Science Olympiad Reach for the Stars (2020) Webinar Transcript

Slide 1:
This presentation is an overview of the content and resources for the National Science Olympiad (NSO) Division B 2020 Reach for the Stars Event (RFTS). The NSO 2020 national competition will be held May 15th-16th at North Carolina State University in Raleigh, NC.

Slide 2:
The National Science Olympiad space science events – Astronomy, Solar System and Reach for the Stars – are supported by the NASA Astrophysics Division Universe of Learning STEM Literacy Network via the Chandra X-Ray Observatory and a partnership with the National Science Olympiad (NSO).

Slide 3:
The recommended resources for this event will be discussed at the end of the presentation. This RFTS Webinar and accompanying transcript will be posted on the Chandra X-Ray Observatory website at https://chandra.harvard.edu/edu/olympiad.html, and the accompanying PowerPoint (PPT) presentation (including links in the notes section of each slide) and transcript will be posted on the NSO website with a link to the Chandra website once the webinar has been posted. The PPT presentation and transcript will be posted on the NSO website.

Slide 4:
This is the first year of the 2-year RFTS rotation and it will be the focus in 2020 and 2021 before it rotates back to 2 years of Solar System. The content for 2020 will concentrate on the properties and evolution of stars and galaxies across the entire electromagnetic spectrum. Each team may bring two 8.5" x 11" two-sided pieces of paper containing information in any form from any source. The notes may be used during both parts of the event. Some regional and/or state competitions may use a planetarium or star dome. Coaches should contact their state directors for this information; if this type of venue is used, teams may need to provide clipboards and red lights for the event. The focus for Part I is star, constellation and deep sky object (DSO) identification. magnitude & luminosity scale, the distance modulus and the inverse square law.
Sometimes there are minor changes to the rules before they become final and available from NSO so be sure and read the event description carefully in case this has happened!

Slide 5:
This is a list of the constellations, stars and deep sky objects for the 2020 competition. The constellations are underlined, followed by major constellation stars in **bold** type and then by *deep sky objects (DSOs)* in italics. Part I focuses on identification using various charts containing these constellations, stars and objects. The list is in alphabetical order by constellation name.

Slide 6:
Part II focuses on various aspects of stars and galaxies themselves – evolution, classification, the electromagnetic spectrum, stellar temperature, radius, luminosity, magnitude and luminosity scale, distance modulus and inverse square law.

Slide 7:
This slide rearranges the deep sky objects into 4 separate categories – Stars (19), Galaxies (12), Star Formation Clusters/Regions (8) and 2 other objects. DO NOT FORGET that many of the stars the teams are responsible for learning are also in some stage of stellar evolution – i. e. Betelgeuse and Antares are red supergiants, and Polaris has transitioned off the main sequence.

Slide 8:
More information about the H-R diagram will be presented further along. Since the presentation of the DSOs includes their spectral class and luminosity classes, the H-R diagram terminology is given here for those unfamiliar with H-R diagrams. The H-R diagram is a plot of absolute magnitude (and/or luminosity) and temperature (and/or stellar classification) and where a star is plotted shows its evolutionary stage. Stars with stable hydrogen fusion in the core i.e. the Sun are located on the main sequence – and they evolve to other branches of the diagram when they have depleted their core hydrogen. Stars are also classified by their luminosity – how bright or luminous they are relative to the sun (G2V).

Slide 9:
The Hubble classification of galaxies is constructed by morphology. It is <u>NOT</u> an evolutionary sequence as galaxies do not have any specific evolutionary sequences but rather change over time due to their motions and interactions with other galaxies and galaxy clusters. This slide shows three classic spiral galaxies on top from tightest to loosest spiral arms and three barred spiral galaxies on the bottom from tightest to loosest structure. In the middle the first three galaxies are ellipticals from almost circular to increasingly elliptical followed by a lenticular galaxy that has a central bulge and a disk – however unlike spirals the disk has no structure. The last galaxy in the image is an irregular galaxy with no specific type of structure. There are also peculiar galaxies which are usually the result of interactions with other galaxies.

Slide 10: The constellation of Andromeda is home for M31 – the Andromeda Galaxy. M31 is very like our own Milky Way Galaxy (MWG) as it has the same spiral structure and with the MWG dominates the local neighborhood of galaxies (Local Group). It is “only” two million light years away. It contains an interesting and large assortment of black holes compared to the MWG black hole population.

Slide 11:
The center of the Andromeda galaxy is thought to be on a direct collision course with the center of the Milky Way Galaxy, or at lease close enough for the outer halos of the two galaxies to become gravitationally entangled. If so they would enter the gravitational dance and merge into one large elliptical galaxy in about 4 billion years or so.

Slide 12:
The constellation of Aquila the eagle contains the bright star Altair. This constellation/star is part of the Summer Triangle asterism. Altair is classified as an A7IV/V star. This means that it is more massive than the Sun and it is transitioning from the main sequence to the subgiant luminosity range on its way to the giant branch. (See the H-R diagram.) For the first time a rapidly spinning star has been imaged directly by the NASA telescope at Mount Palomar. Altair is spinning so fast that it has produced middle-aged spread along its equatorial diameter. Altair spins once every 10.4 hours and at the equator it is rotating at a speed of 470,000 MPH.

Slide 13:
The three massive stars Altair (Aquila the eagle), Deneb (Cygnus the swam), and Vega (Lyra the harp) form the asterism for the Summer Triangle.

Slide 14:
Capella is actually a 4-star system consisting of two binary pairs. One binary pair is bright and is what we "see" as Capella when we look at the constellation of Auriga – they are 10 times the Sun's diameter. These two stars are K/G-classification stars and have completed hydrogen fusion and have evolved to the red giant stage of post main sequence evolution. The second binary pair orbits are a large distance and consists of 2 red dwarf main sequence stars.

Slide 15:
Arcturus is a spectral class K red giant star in the constellation Bootes. It one of the brightest stars above the celestial equator – slightly brighter than Vega. It is part of a group of stars belonging to the Arcturus Stream and is moving at a large rate of speed (150 km/s) perpendicular to the galactic disk. It will eventually evolve into a planetary nebula and white dwarf.

Slide 16:
Procyon is a binary star system in Canis Minor with Procyon A – a main sequence star and Procyon B – a white dwarf. Procyon A is an F5IV-V star. Sirius in Canis Major is also a binary star system consisting of Sirius A – an A1V class main sequence star – and Sirius B, a white dwarf.

Slide 17:
The constellation of Centaurus contains Centaurus A (Cen A), also known as NGC 5128 – an extremely active starburst galaxy. These slides show a lot of detail involving star formation. Cen A is a peculiar elliptical galaxy that has resulted from a collision of two normal galaxies. The galaxy is only 11 billion LY away, making it the closest active galaxy to the MWG. The final slide shows an incredible powerful jet emitted by the massive galactic black hole in the center.

Slide 18:
Coma Berenices (Berenices Hair) is a faint group of stars located at the Galactic North Pole – straight "up" from the center of the MWG. The constellation is the only one named for an actual historical person – Berenices was married to Ptolemy III of Egypt and lived from 267 BC to 221 BC. Galaxy NGC 4555 is located in Coma Berenices. It is a large elliptical galaxy that is not part of a group or cluster. The galaxy is embedded in a huge cloud of 10 million degree Celsius gas which could not stay associated with the galaxy unless there is an enormous halo of dark matter confining the hot gas to the galaxy.

Slide 19:
Another galaxy is located in Coma Berenices. NGC 4676 is referred to as The Mice because of the long "tails" of star formation trailing from the merger of two spiral galaxies. The two spirals have already passed through each other and will continue to do so until they merge and coalesce into one galaxy. The bright blue sources are new massive stars that formed due to the collisions of these two galaxies – greatly increasing the rate of star formation.

Slide 20:
I love this crow! Corvus the Crow poor fellow was punished by Apollo who turned him from a white silvery bird with a musical voice into a black bird with only a “caw” because he lied to him about why he was late returning Apollo’s goblet full of water. Corvus stopped to eat figs but they were not ripe yet so he waited until they were ripe. Then lied to Apollo as to why he was late by saying a snake would not let him near the water. So Apollo placed him in the sky on top of the many headed water snake Hydra with the goblet in front of him to remind Corvus why he was punished!

Slide 21:
The galaxies NGC 4038 and 4039 are located in Corvus and are called the Antennae. The Antennae are two interacting galaxies caught in the midst of a 100 million year collision which is ripping the smaller galaxy apart and the compression of the gas and dust has initiated massive star formation.

Slide 22:
This slide shows the Antennae galaxies in optical (Hubble, brown and gold), infrared (Spitzer, red) and X-ray (Chandra, blue) and a composite of all three wavelengths. The collision which initiated the formation of millions of stars has now resulted in several supernovas which enrich the interstellar medium with metals that will be incorporated into the next generation of star formation. The bright sources are produced by material falling onto black holes and neutron stars, the Spitzer IR data shows where dust clouds are being heated by newly forming stars, the Hubble data shows the older stars and star formation regions, and the Chandra observations show the hot clouds which have been formed and the two largest and luminous stars have recently formed and the radiation is producing infrared radiation.

Slide 23:
The Crux is in the southern hemisphere and is the location of the Southern Cross. The crux is the smallest of the 88 constellations but the 4 bright stars that make up the Southern Cross make it easily recognizable, as seen in the second slide. Within the Crux constellation is the Dragonfish Nebula. The giant stars in the nebula are blowing a bubble that is 100 LY long. More than 400 stars have been detected to date and the cluster produces more microwaves than most clusters. The Dragonfish Nebula is the brightest and most massive cluster discovered so far. Due to its location and distance it is invisible in visible light.

Slide 24:
Cygnus the swan is the location of the northern cross and its brightest star Deneb is one of the three stars that make up the asterism The Summer Triangle. Deneb is a luminous blue supergiant and appears so bright not because it is close but because it is somewhere between 50,000 and 200,000 times more luminous than the Sun. The star produces a tremendous output of energy. The distance is difficult to determine (estimates range from 1500 to 3000 LY); however, it is further away than most of the bright stars in the night sky.

Slide 25:
The constellation of Dorado is in located in the southern hemisphere and is the location of a nearby galaxy – the Large Magellanic Cloud (LMC). The LMC along with the SMC,

Andromeda and the Milky Way Galaxy belong to the Local Group of galaxies along with ~50 other galaxies. The Large Magellanic Cloud (LMC) is located ~160,000 LY away and has always been considered to be a dwarf irregular galaxy. Now it is thought that it might be a disrupted barred spiral galaxy. The LMC is mostly in the constellation Dorado but part of it is in Mensa.

Slide 26:
30 Doradus is commonly known as the Tarantula Nebula and is considered to be the largest and most complex star formation region in the entire galactic neighborhood. 30 Doradus has been extensively studied by all the great observatories so be sure and be able to identify images at all observed wavelengths.

Slide 27:
Gemini has two bright stars – Castor and Pollux. Pollux is the brighter star and yellowish in color. Pollux is a spectral type K0III star – it has transitioned from the main sequence to the giant branch of the H-R diagram. Castor is a multiple star system – consisting of 3 pairs of binary stars all orbiting a common center of mass.

Slide 28:
The brightest star in Lyra is Vega – on of the 3 bright stars in the Summer Triangle. Vega is an A0 main sequence star. Vega is the fifth brightest star in the sky, and the brightest in the northern hemisphere summer sky. It is only 25 LY away and it is twice the size of the Sun but shines with a luminosity of 40 Suns. It rotates once every 12.5 hours and the equatorial bulge is so huge the star has become ellipsoidal in shape.

Slide 29:
Ophiuchus is the 13th zodiacal constellation and borders on Scorpius. Zeta Ophiuchi is a massive hot spectral class O9.5 main sequence star. It was most likely once in a binary system with a more massive star that evolved more quickly. When the companion star collapsed catastrophically producing a supernova event, Zeta Ophiuchi was flung out of the system. The runaway star is plowing through the interstellar medium (ISM) at ~24km/s producing a bow wave in the direction of travel.

Slide 30:
The rho Ophiuchi cloud complex is one of the closest star-forming regions to the solar system. It contains all the elements of active star formation – the blue reflection nebulas where massive stars are emitting high energy radiation, the reddish areas where the dust grains are being heated and emitting IR radiation, and the dark absorption nebulas where the thick clouds of gas and dust do not allow radiation to penetrate and that provides the materials necessary for star formation to begin. The central region contains at least 300 young massive stellar objects less than 300,000 years old.

Slide 31:
Orion includes two bright stars – Betelgeuse and Rigel. Betelgeuse is a red supergiant M2 class star, well on its way to a Type II supernova event which will most probably leave behind a neutron star stellar core. Rigel is a B8 spectral class star. It has exhausted its core hydrogen and

left the main sequence. This is actually a triple star system – Rigel A and a binary pair referred to as Rigel B. The two stars composing Rigel B are B9V spectral class stars.

Slide 32:
M42, the Great Orion Nebula, is a nearby star formation region – easily observable with the naked eye as the middle bright object in Orion's sword. M42 1500 LY away and contains a bright open cluster of young stars known as the Trapezium, as well as many stellar nurseries, proplyds and stellar jets. M42 has been observed numerous times by ground-based telescopes and spacecraft in all bandwidths of the electromagnetic spectrum.

Slide 33:
The second brightest star in Perseus is Algol (Beta Persei). This massive main sequence star is the prototype of all eclipsing binaries and the first one discovered. Algol is a 3-star system with the bright primary Beta Persei A regularly eclipsed by Beta Persei B.

Slide 34:
NGC 1333 is a reflection nebula in Perseus and lies at the edge of a large star-forming molecular cloud. It contains hundreds of stars less than one million years old – most not visible with optical telescopes due to the extensive dust clouds as can be seen in the multiwavelength images on the slide.

Slide 35:
The constellation Sagittarius is in the direction of the center of the Milky Way Galaxy (MWG) and the four million solar mass black hole Sgr A*. The Chandra mission has observed Sag A* extensively, determining the structure of it jets and accretion disk, as well as unanticipated star formation in the accretion disk around Sgr A*.

Slide 36:
The Chandra website has a visualization that gives you a 360 degree view of the center of the galaxy from the location of Sgr A*. It shows the details that Chandra has imaged and you can see the effects of winds being swept away from the massive stars in the crowded neighborhood at the center of the MWG.

Slide 37:
A major star formation region M8 (the Lagoon Nebula) is located in Sagittarius. This is an active star-formation region and is a reflection nebula as radiation from the massive stars embedded within the cloud emit UV radiation that ionizes the gas and causes it to shine.

Slide 38:
Sextans is a faint and small constellation in the southern sky near the celestial equator. It contains J100054+023436, sometimes referred to as the Baby Boom Galaxy. This galaxy is producing between 1000 and 4000 stars a year – compared to the MWG which only produces about 10 a year – putting J100054+023436 into the starburst galaxy category. It is thought to be a group of colliding galaxies which compresses the gas and dust and accelerates the rate of star formation.

Slide 39:
Antares is located in the constellation Scorpius. It is a massive MI highly evolved red supergiant star. It will soon – astronomically speaking – collapse into a neutron star in a Type II supernova event. Antares lies within the rho ophiuchi star formation complex. Antares is now the most detailed image of a red supergiant. The artist illustration shows what the observational data have indicated about the processes ongoing on the surface. How can these stars lose so much mass go quickly? Shows large upwelling and receding turbulence not explained by convection currents.

Slide 40:
There are two star formation regions in Scorpius – NGC 6357 (Lobster) and NGC 6334 (Cat's Paw) – both visible in the first image. The second image is a Hubble closeup of a massive star in NGC 6357. Some of the most massive stars detected to date are forming in this region, and their high energy radiation erodes the surrounding gas and dust around them, creating beautiful and eerie formations of clouds and pillars.

Slide 41:
The second star formation region – NGC 6334 (Cat's Paw) is an emission nebula, its red color the result of ionized hydrogen. Stars 10 times more massive than our Sun have been forming in this region within the past few million years.

Slide 42:
This slide shows two Spitzer IR images of the Cat's Paw nebula. The first image was imaged with the Infrared Array Camera (IRAC) and shows the dust heated by the radiation from nearby stars. The second image is from both the IRAC and the Multiband Imaging Photometer (MIPS) which adds an additional range of IR radiation.

Slide 43:
Aldebaran in Taurus is a spectral class K red giant star. It has evolved from the main sequence to the red giant branch and when it has a carbon core the star will undergo a Type II supernova event and collapse into a white dwarf and a planetary nebula. The protostar T Tauri is also located in this constellation.

Slide 44:
The southern hemisphere constellation Tucana is the location of the neighboring Small Magellanic Cloud Galaxy (SMC) – a member of the Local Group of galaxies along with the MWG, LMC and Andromeda. The SMC contains huge SF regions. It is 190,000 LY away. Tuc 47 globular cluster in MWG also in image 3.

Slide 45:
Ursa Major and Minor, big bear and little bear, are circumpolar constellations in the northern hemisphere and currently Polaris in Ursa Minor is near the center of the north terrestrial pole. Polaris is a spectral type F7I supergiant star. It has evolved off the main sequence and undergoes radical variation in brightness. Polaris is currently the star closest to the north celestial pole due to the 26,000 year precession of the Earth's axis. Mizar and Alcor make up a 6-star system. Mizar is a binary system and it is gravitationally bound with Alcol which consists of 2 binary systems. The Mizar system is composed of A2– A7 main sequence stars.

Slide 46:
Galaxy GN-z11, located in the direction of Ursa Major, is currently the oldest and most distant known galaxy in the observable universe. It is located in the GOODS-North field of galaxies with a redshift number of z11 hence the name GN-z11. The distance was measured spectroscopically using data from the CANDELS Legacy Survey. The galaxy is 13.4 billion LY away, placing it between the near end of the Dark Ages and near the beginning of the reionization era. It has 1% of the mass of the MWG and formed stars 20 times faster. The fact that a galaxy this massive existed so soon after the first stars started to form challenges current theoretical models of galactic formation.

Slide 47:
M101 (Pinwheel Galaxy) is a face on spiral galaxy located in Ursa Major. The pink and blue areas are the locations of star formation regions that may have formed from an interaction with a neighboring galaxy. This compressed clouds of gas and dust that were produced by the interaction then condensed and eventually formed stars – greatly accelerating the rate of star formation of M101.

Slide 48:
This slide shows the multiwavelength observations of M101 from Chandra (X-ray), GALEX (UV), Hubble (optical), and Spitzer (IR).

Slide 49:
Spica in the constellation of Virgo is a B1III class star – it has evolved off the main sequence and is in the sub giant phase as it approaches the red giant stage. It will eventually collapse in a Type II supernova event. Spica is 2-star system that is so close the shapes of both stars are distorted by gravitational interaction.

Slide 50:
Virgo also contains two interesting galaxies, M60 and M104 (Sombrero Galaxy). M60 is a massive elliptical galaxy with randomly swarming older stars. It is one of the largest galaxies in the Virgo Cluster. It may end up in a gravitational encounter with the neighboring spiral galaxy.

M60 contains an ultra-compact dwarf galaxy – the densest galaxy in the nearby universe. There is a bright X-ray source in the middle of the dwarf galaxy which may be a supermassive black hole. The origin of this type of galaxy may well be the result of gravitational stripping of its gas and dust by encounters with other galaxies.
M104 (Sombrero Galaxy) is also in Virgo. It is a nearly edge-on spiral galaxy and like M60 is one of the largest galaxies in the Virgo cluster of galaxies. The edge on disk with all the gas and dust lanes obscures much of the interior of the galaxy.

Slide 51:
Part II-i in the event description involves stellar and galactic evolution.The first graphic illustrates stellar evolution. The information about the stars needs to be kept in the context of stellar evolution. Protostars form in star formation regions next to giant molecular clouds. The condensing clumps of dust are the beginnings of new stars whose radiation then carves away the surrounding gas and dust. The stars fuse core hydrogen and when the hydrogen fuel is

exhausted, depending on the initial mass of the star, start a sequence of fusing heavier and heavier atomic nuclei. Eventually stars with enough mass collapse into planetary nebulas, white dwarfs, supernova remnants, neutron stars and black holes (Type II events). White dwarfs in contact binary systems may also undergo thermonuclear destruction and lead to Type Ia events.

The H-R diagram is a plot of stellar temperature (spectral class) versus absolute magnitude (luminosity). The location of a star on the H-R diagram shows its evolutionary stage. The main branches are the main sequence, the giant branch, the supergiant branch, and the white dwarf branch. Stars on the giant branch most probably will result in planetary nebulas and white dwarfs; the supergiant branch supernova remnants, neutron stars and black holes. Stellar evolution is very complex and the mechanics of the process unique to each event.

Slide 52:
Part II-ii focuses on the spectral classification of stars. Everything known about stars has been determined by analyzing their light – spectroscopy. Spectra are extremely complicated – even just the visual bandwidth as shown on this slide of the Sun, Arcturus and Procyon – so they are condensed into the familiar bar codes to show only the major absorption lines associated with each spectral type as shown on the lower left.

Slide 53:
The bar code spectra are images and it would be difficult to measure the exact wavelength for each absorption line using the images. The spectral plot version allows a specific measurement to be made for each absorption line. Since each wavelength represents a unique element, this allows the composition for stars to be determined. Besides the Balmer lines, there are other elements that are unique to stars of specific classification types (temperatures). For instance, the Sun has a double calcium absorption line that is unique to all G class stars.

Slide 54:
This table summarizes the temperature, strength of Balmer lines, and other unique elemental lines for spectral classes O, B, A, F, G, K and M. The graph on the lower left shows the dominant strength of the neutral and ionized elements, and the graph on the lower right shows how the strength of the Balmer lines relate to the temperature (spectral class) of the stars.

Slide 55:
Part II-iii includes the Hubble Classification of Galaxies. When Hubble put together his “tuning fork” diagram of galaxies it was thought that galaxies evolved from one shape to another over time. The Hubble Classification still focuses on the morphology of galaxies; however, we now know that they do not evolve from one type to another. Galaxies mostly change over time from their interactions with each other, either individually or in groups or clusters. The major types of galactic classification by morphology are the Ellipticals, Lenticulars, Normal Spirals, Barred Spirals and Irregulars.

Slide 56:
Part II-iv is on the multiwavelength universe. Teams need be familiar with the deep sky objects in all bands of the electromagnetic spectrum (EMS). The different bandwidths are produced by different processes. The deep sky objects cannot be understood unless all the ongoing processes

are studied. Some objects are only strong in X-ray and cannot be detected in the visible, and some visible objects are not emitting in the X-ray part of the spectrum. Most objects, just like the Sun, are emitting radiation across the EMS.

Slide 57:
Due to interference, absorption and/or opacity, some radiation can be observed from ground-based telescopes, and others can only be detected from orbiting spacecraft. Knowledge of the locations of different types of spacecraft and telescopes is important to understand.

Slide 58:
Parts II-v and II-vi involve the physical properties of stars. The Absolute Magnitude (M_V) is the intrinsic brightness of a star. It is a logarithmic scale with the brightest stars having the largest negative number and the dimmest stars having the largest positive number. The Luminosity scale is an arbitrary scale with the Sun assigned the value of one solar luminosity. Luminosity is a measure of the total power of a star. Stellar surface temperatures (Kelvin) range from hottest (spectral class O) to coolest (Spectral Class M). Radius on the main sequence increases from coolest (spectral class M) to hottest (spectral class O). Giants have larger radii than main sequence stars, and supergiants have larger radii than giants. White dwarfs have the smallest radii. The second H-R diagram shows the H-R diagram locations and luminosities of most of the constellation stars in this year's competition.

Slide 59:
The distance modulus is a logarithmic relationship among absolute magnitude, apparent magnitude, and distance. It is used to calculate distances of stars and objects. The Inverse Square Law simply states that for stars, their brightness (or luminosity) is inversely proportional to the square of their distance.

Slide 60:
Here are two examples of the H-R diagram showing the different branches. Many of the stars in this event are plotted on one or both of these diagrams. Their placement shows their evolutionary stages. Once a star is plotted on the H-R diagram, its age, composition, and evolutionary history is known.

Slide 61:
One of the webinars posted on the Chandra website is Stellar Evolution for Science Olympiad Coaches & Teams. This is basically a stellar evolution 101 introduction of how stars form in star formation regions and evolve over time into their final end products. If this is your first year of the Reach for the Stars B Division event, it is a good place to begin your understanding of the process of stellar evolution. The image on the lower left is further explained in the next slide.

Slide 62:
This slide represents the essence of understanding the process of stellar evolution. These 4 segments – Stellar Evolution, the Deep Sky Objects, the H-R diagram and the Light Curves should not be treated as separate topics to learn but an integrated portrayal of the entire process. Teams think they need to learn about the DSOs and the Light Curves and the H-R diagram and treat them as separate topics – instead of different methods of learning about stellar behavior during the transition from Main Sequence to final end products. Light curves are not listed in

the event description – they are the change in brightness over time of stars transitioning from one branch of the H-R diagram to another branch as they evolve.

Slide 63:
These websites are the best places to search for additional information. The APOD website is a great place to search as it will list all public release images for each DSO. The CDs are on the NSO website.

Slide 64:
The Cool Cosmos Website was developed by the Spitzer mission. It is designed to teach basic multiwavelength astronomy and missions that observe in specific bandwidths of the

electromagnetic spectrum. The explanations are basic but cover all the essential information. The website URL is located at
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_astronomy/
There is an activity posted on the Chandra website that you can have teams complete based on the Cool Cosmos materials at
https://chandra.harvard.edu/edu/formal/ems/ems_explore_universe.html

Slide 65:
The Cool Cosmos Website has pages which show and explain multiwavelength astronomy for several deep sky objects. This slide displays the contents of the page for the Antennae, M104 and 30 Doradus – all DSOs in the RFTS 2020 event description. Other deep sky objects for the 2020 competition are also listed on the Cool Cosmos Multiwavelength Astronomy Page – LMC, SMC, Centaurus A, M101, and the Andromeda Galaxy M3.

Slides 66 & 67:
Sample pages from the NSO Reach for the Stars event. The entire test (4 pages) with image sets (8), response pages and answer key is available from the NSO Store website for $18 (. A Great resource to prepare for the 2017 competition! Posted at http://store.soinc.org/c-7-test-packets.aspx

Slide 68:
Follow these suggestions to prepare for competition. If you have any questions about the event description, please submit them online at the rules clarification page. Event supervisors are not allowed to answer any individual questions about the event as this would be unfair to others. The 2016 and 2017 Test Packets on the NSO website includes the Reach for the Stars tests and answer keys. A state test will be available for teams to use as an assessment for what content they may need to further study in preparing for competition. Some of the invitational and regional competitions that take place early will also be posted on the NSO website so all teams will have access to tests to help them prepare for the RFTS event.