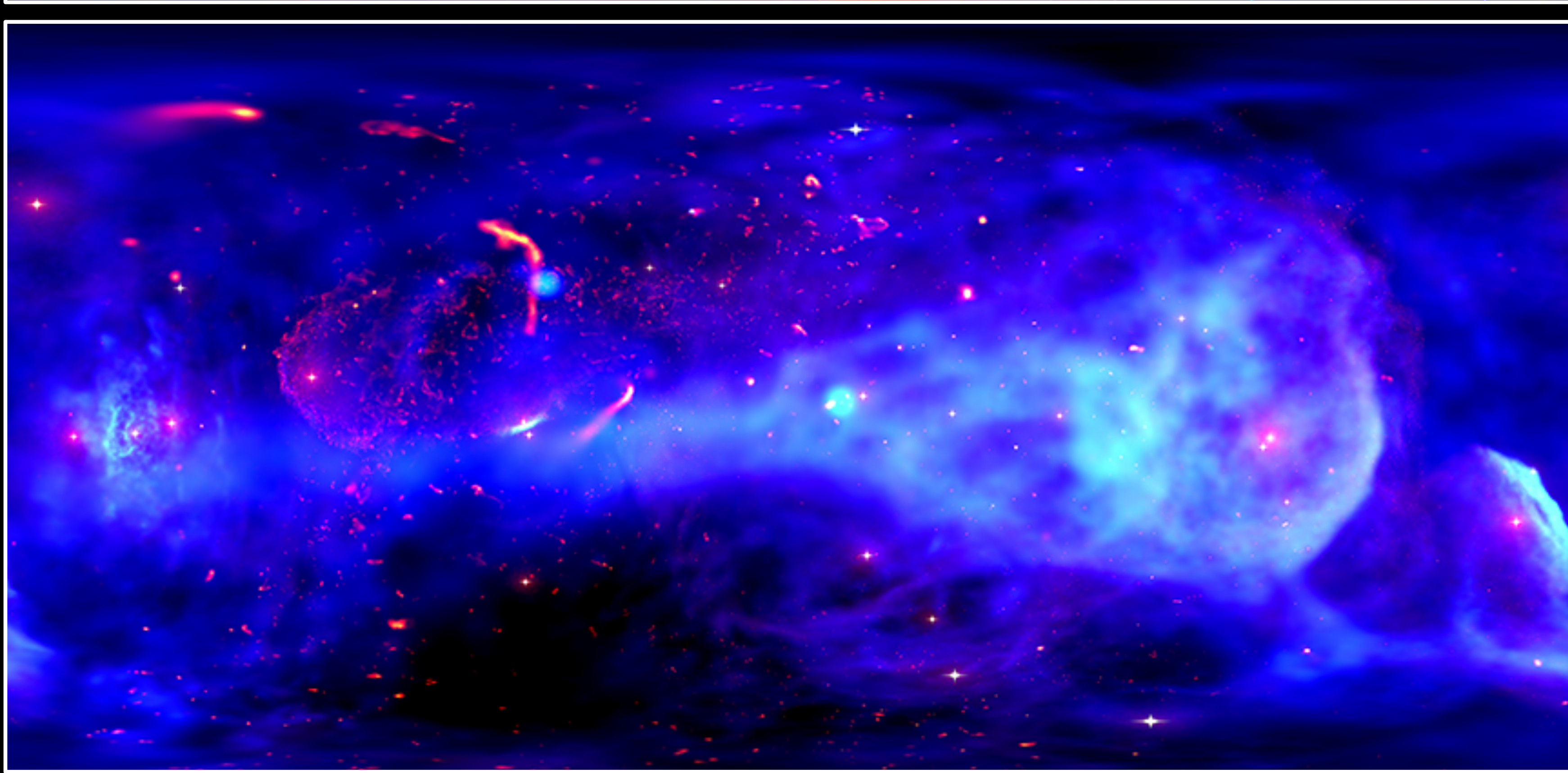
DSS-NOAO Optical

Sagittarius: Sgr A* black hole at center of Milky Way Galaxy



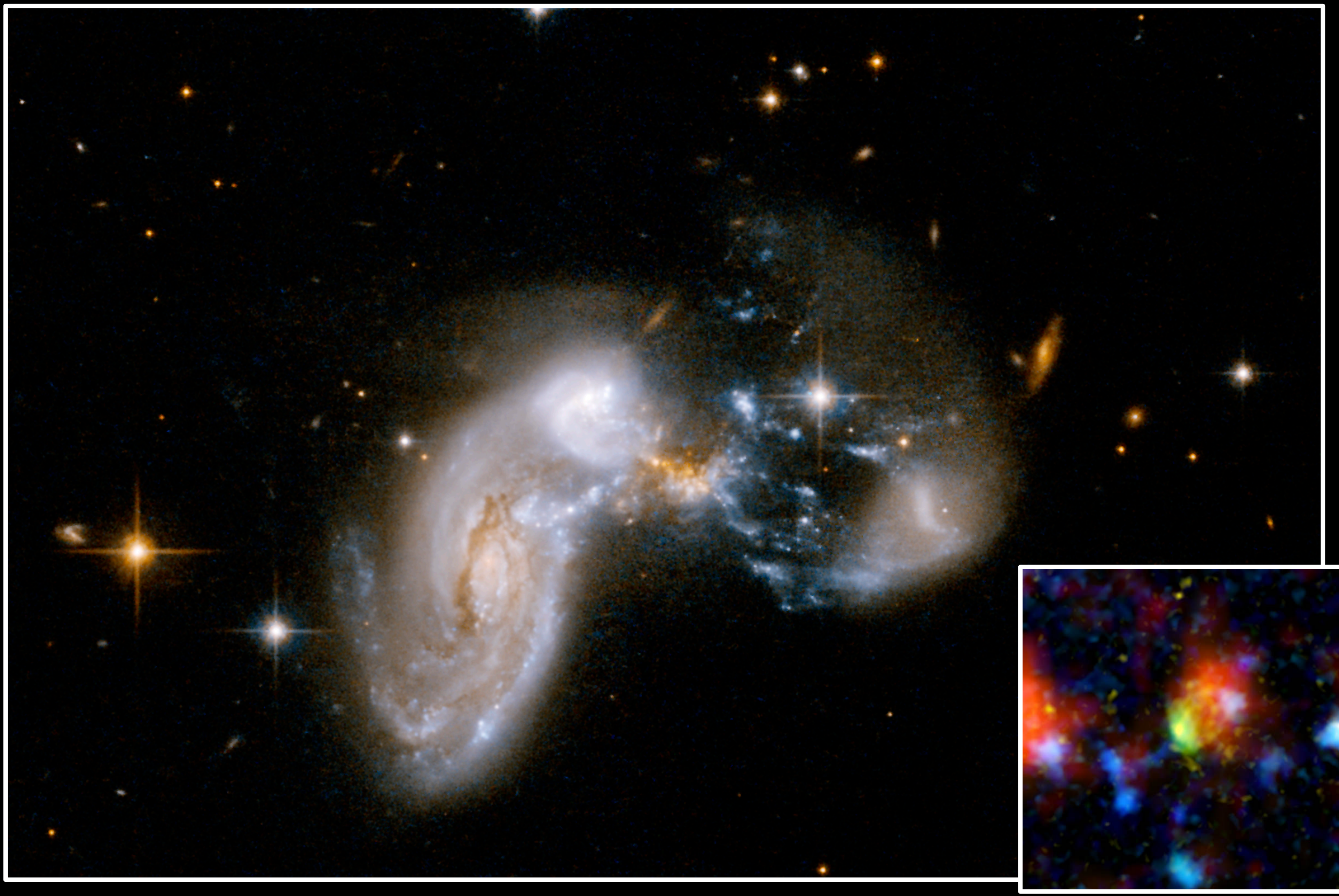
Sagittarius: Sgr A* black hole at center of Milky Way Galaxy



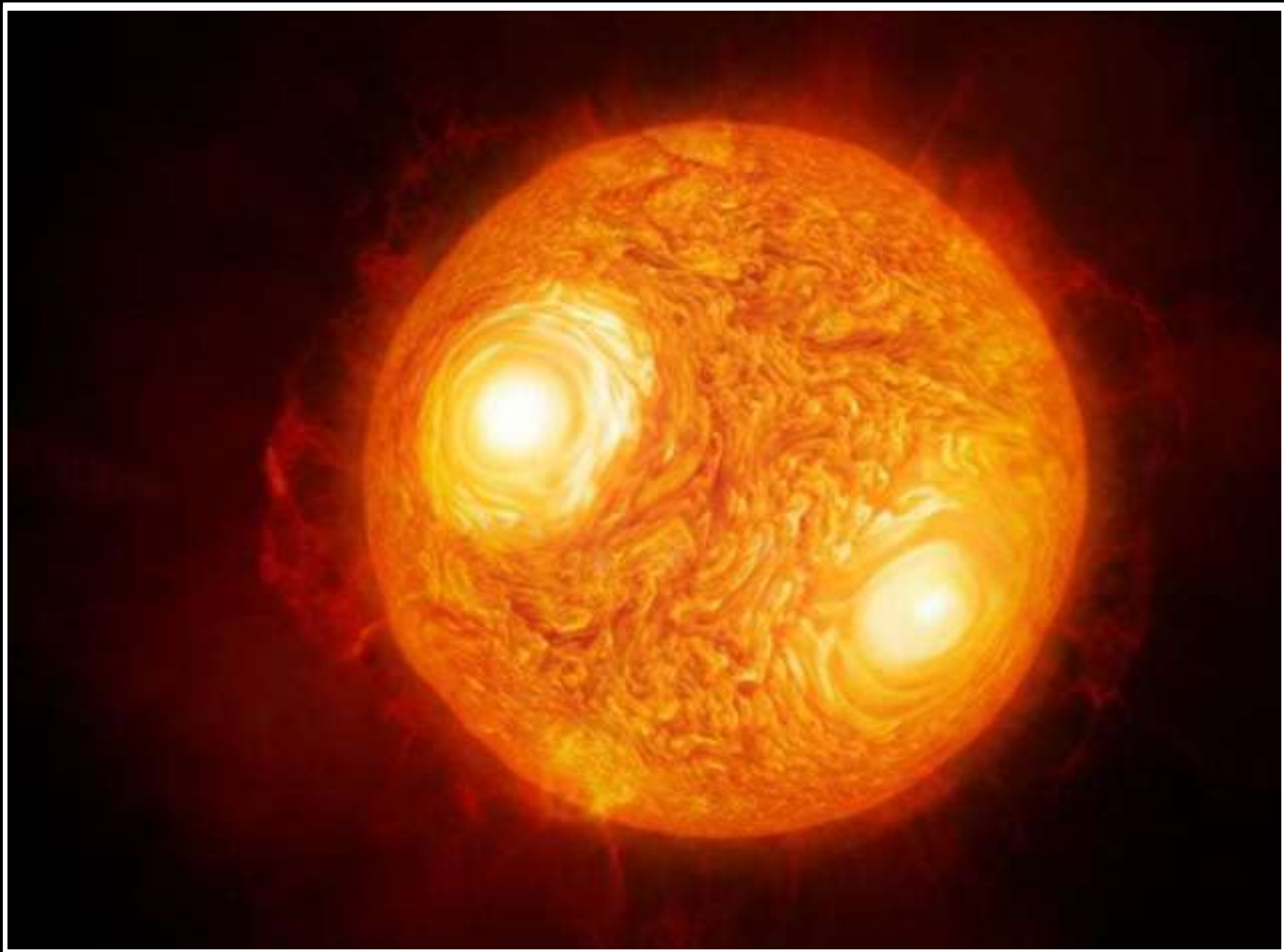


Sagittarius: Star Formation Region – Lagoon Nebula (M8)

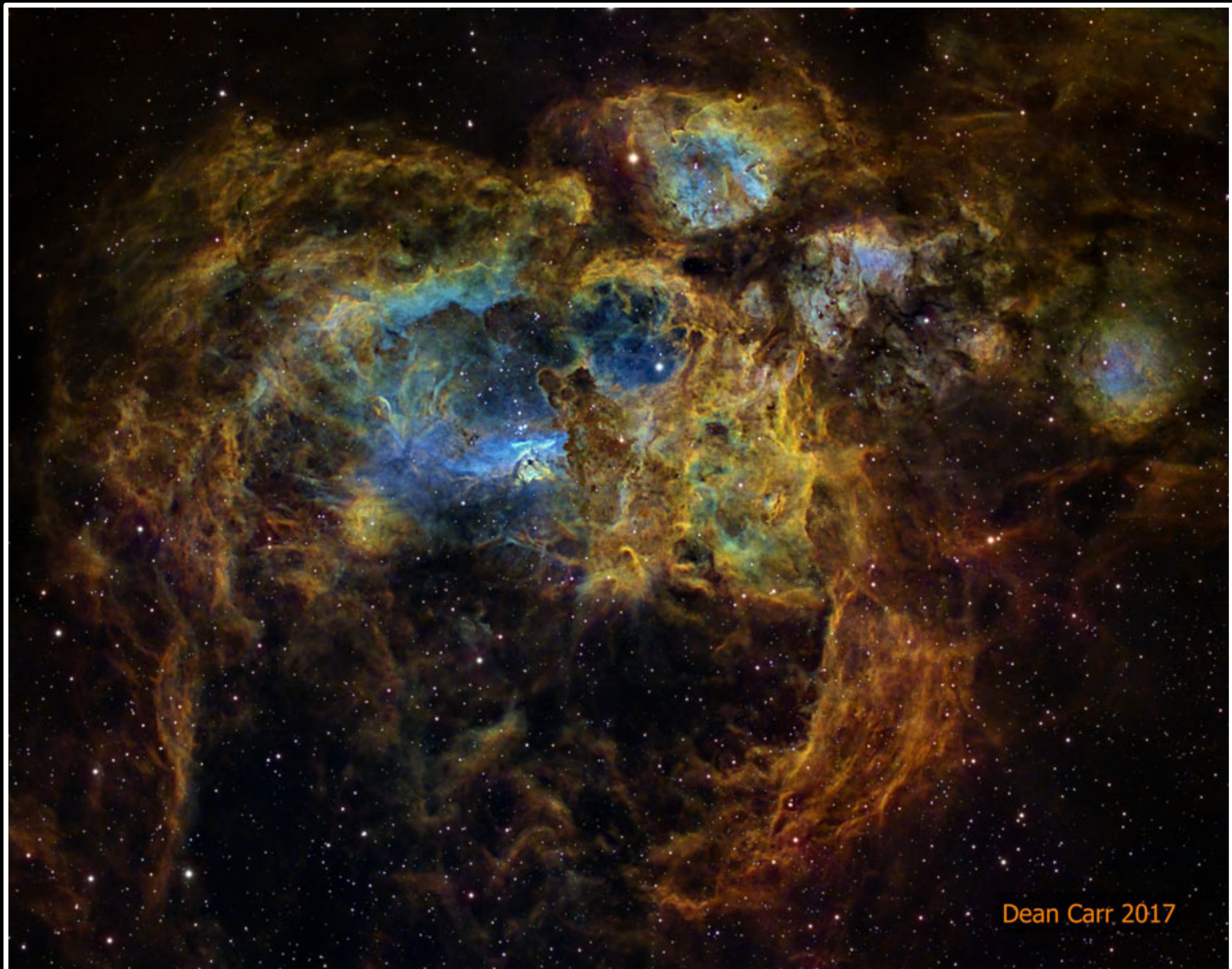
Sextans and J100054+023436 – Baby Boom Galaxy



Scorpius: Antares (M1-1.5I)



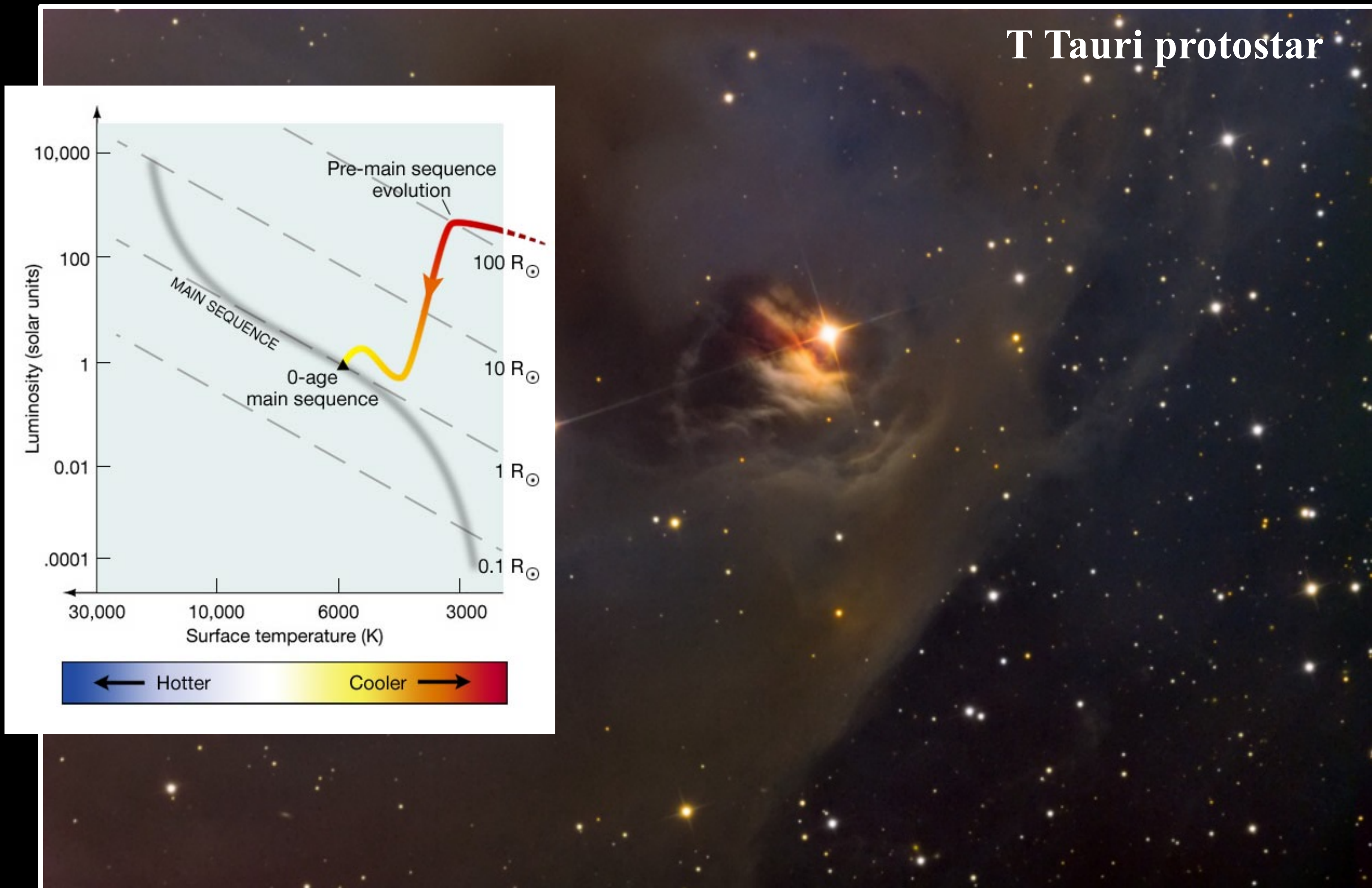
Scorpius: Star Formation Region NGC 6357 (Lobster)



Scorpius: Star Formation Region NGC 6334 (Cat's Paw)

Scorpius: Star Formation Region NGC 6334 (Cat's Paw)

Taurus: Aldebaran (K5III)



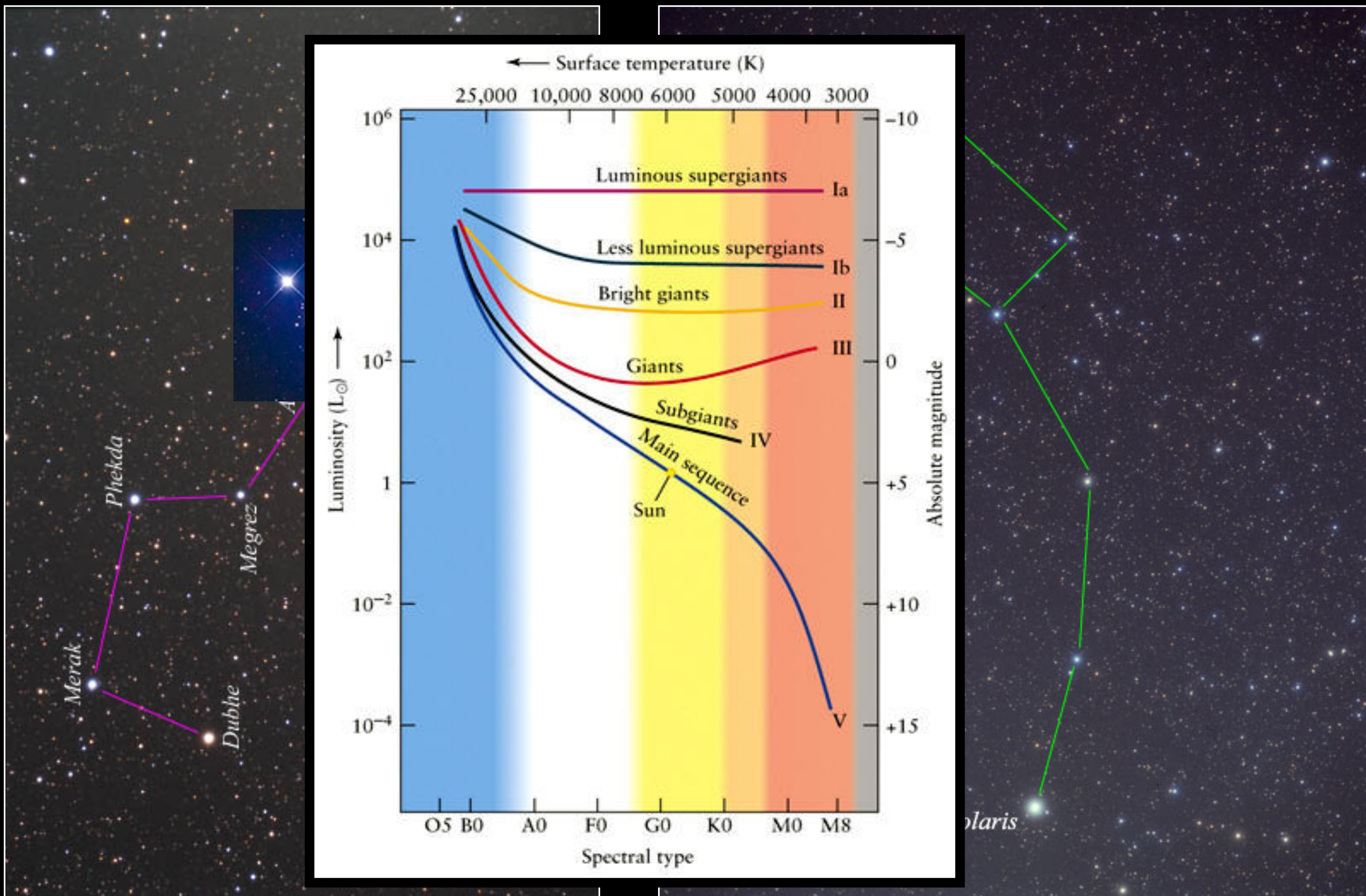
Tucana & the Small Magellanic Cloud Galaxy (SMC)

Ursa Major

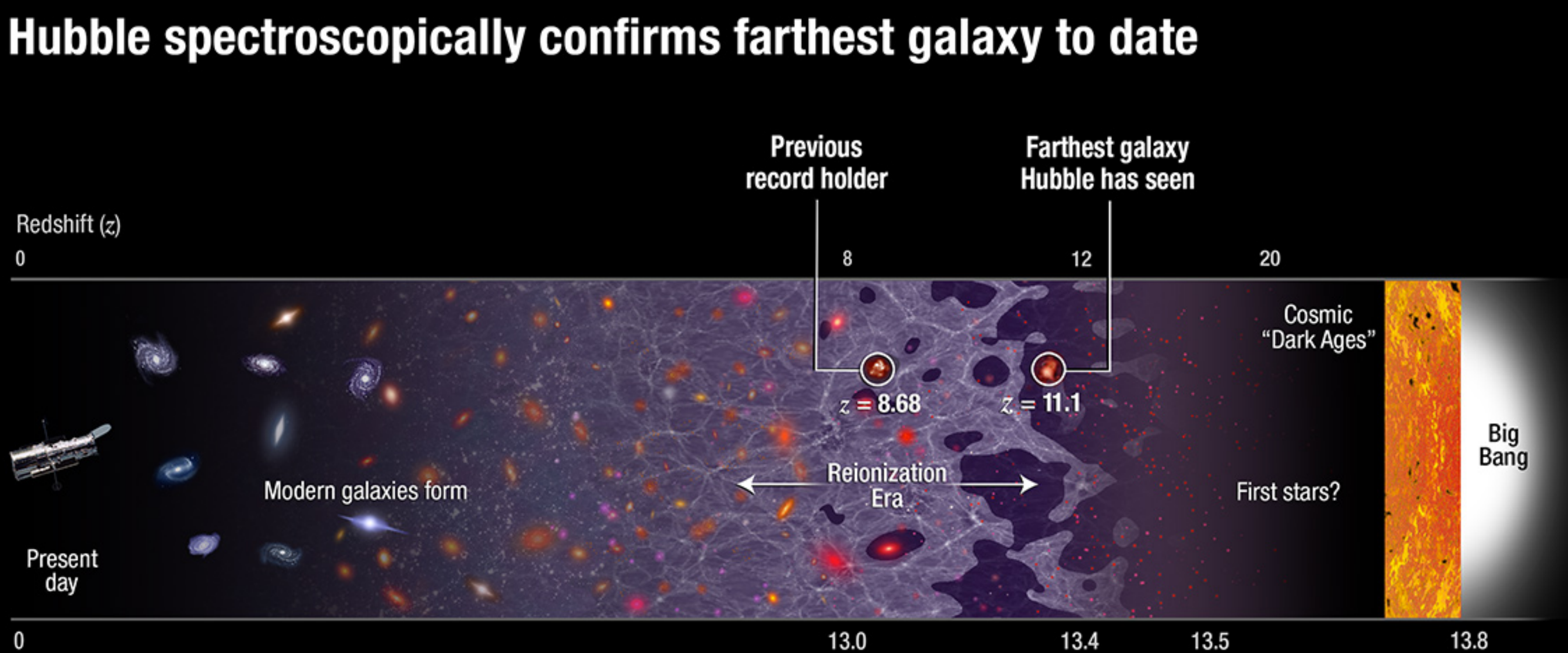
Mizar (A2-A7V) & Alcor (A5V)

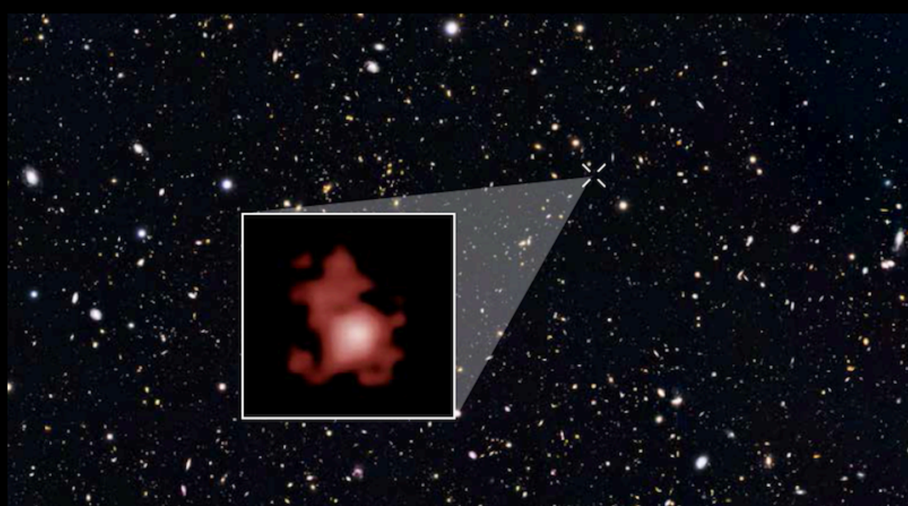
Ursa Minor

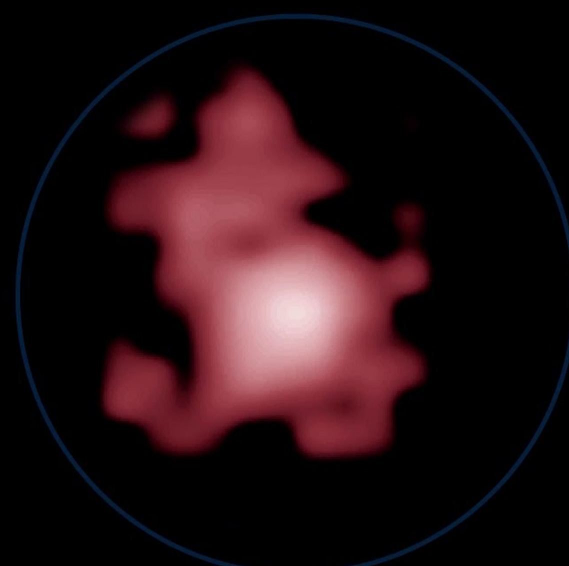
Polaris (F7I)



Ursa Major & galaxy GN-z11



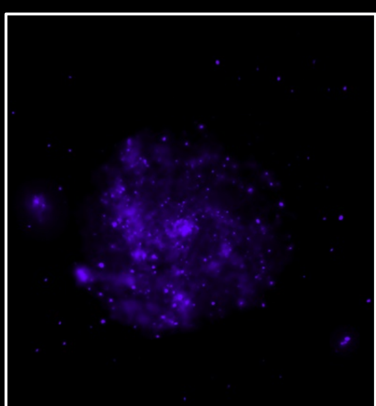




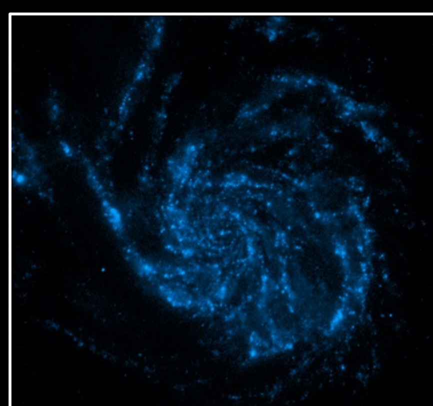
Ursa Major & M101 (Pinwheel Galaxy)

Ursa Major & M101 (Pinwheel Galaxy)

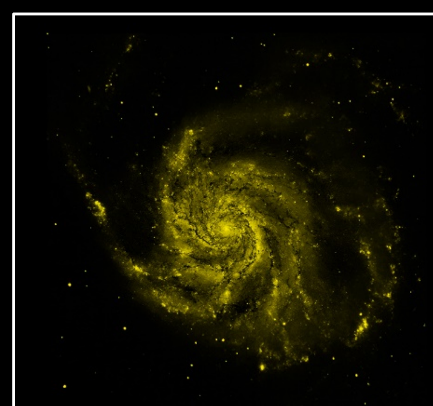
Chandra X-Ray



UV GALEX



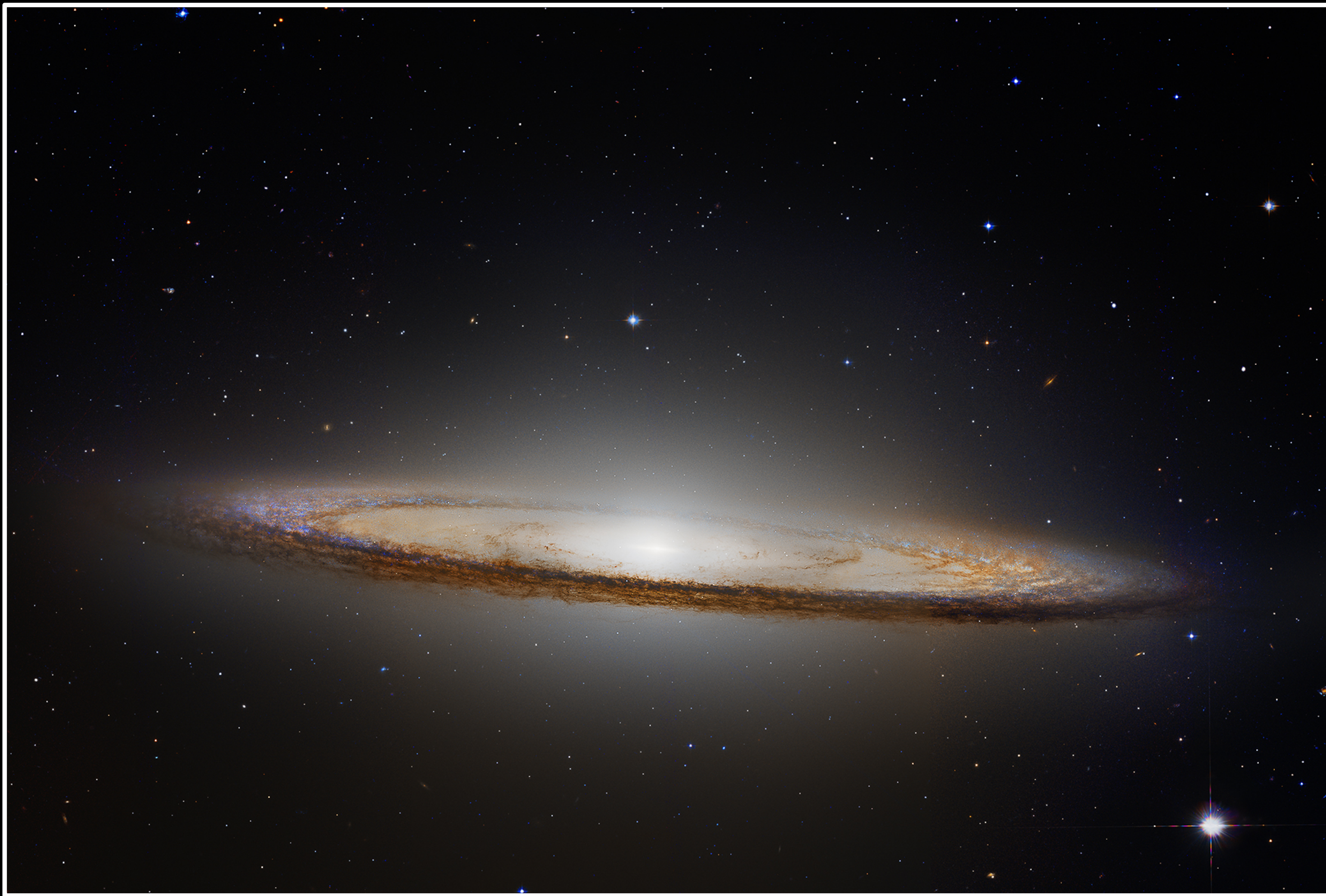
Optical Hubble



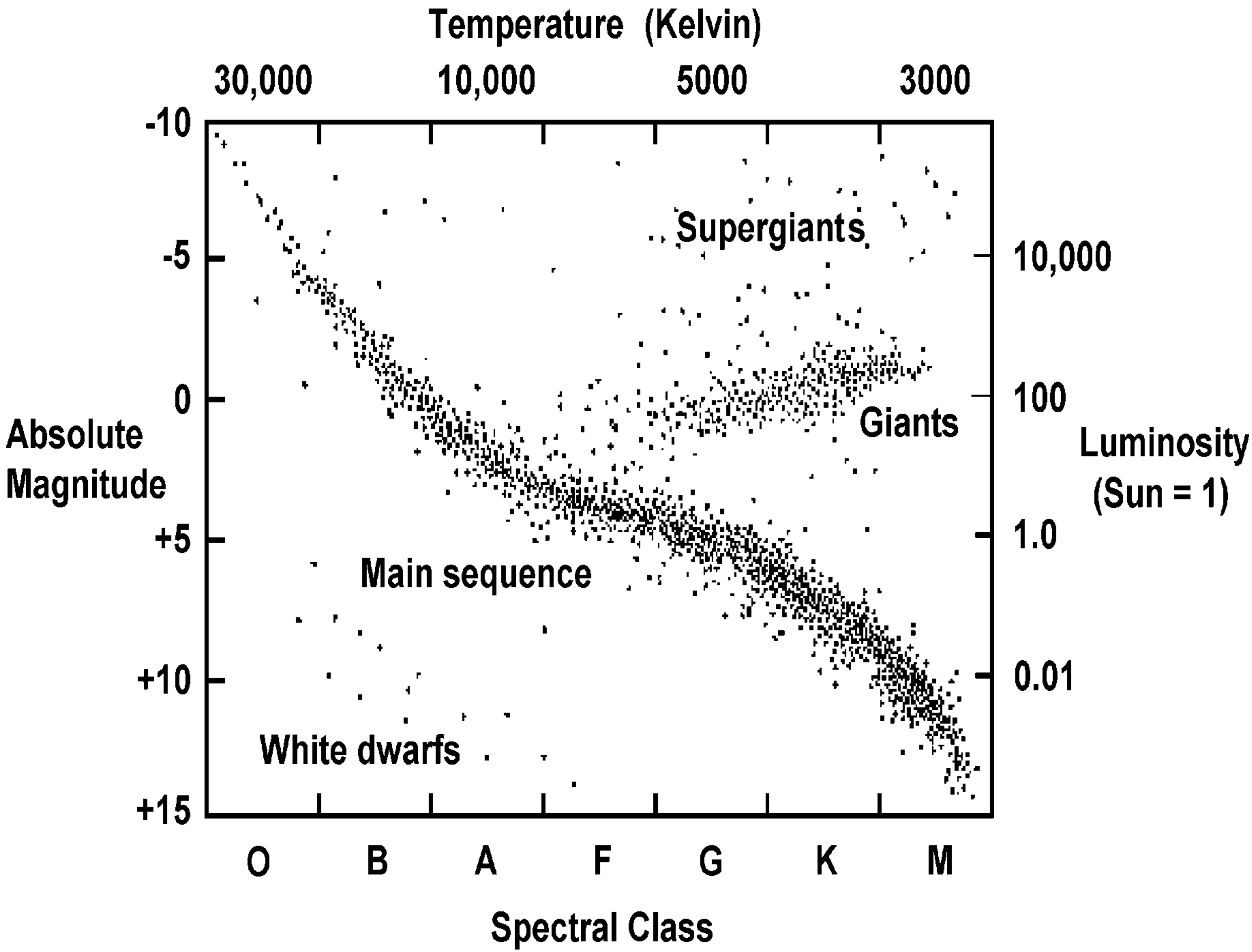
IR Spitzer

Virgo: Spica (B1III/IV)

Virgo: Galaxies M60 & M104 (Sombrero Galaxy)

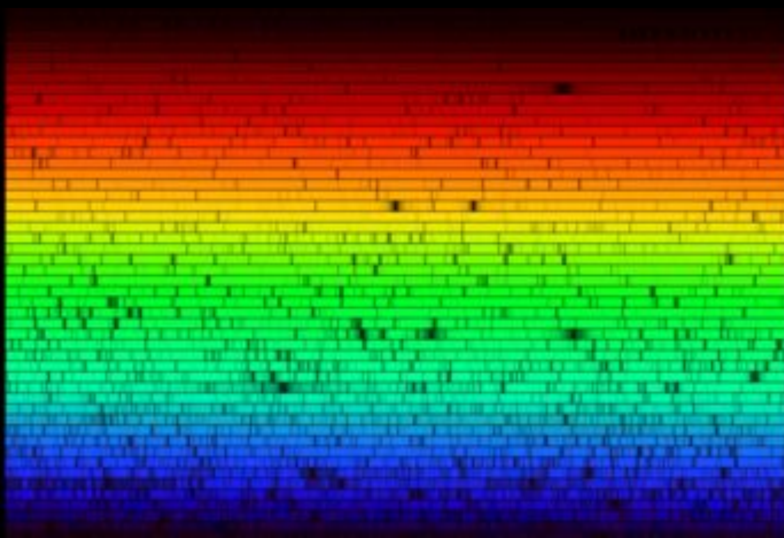


Part II-i: Stellar & Galactic Evolution

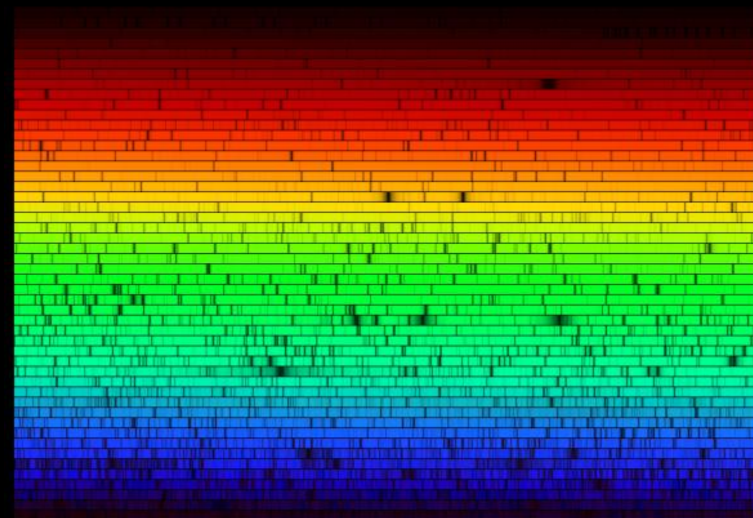


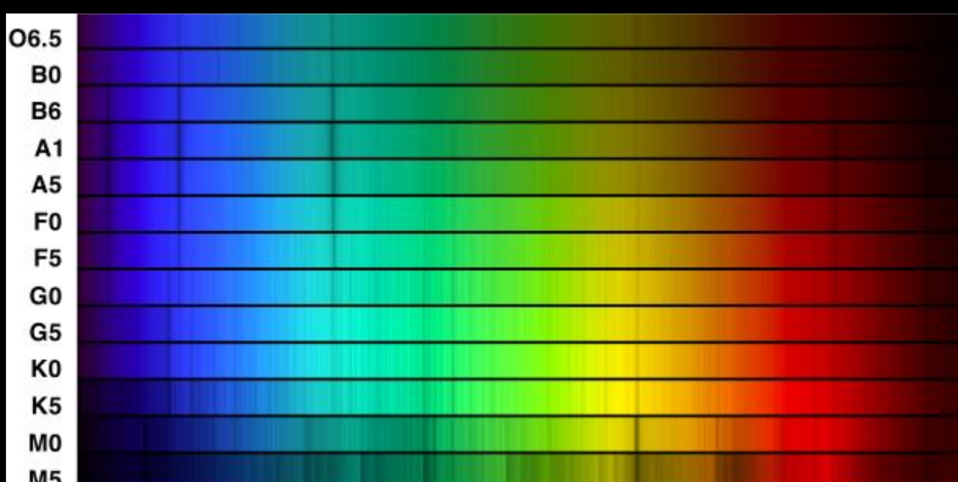
Part II-ii: Spectral Classification of Stars

Sun – G2

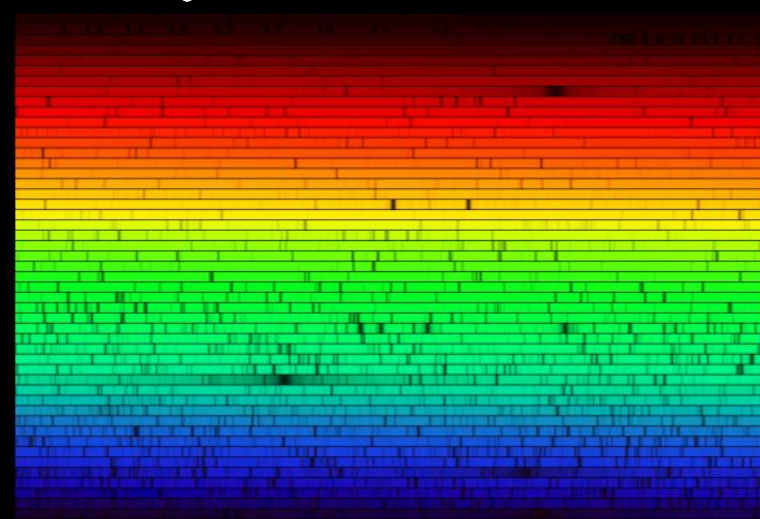


Arcturus – K1



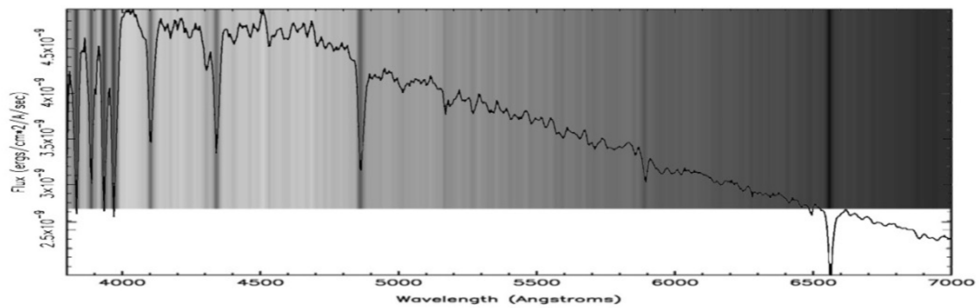


Procyon – F5

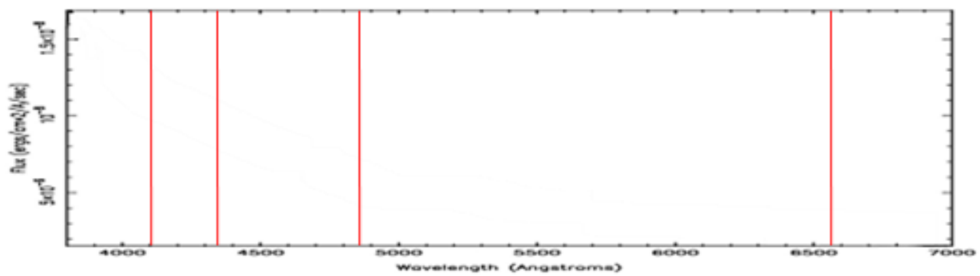


Spectroscopy & Stellar Classification

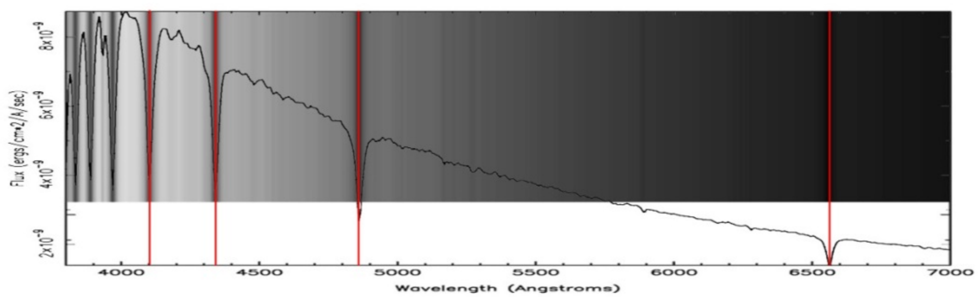
Spectral Image & Spectral Plot



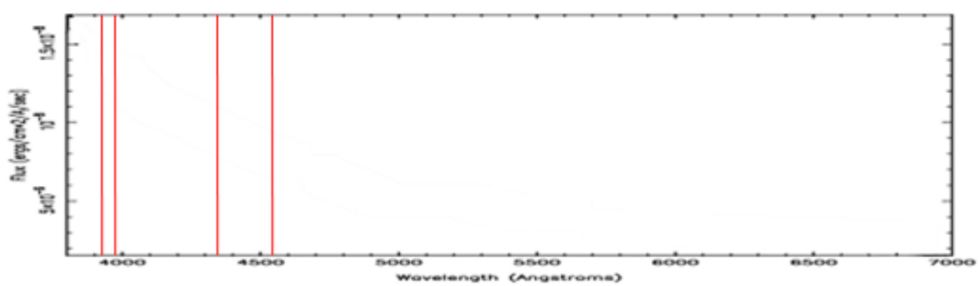
Hydrogen Balmer Lines



Spectral Image, Spectral Plot & Balmer Lines

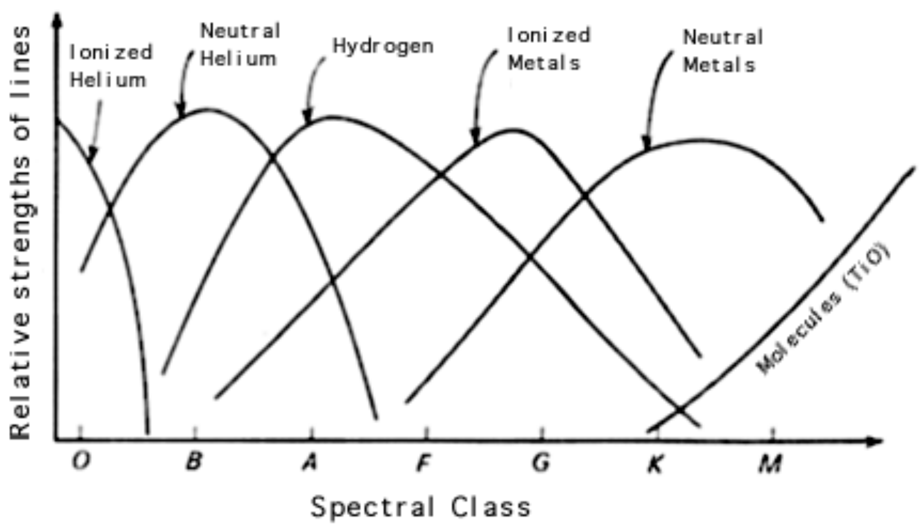


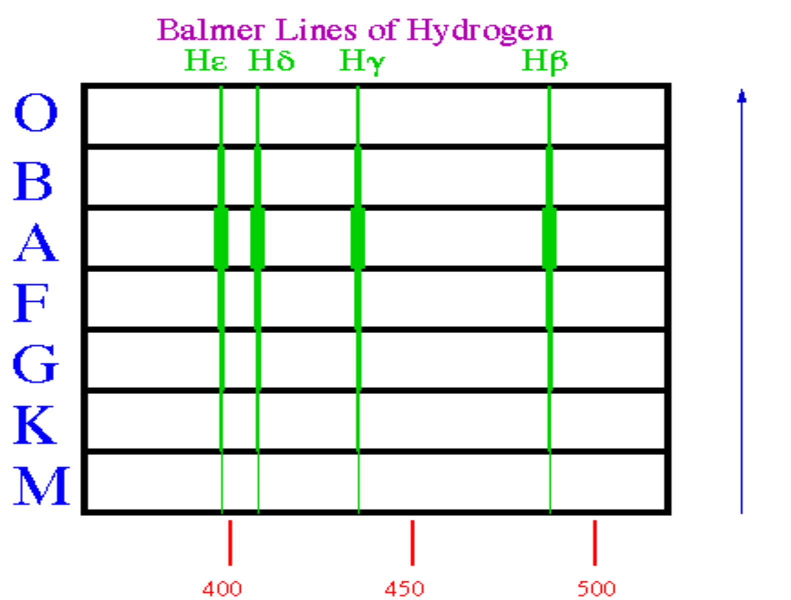
He, Ca, H Lines



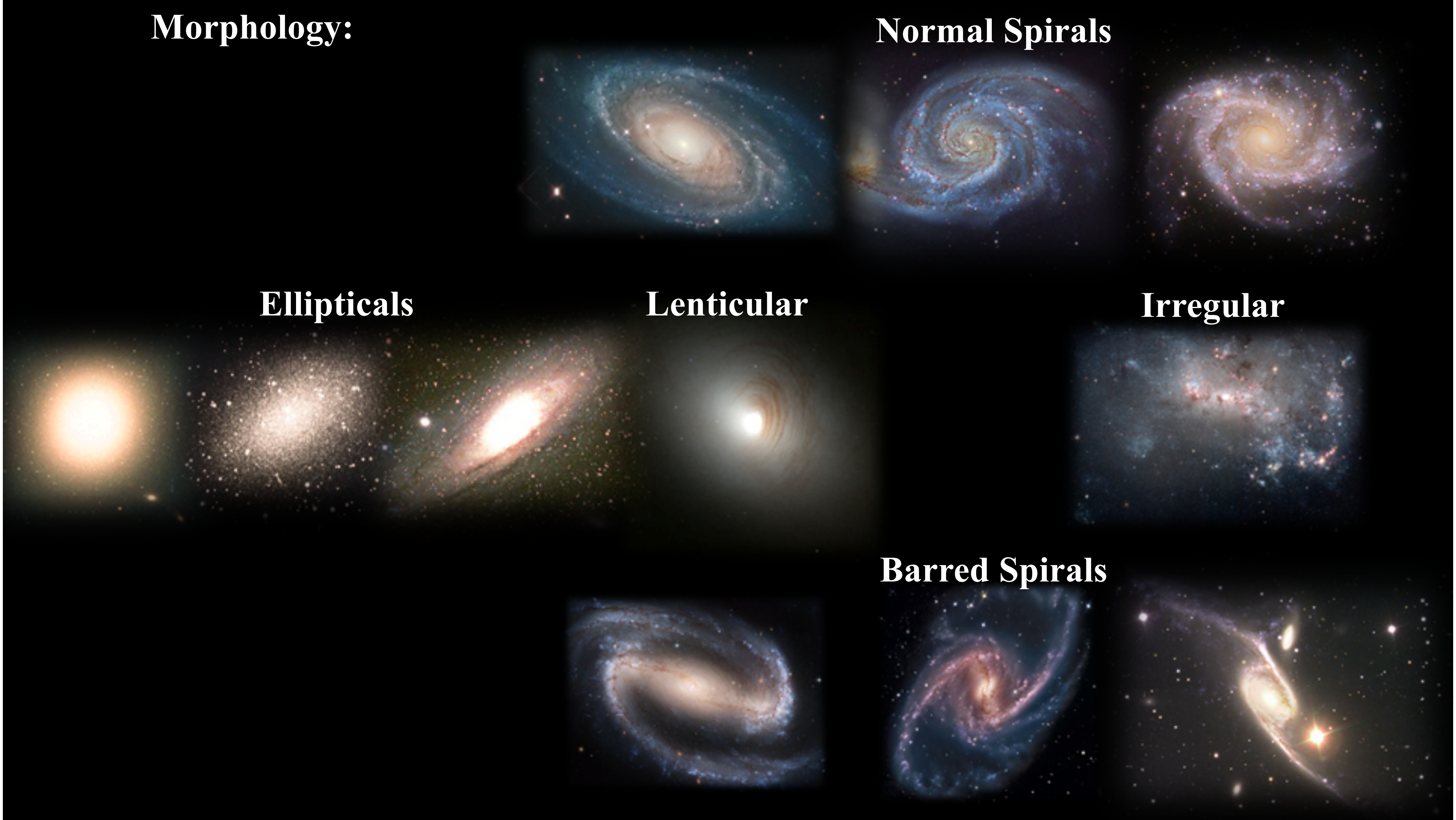
Summary of the Classification of Stars

Spectral Class	Temperature (°K)	Strength of Balmer lines	Other lines to look for
O	30,000 - 60,000	weak or not visible	Ionized He (4540Å)
B	10,000 - 30,000	moderate	
A	7,500 - 10,000	strong	
F	6,000 - 7,500	weak	Ionized Ca (3930Å, 3970Å) strong compared to neutral H (4340Å)
G	5,000 - 6,000	weak	Ionized Ca (3930Å, 3970Å) strong compared to neutral H (4340Å)
K	3,500 - 5,000	weak or not visible	Many lines, neutral Ca 4230 Å
M	< 3,500	not visible	Many lines





Part II-iii: Hubble Classification of Galaxies

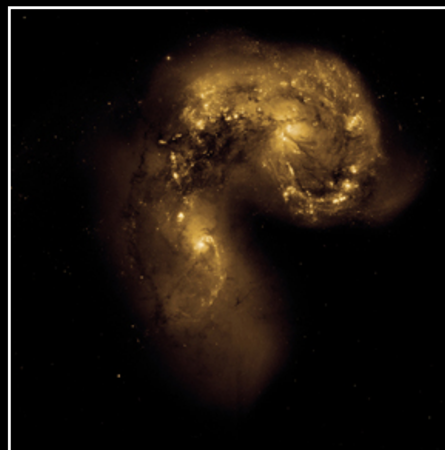


Part II-iv: Multiwavelength Universe

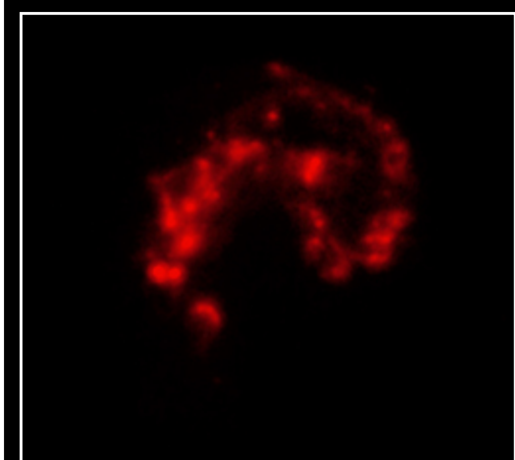
Antennae

Composite

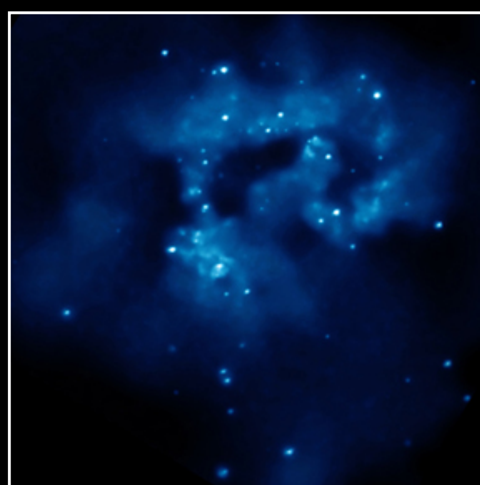
Optical



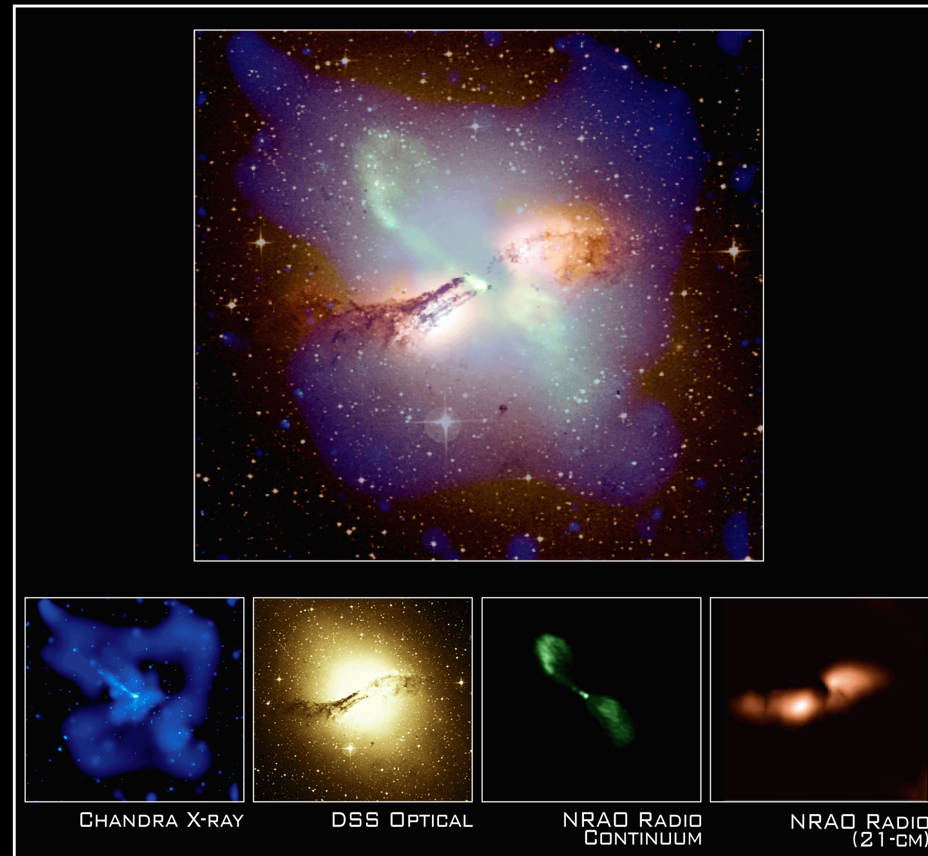
IR



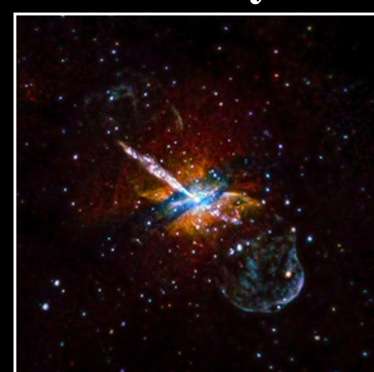
X-Ray



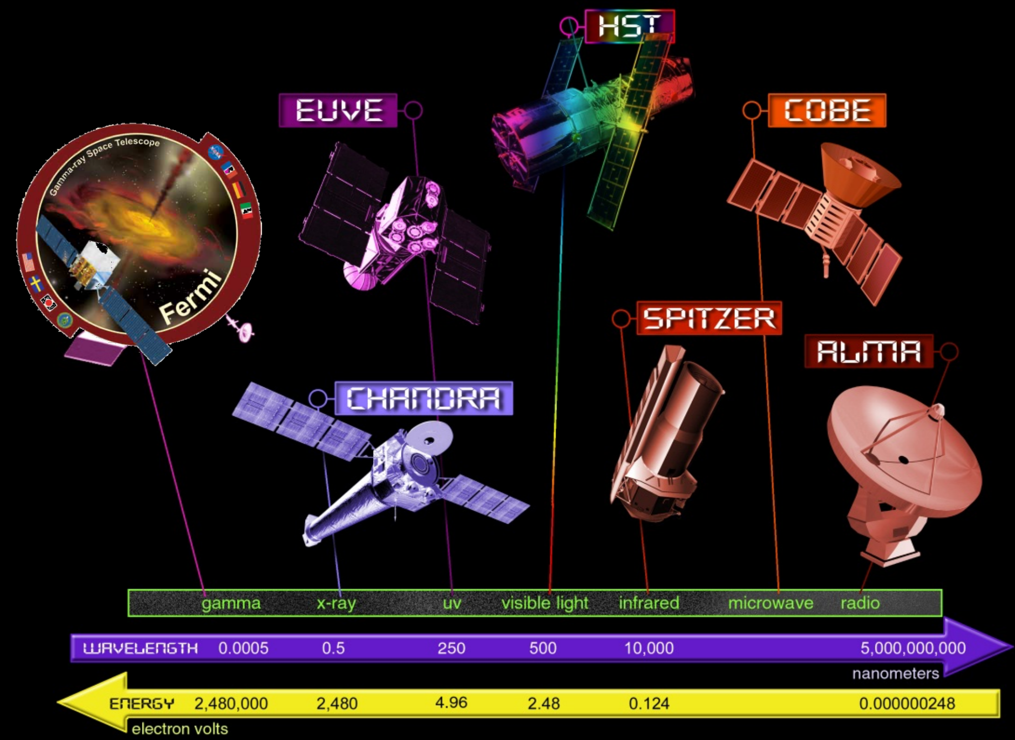
Cen A



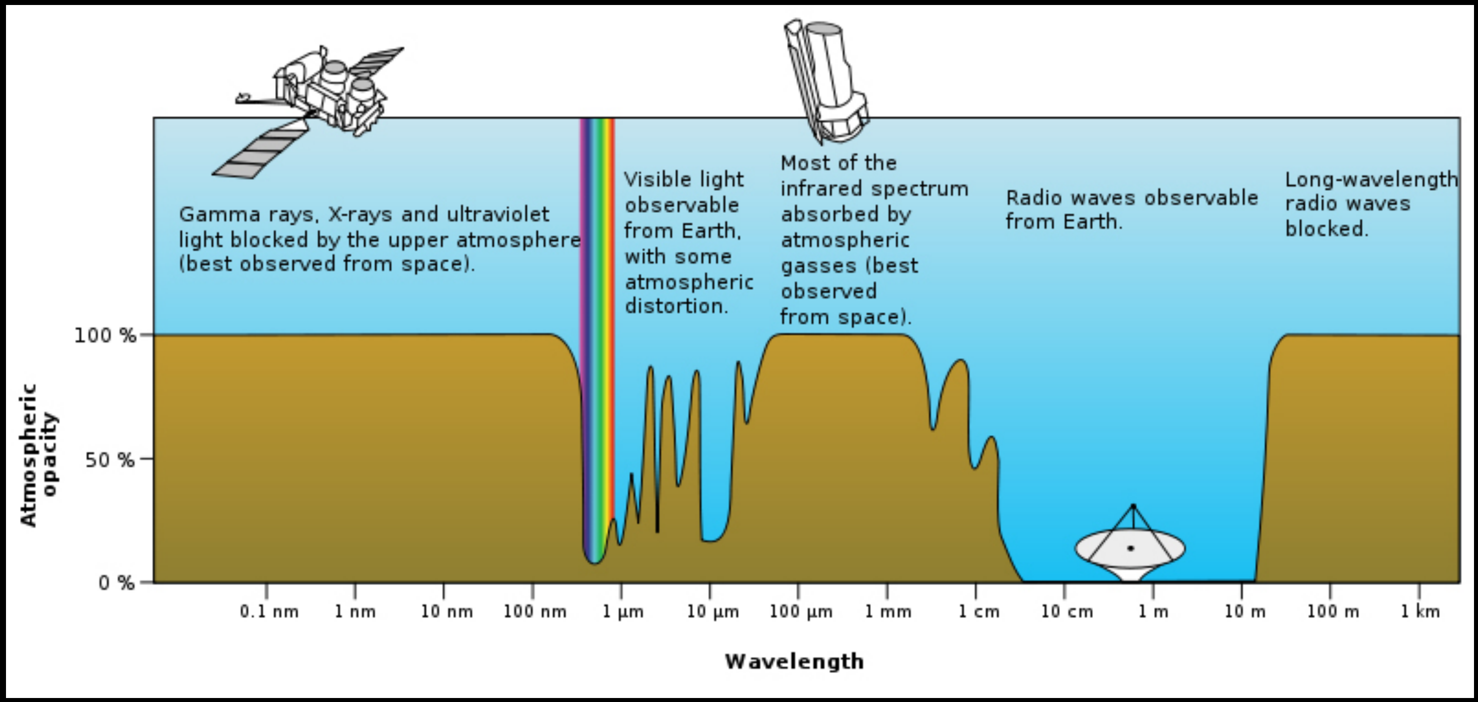
X-Ray



Radio

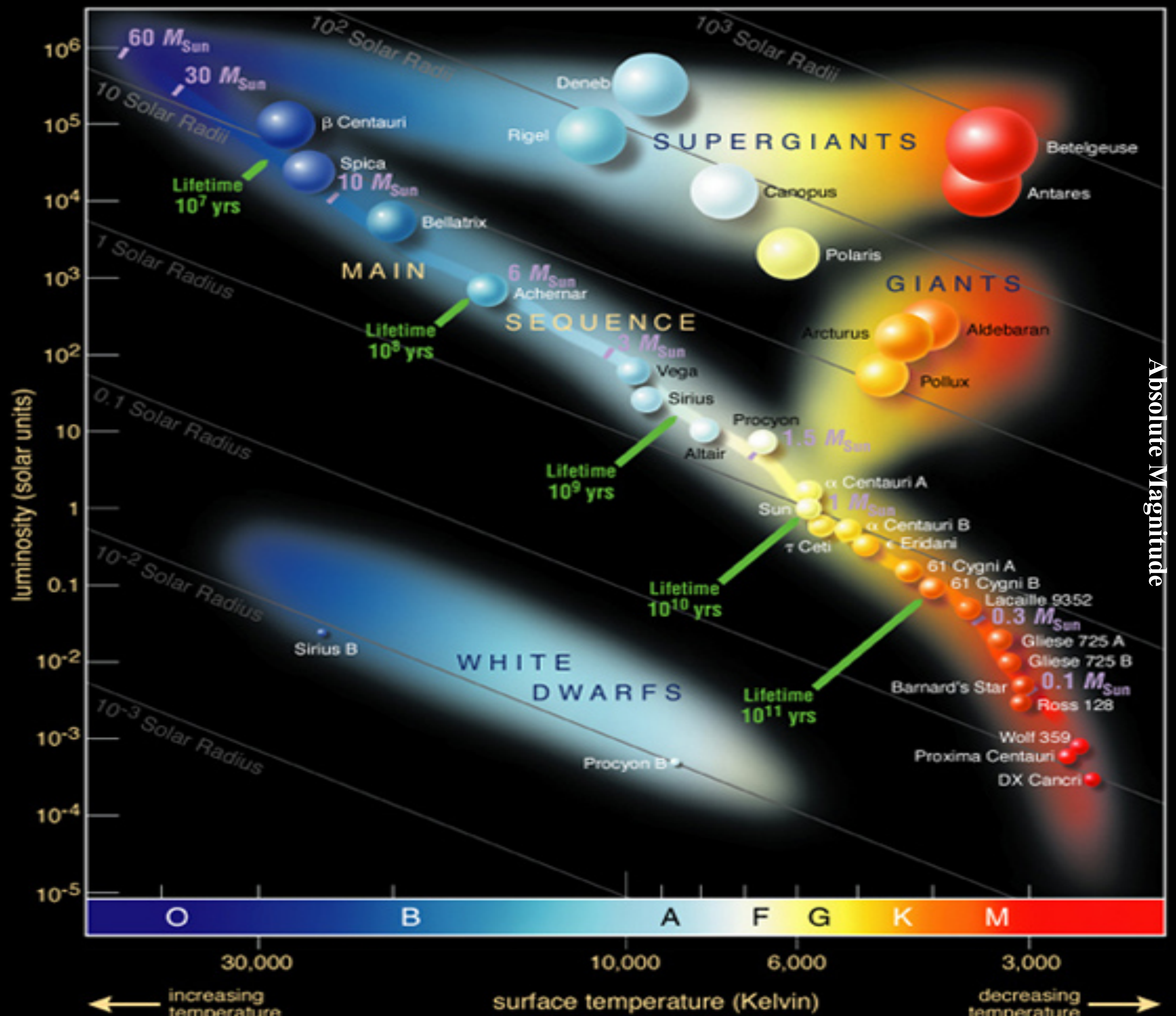


HST
EUVE
COBE
Fermi
SPITZER
ALMA
CHANDRA
gamma
x-ray
uv
visible light
infrared
microwave
radio
WAVELENGTH
0.0005
0.5
250
500
10,000
5,000,000,000
nanometers
ENERGY
2,480,000
2,480
4.96
2.48
0.124
0.000000248
electron volts



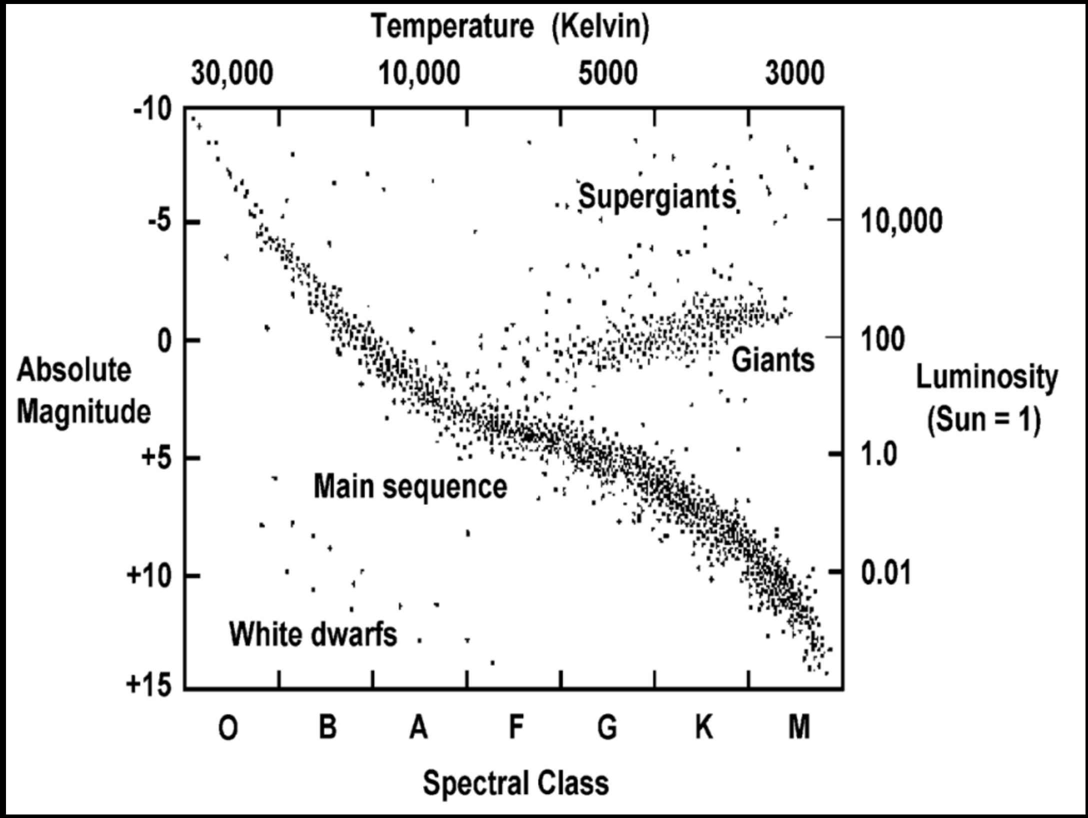
Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).
Visible light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio waves observable from Earth.
Long-wavelength radio waves blocked.
Atmospheric opacity
100 %
50 %
0 %
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength

Part II-v: Stellar Temperature, Radius, and Luminosity
II-vi: Magnitude & Luminosity Scales………



Part II-vi: Distance Modulus & Inverse Square Law

The Distance Modulus: $M = m - 5\log_{10}\frac{(r)}{10}$

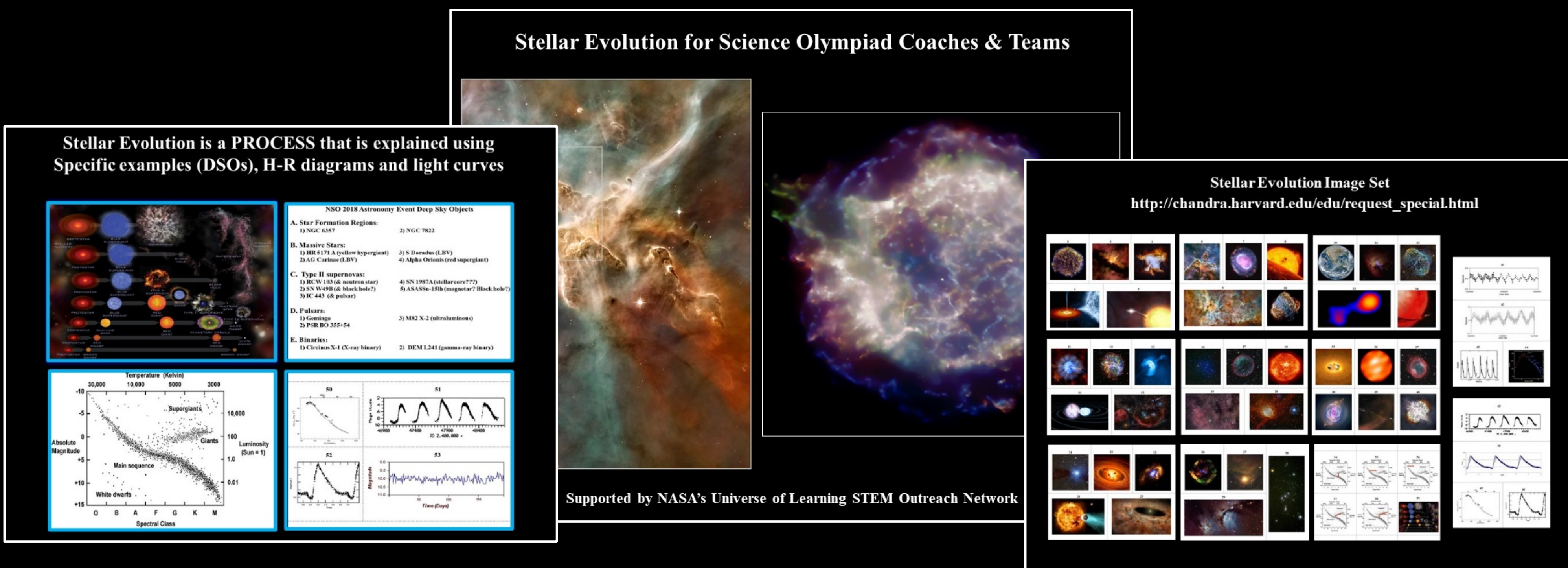


Inverse Square Law: $L = 1/r^2$

Resources

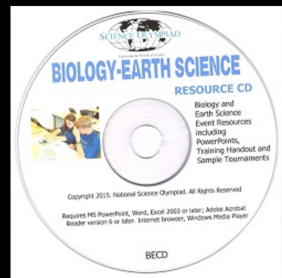
http://chandra.si.edu/edu/olympiad.html

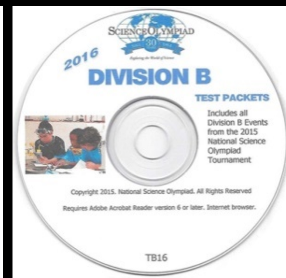
Stellar Evolution 101 for National Science Olympiad Coaches and Teams Webinar.

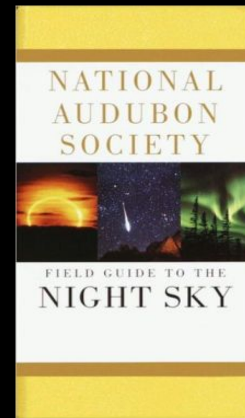


Resources

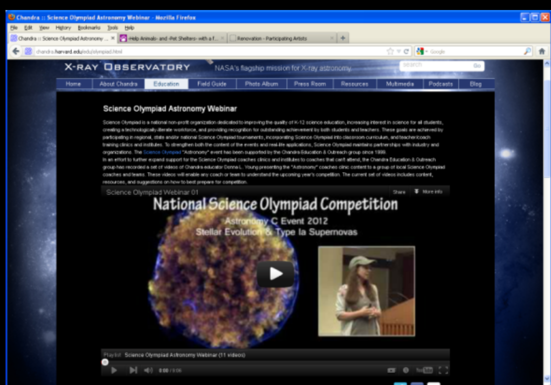
http://soinc.org



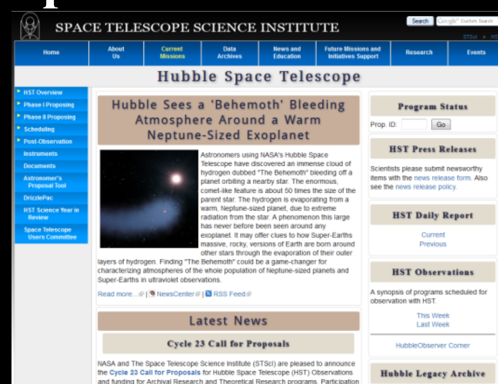




chandra.harvard.edu



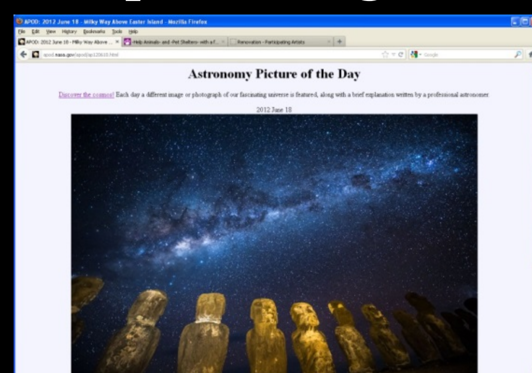
http://www.stsci.edu/hst/



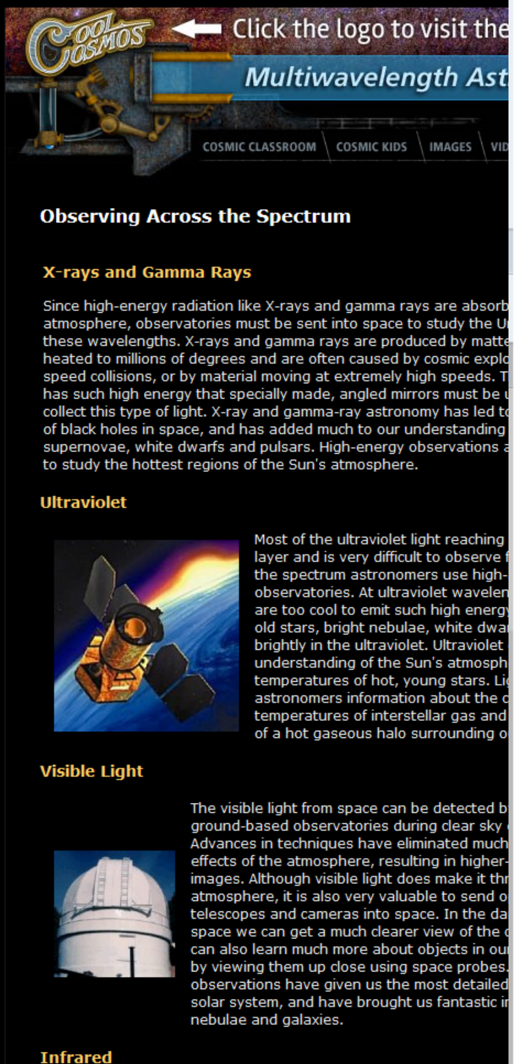
https://public.nrao.edu/

http://www.spitzer.caltech.edu/

apod.nasa.gov



Resources
The Cool Cosmos Website



Using the Electromagnetic Spectrum to Explore the Universe

Introduction

Celestial objects emit various forms of radiation depending upon their characteristics, and through the analysis of this radiation we gain an understanding of the universe. But how do we gather this information? The most common "tool" is the telescope which is used to gather visible light, but as you know the visible portion of the spectrum is only a small portion of the spectrum. To gather energy from other portions of the spectrum, we must developed more sophisticated tools sensitive to those particular frequencies. We know that our eyes are not sensitive to gamma rays, x-rays, ultraviolet, infrared, and radio waves, and so how are going to create tools that to collect something we cannot see? The ingenuity of astronomers has given us tools with gamma ray eyes, x-ray eyes, ultraviolet eyes, etc. A small complication of creating these tools is the decision about where to place these tools. Optical telescopes gathering visible light can be ground-based or space-based, with the best locations being in remote locations above the light and moisture in the atmosphere. For the balance of the spectrum we need to consider the characteristics of our atmosphere along with the characteristics of the frequency of energy.

Task Description

A new celestial object has been discovered and you and your research team have been asked to explore and provide as much information as possible about this object. You and your team have expertise in all areas of electromagnetic radiation and so your exploration will incorporate all the information you can find be using your knowledge of the electromagnetic spectrum. Once you find out the name of your object, you are to create a PowerPoint presentation or poster of the information you discovered about this object. Your presentation must include:

1. Images of your object in each form of electromagnetic radiation with the name and description of where the images came from.
2. The type of object it is and the distinguishing features of your object as revealed by each form of electromagnetic radiation. Discuss what these features are and how they were created
3. Explanations of why it is important to study this object using all areas of the spectrum while providing examples from your findings
4. An explanation of why it is important to study all areas of the spectrum.
5. An explanation of why astronomers use different types of tools and why some of these tools are ground-based and some are space-based.

Procedure

Go to the Multiwavelength page of Cool Cosmos.

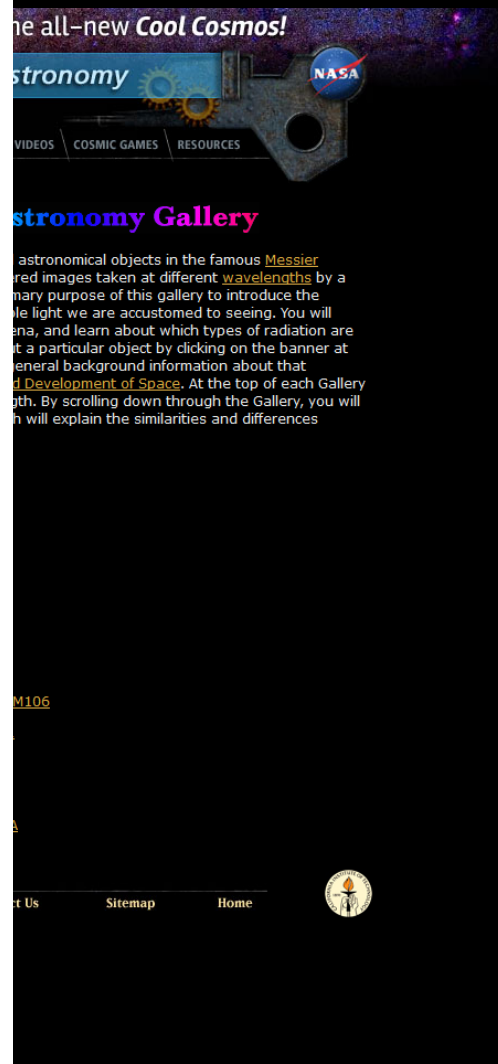
Search this website to complete the Table 1 and Table 2 below.

Table 1

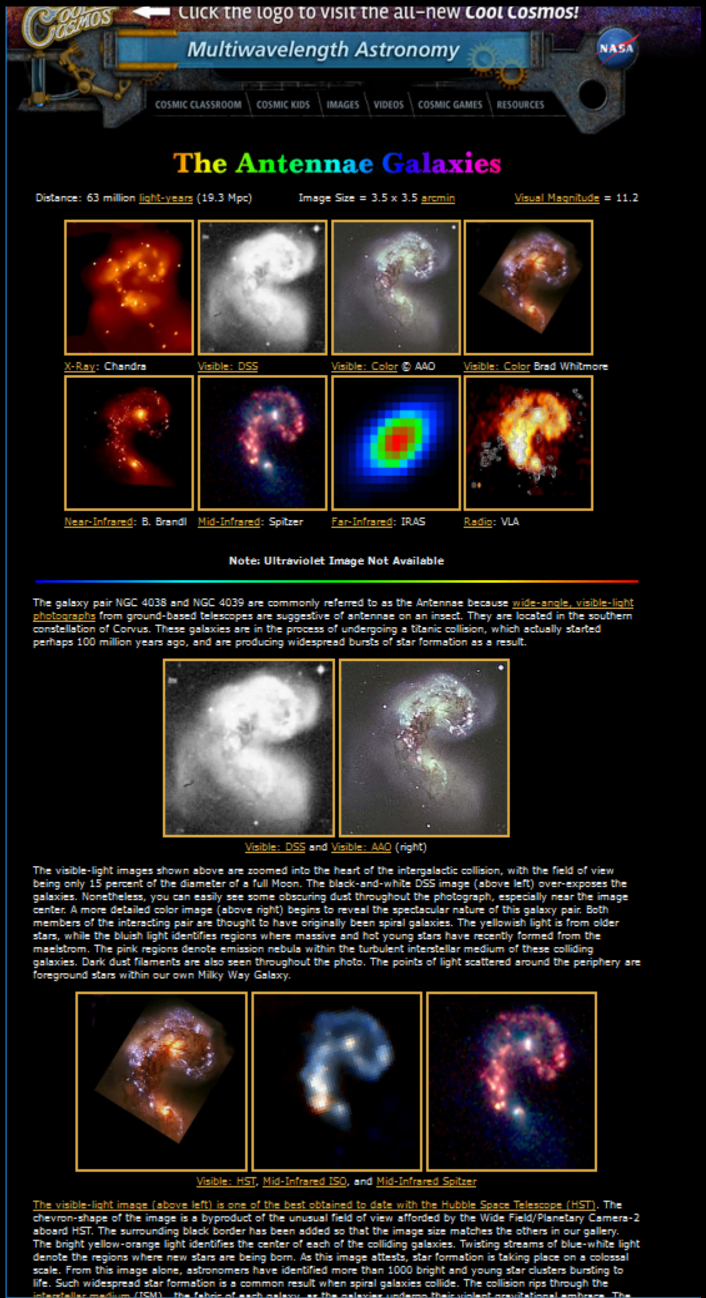
Type of Radiation	Objects Emitting This Type of Radiation
Gamma Rays	
X-rays	
Ultraviolet	
Visible	
Infrared	
Radio	

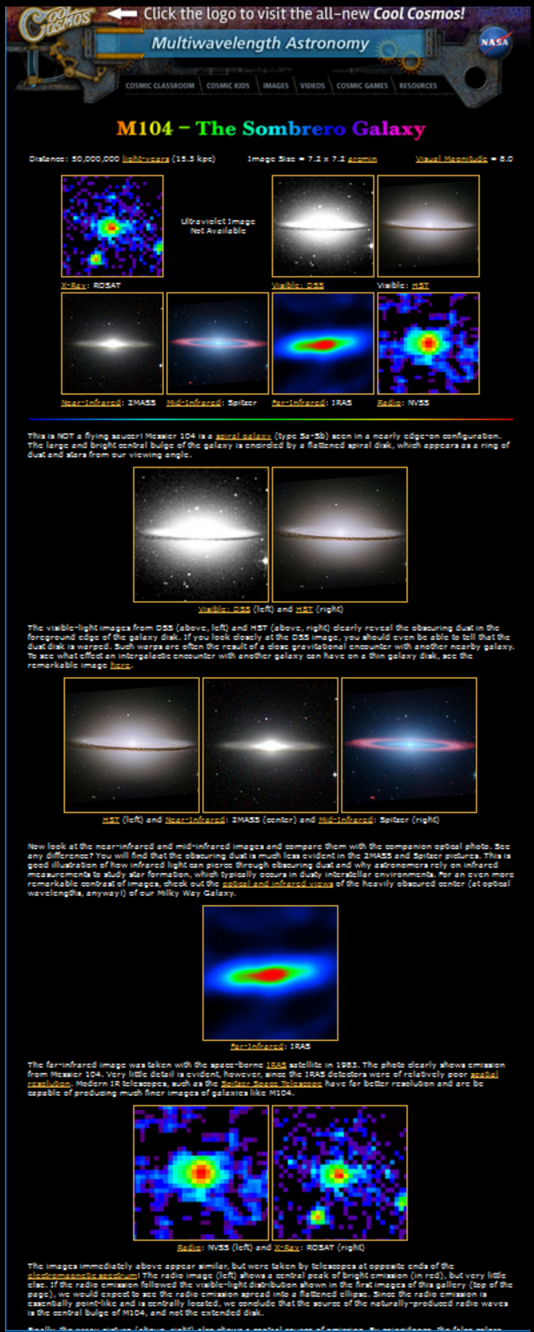
Table 2

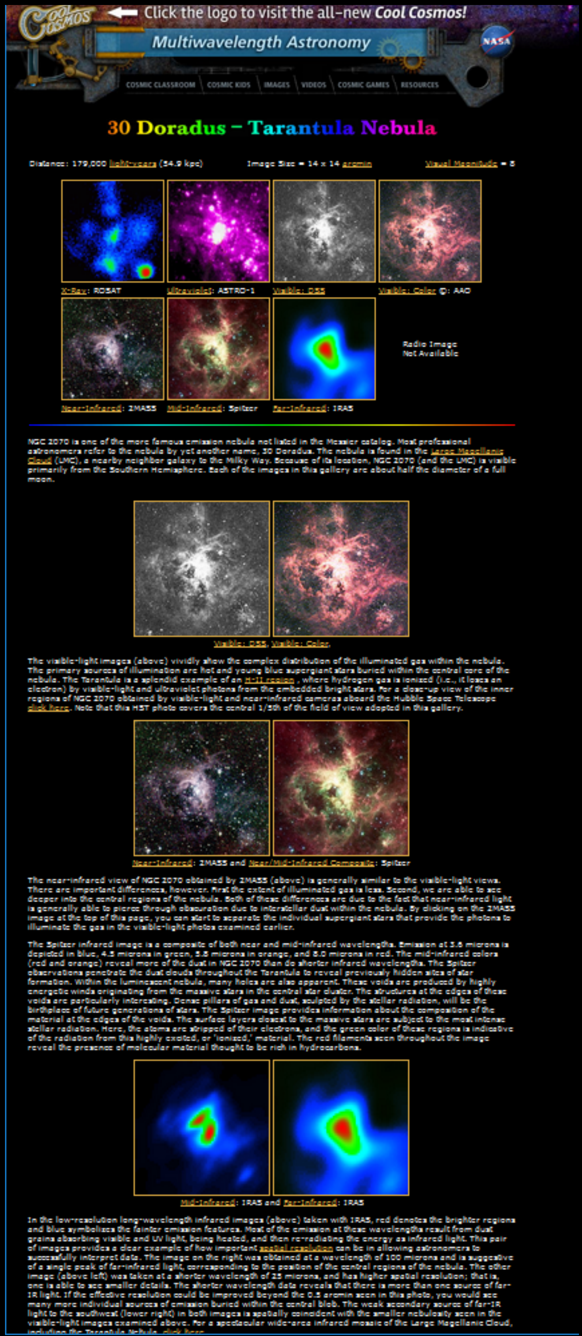
Type of Radiation	Tool Description - describe the tool that's used to observe this portion of the spectrum. Where is it located? What does it look like? How does it work?	Object Description - select one galaxy from the Multiwavelength Gallery which has images for each type of radiation. How does the object look using each tool?
Gamma and X-rays		
Ultraviolet		
Visible Light		
Infrared		
Radio		



The Cool Cosmos Website







Sample Pages NSO 2016 Reach for the Stars from Test Packet available at the NSO store

Questions 31 – 40 Refer to Image Set III

31. Which *Direction* would you be facing to see **Image 5** just above the horizon in Menomonie tonight?
32. What is the name of the *Constellation* that contains **Letter at** in Image 5?
33. Which *Letter* in Image 5 is contained within the **same constellation as** the star **Algol**?
34. What is the name of the *Star* that is labeled with **Letter as** in Image 5?

35. In which *Season* would see **Image 6** just above the horizon in Menomonie?
36. Which *Letter* in Image 6 is contained within the **same constellation as** the deep sky object **M1**?

Image 7 shows a light polluted sky just above the horizon near a large city in Wisconsin. The star labeled with Letter ba in Figure 7 is a main sequence star with an apparent magnitude of ~0.0

37. Does the star labeled with **Letter bd** have a positive or negative *apparent magnitude*?
38. What is the name of the *Star* that is labeled with **Letter bb** in Image 7?
39. What is the name of the *Constellation* that contains **Letter bc** in Image 7?
40. What is the name of the *Star* that is labeled with **Letter bd** in Image 7?

Questions 41 – 49 Refer to Image Set IV

The star labeled with Letter bc is a Red Supergiant with an apparent magnitude of ~ +1.0

41. What is the name of the *Star* that is labeled with **Letter bc** in Image 8?
42. What is the name of the *Constellation* that contains **Letter bc** in Image 8?
43. Is the star labeled with **Letter bb** in the *same constellation* as the star with **Letter bc** in Image 8?

44. What is the name of the *Constellation* that contains **Letter bd** in Image 9?
45. What is the name of the *Constellation* that contains **Letter be** in Image 9 ?

46. What general category of *Event* in stellar evolution is illustrated in both Image 10 and Image 11?
47. Does *Image 10* depict the process for a **Type 1a** or **Type 2** sub-category for this category of event?

48. How is the explosion triggered in the process shown in **Image 10 (3 points)**
49. How is the detonation is triggered in the process shown in **Image 11 (3 points)**

Questions 50 – 56 Refer to Image Set V

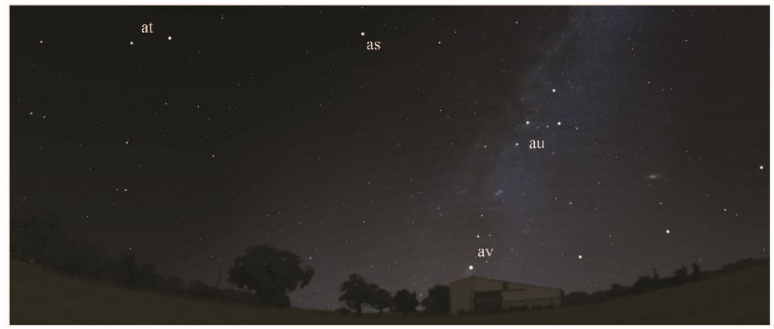
50. Which curve within **Image 12** was collected at an earlier date?
51. Which curve within **Image 13** corresponds to the process in **Image 11** in Image Set IV?
52. Which curve within **Image 14** corresponds to a star with the coolest surface temperature?

53. Which Image shows the absorption spectrum of the star with the hottest surface temperature?
54. Which Two Images show the absorption spectra for main sequence stars with **Spectral Class M**?

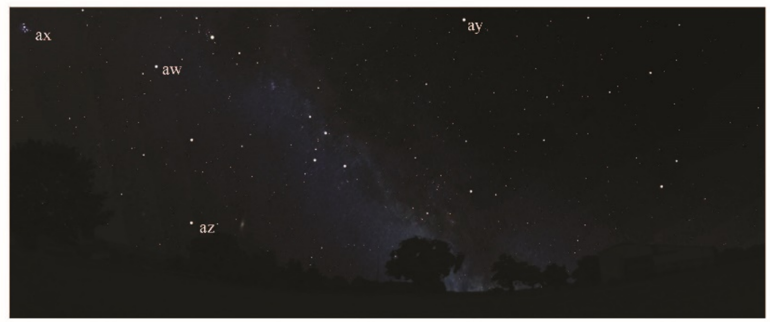
55. *Which Image* shows the light curve for the **Algol**?
56. *Which Image* shows the light curve for **Eta Carinae**?

Image Set III

5



6



7

Sample Pages NSO 2016 Reach for the Stars from Test Packet available at the NSO store

90. What is the *Name* for the dark features in the object in **Image 54**?
91. Which other *Image* shows that object that contains that image?

92. From *which Hemisphere* would the object in **Image 50** be visible?
93. Which other *Image* is contained within this object?

94. Which *Image* shows deep sky object **M17**?
95. Which *Two Images* show the **Rosette Nebula**?

96. Which *Image* shows **NGC 602** in the **X-Ray** portion of the electromagnetic spectrum?
97. Which other *Image* shows **NGC 602**?

98. Which *Image* shows the pulsar that produced the light curve in **Image 21** of Image Set V?
99. Which other *Two Images* shows the object containing that pulsar?
100. What is different between these three images of the same object and why is that the case? **(3 points)**

Questions 101 – 111 Refer to Image Set VIII

101. Which *Image* shows **W3 Main** in the **Infrared** portion of the electromagnetic spectrum?
102. Which *Image* shows **W3 Main** in the **X-Ray** portion of the electromagnetic spectrum?
103. Why are X-Ray and Infrared each useful for observing star forming regions? (**3 points**)

104. What is the *Name* of the deep sky object **labeled cn** in radio imagery in **Image 66**?
105. Which *Image* shows this same object in the **Gamma-ray** portion of the electromagnetic spectrum?
106. Which other *Image* also shows this same object?

107. What does *Image 63* show about **Cas A**? (**3 points**)
108. Which *Letter* in *Image 64* shows the location of **Eta Carinae**?
109. What *Type of Star* is shown in the black and white sub-panels of *Image 65*?
110. What *Type of Star* is shown with **Letter cp** in **Image 67**?

111. Describe the role of supernovae in star forming regions. (**3 points**)

Questions 112 – 120 Do not Refer to an Image Set

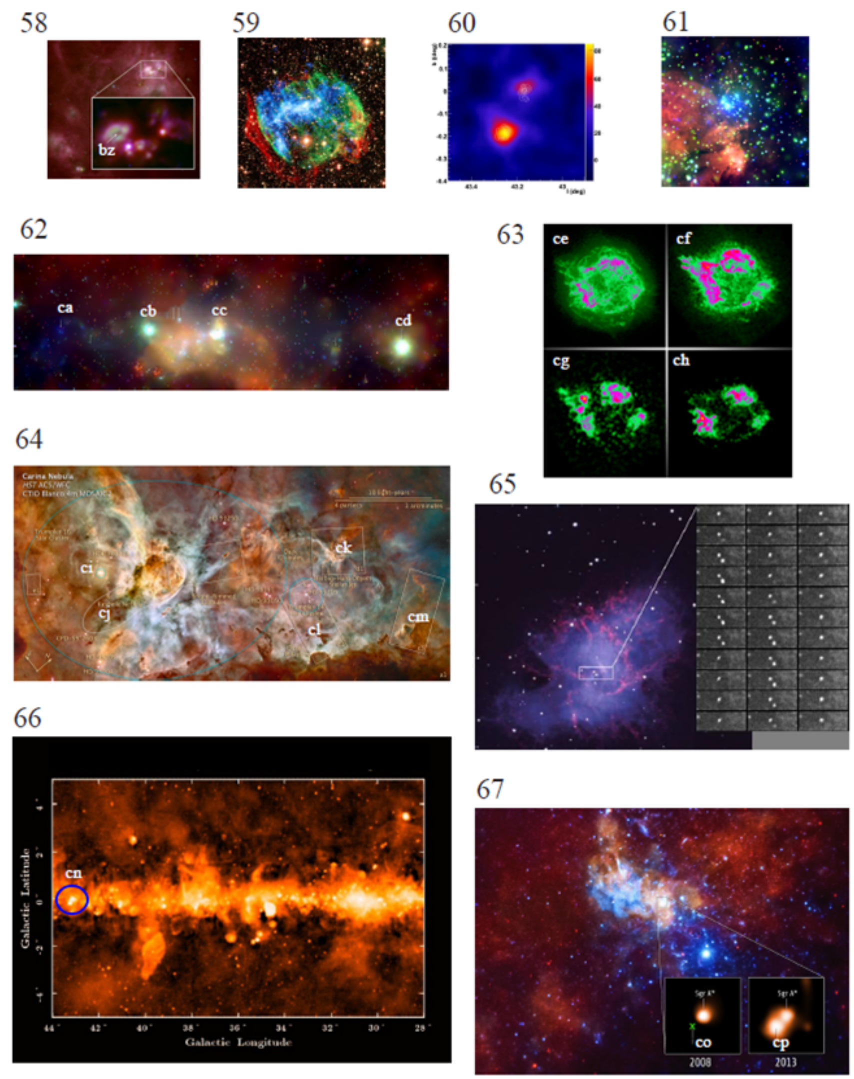
112. **Star A** and **Star B** have the same radius, but **Star A** is 16 times as luminous. Which is hotter?
113. How many times hotter? (**2 points**)

114. **Star C** has the same surface temperature as **Star D**, but twice its radius. Which is more luminous?
115. How many times more luminous? (**2 points**)

116. **Star E** and **Star F** have the same luminosity, but only 1/9 as much energy from **Star E** reaches Earth as from **Star F**. Which star is more distant from Earth?
117. How many times more distant? (**2 points**)

118. **Star G** has an absolute magnitude of − 6 and is 10 pcs away, what is its apparent magnitude?(**2 points**)
119. **Star H** has an absolute magnitude of − 1. Which star (**Star G or Star H**) is brighter?
120. How many times brighter? (**2 points**)

Image Set VIII



National Reach for the Stars Event Supervisor:
Claire Burch: claire.b.burch@gmail.com

Rules clarifications:
available at **www.soinc.org** under event information

Event Preparation:

1. Read the Event Description for content and allowable resources.
2. Use the Webinars (Chandra) and PowerPoints (NSO) for an overview of the content topics and deep sky objects.
3. Use the Astronomy Coaches Manual and/or links provided in the PPT notes section for information on stellar evolution and DSOs.
4. Use the websites in the event description for images and content.
5. The 2016 & 2017 test packets on the NSO website include Reach for the Stars tests and answer keys for those 2 years.
6. A sample state test and some early invitational and regional tests will be posted on the NSO website for teams to use as practice so keep checking at: https://www.soinc.org/officials/event-supervisors