Science Olympiad Reach for the Stars Event (2017) Webinar Transcript

Slide 1:

This presentation is an overview of the content and resources for the National Science Olympiad (NSO) Division B 2017 Reach for the Stars Event (RFTS). The NSO 2017 national competition will be held at Wright State University in Dayton, OH on May 19th and 20th.

Slide 2:

My name is Donna Young, and I work with the NASA Astrophysics Division Chandra X-Ray Center to produce materials, clinics and workshops for NSO. The NASA Astrophysics Division/CXC is supporting both the Division B Reach for the Stars t and the Division C Astronomy space science events.

Slide 3:

The recommended resources for this event will be discussed at the end of the presentation. The Webinar and transcript is posted on the Chandra X-Ray Observatory website at <http://chandra.harvard.edu/edu/olympiad.html> and the accompanying PowerPoint presentation (including links in the notes section) will be posted and available for download on the NSO website.

Slide 4:

This is the second year for the RFTS content rotation, and like 2016, the content focus in 2017 will concentrate on stars and stellar evolution. As in 2016, the specific focus for the 2017 competition is the properties and evolutionary stages for stars – especially star formation regions and supernova remnants – as observed 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 will need to provide clipboards and red lights for the event. The focus for Part I is star, constellation and deep sky object identification and the focus for Part II focuses on various aspects of stars themselves – evolution, classification, the electromagnetic spectrum, stellar temperature, radius, luminosity, magnitude & luminosity scale, the distance modulus and the inverse square law. The only difference in 2017 from 2016 is that a few of the constellations and deep sky objects have been changed.

Slide 5:

This is a list of the constellations, stars and deep sky objects for the 2017 competition. The constellations are listed, followed by major constellation stars in bold type and then by deep sky objects. Part I focuses on identification using various charts containing these constellations, stars and objects. The difference between 2016 and 2017 is that Monoceros is out and Serpens and Tucana have been added. There are 5 new deep sky objects – geminga, M57, M16, T Tauri and the SMC.

Slide 6:

This slide rearranges the deep sky objects into 4 separate categories – Star Formation Regions (8), Supernovas (4), Specific Evolutionary Stages (5) and Galactic (3). 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 7: More detailed information about the H-R diagram will be presented further along. Since the presentation of the deep sky objects 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 are located on the main sequence – and they evolve to other branches of the diagram when they have depleted their core hydrogen.

Slide 8:

The constellation Aquarius contains NGC 7293 – also known as the Helix Nebula. It is the end result of a Sun-sized star that ran out of hydrogen, evolved to a red giant, and collapsed into a white dwarf core with a surrounding planetary nebula. Planetary nebulas are all less than ~50,000 years old as the materials becomes more and more tenuous over time as they spread into the interstellar medium. Eventually the white dwarf remains as the stellar core end product. If the white dwarf is in a multiple star system and a companion star evolves into a red giant then the white dwarf might not be the final product – it could accrete enough materials from the red giant to approach the Chandrasekhar Limit and undergo a thermonuclear explosion as a Type Ia supernova event. Otherwise the white dwarf will lose energy over time and after more than a trillion years will become a black dwarf. The universe if “only” 14.7 billion years old so no white dwarfs have turned into black dwarfs.

Slide 9:

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)

Slide 10:

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 KG-classification stars and have completed hydrogen fusion and are evolving 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 11:

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 to a planetary nebula and white dwarf.

Slide 12:

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 13:

Many intense star formation regions lie in the direction of the southern hemisphere constellation Carina. NGC 3606 is an open cluster of young hot stars located in the Carina spiral arm of the Milky Way Galaxy. It has been studied extensively because it is “only” 20,000 LY away, has a low visual extinction, and is extremely bright and very compact.

Slide 14:

The Great Carina Nebula (NGC 3372) is one of the largest star formation regions in the Milky Way Galaxy. It contains several young massive stars; it is estimated that at least a dozen of these stars are at least 50-100 times more massive than the Sun. It is also a site of rigorous supernova production as these massive stars evolve and collapse into neutron stars and black holes.

Slide 15:

Cassiopeia is a northern hemisphere circumpolar constellation and contains several interesting deep sky objects.

Slide 16:

Cassiopeia A (Cas A) is a supernova remnant that resulted from the collapse of a massive star into a neutron star stellar core. Tycho’s SNR is also a supernova remnant; however, it is the result of the thermonuclear destruction of a white dwarf and there is no stellar core. The Tycho progenitor star was a mid-sized star in a binary system with another star that evolved into a red giant and collapsed into a white dwarf and a planetary nebula. The companion star then evolved into a red giant. The gravitational field of the white dwarf was close enough to the red giant for mass transfer to take place forming an accretion disk around the white dwarf. Enough material from the accretion disk dropped onto the surface of the white dwarf to approach Chandrasekhar’s limit and runaway fusion caused a thermonuclear event which destroyed the white dwarf.

Slide 17:

Cygnus X-1 is a stellar mass black hole containing ~15 solar masses. Cygnus X-a is orbiting a stellar class B0 main sequence star and the extreme gravitational field of the black hole is pulling the material from the companion star into an accretion disk. Material that does not enter the black hole is redirected away in the form of power jets. Cygnus X-1 is the result of the core collapse of a star in excess of 24 solar masses. This type of system, which emits strong in the X-ray band, is called an X-Ray Binary system.

Slide 18:

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.

Slide 19:

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. 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 20:

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.Geminga is a powerful pulsar – a rapidly spinning neutron star that emits gamma rays. This object is not well understood and is a bit of a mystery.

Slide 21:

Hydrus is a southern hemisphere constellation, not to be confused with hydra – a northern hemisphere constellation. Hydrus – the lesser water snake – is bordered on one edge by Dorado and Mensa (with the LMC) and another edge with Tucana. Tucana includes the Small Magellanic Cloud (SMC) which is also partly in Hydrus.

Slide 22:

On the outskirts of the SMC in the constellation Hydrus is NGC 602, also called the Flying Lizard Nebula, which contains a an open cluster of newly formed massive clouds. This nebula is ~200,000 LY away and radiation from the massive star formation is eroding the dusty materials and has triggered a progression of star formation.

Slide 23:

The star Regulus is a massive B8 main sequence star. It is actually part of a 4-star system, with a double star system orbiting 100 times further from Regulus than Pluto from the Sun. The fourth star is orbiting Regulus at the same distance as Mercury is from the Sun and is a white dwarf.

Slide 24:

The brightest star in Lyra is Vega – on of the 3 bright stars in the Summer Triangle. Vega is an A0 main sequence star. M57 (the Ring Nebula) is a planetary nebula with a white dwarf stellar core. Last image is an optical/IR composite from 3 telescopes - Hubble, LBT and Subaru.

Slide 25:

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 26:

Kepler’s SNR is a type Ia supernova event – the thermonuclear destruction of a white dwarf. Extensive observations and the study of the mechanics of the explosion led to the conclusion this was the destruction of a white dwarf. The disk structure seen in the Chandra/Spitzer composite is thought to be an indication that Kepler had a companion star that was destroyed in the thermonuclear explosion that destroyed the white dwarf.

Slide 27:

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 28:

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 29:

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 30:

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 31:

Two major star formation regions are located in Sagittarius: M17, the Omega Nebula (also referred to as the Swan Nebula) and M8, the Lagoon Nebula.

Slide 32:

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.

Slide 33:

The constellation Serpens is the location of M16 – the Eagle Nebula. This massive star formation complex is only 6500 light years distant and provides a detailed view of intense radiation from massive star formation photoevaporating the surrounding material – creating beautiful sculptured transitory pillars of gas and dust.

Slide 34:

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 Crab Nebula (M1) is not a nebula at all – it is a Type II supernova remnant of a collapsed star that left behind a millisecond pulsar. The pulsar emits extensive X-Ray and radio emissions from the jets of matter and

antimatter spewing out from the rotational axis of the pulsar. The shock wave can be seen moving through the accretion disk. T Tauri is a protostar stage unique to newly forming stars with masses similar to the Sun (~0.8 – 2 solar masses).

Slide 35:

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 star formation regions.

Slide 36:

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 37:

Spica 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 38:

The information about the stars and deep sky objects 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.

Slide 39:

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. This H-R diagram shows the locations of many of the designated stars for the 2016 event.

Slide 40:

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 41:

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 42:

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 43:

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 44:

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 45:

The Absolute Magnitude (MV) 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 46:

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 47:

Here are two examples of H-R diagram showing the different branches. Most 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 48:

A blackbody absorbs all the radiation that it receives and then re-emits it all away. Stellar atmospheres approximate blackbodies because they absorb all the emissions produced in the core and then re-emit it into the interstellar medium. The hotter the star the more energy it emits at every single wavelength than a cooler star. The 3,000K star will never emit more radiation at any wavelength than a hotter star. This is Planck’s Law. Wien’s Law states that a star or blackbody has a maximum peak of radiation which has a specific wavelength. The maximum radiation peak from any star is equal to the wavelength divided by T.

Slide 49:

Use the resources listed in the Reach for the Stars event description to prepare for the event.

Slide 50:

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 <http://chandra.harvard.edu/edu/formal/ems/ems_explore_universe.html>

Slide 51:

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 Crab Nebula (M1). Other deep sky objects for the 2017 competition are also listed on the Cool Cosmos Multiwavelength Astronomy Page. (Also includes 30 Doradus, M57, M17, CasA, LMC, SMC)

Slide 52:

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. Download the 2013 event as a practice event or just to get an idea of the format for the event. The 2016 Test Packet on the NSO website includes the 2016 Reach for the Stars event and answer key. Flash card sets of the deep sky objects will also be available on the NSO website. A sample regional and state event will be available early in 2017 for teams to use as an assessment for what content they may need to further study in preparing for competition.

Slides 53 & 54:

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>