Slide1: This slide set is an overview of the content and resources for the National Science Olympiad (NSO) Division C 2025 Astronomy Event. The NSO 2025 national competition will be held at the University of Nebraska-Lincoln on May 16th -17th.

The accompanying transcript includes links for most of the slides - the links will provide you with 1-3 websites to access that will give you a starting point for collecting information about the content and the DSOs. You can download both the PPT slide set and transcript in PDF format from the NSO website. The webinar recording itself will be posted on the Chandra website and linked to NSO and Universe Unplugged.
LINK: https://www.soinc.org/

Slide 2: The space science events, Astronomy, Reach For The Stars (RFTS), and Solar Systems are supported by NASA's Universe of Learning (UoL) informal STEM outreach program. The UoL program is a unique partnership between the STScI (Hubble), the Smithsonian Astrophysical Observatory (Chandra), Caltech/IPAC, and the Jet Propulsion Laboratory (JPL). Each of the partners have their individual network of additional partners – including the NSO.
LINK: https://universe-of-learning.org/home

Slide 3: The webinar has 4 parts. A basic understanding of stellar evolution is necessary to understand how exoplanets form, and how the motions and physical properties of stars and exoplanets provide us the ability to detect and study them. The last segment will focus on locating the resources and some suggestions on how to prepare for the test. So, here we go!

Slide 4: The only change in the event parameters is a statement that AI tools, such as ChatGPT, are not allowed under any circumstances. Otherwise, the same resources apply. Each team can bring two laptops, two 3-ring binders, or one laptop and one binder. Because JS9 is now browser based and works very well, we try to have the Astronomy event held in a computer lab whenever possible. This makes the js9 question much easier, as the website will be active during the entire event so teams can work on the JS9 question at any time during the session. If a computer lab is not available, teams will access the NASA js9 website. If you do not have a laptop, one will be provided for you.

The Competition (number 3) lists the tools and concepts that are necessary to understand stellar evolution and orbital mechanics in parts 3a and 3b. The words in red in the Competition and 3a are all closely related, and also relate to some of the red content listed in 3b. Understanding how they are all related will give you a solid foundation.

Slides 5: Stellar evolution is a process. 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 transitions onto and off the main sequence through instability strips to other branches the final stellar end products.

The illustration on the upper left is an artistic view of the H-R diagram. The graph on the lower left is basically a plot of some combination of physical characteristics of stars – temperature, classification, luminosity and/or absolute magnitude. The image on the upper right of this slide is M42, our good friend the Orion Nebula. It is one of the DSOs for this year's competition and I will discuss it when we get to the DSO segment. For a basic walk through of stellar evolution, there is an introduction and background on the Chandra website that is a good beginning. **LINK: https://chandra.harvard.edu/edu/formal/stellar_ev/story/index.html**

Slide 6: There are a multitude of different H-R diagrams, and there are many ways to construct them, depending on what is being emphasized. There are of course, some misleading and incorrect ones so it is important to understand the graph. There are also several videos and interactive websites that work well to increase understanding.

This slide shows the three different H-R diagrams that I have used for questions written for invitational, regional, state and national competition. The H-R diagram is a plot of the temperature/stellar classification and absolute magnitude/luminosity of a star. The location of a star on the H-R diagram is a plot of its current stage of evolution – providing the age, mass, composition, and evolutionary past and future of the star. Absolute magnitude is the intrinsic brightness of the star, and luminosity is how much power the star is emitting relative to the Sun. The sun is arbitrarily assigned the value of one solar luminosity and other stellar luminosities are relative to the luminosity of the Sun. The sun's position on the H-R diagram it is plotted at one solar luminosity and ~6000K, which corresponds to a G2 stellar classification.

Objects plotted on the H-R diagram change position as they evolve. Look at the two H-R diagram illustrations. The illustration on the right has an extra line at the top that is not on the illustration on the left. This is because that stellar evolutionary stage only existed in theory until the Chandra mission discovered a supernova event that supported the theory, and this type of event is no longer theoretical. It is a depiction of a star so massive that it has used up its core hydrogen by the time it reaches the main sequence, and the implosion produces matter and antimatter which annihilates each other and there is no remnant or stellar core left behind. The star transitions from formation to collapse in such a short time, that it's amazing such an event was even detected. The stellar classifications on the middle and right show different classifications.

Look at the three H-D diagram plots. Again, the one on the right shows absolute magnitude, luminosity, temperature, and stellar classifications OBAFGKM.

The middle graph has classifications C and S after M, and the plot on the right has L and T after M – as well as the B-V color index above the classifications. There are many classifications besides OBAFGKM. Basic information about stellar classification is provided in the 2 Chandra links. For in-depth information about stellar classification, the following Wikipedia article is a great website. Wikipedia also has a good explanation of the B-V Color Index, which is a measure of a star's color, which is an indication of its temperature. The UBV system classifies stars by spectral type based on photometric measurements of the ultraviolet (U), blue (B), and visual (V, yellow) magnitudes. Hot stars appear bluer than cooler stars. Cooler stars are redder than hotter stars. The "B-V color index" is a way of quantifying this using two different filters; one a blue (B) filter that only lets in a narrow range of colors or wavelengths through centered on the blue colors. And a "visual" filter that only lets the wavelengths close to the green-yellow band through. A hot star has a B-V color index close to 0 or negative, while a cool star has a B-V color index close to 2.0. Other stars are in between.

LINKS: **https://en.wikipedia.org/wiki/Stellar_classification**
https://en.wikipedia.org/wiki/Color_index
https://chandra.harvard.edu/edu/formal/stellar_ev/story/index3.html
https://chandra.harvard.edu/edu/formal/stellar_ev/story/index4.html

Slide 7:

Different H-R diagrams can have stellar classes besides the common OBAGKM classes on most diagrams. The graph on the right is an interesting diagram and shows where stars in different stages of evolution are located. The diagram on the top in the middle was produced for the "Plotting Pulsating Variable Stars on the H-R diagram" activity. The answer key below it shows how variable some of these pulsators are as they transition from one branch to another. This activity is posted on the Chandra and AAVSO websites.

LINKS: **https://www.aavso.org/education/vsa**
https://chandra.harvard.edu/edu/formal/index.html

Slide 8:
Let's review the content listed in Parts 3 and 3a of the event description. We have looked at a majority of the topics listed in this section. The next 2 slides will show the locations of different classes of variable stars, and their associated unique light curves. The AAVSO and the Australia Telescope have good basic information about variable stars.
LINKS: https://www.aavso.org/types-of-variables-guide-for-beginners
https://www.atnf.csiro.au/outreach/education/senior/astrophysics/variable_types.html

Slide 9:
This slide shows the location of two types of protostars as they transition from collapsing clouds of gas and dust onto the Main Sequence. Their position on the H-R diagram is determined by their mass. When the object is hot enough for core hydrogen to fuse into helium, it joins the Main Sequence. Their light curves are very erratic, as this produces energy, especially in the X-Ray part of the spectrum.

Slide 10:
This slide shows the location of the instability strips as the variable stars transition from one branch to another. While in these stages of instability, some of them produce a periodic light curve as they fuse heavier and heavier nuclei. These light curves are used to measure cosmological distances – the Cepheids, RR Lyrae, and Mira variables. There is also a group of Semiregular variables. Each class of variable produces their own unique light curve – and their cycles range from less than a day to 300 years.

Slide 11:
The Period-Luminosity Relationship and the Distance Modulus are relationships are used to calculation distance.
Link: https://astro.unl.edu/naap/distance/distance_modulus.html

Slide 12:
Transition – End of Part 1 on Content to Segment 2 on Deep Sky Objects. We will return to some of the concepts presented in Part 1 that are related to the DSOs themselves.

Slide 13:
Part 2 summarizes the deep sky objects (DSOs) for the 2025 tournament year. A lot of time, energy and other factors such as a range of major missions,

multiwavelength observations, history, first evidence observations, changing knowledge as image analysis and technology, and representations of different types of exoplanets, different stages of evolution of the parent stars, exoplanet scientists (including our own ATeam experts Andrea and Tad), and just plain FUN objects are all weighed for consideration.
It is up to you, of course, to study and understand this year's DSOs. The following slides are a brief summary, mostly to give you a feel for the overall content and maybe some especially interesting information that makes them unique.

Slide 14:
The DSOs on this slide are colorized by the type of DSO. This is a purely arbitrary grouping that I find useful for myself so I can present them in at least some kind of organized list. It is an arbitrary list; however, hopefully not random! You will see, as we go along, that one difference between the 2024 and 2025 DSOs is that most of the parent stars have either arrived on the main sequence or orbit stellar cores. None of the stellar objects are T tauri or Herbig Haro objects – everything is pretty much post main sequence. However, if you competed in astronomy for the 2024 season, you would have a good foundation for the formation environment for this year's exoplanets and their parent stars.

Slide 15:
I love this animated sonification which shows the number and locations of exoplanets and their methods of detection from the first one detected in 1991 through 2022. Later on in this segment we will look at the missions, past and present, that detect exoplanets.
LINK: **https://drive.google.com/file/d/1fB0mKTg1ZYCcFZ7vr-imrLFLHt30KDzn/view**

Slide 16:
The Orion Nebula (M42) – has been a favorite for decades! What's not to love? It is a star formation region only 1500 light years distant, and detectable with the unaided eye. It contains a large range of objects – from the young massive blue stars forming in the Trapezium to a collection of failed brown dwarfs and low-mass stars. It has all the usual activity associated by this type of region, including cold molecular clouds, collapsing clouds of gas and dust, and emission and reflection nebulas. It has been observed by several missions in all wavelengths, including ground based, so there is a wealth of observational data for Orion. The

image on this slide was collected using the HAWK-I infrared instrument at the VLT in Chile.
LINK: https://www.smithsonianmag.com/smart-news/new-images-inside-orion-nebula-reveal-failed-stars-and-planet-sized-objects-180959796/

Slide 17:
30 Doradus is also a star formation region, located in the neighboring galaxy the Large Magellanic Cloud. Also known as the Tarantula Nebula, it is the largest and brightest region of star formation in the Local Group of galaxies. This region has also been extensively imaged by missions in every wavelength. I like the image on this slide, as the background image is a Chandra/Hubble/Spitzer composite, and the highlighted region a Chandra/JWST composite. This is a really nice image that shows why wavelengths from one end of the spectrum to the other need to observe and study deep sky objects.
LINK: https://www.nasa.gov/image-article/enduring-stellar-lifecycle-30-doradus/

Slide 18:
The hot Jupiter exoplanet HD 80606b is orbiting a stellar classification G star. As you know, this is the classification for the Sun, so when the star has run out of core hydrogen it will become unstable and transition to the red giant stage through the Mira variable instability strip and collapse into a white dwarf. HD 80606b is in a highly eccentric orbit, taking 100 days away from and then back to HD 80606, then in 20 hours it whips around the star, nearly touching it. If the Earth was that close to the Sun, it would lose its atmosphere, and its surface would be magma. The exoplanet heats up to 1400K, then in 10 hours cools so much that Spitzer can not detect it for the remainder of its orbit.
LINKS: https://skyandtelescope.org/astronomy-news/hd-80606b-the-hotheaded-exoplanet/
https://www.nasa.gov/image-article/hd-80606b-light-curve/
https://news.mit.edu/2016/highly-eccentric-extreme-weather-exoplanet-0328

Slide 19:
WASP-17b is a very unusual exoplanet. WASP is the catalog for the Wide Angle Search for Planets project. It is an international group of several organizations searching for exoplanets using transit photometry. It is tidally locked and the first planet to have a retrograde orbit. It is half the mass of Jupiter, and one year is the

equivalent to an orbit of 3 ½ Earth days. The radius is 7 times greater than Jupiter. The surface temperature is ~1550K, hot enough to melt nickel and lead. The UTube link shows the details of WASP-17b. Note that the exoplanet is orbiting an F classification star – again similar to the Sun – thus giving you the history of WASP-17 from pre-main sequence through formation.
LINKS: **https://info3.com/space/136645/text/short/an-exoplanet-so-hot-it-has-clouds-made-of-quartz**
https://en.wikipedia.org/wiki/WASP-17b
https://www.google.com/search?client=firefox-b-1-d&q=WASP-17b#fpstate=ive&vld=cid:b9d1ac41,vid:kHgz8-pWwnk,st:0

Slide 20:
Like many other hot Jupiters, WASP-121b has shown evidence of heavy metals. Observations have shown evidence that magnesium and iron gases and escaping WASP-121b due to the extreme heat. Again, as in WASP-17b above, the host star is very similar to the Sun's position on the H-R diagram. The temperature is 4600 F. It is so close to the parent star that is only takes 1.1 days for one orbit. And you thought 3 ½ days for WASP-17b was short! Tidal forces will eventually destroy WASP-121b. This was the first exoplanet atmosphere observed to have water in its atmosphere.
LINKS: **https://wasp-planets.net/tag/wasp-121b/**
https://exoplanets.nasa.gov/news/1595/wasp-121b-a-heavy-metal-exoplanet-shaped-like-a-football/
https://www.youtube.com/watch?v=lybjDPxCEYc

Slide 21:
And if you thought the two WASP exoplanets had short orbits – take a look at ultra-hot Neptune-like ice giant LTT 9779b. This is the only exoplanet in this category, and, like all hot planets, is not expected to be visible in UV/optical part of the spectrum. However, this exoplanet has an unusual high albedo, and TESS and CHEOPS observations show evidence of scattered light from its atmosphere. Clouds should not exist on this planet! This exoplanet has an orbital period of 0.8 days! Its parent star has the same stellar classification as the sun – it is a G class star.
LINKS: **https://www.aanda.org/articles/aa/full_html/2023/07/aa46117-23/aa46117-23.html**
https://ui.adsabs.harvard.edu/abs/2022hst..prop16915R/abstract

Slide 22:
K2-18b was an exciting discovery, as a significant amount of water vapor was detected in its atmosphere. And though the exoplanet is significantly larger and more massive and orbits a cooler Class M red dwarf star, it orbits within the habitable zone. The water vapor was detected by Hubble, Spitzer, and Kepler. After further observations with JWST, other life-indicating molecules including carbon dioxide and methane were also detected. Other studies have questioned this result. The UTube link below give a detailed summary of the observational data.
LINKS: **https://www.sci.news/astronomy/webb-biosignature-gas-k2-18b-12904.html**
https://www.sci.news/astronomy/webb-biosignature-gas-k2-18b-12904.html
https://www.youtube.com/watch?v=r0lGz73rluo

Slide 23:
Like K2-18b, TOI-270 d also orbits a class M red dwarf star. However, unlike K2-18b, exoplanets like TOI-270 d are good candidates for life within or even outside, of the habitability zone. The term "hycean planet" is used to describe planets that have large oceans and hydrogen-rich atmospheres. Hycean planets are thought to be common around cool red dwarf stars. Any life forms would most probably be aquatic.
CAVEAT: The first confirmed exoplanet was 32 years ago. Our ability to detect, confirm, and study exoplanet surfaces and atmospheres has grown exponentially over the past few years. I have enjoyed having exoplanets be the focus for the Astronomy event. I have tried to present recent research observations and results. It is a field that is constantly changing as more data is gathered. The links I have selected hopefully present current results; however, even if it is, conflicting results could negate current theory at any time. I try to use the words "likely", "possibly" "current thought or theory" as information changes so rapidly!
LINK: **https://www.universetoday.com/166109/another-hycean-planet-found-toi-270-d/**

Slide 24:
The class M red dwarf star GJ 1214 has a super Earth exoplanet GJ 1214 b orbiting it. Super-Earth planets have a rocky surface and are significantly more massive than Earth, but much lighter than ice giants such as Neptune and Uranus. The planet is too hot to be habitable, however, likely contains atmospheric water vapor. These planets are thought to make up the majority of the exoplanet population. JWST has recently observed GJ 1214 b and has produced the latest information

about this object. Upcoming missions will have the ability to study super Earth exoplanets.

LINKS: **https://science.nasa.gov/universe/exoplanets/seeing-blue-exoplanet-with-water-rich-atmosphere-observed/**
https://medium.com/@rwtont/the-interstellar-are-offering-us-its-mercy-gliese-1214-b-water-promising-independent-party-4c39314e44f8
https://news.uchicago.edu/story/researchers-get-first-close-look-mysterious-planets-atmosphere

Slide 25:
LHS 3844 b is another super Earth exoplanet orbiting a red dwarf parent star. It has a diameter 1.3 times the earth and its dayside temperature reaches 100 degrees Fahrenheit. It was detected by the TESS mission. JWST has planned observations of the planet's thermal emission spectrum with the MIRI instrument to determine the surface composition.

LINKS: **https://www.sci.news/astronomy/lhs-3844b-hemispheric-tectonics-09417.html**
https://scitechdaily.com/volcanoes-might-light-up-the-night-sky-of-this-super-earth-exoplanet/

Slide 26:
The PSR B1257+12 System consists of a pulsar and 3 exoplanets. These exoplanets were the first extrasolar system planets discovered – by radio astronomers at Aricebo. How these exoplanets formed is not understood. They could not have formed by the massive supernova event that resulted in the pulsar. It is thought that they could have formed from a disk of stellar material that fell back towards the pulsar after the supernova event. The constant bombardment of high energy radiation that rains down on the exoplanets from the pulsar are not conducive for life!

LINKS: **https://exoplanets.nasa.gov/news/250/let-the-great-world-spin/**
https://www.nbcnews.com/id/wbna7684871

Slide 27:
WD 1856 +534 is a triple star system comprised of a red dwarf binary pair gravitationally bound to a white dwarf with a gas giant exoplanet. The collapse of a mid-sized star into a white dwarf would destroy any nearby planets. Any object or material would be torn apart by the strong gravitational field if it approached the

white dwarf. So this exoplanet might well be an extremely rare survivor planet as it is only 9.02 AU from the white dwarf.
LINK: https://en.wikipedia.org/wiki/WD_1856%2B534

Slide 28:
The 55 Cancri System gives evidence that planetary systems similar to the Solar System can exist. 55 Cancri is a Type K star in a binary system with a red dwarf, and has 5 orbiting exoplanets. One of these planets, the super Earth 55 Cancri e, has a molten surface of lava and like the moon and Earth, it is probably tidally locked with 55 Cancri. JWST observations indicate that energy is being distributed from the dayside to the nightside because of the lower than the expected temperatures. Currents of lava can not account for the amount of heat transfer to the nightside.
LINKS: https://www.jpl.nasa.gov/news/nasas-webb-hints-at-possible-atmosphere-surrounding-rocky-exoplanet
https://webbtelescope.org/contents/media/images/2024/102/01HWQWN21X8Q7H2W4VX7FVKT1R

Slide 29:
The Kepler-62 System, like the 55 Cancri system, consists of a K type star and 5 exoplanets. However, the similarity ends there. Two of the exoplanets, Kepler-62e and Kepler-62f orbit within the habitable zone and Kepler-62e, is close to the holy grail of a habitable Earth-like planet. Modeling by the Harvard Center for Astrophysics (CFA) suggests that both planets are water worlds, with their surfaces completely covered by water – no land in sight! Any life would be underwater with no access to the physical elements and properties that could lead to the formation of life.
LINKS: https://www.space.com/24129-kepler-62e.html
https://insider.si.edu/2013/04/two-water-worlds-for-the-price-of-one/

Slide 30:
The AU Microscopii System is only 23 million years old, and AU Mic is a K type red dwarf – the most common type of star in the Milky Way Galaxy. Studying this system will provide a lot of information about how planetary systems form. The star is still producing high energy flares of radiation, which is stripping planet AU Mic b of its atmosphere. Researchers believe they are observing essential evolutionary mechanisms that most planets go through which will allow us to

understand the extremely early stages of planet formation. The Dartmouth article describes the research results extremely well.

LINKS:
https://faculty.dartmouth.edu/artsandsciences/artsandsciences/news/2023/07/violent-atmosphere-gives-rare-look-early-planetary-life
https://hubblesite.org/contents/media/images/2019/02/4302-Image.html

Slide 31:

Epsilon Eridani is only 10 LY distant, and the third closest naked eye star. It is ~800,000 years old – approximately the same age as Earth when life started to form. Epsilon Eridani also is surrounded by a belt of comets – similar to the Solar System's Kuiper Belt. The system also has two asteroid belts – one at about the same location as the Solar System's asteroid belt, and one much distant one – around the orbital distance of Uranus. Exoplanet Epsilon Eridani b orbits exterior to the first asteroid belt. Data indicates that an unconfirmed second planet may lie near the outer asteroid belt.

LINKS: https://www.forbes.com/sites/briankoberlein/2017/05/03/a-young-star-system-holds-clues-about-the-history-of-our-own/
https://science.nasa.gov/resource/double-the-rubble/
https://science.nasa.gov/universe/exoplanets/sofia-confirms-nearby-planetary-system-is-similar-to-our-own/

Slide 32:

This slide shows all of the DSO exoplanets and systems and their method of detection.

Slide 33:

This slide shows the exoplanet missions - past, currently operating, and future

LINK: https://exoplanets.nasa.gov/exep/about/missions-instruments/?page=0&per_page=40&order=position+asc&search=&category=160

Slide 34:

The Chandra mission and the ESA XMM-Newton teamed up to map the location of nearby stars to help identify the best targets to search for exoplanets with conditions suitable for life. Planets that are being bombarded by high energy X-ray and UV radiation would damage or destroy any developing atmospheres. The most viable exoplanets could then be targeted and directly imaged by future missions.

LINK: https://chandra.harvard.edu/photo/2024/exoplanets/

Slide 35:
Now let's revisit a summary of the number and types of exoplanet discoveries. The chart also shows more recent information, including the mission involved. Note the numbers from TESS. As we refine and develop the technology to detect and image exoplanets, the numbers will continue to grow at an amazing rate.

Slide 36:
We have now visited and become a bit familiar with the DSOs for the NSO 2025 competition year. Part 3 will summarize the basic motions, properties, mathematics and relationships associated with the DSOs.

Slide 37:
Paragraph 3b in the event description lists the motions and conditions that contribute to the range of exoplanet surface and atmospheric compositions which help determine the likelihood of habitability and the parameters of the habitable zone.

Slide 38:
The radial velocity method uses the fact that if a star has a planet (or planets) around it, it is not strictly correct to say that the planet orbits the star. The planet and the star orbit their common center of mass. Because stars are so much more massive than planets, the center of mass is within the star and the star appears to wobble slightly as the planet travels around it. This wobble is measured by using Doppler spectroscopy. If a star is traveling towards Earth, its light will appear blueshifted, and if it is traveling away from Earth the light will be redshifted. Spectroscopy shows this change in color from a star as it moves towards or away from Earth as it orbits the center of mass of the star-planet system. This method enables calculation of the mass and orbital period of an exoplanet.
LINK: https://www.planetary.org/articles/color-shifting-stars-the-radial-velocity-method

Slide 39:
This graphic illustrates the transit timing method of detecting exoplanets**.**
LINK: https://www.planetary.org/articles/timing-variations

Slide 40:
This animation of the illustration in the previous slide shows the orientation for the transit photometry method to provide information about exoplanets. If the orientation of the planet-star system is oriented to Earth so that the planet passes in front of the star, the change in magnitude can be detected. The duration of the

partial eclipse is an indication of the size of the planet, and the depth of the partial eclipse is an indication of the size of the star.
LINK: https://exoplanets.nasa.gov/faq/31/whats-a-transit/

Slide 41:
Photometry and spectroscopy of extrasolar planets provides information about their atmospheres and surfaces. From extrasolar planet spectra and photometry, the composition and temperature of the atmospheres as well as the presence of molecular
species and gases can be inferred. As the light from the parent star filters through the atmosphere of a transiting exoplanet, a small fraction of the light is absorbed by the upper atmosphere of the planet making the exoplanet appear larger. The degree of atmospheric absorption is dependent on which atomic and molecular species are present, as well as the wavelength of the observations. An example of an Earth-like exoplanet transmission spectrum designed by JWST is on the right in this slide. The JWST link discusses the example.

LINKS: https://www.planetary.org/articles/down-in-front-the-transit-photometry-method
https://webbtelescope.org/contents/media/images/01FEE26XVSM851DHPVCE1KB4S2

Slide 42:
Young debris disks can constitute a phase in the formation of a planetary system following the protoplanetary disk phase, when terrestrial planets may finish forming. These disks can also be produced and maintained by collisions between objects such as asteroids and comets. Exoplanets in debris disks can be detected through direct imaging. Interactions of giant planets with the disk produce characteristic signatures, and primary signatures of planets embedded in disks are gaps in young disks and asymmetric density patterns. So, features in dust disks suggest the presence of full-sized planets. Some debris disks have a central cavity, meaning that they are really ring-shaped. The central cavity may be caused by a planet "clearing out" the dust inside its orbit. Other disks contain clumps that may be caused by the gravitational influence of a planet.
LINK: https://lco.global/spacebook/exoplanets/direct-imaging/

Slide 43:
The stellar radiation laws and blackbody radiation have been a part of every past Astronomy event as they explain basic physical properties fundamental to all stars. A blackbody is an artificial construct that absorbs all radiation it receives and then emits it all away – everything that goes in comes out. Stellar atmospheres are very

good blackbody radiators, absorbing radiation produced by the core and emitting it out into the interstellar medium. The hotter the star the more energy it emits at every single wavelength than a cooler star. The graphic shows a 12,000K star, a 6,000K star and a 3,000K star and nowhere does the 3,000K star emit more radiation at any wavelength than the two hotter stars. That principle is called Planck's Law. Wien's Law states the maximum radiation that comes from any star or blackbody has a peak with a specific temperature and corresponding wavelength. The mathematical relationship is used to determine the temperature and/or wavelength of stellar objects. The Stefan-Boltzmann Law shows that the area beneath the curve is equal to the total power of the star and is related to the temperature and area of the star.
LINK: https://asd.gsfc.nasa.gov/archive/mwmw/mmw_bbody.html

Slide 44:
The spectrum in the upper left corner is the optical portion only of the total radiation produced by the Sun. There are several absorption lines – which show the elemental
composition of the Sun. The typical spectral images shown in textbooks are gross cartoons of a stars total emission. The other images show spectral plots – wavy lines with dips to show where absorption is happening. Stars are classified by their spectra – and their spectral classification depends on their temperature. Spectral plots are more useful than images for scientific measurements. Hydrogen Balmer lines and the Fraunhoffer lines from other elements are used for classification and each stellar temperature has a unique set of absorption spectra.
LINK: https://www.eso.org/public/teles-instr/technology/spectroscopy/

Slide 45:
The radiation laws and the basic mathematical relationships and equations shown on this slide are the most important for answering the problem sets in this event. All of these equations and relationships have been a part of every NSO Astronomy Event. The only difference is the addition of the Equilibrium Temperature equation highlighted in white. The planetary equilibrium temperature is a theoretical temperature that the planet would be at when considered as if it were a black body being heated only by its parent star. The theoretical black body temperature is treated as if it came from an idealized surface of the planet. This calculation can help determine the habitability of the planet.

Slide 46:
We have now covered the basic content for the Astronomy 2025 event. I have included links for nearly all the slides in this 4 Part overview for this year's DSOs. There are so many websites that discuss the exoplanets and explain the topics that it can be confusing. Remember the CAVEAT as you start accessing the web. The information changes at quite a fast rate. Try and keep as current as you can!

Slide 47:
This has been a brief overview of the content and DSOs in this year's competition. As I said earlier, I have listed links in the transcript that I thought might be helpful. The transcript pages for the DSOs are shown in this slide. There are no links on the transcript pages for this last part on resources and preparation because I have placed them directly onto the slides.

Slide 48:
NASA's Universe of Learning (UoL) program supports the space science events. From the homepage you can click on Resources. From here you can search for anything on the website that you are looking for. If you click on Projects on the Resources menu, all of the UoL partnerships and projects appear. One project is Exoplanet Watch. Towards the end of the list is the National Science Olympiad.

Slide 49:
Universe Unplugged is part of the Universe Unplugged program. I find it easier to search, and the information is more appropriate for our purposes. Scroll down through the home page. There is a lot of great information and programs. One of those programs is NSO Webinars. The annual RFTS and Astronomy webinars are posted here. Future Space Mission Experts talks and presentations are posted here.

Slide 50:
The NASA Exoplanet Travel Bureau is a treasure chest of information about every aspect of exoplanets you can imagine. Great information. Not only is there technical information. The Immersive and Search for Life menus keep the imagination and fascination alive – it's not all about the data!

Slides 51:
The JWST website, as well as Hubble, Spitzer, Chandra et al, are great places to learn about exoplanets and the different ways they are observed. The APOD website has always been a good place to search for different images from different missions for stars and other DSOs. However, even though it is still supported, lack

of staff and funding is making it difficult to try and keep the information and links updated. So, a lot of the older links no longer work. The newer information should still be ok though. Besides the webinars, Chandra hosts the js9 image analysis tool website, along with tutorials and investigations for you to learn the tools. This is the website you will be using to answer the js9 question.

Slide 52:
The Astronomy webinar is posted on the Chandra website, using the Education and Science Olympiad menus. The NSO has a link to the webinar, and they will have the transcript in PDF format that you can download so you can have the links.

Slide 53:
Besides the webinars, Chandra hosts the js9 image analysis tool website, along with tutorials and investigations for you to learn the tools. This is the website you will be using to answer the js9 question. A very few teams use binders, and not laptops. If you are going to answer the js9 question, and are using a binder, you will not be able to answer that question. We used to hand out a screenshot version; however, realized that it was a disadvantage to being online. Js9 questions are going to be appearing on more and more tests. It is the tool astronomers use. Spectroscopy has given us every single bit of information we have of the universe. It is a power and essential tool, js9 questions are not the most difficult questions.

If we have a computer lab situation we can have each monitor connected to the js9 website during the entire competition and teams can answer the question when they feel like doing it. If there is no a computer lab available, at the national competition we loan computers to those who only have binders.

Slide 54:
The WIKI - Sioly,org website is interesting! There is a lot of information there, as the group maintains knowledge about the individual events, the competitions from invitationals through regionals and states to nationals. They have sample tests, write tests for each other, rummage around for tests from competitions, and answer questions. They have an outstanding different approach on how to use js9. It was written by one of the co-event supervisors for Astronomy, Rio Sessions. That would be another great way to learn js9.
And a really nice touch is the Saturday Morning Astrophysics at Purdue video which uses JS9 to show how the universe is colored!

Slides 55-58:
Self-Explanatory!