Astronomy 2022 PPT Transcript

Slide 1:
The Astronomy 2022 event will focus on variability in small and mid-mass stars. The Astronomy and Solar System events are supported by the NASA Astrophysics Division Universe to Learning STEM outreach program.

Slide 2:
The event description parameters include the possibility of accessing a dedicated NASA website for JS9. If the 2022 national tournament is virtual, the JS9 question will use screen shots. If it is on-site, we will provide each team with a JS9 dedicated laptop.

Slide 3:
This slide lists the content and information included in the 2022 event related to the focus of variability in small and mid-mass stars. This PowerPoint slide set and transcript will be available to SOSI participants, and it will be posted on the NSO website. The slides have a notes section with links to websites with information pertaining to the content for each slide, especially valuable for accessing relevant websites with information about the deep sky objects (DSOs)

Slide 4:
This slide shows the DSOs for this competition year. As well as listing them, they are also listed and sorted by type. There are 5 objects in Protostar and Star Formation Regions, 4 listed in Stars, 4 listed in Binary Systems, and 5 listed in Supernova Remnants & Stellar Cores.

Slide 5:
This stellar evolution graphic shows the basic transitions from protostar to final objects based on stellar masses. Astronomy focuses on the lower mass stars at the bottom of the stellar evolution graphic. The lower mass stars at the bottom of the graphic involve several types of evolution – including red giants, Mira variables, planetary nebulas, white dwarfs and Type Ia supernovas. Brown dwarfs are not part of the content but are included because one of the binary systems contains a brown dwarf.

Slide 6:
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 the final stellar end products.

Slide 7:
This graphic shows the relationship of major classes and types of variable stars. There are more than 400 different types of variable stars. The variable stars that teams are responsible for understanding for the 2022 content are the pulsating variables RR Lyrae and Mira, and the eruptive (cataclysmic variables) Type I supernovas, novas, recurrent novas and dwarf novas.

Slide 8:
The H-R diagram on this slide shows the general location of the RR Lyrae and Mira instability strips, and the T Tauris protostars – along with their unique and representative light curves.

Slide 9:
The star in the center of the dark cloud is V 1331 Cyg and it is a T Tauri star – a young star that is starting to contract onto the main sequence of the H-R diagram. V 1331 Cyg is special because we are looking at one of its poles. Usually, the view of a young star is obscured by the dust from the circumstellar disc and the envelope that surround it. However, with V1331Cyg we are looking in the exact direction of a jet driven by the star that is clearing the dust and providing an unusual view of the contracting protostar.

Slide 10:
The Orion Nebula (M42) is only ~1500 LY away in the constellation of Orion. It is the closest massive star formation region and has been extensively observed in every wavelength for decades. The nebula is home to a wide variety of objects, from the massive stars forming in the open cluster known as the Trapezium, to newly formed protostars and young stellar objects.

Slide 11:
HH 24-26 is a molecular cloud and star-forming region which contains Herbig-Haro objects HH 24, HH 25, and HH 26. The region contains the highest concentration of astrophysical jets yet discovered. The image on the slide is HH 24. When stars form within giant clouds of cool molecular hydrogen, some of the surrounding material collapses under gravity to form a rotating, flattened disk encircling the forming protostar. Gas from the disk rains down onto the protostar and surrounds it. Superheated material spills away and is shot outward from the star in opposite directions along the star's rotation axis. These young stellar jets are ideal targets for NASA's upcoming James Webb Space Telescope, which will have even greater infrared wavelength vision to see deeper into the dust surrounding newly forming stars.

Slide 12:
HOPS 383 is a protostar and NASA's Chandra X-ray Observatory has made the first detection of X-rays from this earliest phase evolution of a star like our Sun. The X-rays came from a flare emitted by HOPS 383, located about 1,400 light years from Earth in the star-forming region of the Orion Molecular Cloud Complex. Astronomers refer to HOPS 383 as a young "protostar" because it is in the earliest phase of stellar evolution that occurs right after a large cloud of gas and dust has started to collapse. Once it has matured HOPS 383 will have a mass about half that of the Sun. This result is significant because it resets the timeline for when astronomers think Sun-like stars start blasting X-rays into space. While scientists know that young stars are much more active in X-rays than older ones, they have debated just when X-ray emission begins. The illustrations show HOPS 383 surrounded by a donut-shaped cocoon of material (dark brown) that is falling in towards the central star. Much of the light from the infant star is unable to pierce this material, but X-rays from the flare (blue) can. Infrared light is scattered off the inside of the cocoon (white and yellow).

Slide 13:
The image on the slide is HBC 672 (Serpens nebula) and was taken with the NASA/ESA Hubble Space Telescope. It shows the Serpens Nebula, a stellar nursery about 1300 light-years away.

Within the nebula, in the upper right of the image, a shadow is created by the protoplanetary disc surrounding the star HBC 672. While the disc of debris is too tiny to be seen even by Hubble, its shadow is projected upon the cloud in which it was formed. In this view, the feature — nicknamed the Bat Shadow — spans approximately 200 times the diameter of our own Solar System.

Slide 14:
Mira (Omicron Ceti) is the protype of the pulsating Mira variable stars, and currently resides in the Mira instability strip on the H-R diagram. Miras are red giants with pulsation periods longer than 100 days and are in the late stages of stellar evolution before collapsing into a white dwarf stellar core and a planetary nebula remnant. The Sun will enter the Mira instability strip as it evolves to the red giant branch of the H-R diagram – its surface eventually extending past the terrestrial planets before collapsing into a white dwarf and planetary nebula. The UV GALEX image on the upper right shows Mira plowing through spacetime and building up a bow wave in front.

Slide 15:
The variable star RR Lyrae is the prototype of the pulsating RR Lyrae variable class of stars. They are horizontal branch stars with periods ranging from a few hours to 2 days and have a distinctive light curve as shown on the slide. They occupy the RR Lyrae instability strip on the H-R Diagram. RR Lyrae stars are low metallicity (population II) stars with initial masses similar to the Sun. They become RR Lyrae stars late in the red giant phase, late in the evolution of the star. They are generally found in globular clusters, and in the bulges and halos of galaxies. The slide shows many RR Lyrae stars within a globular cluster. The pulsations are periodic and can be used as standard candles to measure distances. They exhibit a period-luminosity relationship.

Slide 16:
U Antliae is a carbon star. The image on the slide is from the Atacama Large Millimeter/submillimeter Array (ALMA). Carbon stars have evolved to the asymptotic giant branch of the H-R Diagram and are cool and luminous. U Antliae underwent a period of rapid mass loss which was ejected at high speed and formed the shell surrounding the star. The shell material contains a high percentage of carbon-based chemicals compounds.

Slides 17:
Alpha Tauri (Aldebaran) is a red giant branch star located in the foreground of the Hyades open cluster in the constellation Taurus. Aldebaran will eventually collapse into a white dwarf and a planetary nebula.

Slide 18:
AR Scorpii is a binary system consisting of a white dwarf and a red dwarf. The white dwarf is the only known radio-pulsing white dwarf binary. The system shows emission from radio to X-rays, likely dominated by synchrotron radiation. The mechanism that produces most of this

emission remains unclear. Two competing scenarios have been proposed: collimated outflows, and direct interaction between the magnetospheres of the white dwarf and the M star. The latest research suggests that the radio emission in AR Sco is likely produced in the magnetosphere of the M class companion star.

Slide 19:
ASASSN 16-oh is a white dwarf /red giant binary system in the Small Magellanic Cloud. “Supersoft” X-rays have been detected coming from this object, and a combination of X-ray and optical data indicate that the source of the radiation is what may be the fastest-growing white dwarf ever observed. Astronomers have thought that supersoft X-ray emission from white dwarf stars is produced by nuclear fusion in a hot, dense layer of hydrogen and helium nuclei. This volatile material accumulated from the infall of matter from the companion star onto the surface of the white dwarf and led to a nuclear fusion explosion. If nuclear fusion is the cause of the supersoft X-rays from ASASSN-16oh then it should begin with an explosion and the emission should come from the entire surface of the white dwarf. However, the optical light does not increase quickly enough to be caused by an explosion and the Chandra data show that the emission is coming from a region smaller than the surface of the white dwarf. The source is also a hundred times fainter in optical light than white dwarfs known to be undergoing fusion on their surface. These observations, plus the lack of evidence for gas flowing away from the white dwarf, provide strong arguments against fusion having taken place on the white dwarf.

Slide 20:
V Sagittae is a white dwarf with a main sequence companion similar to the mass of the Sun. As is usual with this type of system, the white dwarf is pulling mass from its companion star into an accretion disk surrounding the white dwarf. What is different about this system is the speed at which the two stars are spiraling inwards towards each other. Eventually the accretion rate will pull mass at extremely high rates onto the white dwarf. All of the mass from the companion star will fall onto the white dwarf, creating a super-massive wind. The resulting thermonuclear explosion will cause V Sag to become the brightest star in the Milky Way Galaxy and is calculated to happen ~2083.

Slide 21:

SDSS 1035+0551 is a binary system with a white dwarf and a brown dwarf. An unverified prediction of binary star evolution theory is the existence of a population of white dwarfs accreting from substellar donor stars. Such systems ought to be common, but the difficulty of finding them, combined with the challenge of detecting the donor against the light from accretion, means that no donor star to date has a measured mass below the hydrogen burning limit. In this type of cataclysmic variable system, every kilogram of material that falls onto the white dwarf gains the energy equivalent of a few kilotons of TNT. Much of this energy is released as ultraviolet or x-ray radiation. Many CVs have been identified from this highly variable, short-wavelength light produced by rapid mass transfer onto the white dwarf. However, most CVs should have evolved through this violent phase to become a "dead CV" with a low-mass companion that can support only weak mass transfer. Extensive efforts to confirm this long-standing prediction have failed to identify any CVs that have clearly survived the rapid mass transfer phase of their evolution. SDSS 1035+0551 is the first unambiguous detection of a dead CV from a direct mass measurement of the low-mass companion.

Slide 22:

DEM L71 is a Type Ia supernova remnant in the Large Magellanic Cloud. DEM L71 presents a textbook example of the double-shock structure expected to develop when a star explodes and ejects matter at high speeds into the surrounding interstellar medium. The expanding ejecta drive an outward-moving shock wave that races ahead of the ejecta into the interstellar gas (bright outer rim). The pressure behind this shock wave drives an inward-moving shock wave that heats the ejecta, seen as the aqua cloud. The clear separation of the shocked matter and the heated ejecta in this Chandra observation allowed astronomers to determine the mass and composition of the ejecta. The computed ejected mass was found to be comparable to the mass of the Sun. This and the X-ray spectrum, which exhibits a high concentration of iron atoms relative to oxygen and silicon, convincingly show that the ejecta are the remains of an exploded white dwarf stellar core when its mass started approaching Chandrashekar's limit. Type Ia supernovas are used as standard candles, as are RR Lyraes, to measure cosmological distances.

Slide 23:

ESO 577-24 is a planetary nebula. Planetary nebulas (PHs) represent the last stages of stellar evolution for low and mid-mass main sequence stars with initial masses less than ~8 solar masses. Mira variable stars transitioning to the red giant branch pulsate as heavier and heavier atomic nuclei and created and consumed. The creation of carbon is the last fusion product; the star begins its final collapse leaving behind a white dwarf and a planetary nebula. ESO 577-24 shows how tenuous these objects are; these nebulas continue to expand into the interstellar medium, getting fainter and fainter and becoming too faint to detect after ~50,000 years. The white dwarf core will continue to lose energy before turning into a black dwarf over tens to hundreds of billions of years.

Slide 24:

Tycho's SNR is a Type Ia supernova remnant, resulting from the thermonuclear destruction of a white dwarf. Observations indicate that the Kepler event was triggered by an interaction between a white dwarf and a read giant star – and not the merger of two white dwarfs. Observational data from a shadow within the remnant las located the probable runaway companion star which is moving through space three times the speed of the other stars in its neighborhood.

Slide 25:

LP 40-365 is a white dwarf that is moving through the galaxy at a high rate of speed ~500-800 km/s. LP 40-365 contains an unusual collection of elements and research indicates that it is possible that it avoided destruction during the thermonuclear explosion and survived. Both the surface gravity and temperature are low for a white dwarf, suggesting an unusually low mass – which could indicate a partially destroyed white dwarf.

Slide 26:

IC 4593 is a planetary nebula. This composite Chandra X-ray and Hubble optical image shows a bubble of gas heated to more than a million degrees. IC 4593 is small compared to the general population of planetary nebulas, and at 78,000 LY away, the furthest planetary nebula imaged by Chandra.

Slides 27 & 28:
These 2 slides show the most useful resources for teams. There are a couple of other slides listing resources also.
Slide 27 shows some of the resources available on the Chandra website. Some of the most relevant for this year's content are:

Chandra sponsored the 2012 spring edition of The Earth Scientist. One of the investigations included is the Plotting Pulsating Variables on the H-R Diagram. There are still a few of these

magazines remaining and are available upon request. However, you can download the Plotting Pulsating Variables on the H-R diagram from the Chandra website. The magazine includes a set of the Stellar Cycle image set. This image set is still posted online; however, they are out of stock. The Cosmic Connections and Stellar Evolution sets can be requested – as many as you need. Just email me.
The Stellar Cycles set is still posted online, and though they are out of stock you can still download them.

For JS9 tutorials, investigations and guides go to http:/chandra.si.edu/js9. There are also sample js9 questions posted on the NSO website under Astronomy resources.

Slide 34:
The Chandra website has several products available upon request that are located at http://chandra.harvard.edu/edu/request.html
NOTE!!!! Due to COVID restrictions missions are not currently mailing materials. I am not sure when the materials will become available.
Please let me know if you have any questions. dlyoung.nso@gmail.com

The Stellar Evolution image set that was constructed for Science Olympiad teams to use to learn the processes involved in the evolution of stars. Different ways that it can be used will be discussed further on in the presentation. Coaches, state directors and event supervisors can request as many sets as necessary at no cost. The link to this image set, as well as the Cosmic Connection image set is located at: http://chandra.harvard.edu/edu/request_special.html
The description of each object in the image set with a link to an explanation of what the object is and its evolutionary stage is located in the Stellar Evolution module also at: http://chandra.harvard.edu/edu/formal/stellar_ev/imageset_description.html

The 13-page introduction to stellar evolution is posted on the Chandra X-Ray Observatory website in the Stellar Evolution module at:
http://chandra.harvard.edu/edu/formal/stellar_ev/story/
There are two image sets – Cosmic Connection and Stellar Cycle – on the Chandra website with complete instructions on how to use the sets. There are also short webinars to explain those two activities