Highlights of the May Sky. . .

- - - 5th - - -
AM: Eta Aquariid meteor shower peaks.

- - - 7th - - -
Full Moon
6:45 am EDT

- - - 12th - - -
DAWN: A waning gibbous Moon, Jupiter, and Saturn form a triangle.

- - - 13th → 14th - - -
DAWN: The Moon moves between the Jupiter/Saturn pairing and Mars.

- - - 14th - - -
Last Quarter Moon
10:08 am EDT

- - - 15th - - -
DAWN: A waning crescent Moon is 4½° to lower left of Mars.

- - - 21st - - -
DUSK: Look for Mercury about 1° to the lower left of brilliant Venus.

- - - 22nd - - -
New Moon
1:39 pm EDT

- - - 23rd - - -
DUSK: A very thin waxing crescent Moon is 4½° to the lower left of Venus.

- - - 24th - - -
DUSK: The Moon, Mercury, and Venus form a line about 12° long.

- - - 26th - - -
PM: The Moon is 6° left of Pollux in Gemini.

- - - 28th - - -
PM: The Moon is 6½° right of Regulus in Leo.

- - - 29th - - -
First Quarter Moon
11:30 pm EDT

Prime Focus

A Publication of the Kalamazoo Astronomical Society

★ ★ ★ May 2020 ★ ★ ★

This Months KAS Events

General Meeting: Friday, May 1 @ 7:00 pm

Held Online via Zoom - See Page 24 for Details

Observing Session: Saturday, May 16 @ 9:00 pm

Pandemic Conditions Permitting - See kasonline.org for Latest Info

Board Meeting: Sunday, May 17 @ 5:00 pm

Held Online via Zoom - All Members Welcome

Observing Session: Saturday, May 30 @ 9:00 pm

Pandemic Conditions Permitting - See kasonline.org for Latest Info

Inside the Newsletter. . .

The People of the KAS

by Mike Sinclair

In honor of Richard Bell's 250th issue of the Kalamazoo Astronomical Society's newsletter, *Prime Focus*, I thought I would submit some passing observations about the club and all that has changed in the time I've been a part of it. As a +25-year member of the organization, and (at least for a few years) a past president, I've come to recognize that any club is only as good as its members. We've had a lot of people join and leave the KAS over the years, and the only thing I regret was not getting to know many of you. Amateur astronomy is often a solitary activity, and only rarely do we ever meet to look out at the night sky. Our primary contact tends to be monthly meetings and the occasional weather-dependent club gatherings such as Public Observing Sessions, the February Freeze Out, the Messier Marathon, or the annual Perseid Potluck Picnic.

But the success of any organization really only comes down to this truism: Those who continue their membership, through good times and rough times, through exciting upcoming astronomical events or years of doldrums (and I'm thinking of the current Solar Minimum of sunspot activity on the Sun right now), these are the people who keep this club alive.

We all have incredibly active lives, with few opportunities to enjoy a cool, clear night sky. As a science teacher at KAMSC, my year is a constant drive forward, with stressful months and even more stressful weeks and days. My wife, Karen, will tell you that October finds me devoting all my free time to writing recommendation letters for seniors aiming for admission to the best colleges and universities in the country. January and June are semester final months, February through March are eaten up by scholarship recommendations, April is prepping for our annual Project Night with compiling and evaluating a variety of research projects, May is our Awards Ceremony and graduation, and even the end of the school year isn't time off. That's because I spend several months doing research at the University of Notre Dame. Along with my teaching at KAMSC, I also teach classes at KVCC, and a lot of "high priority" projects just get pushed aside. But I wouldn't willingly walk away from any of it, especially the KAS. Because these activities are what drives me.

I hope you will all continue to look up, track the planets, seek to discover comets, study the Moon, find every deep-sky object you can, and learn the night sky. Amateur astronomy is all-encompassing; it is for everyone, and even a little observing is better than no observing.

Stay safe, stay healthy, and enjoy the stars!

Observations by Richard S. Bell

Welcome to my 250th issue of *Prime Focus*! When I was elected Editor/Secretary at the end of 1995, never would I have guessed that I would still be editing the newsletter today. I did enjoy a four year break from 2002 to 2005, but other than that I've been assembling *Prime Focus* once-a-month every month for the KAS membership since the January 1996 issue. Believe it or not, I actually still enjoy doing it. Sometimes, sure, it does get a little tedious. Doing the layout is what I enjoy most. Writing the general meeting minutes can be difficult (especially when it's one of our more technical talks) and it's often the last thing I put together. I do feel that summarizing each talk is important though - not just for history's sake, but for those members who often cannot regularly attend our monthly meetings.

People often ask how long it takes me to put each issue together. The average time is ~6 hours spread out over several days. This issue, obviously, took considerably more time. I hope you take the time to enjoy it. At least it kept me busy during these difficult times. I know that not every member takes the time to read the newsletter each month, but many of you do and I appreciate it. Special thanks to Kevin Jung, Mike Sinclair, and *especially* Kirk Korista for contributing to this special issue. I also hope you enjoy my special article on Leonard James Ashby. That is the result of 2 years of research.

Prime Focus got its start in 1970 when the old guard handed the club over to its younger members. At that time our group was dubbed the Kalamazoo Amateur Astronomical Society. That means *Prime Focus* predates the KAS! There was a newsletter previous to *Prime Focus*, but I've only seen a handful of issues. It was titled *The Northern Lights*, but I know nothing more than that. At times *Prime Focus* was sent out bi-monthly or even quarterly, but most publications have been monthly during its 50 year history. (Geesh, maybe I should consider this issue the "50th Anniversary Special Issue" as well! How about that?)

Richard mounted the new Tele Vue NP101is refractor atop the Meade 16-inch SCT in Owl Observatory on April 26th. Notice his use of PPE in this time of COVID-19.

Dave Garten installed the new roll-off roof motor on April 26th as well. It's an Alecko AR2750 Sliding Gate Opener!

Some of the past *Prime Focus* issues I've looked through were fairly well done for the time, but some (to be honest) are pitiful. I shouldn't be too harsh, since I've had the advantage of desktop publishing software. Plus, starting in 2005, we started moving away from hard copy issues and switched to electronic PDFs. That has saved us a tremendous amount of money on postage and other costs over the years. Both Mike Sinclair and I were getting really getting tired of prepping 60+ issues for mailing each month during my first 6 years as Editor. (At least Mike and I used a photocopier as opposed to a mimeograph machine!) Plus, with this electronic version, I'm able to use full-color images and issues don't arrive mangled in your mailbox.

We do not have a complete list of past *Prime Focus* editors, but here's a list of the ones I know of: Brian Akers, Robert Cobez, Joe Medsker, Pete Mumbower, Bill Nigg, Alan Otterson, Mike Potter, Jim Rix, Mike Sinclair, Eric Schreur, Robert Wade, and Joyce Winters.

For me, *Prime Focus* has been an invaluable learning experience. It has helped increase my knowledge of software and both my grammar and writing skills have improved. Being the Editor can be a demanding job. Honestly, it can be more work than any position on the Board. I've always felt it's the most important job though. For many members, *Prime Focus* may be the only thing they'll see from the KAS. The objective of a newsletter may be to inform its members of club news and activities, but it could be so much more Members have shared star party reports and equipment reviews. Others have provided previews of upcoming astronomical events or passed on their knowledge of observing or astrophotography. That's what the KAS is all about. Sharing your passion and knowledge of astronomy

Famed planetary imager Damian Peach took this image of Comet C/2020 F8 (SWAN) from Chile on April 28th. A 200mm f/2 lens was used with FLI CCD camera. The tail seen above is at least 8° long.

with others. The newsletter should reflect that. So why not contribute? Not every issue needs to be as large as this one, but each one should contain a contribution from a member. The deadline is the 15th of every month. Put something together and send it to me today!

And in other news...Last month I wrote about Comet C/2019 Y4 ATLAS. Update: NEVER MIND! The poor little thing started breaking up in early April. As a result it has decreased dramatically in magnitude. It will not be the spectacle in mid-May that we all had hoped for. Perhaps Comet C/2020 F8 (SWAN) will come to the rescue. This Comet SWAN (there have been many others) was discovered on March 25th. It is predicted to reach a peak magnitude of 3.5 between May 15th and 23rd in the pre-dawn sky. SWAN will be visible in the constellations Triangulum and Perseus during that time. We'll keep you updated!

One thing missing from this month's newsletter are minutes from the April meeting, which had to be canceled thanks to the continuing pandemic. For the first time in KAS history, the May meeting will be held online using Zoom. Our planned guest speaker offered to present on Zoom, but I thought we should wait and see how many members participate before bringing in the "heavy hitters" online. Therefore, I'll be presenting *Observing Mars; Then & Now* on May 1st. This will help some of you prepare for the Mars opposition this Fall.

As for the May observing sessions, there's little chance those will take place. The real shame is we were planning the new telescope dedication for May 30th. That's now off as well. We waited all winter to debut the new telescope in Owl Observatory only for COVID-19 to come along. At least we're making progress (as seen by the images on page 3). Once the upgrades are complete, we'll do our best to offer training sessions when conditions improve. I'm hoping to release an updated *Owl Observatory User's Manual* in the next month. Please be patient with us. Stay healthy!

BOARD Meeting Minutes

The Kalamazoo Astronomical Society Board held an experimental meeting on April 19, 2020 at 5:00 pm EDT. Because of the limitations on group meetings brought about by the COVID-19 pandemic, the meeting was held by use of Zoom technology, with members present in their own living quarters. Those logged in were Richard Bell (who hosted the meeting), Joe Comiskey, Scott Macfarlane, Jack Price, Don Stilwell, and Roger Williams.

Don had e-mailed the Treasurer's Report earlier in the afternoon, but since not all of the members had seen it yet, action was deferred.

Coming events were entirely constrained by the closures of KNC (for observing sessions) and KAMSC (for general meetings) as part of Governor Whitmer's stay-at-home order. Restarting public viewing was considered out for May and questionable for even June or July. Members were also polled about the use of Zoom for general meetings and the like, and the opinions were favorable. A proposal to acquire the Pro level of Zoom ($14.99/month) was passed unanimously. This removes the limitation of 40 minutes per meeting. Richard will give a presentation that was originally planned for September during the meeting on May 1st. He will discuss how best to observe Mars during the upcoming opposition this Fall (see page 24 for details). Richard said he would prefer a member, rather than a special guest speaker, give the first presentation via Zoom in case participation from the membership is low.

In follow-up on the Owl Observatory Upgrade Project, Richard reported no significant progress so far in readying the donated 10-inch Meade telescope for sale, but he planned to clean it soon. Dave Garten was ready to install the motor for the roll-off roof, but he would need a key for access. There was some discussion about how under current social distancing conditions two people could work safely on the project. Richard reported that he had uncovered much information about Leonard James Ashby (see the special article starting on page 8). It was fortunate that the plaque for the Owl telescope pier had not yet been ordered, since the May 30th date which was to be printed on it fell victim to the novel coronavirus.

In Other Business, Richard mentioned an offer for donation of an 8-inch Meade telescope that should need only some cleaning and adjustments. Joe Comiskey volunteered to contact the donor and gather more information. Don was willing to pick-up or take delivery of the telescope if the person resided in the Battle Creek area.

With the end of business, the meeting was adjourned at 5:40 pm. The next board meeting was set for May 17th at 5pm, probably still using Zoom.

Respectfully submitted by Roger Williams

ESA astronaut Luca Parmitano and NASA astronaut Drew Morgan take you on a unique tour of the International Space Station shot in one take with two cameras strapped together. Luca and Drew take it in turns to guide you through the modules and spacecraft docked to the orbital outpost.

→ https://youtu.be/Snn1k_qEx20

For people who are able to work remotely during this time of social distancing, video conferences and emails have helped bridge the gap. The same holds true for the team behind NASA's Curiosity Mars rover. They're dealing with the same challenges of so many remote workers - quieting the dog, sharing space with partners and family, remembering to step away from the desk from time to time - but with a twist: They're operating on Mars.

→ https://go.nasa.gov/3cDb93m

Mars Perseverance scheduled for July 2020 launch to Jezero Crater, for a February 18, 2021 landing.

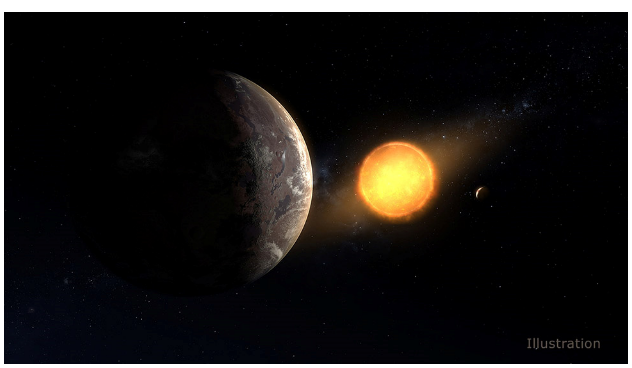
→ https://www.jpl.nasa.gov/missions/mars-2020/

Five days before NASA's Spitzer Space Telescope ended its mission on January 30, 2020, scientists used the spacecraft's infrared camera to take multiple images of a region known as the California Nebula - a fitting target considering the mission's management and science operations were both based in Southern California at NASA's Jet Propulsion Laboratory and Caltech.

→ https://go.nasa.gov/3eKXedB

A team of transatlantic scientists, using reanalyzed data from NASA's Kepler Space Telescope, has discovered an Earth-size exoplanet orbiting in its star's habitable zone, the area around a star where a rocky planet could support liquid water.

→ https://go.nasa.gov/3bD7W3S



As the world observed the 50th anniversary of Earth Day on Wednesday, April 22nd, NASA highlighted the agency's many contributions to sustaining and improving our home planet's environment with a week of online events, stories and resources.

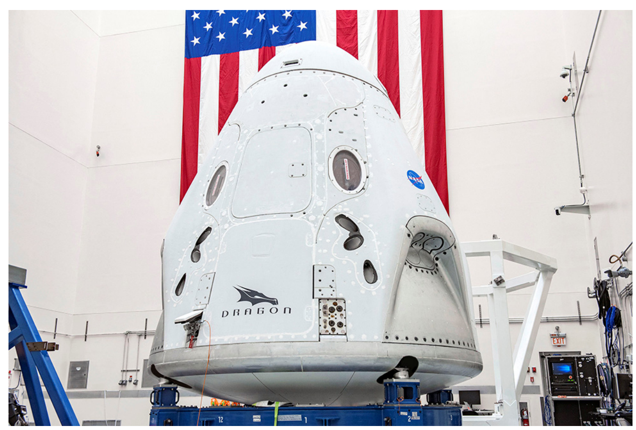
→ https://go.nasa.gov/2VSDQCP

For the first time, scientists have directly measured wind speed on a brown dwarf, an object larger than Jupiter (the largest planet in our solar system) but not quite massive enough to become a star. To achieve the finding, they used a new method that could also be applied to learn about the atmospheres of gas-dominated planets outside our solar system.

→ https://go.nasa.gov/3azysKe

A new era of human spaceflight is set to begin as American astronauts once again launch on an American rocket from American soil to the International Space Station as part of NASA’s Commercial Crew Program. NASA astronauts Robert Behnken and Douglas Hurley will fly on SpaceX’s Crew Dragon spacecraft, lifting off on a Falcon 9 rocket at 4:32 p.m. EDT on May 27th.

→ https://go.nasa.gov/3bzRYrg

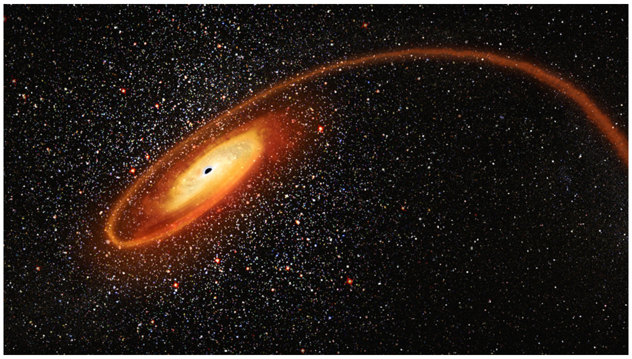


After the successful completion of its “Checkpoint” rehearsal, NASA’s first asteroid-sampling spacecraft is one step closer to touching down on asteroid Bennu. NASA’s OSIRIS-REx spacecraft performed the first practice run of its sample collection sequence, reaching an approximate altitude of 246 feet (75 meters) over site Nightingale before executing a back-away burn from the asteroid.

→ https://go.nasa.gov/2VSJm8v

Like detectives carefully building a case, astronomers gathered evidence and eliminated suspects until they found the best evidence yet that the death of a star, first witnessed in X-rays, could be traced back to an elusive mid-sized black hole. The result is a long-sought win for astronomy, as the mid-sized "missing link" in the black hole family has thus far thwarted detection. NASA's Hubble Space Telescope was used to follow up on multiple X-ray observations of a suspected tidal disruption event.

→ https://bit.ly/3cGYnB1

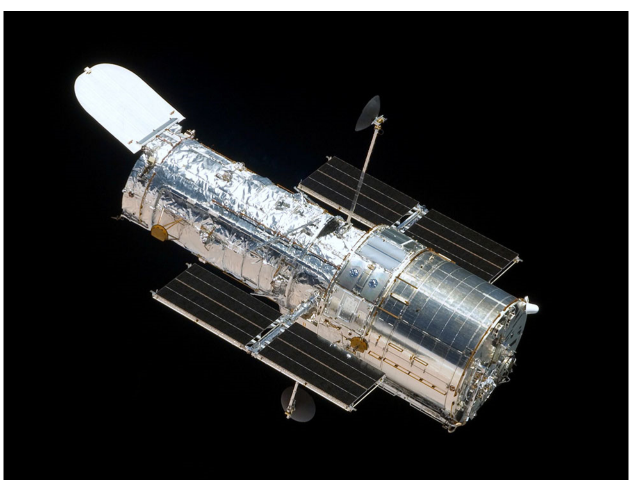


Interstellar comet 2I/Borisov is providing a glimpse of another star system's planetary building blocks, using new observations from NASA's Hubble Space Telescope.

→ https://bit.ly/2VWRAg1

On April 24, 1990, the space shuttle *Discovery* lifted off from Earth with its precious cargo, the Hubble Space Telescope. The next day, astronauts released the telescope into space to begin its journey of discovery. No one could have predicted what wonders Hubble would see in the 30 years that followed. From our own cosmic backyard to the far reaches of the universe, Hubble showed us properties of space and time that for most of human history could only be imagined.

→ https://hubblesite.org/hubble-30th-anniversary



Have you heard the buzz about a big – very big – asteroid that will pass relatively close to Earth later this month? Asteroid (52768) 1998 OR2 will pass at a safe distance, at some 4 million miles (6 million km), or about 16 times the Earth-moon distance.

→ https://bit.ly/3bAf8O9

BepiColombo, the joint European-Japanese mission, performed an Earth flyby on April 10, 2020 to adjust its trajectory en route to its destination, Mercury. The spacecraft, equipped with three 'selfie' cameras, captured a series of stunning images of the planet, and was also photographed by astronomers, including amateurs, on Earth.

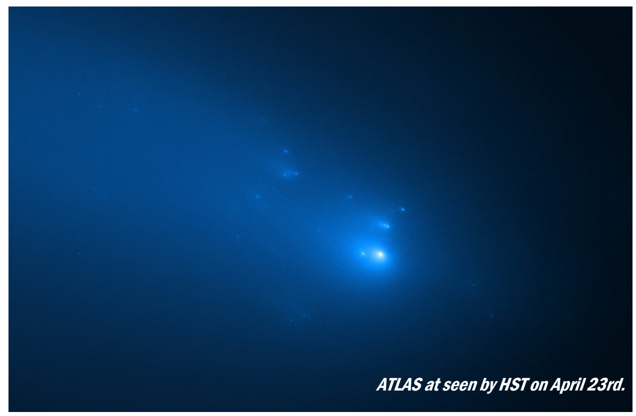
→ https://bit.ly/3ayJO19

An eclipsing binary millisecond pulsar has been discovered by the FAST. Named as PSR J1717+4307A or M92A, it is the first pulsar known in globular cluster M92, with a spinning period of 3.16 ms. The companion is a 0.18 solar mass star, evolving to be a sub-giant.

→ https://bit.ly/2Sf2aO6

Comet Y4 ATLAS Breaks Up…Enter Comet F8 SWAN

→ https://bit.ly/2VyHxPd



A group of citizen astronomers scattered all over the world has just demonstrated how a network of digital Unistellar eVscopes can work together to deliver the first-of-its-kind crowd-generated images of Comet ATLAS while its disintegrating.

→ https://bit.ly/2VVNvbB

Data from the Lunar Reconnaissance Orbiter spacecraft now makes it possible to show what the Apollo 13 astronauts saw as they flew around the far side of the Moon. This video showcases visualizations in 4K resolution of many of those lunar surface views, starting with earthset and sunrise, and concluding with the time Apollo 13 reestablished radio contact with Mission Control.

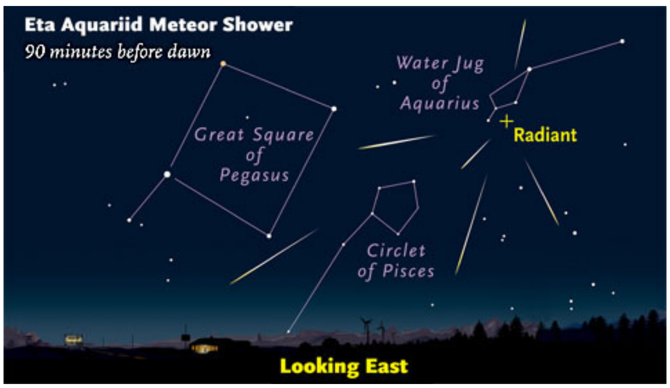
→ https://svs.gsfc.nasa.gov/13537

Observations led by the Max Planck Institute for Extraterrestrial Physics have revealed for the first time that a star orbiting the supermassive black hole at the center of the Milky Way moves just as predicted by Einstein's general theory of relativity. Its orbit is shaped like a rosette and not like an ellipse as predicted by Newton's theory of gravity. This long-sought-after result was made possible by increasingly precise measurements with ESO telescopes over nearly 30 years, which have enabled scientists to unlock the mysteries of the behemoth lurking at the heart of our galaxy.

→ https://www.mpe.mpg.de/7433286/news20200416

May Sky Highlights

May 4^{th}, 5^{th} - Eta Aquariid Meteor Shower. The Eta Aquariids is an above average shower, capable of producing up to 60 meteors per hour at its peak. Most of the activity is seen from the Southern Hemisphere. In the Northern Hemisphere, the rate can reach about 30 meteors per hour. It is produced by dust particles left behind by Comet Halley, which has been known and observed since ancient times. The shower runs annually from April 19^{th} to May 28^{th}. It peaks this year on the night of 4^{th} and morning of the 5^{th}. The nearly full Moon will be a problem this year, blocking out all but the brightest meteors. But if you are patient, you should still should be able to catch a few good ones. Best viewing will be from a dark location after midnight. Meteors will radiate from the constellation Aquarius, but can appear anywhere in the sky



May 7^{th} - Full Moon. The Moon will be located on the opposite side of Earth as the Sun and its face will be fully illuminated. This phase occurs at 6:45 am EDT. This full Moon was known by early Native American tribes as the Flower Moon because this was the time of year when spring flowers appeared in abundance. This moon has also been known as the Corn Planting Moon and the Milk Moon.

May 12^{th} - The Moon hangs out with Jupiter and Saturn. The three objects will be visible in the dawn sky, rising at 1:37 am EDT and reaching an altitude of 26° above the southern horizon before fading from view as dawn breaks around 6:01 am. The Moon will be at magnitude -12.2; Jupiter will be at magnitude -2.5, and Saturn will be at magnitude 0.3. They will be too widely separated to fit within the field-of-view of a telescope, but will be visible to the naked eye or through a pair of binoculars.

May 23^{rd} - Comet ATLAS. Comet ATLAS will make its closest approach to Earth at a distance of 72 million miles (116 million kilometers). With the comet's nucleus breaking up, all forecast for it to get very bright are up in the air at this moment.

NASA Night Sky Notes…

Become a Citizen Scientist with NASA!

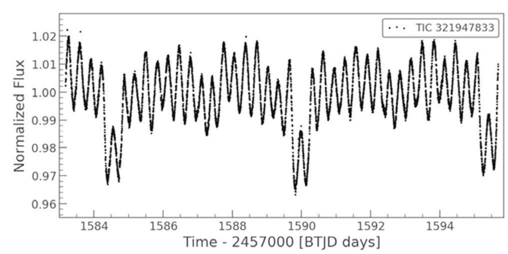
by **David Prosper**

Ever want to mix in some science with your stargazing, but not sure where to start? NASA hosts a galaxy of citizen science programs that you can join! You'll find programs perfect for dedicated astronomers and novices alike, from reporting aurora, creating amazing images from real NASA data, searching for asteroids, and scouring data from NASA missions from the comfort of your home. If you can't get to your favorite stargazing spot, then NASA's suite of citizen science programs may be just the thing for you.

Jupiter shines brightly in the morning sky this spring. If you'd rather catch up on sleep, or if your local weather isn't cooperating, all you need is a space telescope - preferably one in orbit around Jupiter! Download raw images straight from the Juno mission, and even process and submit your favorites, on the **JunoCam** website! You may have seen some incredible images from Juno in the news, but did you know that these images were created by enthusiasts like yourself? Go to their website and download some sample images to start your image processing journey. Who knows where it will take you? Get started.

Interested in hunting for asteroids? Want to collaborate with a team to find them?? The **International Astronomical Search Collaboration** program matches potential asteroid hunters together into teams throughout the year to help each other dig into astronomical data in order to spot dim objects moving in between photos. If your team discovers a potential asteroid that is later confirmed, you may even get a chance to name it! Join or build a team and search for asteroids at: iasc.cosmosearch.org

Want to help discover planets around other star systems? NASA's TESS mission is orbiting the Earth right now and scanning the sky for planets around other stars. It's accumulating a giant horde of data, and NASA scientists need your help to sift through it all to find other worlds! You can join **Planet Hunters TESS** at: planethunters.org



Intrigued by these opportunities? These are just a few of the many ways to participate in NASA citizen science, including observing your local environment with the GLOBE program, reporting aurora with Aurorasaurus, measuring snowpack levels, training software for Mars missions – even counting penguins! Discover more opportunities at Citizen Science and join the NASA citizen science Facebook group. And of course, visit nasa.gov to find the latest discoveries from all the research teams at NASA!

Leonard James Ashby

Founder and First President

by Richard S. Bell

Students at Kalamazoo College wanted to continue learning about the universe around them after taking a one-semester astronomy course in the winter of 1936. To that end they formed the Kalamazoo Amateur Astronomical Association (KAAA). It turns out that was only part of the story. It has recently been rediscovered that the true founder and first president of the KAAA was a gentleman by the name of Leonard James Ashby.

The story of rediscovering our organization's origins began on Earth Day in 2017. The KAS shared views of the Sun and sold Eclipse Shades during a celebration in Bronson Park. At one point in the day a lady walked up to our booth and said that her grandfather was the founder of our group. I was skeptical, because I faithfully accepted the story of K-College astronomy students establishing the KAAA in 1936. Thankfully, I took down the information she provided, but I forgot to ask for her name! Some time went by before I searched for additional evidence to support this person's claim.

Thanks to the Internet, I was able to find some background information on the life of Mr. Ashby. The most valuable find came from the July 1945 issue of the *Kalamazoo College Alumnus* newsletter (page 8). Here's what it says:

> ***Ex-Professor Dies***
> *Leonard James Ashby, research physicist at the University of Michigan who taught at Kalamazoo College from 1921 to 1924, died in Ann Arbor on June 12. Ashby, an assistant professor of physics during his tenure here, was founder and former president of the Kalamazoo Amateur Astronomy Association. A son, Frederick Ashby, is an ensign in the navy.*

This certainly supports what I was told in Bronson Park, but I still wasn't 100% convinced. That changed after I looked through some old issues of *Prime Focus* graciously donated by long-time member Phyllis Buskirk in June 2019. The inside cover of the July 1970 issue has some background information on the newsletter and the Kalamazoo Amateur Astronomical Society (as we were known at the time). The last paragraph briefly covers the history of the organization. One line reads as follows:

> *Its history dates back to 1936 when it was organized under Leonard Ashby, the Society's first president.*

There you have it! Three different sources clearly state that Mr. Ashby was the key figure in starting our group in 1936. Now that this was confirmed to my satisfaction, the next step was to learn more about his life. The best way was to somehow locate the woman I met in Bronson Park two years prior. After doing some more cyber sleuthing, I found an obituary for Ellen Rood Ashby, the wife of Ashby's son Frederick. Ellen was also the daughter of WMU physics professor Paul Rood. Paul was a one-time member of the KAAA, and Rood Hall was named in his honor. Fred and Ellen had four children, one of whom is Cathy McMinn, who resides in the Delton area. She seemed the most likely candidate, so I found her home address and wrote her a letter. She enthusiastically responded and confirmed she was the woman I met in Bronson Park. In the months ahead, she provided me with a tremendous amount of information on the life of her grandfather.

Leonard James Ashby was born on December 1, 1891 in Oldham, Lancashire, England and later moved to Southsea, Portsmouth. His parents were Richard Ashby and Jane Taylor. Leonard had two siblings, a brother named George Oswald Ashby and a sister named Ethel Gillies Ashby. George was killed in action in France during World War I on July 20, 1916. Ethel married a gentleman named David S. Houston. They would go on to have one son, named in honor of her fallen brother.

In his youth Leonard apprenticed himself to a textile mill operator, and from 1903 to 1913 he studied nights and in his free time at the Oldham Technical School. In 1911 he won a scholarship to Manchester University and continued between terms his studies at the Oldham Technical School. In 1912 he won a medal, one of 20 so honored in an empire contest, called in English phraseology the Whitworth Exhibition. His Bachelor of Science degree, with honors, in engineering was obtained from Manchester University in 1915.

Leonard and George Ashby in uniform.

Ashby enlisted in the British army in 1915 and by 1917 had become a lieutenant of the Royal Corps of Signals with service in France. On leave, he visited one of his former professors at Manchester University, who suggested that the school of mines in the Royal Navy was looking for someone with his training. The professor suggested a visit and application for transfer. Transfers from one branch of the service to another in wartime is evidently difficult to effect, and especially so in the British military and naval establishments. However, after his interview with naval officers, his application slid through without a hitch, and he soon shed the army's khaki for the navy's blue. *"I wouldn't have gotten it,"* he said in an interview with the *Kalamazoo Gazette*, *"if the navy hadn't wanted it. In England the navy is considered the senior branch and it gets whatever it wants."* From then until the end of World War I and in fact until 1920, Ashby designed mines, and supervised manufacturing operations when the industrial concerns got into difficulties.

Ashby married Nona Gwendoline Wormald, of Oldham, in Crowborough, Sussex on January 15, 1916, during a leave. (On their marriage license under the heading "Condition," Leonard was listed as "Bachelor," while Nona was a "Spinster." It was a different time.) Nona was born on December 31, 1888 on Gamston Road in West Bridgford, a town in the Rushcliffe borough of Nottinghamshire, England. Her parents were Frederick Wormald and Emma Pawson. Perhaps their mutual interest in the same sport brought them together. Both Leonard and Nona were Olympic-class fencers. Apparently, they even qualified for the Olympic Games, but Leonard was wounded (stabbed) during practice and unable to compete.

The happy couple immigrated to the United States in June 1920. Cathy McMinn, granddaughter of Leonard & Nona, has a receipt for Mrs. Ashby's passport from Thomas Cook & Son. It is dated May 31, 1920 and she paid £10. They likely traveled to the New World across the Atlantic via steamship. Settling in Kalamazoo, Ashby applied and obtained an appointment to the faculty of Kalamazoo

Ashby founded the first-ever radio station, WOAP, in Kalamazoo in 1923. Ashby is on the left. The newspaper insert publicizes an appearance by Ashby at a meeting of the Ladies' Library Association.

Ashby (and his wife, Nona) were both Olympic-class fencers. They would have competed in the Olympic games if Ashby didn't suffer an injury during training.

College in 1921, where an engineering department was contemplated. That failed to develop, and he taught physics for three years.

While at K-College, Ashby built and operated the first broadcasting station in the city. The radio station, WOAP, opened on January 3, 1923 with a wavelength of 360-meters. It broadcast programming every Monday, Wednesday, and Friday. To prevent conflict with the programming from Detroit and Chicago, the hour of broadcasting was set at 6:30 pm. For a few minutes before this time students of a radio course gave stock and crop reports of interest to farmers around Kalamazoo. The regular programming consisted of orchestra music, vocal and instrumental selections, with special numbers and educational features. From time to time additional numbers were furnished by the Gaynor club and the Glee club. A license was also obtained to enable the station to be used for experimental purposes by the college classes in radio communication.

The Ashby's first attempt at starting a family ended in tragedy. Cyril George Ashby was born on July 18, 1922 and died of unknown causes that same day. Their second child, Frederick James Ashby (named after Nona's father), was born on June 29, 1923. Young Frederick had an interest in the relatively new field of aviation. Some photos, taken while on vacation in Port Washington, Long Island, show him wearing a leather aviator cap. He was also eminently skilled at making model airplanes. Fred was an ensign in the navy, serving stateside during World War II. I'm told he also taught sea cadets in Kalamazoo. Fred lived to the ripe old age of 77 – passing away on February 1, 2001. It is a shame we didn't learn about Leonard James Ashby during the rise of the KAS in the mid-1990's. We could have had the opportunity to speak with Fred while he was still alive.

Ashby left Kalamazoo College in 1924, which brought about the end of WOAP. The *Who's Who in Kalamazoo* article that appeared in the *Gazette* states that he resigned. Cathy tells me that he asked for a leave-of-absence to search for a new home. (The March 1922 *Kalamazoo College Bulletin* lists his residence as 897 Fairview Avenue.) After finding a

This photo accompanied the *Kalamazoo Gazette* article about Ashby's successful completion of grinding a 10-inch f/5 primary mirror.

new home, at 437 Stone Street, Ashby was told his position had been filled. Perhaps Cathy's account is true, and the author of the *Who's Who* article felt it best to omit this bit of information. Ashby may have briefly taught at Olivet College at some point, but the exact details remain unknown. With his teaching career now behind him, Ashby decided to start his own refrigeration installation business – a fairly new vocation at the time. Whether or not he owned (or rented) a shop or worked out of his home is unknown. This was likely his livelihood until he moved to Ann Arbor in 1940.

The *Who's Who* article suggests that Ashby also became interested in amateur astronomy after leaving K-College. Most amateur astronomers of this time were also amateur telescope makers (ATM) by necessity. Commercially made telescopes were quite expensive during this period. It should come as no surprise that Ashby, with his degree in engineering, had a completely equipped workshop in his basement. Even though telescope making was the rule of the day, Ashby shared his thoughts on the hobby in another interview with the *Kalamazoo Gazette* that would resonate with any ATMer active today:

> *That's the fun of it. Anyone can buy the things he wants to use, but to see them grow under his hands, that's the real kick in it. Then when he puts the machine together and it works, it's the thrill of a lifetime, repeated every time he does it.*

This *Gazette* article features Ashby and the 10-inch f/5 primary mirror he ground himself. "*Ten years of work and study and acquired skill have gone into the making of this mirror"* Ashby was quoted as saying. He went on to say that the 10-inch mirror "*took me my spare time all one winter to make*." Ashby also made sure to boost about his skill and the quality of his mirror:

> *In testing these parabolic mirrors, an error of five millionths of an inch is allowable. Mine shows an error of only 1.5 millionths of an inch, and by minute focusing I can cut that margin of error in half.*

Telescopes aren't the only thing Ashby built to support his hobby. The *Who's Who* article states that he "indulges his love of star gazing from an observatory he has built in the top of his garage, where a section of the roof has been so constructed that it can be slid back on rails to give him a chance to train his telescope on the sky." I wonder how common roll-off roof observatories were in the 1930s? It is a shame no known photographs of "Ashby Observatory" exist. I'd love to see it.

Nona wasn't one to wait for her husband to get through "*tinkering with that gadget*," as she put it, but also built a telescope of her very own. The *Gazette* article states that she ground a 4-inch mirror. The completed telescope was likely featured in *The Beginner's Corner* section of the November 1939 issue of *Scientific American* (page 316). Ashby explains why they built a 4-inch rather than the more common 6-inch aperture Newtonian:

> *There are a few who want a really portable instrument-one which does not require several strong backs and a truck to handle and transport. My wife cannot conveniently carry around even a 6", hence this 4" Newtonian which carries easily in the family car and can be handled by a woman.*

Ashby also boasted about the resolving power of Nona's new 4-inch telescope by saying "*This little telescope resolves components of Epsilon Lyrae with ½" eyepiece, Pi Aquilae with ¼"*." From here on out, every time I observe the "double double" I'll think of Leonard and Nona doing the same through that 4-inch Newtonian.

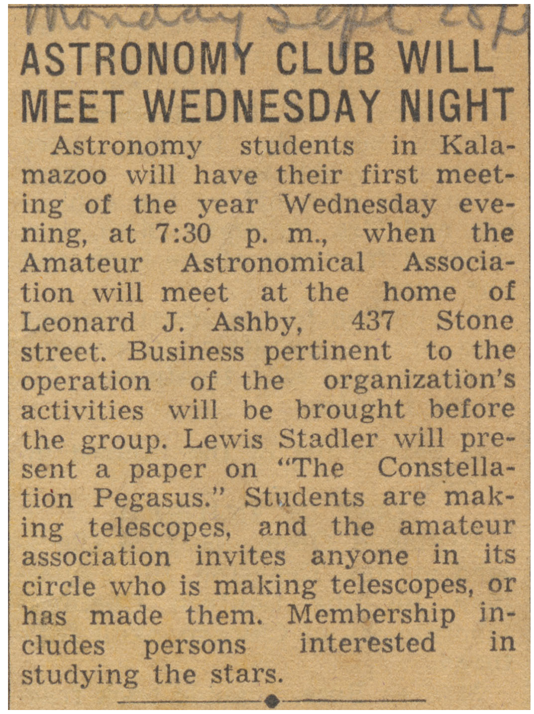
Nona had many other talents in addition to grinding telescope mirrors. The *Gazette* piece states that she had a "gable studio" in their attic where she modeled in clay. When the article was being written, she was working on a portrait bust of a neighbor child, and she "caught the delicate, mysterious beauty of the child in remarkable fashion." Nona was also a talented painter, and many of her works featured dogs and landscapes.

Perhaps Nona's most remarkable talent was as an amateur veterinarian. Cathy tells me that Nona helped a dog with a broken leg after a veterinarian said the dog was too old to help. Leonard and Nona made sandbags and buried the dog for several weeks. Once the dog was removed it was able to walk without much difficulty! Then there was their cat, Tuesday, that grew a giant tumor. Again, their professional vet thought the feline was too old to treat, so Nona sedated poor Tuesday, tied her to a washing machine, and removed the tumor herself. The cat got up for water the next day and lived for many more years! These seem like rather daring procedures to attempt without proper training, but upon closer inspection of the Ashby's marriage license, I noticed that Nona's father, Frederick, was a veterinary surgeon. Obviously, she picked up some surgical techniques from her father!

The exact circumstances that led to the formation of the Kalamazoo Amateur Astronomical Association will likely never be known. Ashby probably already had several friends in the amateur astronomy community and his connection to Kalamazoo College helped attract younger students to the new organization. This is clear from extraordinary group photographs Cathy has in her family collection (see page 13), along with an invaluable newspaper clipping. The names of several prominent amateur astronomers in Kalamazoo at the time are hand-written on the back of one group photo. Many are names well-known and others are ones I've discovered in additional research. These include Hans & Lillian Baldauf, Alfred Bryant, Jim Hopkins, Leonard Hayden, Edgar Pashby, William Persons, James Sigler, Louis Stadler, and Dr. Lawrence Upjohn. The clipping starts off by saying "astronomy students in Kalamazoo," suggesting that students from K-College (and perhaps even Western Michigan College) were involved from the start. For this meeting, members gathered in Ashby's home at 437 Stone Street, very close to both campuses. The group photographs clearly show student-age people in it, so the KAAA began with both young and old alike.

The clipping, which has a hand-written date of September 28, 1936 on it, publicizes the "first meeting of the year Wednesday evening, at 7:30 p.m." That would make the meeting date September 30th, since the 28th was a Monday. "First meeting of the year" could mean the school year or of the season, since the KAAA met from September – May at first. However, I speculate this could be the first formal meeting of the KAAA *ever*. The newspaper clipping says that "business pertinent to the operation of the organization's activities will be brought before the group." This seems like an appropriate topic to discuss at an inaugural meeting. And why would Ashby save this clipping if it weren't important? However, the KAAA did regularly meet in Ashby's observatory for viewing before then. Cathy provided me with an "Observatory Record" of visitors kept by Ashby. The first

The Leonard James Ashby Telescope located within Owl Observatory at the Kalamazoo Nature Center.



Monday Sept 28

ASTRONOMY CLUB WILL MEET WEDNESDAY NIGHT

Astronomy students in Kalamazoo will have their first meeting of the year Wednesday evening, at 7:30 p. m., when the Amateur Astronomical Association will meet at the home of Leonard J. Ashby, 437 Stone street. Business pertinent to the operation of the organization's activities will be brought before the group. Lewis Stadler will present a paper on "The Constellation Pegasus." Students are making telescopes, and the amateur association invites anyone in its circle who is making telescopes, or has made them. Membership includes persons interested in studying the stars.

KAAA gathering was recorded on May 6, 1936. The K-College astronomy class, taught by Prof. John Hornbeck, met at Ashby's observatory two days earlier.

Leonard & Nona Ashby were members of the KAAA for only the first four years it seems. In 1940, they moved to Ann Arbor where Leonard became a student at the University of Michigan. His name appears on a list of registered students dated from July 1, 1940 to June 30, 1941. In *The Michigan Alumnus* (Index Volume LI dated October 7, 1944 to September 22, 1945), he held the job title of Special Instructor of Physics from 1943 – 1944. Ashby died unexpectedly on June 12, 1945. He developed some sort of infection and the doctors tried to treat it by raising his body temperature. This procedure was done improperly, and his spleen burst. He was only 53 years old. It's not clear if Nona remained a member of the KAAA after her husband's death, but she did return to Kalamazoo – living at 303 Woodward Avenue. She passed away in August 1966 at the age of 77. All members of the Ashby Family are buried at Mountain Home Cemetery in Kalamazoo.

Thanks to the rediscovery of Leonard James Ashby, we now have a clearer understanding of the Kalamazoo Astronomical Society's origins. On June 23, 2019, the KAS Board voted unanimously to approve my proposal to name the new Owl Observatory telescope after Mr. Ashby, our founder and first president. It seems a fitting tribute to a talented man who lived an interesting, but brief life. As an engineer, he would appreciate the mechanical precision of our new Astro-Physics 1600GTO German mount with capabilities he could only dream of. Many thousands of people from the KAS membership, to students, and the general public will enjoy views of the universe for decades to come through the telescope dedicated in his honor.

Richard Bell is one of only three lifetime members and the longest-serving president in KAS history.

Kalamazoo Amateur Astronomical Association (circa late-1930s)

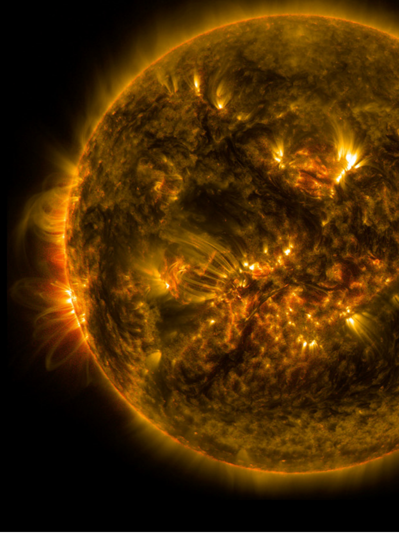
From left to right: Dr. Lawrence N. Upjohn, unknown man (behind refractor), Leonard Hadyn, unknown man (behind Leonard), unknown man (left of reflector), Louis Stadler (front), Jimmie Sigler, Mrs. Hadyn, Leonard James Ashby, Nona Ashby, Edgar Pashby (behind Nona), Hans Baldauf (front and center), Shiley? (behind Hans), Alfred Bryant (in profile), unknown man, Harriet Sigler (partial), Jim Hopkins, Fred Ashby (kneeling), Lillian Baldauf, unknown woman, unknown woman, Gratia Upjohn (dark dress), Bertha Ashby (front), William Persons, unknown woman (behind telescope), unknown man sitting on far right.

KAAA members gather for an observing session. Does anyone recognize the building in the background?

Why Do Stars Shine?

Or what is a star and how does it work?

by **Dr. Kirk Korista**



A Beautiful Story – Nearly Lost

Try googling "Why do stars shine?". A common answer in reply usually has the word "fusion" appearing in the first two sentences in addressing that most basic question. Often, it is said that photons emitted in nuclear fusion reactions are the ultimate source of the light the star emits at its surface. Or perhaps you will be informed that the energy generated by fusion is what makes the gases of the star hot – and therefore luminous.

The story of how a star works will then frequently go on to say that fusion provides or exerts the pressure that supports the star against the force of gravity to prevent gravitational collapse. The narrative might then go onto explain where this pressure comes from: that photons emitted in the nuclear fusion reactions exert *radiation pressure*. Or it might hedge a bit and inform the reader that the energy from fusion is what provides the thermal energy content in the gas ("keeps the star hot"), so that the gas can exert the appropriate pressure to oppose the force of gravity. Or it might just say that it is the photons inside a star, origin left unspecified, that exert the pressure to oppose the force of gravity. But that in any case in the absence of fusion the star (or perhaps just its central core) loses its ability to exert the pressure needed to oppose gravity, and must therefore undergo rapid gravitational collapse.

In the course of painting the story of the lives of stars, a substantial majority of narratives will then inform the reader that once a massive star forms an *iron core*, it is doomed to "collapse under the crush of gravity". It will then go on to explain that iron, having the highest nuclear binding energy per nucleon (i.e., per proton plus neutron number), does not participate in exothermic nuclear reactions: those that release energy into the surrounding gas. Without energy generated by fusion, the poor core can no longer generate the pressure it needs to support itself or the rest of the star above, and so gravity wins and crushes the core in a violent collapse. This is the lead-in narrative to the creation of a neutron star or black hole, and of the spectacular stellar explosion called a 'supernova.'

If you're reading this article, it's because you're curious about the universe you live in, and so almost certainly you've read one, many or all of the above. They should sound familiar. You might have encountered them on internet science/astronomy education sites, *including those sponsored by NASA* or on-line notes from 100- or 300-level university astronomy courses. Or perhaps you've read them in a book or introductory astronomy textbook, or seen and heard them described on an astronomy special on TV. These explanations of what stars are, how they work, why they shine are ubiquitous.

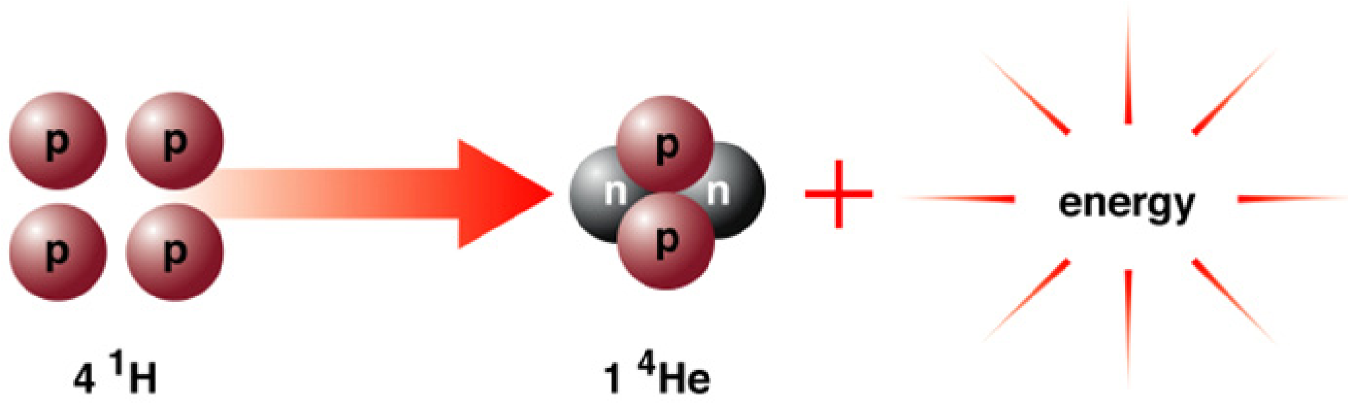
And they are also *all wrong*.

They're not just a little bit wrong, or "technically" wrong. Nor are they merely reasonable simplifications of complex physics to help the non-specialist understand something really cosmic about the universe they inhabit. They are wrong in the sense that these explanations *explain nothing* and even *raise their own conundrums* regarding stars and how they work. These two attributes are polar opposites of the scientific endeavor to understand world around us and the universe.

I do not know where they all came from, nor do I understand why they continue to be perpetuated. Not all of these fallacies and falsehoods are aerosolized by all educational outlets, but the vast majority spray out least one of them. Some sources are better than others, some worse, others are horrible. And I am not even discussing websites that offer crackpot conspiracy theories about stars. Whatever the origins, the internet has been a fantastic vector for the virus of misconception. But sorting out where they came from and when they arose isn't my purpose here.

Mine, here, is to shine some light (*cough*).

Ok, so where to start? Well, let's start with an observation. Look briefly back at that list of misconceptions. Nearly all of them have one thing in common – fusion. *Nuclear fusion has somehow become the answer to all questions about what a star is, how it works, and even how it shines*. But if the above *are not* the roles of nuclear fusion in stars, then what are these roles?



Most stars generate energy in their central regions by a process known as nuclear fusion. In Main Sequence stars, such as our Sun, 4 hydrogen nuclei become a helium nucleus plus energy, as shown in the above simplified summary of the process.

A bit of background on nuclear fusion: Nuclear fusion is the process by which two atomic nuclei *fuse* together, under the strong nuclear interaction. If the product atomic nucleus is bound more tightly under the strong nuclear interaction than the reactant nuclei, energy is deposited into the environment via an increase of the particle kinetic energies. Because atomic nuclei contain 1 or more positively charged protons (and often a roughly equal number of neutrons), they feel a repulsive force upon approach to one another during a collision ("like charges repel"). Only in the central most regions of the star (its "core"), where the temperatures and densities are greatest, are the conditions appropriate for collisions of sufficient kinetic energy that a few of the nuclei approach close enough during a collision to "tunnel through" the repulsive barrier to allow the strong nuclear interaction to fuse the colliding nuclei into a heavier element, releasing energy into the environment.

The primary roles of fusion in stars are:

1. Fusion *dumps energy into the star*, so that the star doesn't simply slide deeper (*slowly contract)* into the potential energy well of gravity. *If* the rate of energy production by fusion, L_{fusion}, equals the star's luminous power (its luminosity L_*), the rate at which it dumps energy into space, we say that the star is in *energy balance*. Stars spend most, but not all, of their existence in this state. We'll discuss this further, later in our story.
2. Consequently, the energy released by fusion *slows* the rate of a star's time evolution, by roughly a factor of 400. This number is the ratio of the mass-to-energy conversion efficiencies of hydrogen fusion and the conversion of gravitational potential energy into kinetic energy.
3. Fusion transmutes lighter elements into heavier ones. In particular, stars convert hydrogen and helium, the two most abundant elements in the universe (which originated in the high energy-density early universe), into the periodic table. Thermonuclear fusion in stars is the origin of elements up through those near iron ($^{56}_{26}Fe$) on the periodic table, while other nuclear processes in stars account for the remaining elements heavier than iron. All atoms that compose you, planet Earth and all upon it, with the exception of hydrogen (locked mainly within H_2O and hydrocarbons), were forged in 2-3 generations of stars that lived out their lives prior to the formation of our Sun and solar system, 4.57 billion years ago.

In summary, this transmutation of lighter elements into heavier but-fewer-in-number elements and the resulting energy deposited into the star thus slows and changes its evolutionary trajectory: stars generally evolve much more slowly to become larger, rather than smaller in size in the absence of fusion.

Notice that I've said nothing about fusion being the origin of the star's luminosity, nor anything pertaining to fusion supporting the star against the force of gravity. Those are not accidents of omission. Before exploring any further, however, let's first come up with some defining properties of a star.

A Basic Definition of a Star

A star is a large, massive, dense sphere of *hot*, highly-ionized, opaque *gas* (usually composed of mostly hydrogen and helium), held together under the force of gravity between each of its particles and all of the others.

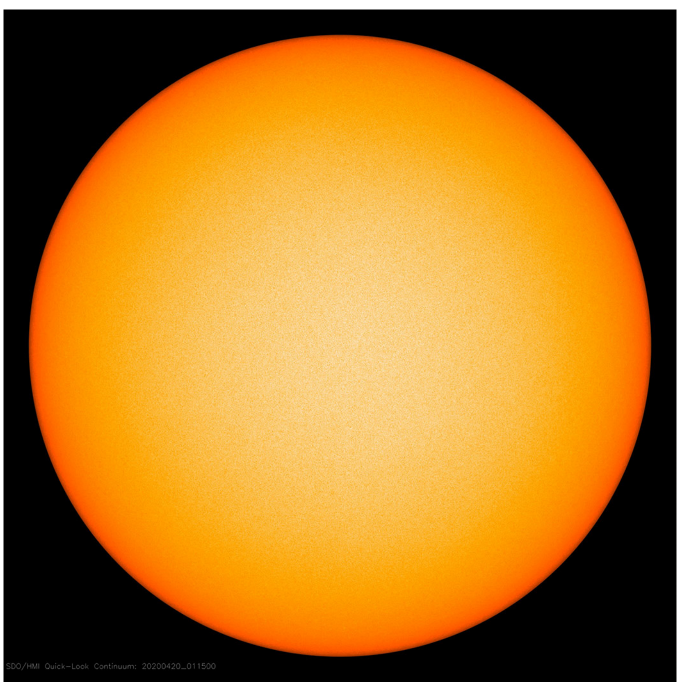
- Unless rapidly rotating, or sharing a tight orbit with a sibling star, stars are spherical (1) because they are very massive and so gravity is a dominant force acting between the particles, and (2) due to the simple radial nature of the force of gravity acting between their constituent matter particles. Left alone, gravity would pull all of the matter into a very small volume otherwise known as a black hole.
- Gas is a state of matter in which the average kinetic energy of the particles is far greater than average interaction energy between the particles (e.g., electrical interactions between charged particles). In "normal" gases the particle average kinetic energy (energy of motion) is directly proportional to the temperature.

- An ionized gas is one that is sufficiently energetic that most of the electrons are free to move independently of, and so are unattached to, the atomic nuclei.
- *The ionized matter within the star emits particles of light*, known as photons, and this matter emits light in a manner determined by its temperature, also known as thermal or blackbody radiation. Higher temperature matter emits more photons of higher energies, and more photons in total per cubic meter of emitting gas.
- Because stars are very dense, they are also highly opaque. The only photons emitted by the ionized gas within the star that can leave the star for the cold vacuum of space are those emitted in gases within a very thin layer defining the star's luminous surface known as its photosphere ("light sphere"). The total luminous energy emitted into space per second at the star's surface is known as the *star's luminosity*, L_*.

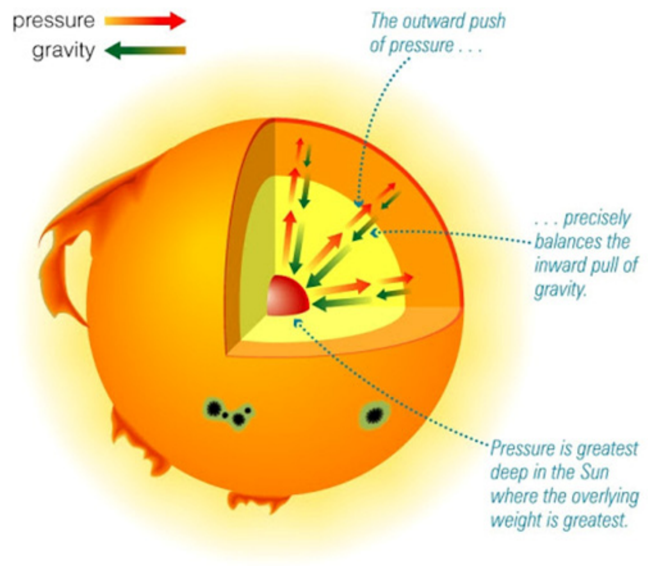
Note that the origin of the light emitted by a star ("why do stars shine?") lies with the emission of light by its hot gases through electromagnetic interactions; *it has nothing to do with fusion*. Next, we'll learn how stars support themselves against the force of gravity, and why it is that they are so hot.

Supporting Stars – It's Gas Pressure!

Other than during very temporary special circumstances, a star is in a state known as "hydrostatic equilibrium." This is a technical-sounding name for a phenomenon otherwise known as force balance – that between gravity and forces generated internally within some structure, e.g., within a building, a bridge, *or a star*. Small disturbances to this force balance result in *very rapid* and most often *tiny adjustments in structure*, mediated by the speed of sound within the structure. However, a sufficiently large disturbance can lead to an instability that can grow to catastrophic failure of force balance, leading either to a *rapid collapse* of the system under its own weight or to an explosion.



The vast majority of the light emitted by a star (above, our Sun) emerges from a thin surface layer known as the photosphere. (The Sun's upper atmosphere, also emits a tiny amount of light, < 0.1% of the total.)



Stars are generally in a state of force balance, often referred to as hydrostatic equilibrium: the inward force of gravity is opposed by a *net outward* push by gas pressure.

In stars, the two opposing agents are *gravity*, which would like to accelerate all of the mass into a tiny point at the center of the distribution, and the *pressure* exerted by the gas within the star. And so this condition is sometimes more colloquially referred to as *pressure-gravity balance*.

> *Details, details*: Within every star, the pressure exerted by the force of gravity (the weight of the overlying layers) diminishes from its center towards its surface, where it is some 12 powers of ten smaller! Within every mass layer at distance r from the center of the star, the pressure exerted by the gas over the surface area of that layer, $4\pi r^2$, must be able to support the weight of the layers above. Or a bit more precisely, the difference in pressure above and below each mass layer multiplied by the surface area of that layer is equal to the weight of that layer. These are the conditions of hydrostatic equilibrium or "pressure -gravity" balance usually found throughout a star.

The pressure exerted by gases can be usually described as follows: $P_{gas} = n \times \frac{2}{3}\langle KE\rangle$, where n is the number of gas particles per cubic meter (the particle number density), and $\langle KE\rangle$ is the average kinetic energy per particle, which is usually directly proportional to the temperature T of the gas. Thus denser, higher temperature gases exert greater pressures. For this reason, the gas within stars is densest and (generally) hottest at their centers – where the pressure imposed by the force of gravity bearing down is greatest. The gas is therefore coolest and least dense at the luminous surfaces of stars.

If somewhere within a star the gas pressure is set well above its pressure-gravity equilibrium value, a *rapid expansion* will ensue, until that mass layer is again in pressure-gravity balance. Likewise if the gas pressure is set to a value well below its equilibrium point, a *rapid collapse* will ensue, until pressure-gravity balance is re-established. If Dr. Evil turned on his ray gun and dramatically reduced the gas pressure within our Sun, the Sun would collapse under the force of gravity to a very small object in about 25 minutes!

The *more massive* a star, the *higher* their average temperatures must be and the *lower* their average densities must be in order to meet the conditions of *pressure-gravity balance* involving a "normal" gas. Stars are composed of *very hot gases* because their high masses, through the force of gravity, demand this to be so in order to be in pressure-gravity balance. Being much less massive than stars, planets (or the bulk of their masses) are not composed of matter in a gaseous state, and are never as hot as stars. Due to their finite temperatures, planets emit light (contrary to some claims) primarily in the infrared, in addition to reflecting light of their parent star. Stars, by contrast, are both hotter and larger in size than planets, and are therefore far more luminous than planets.

To sum up: Stars shine so brightly because they are large, hot balls of matter in pressure-gravity balance emitting thermal radiation!

But what about radiation pressure?

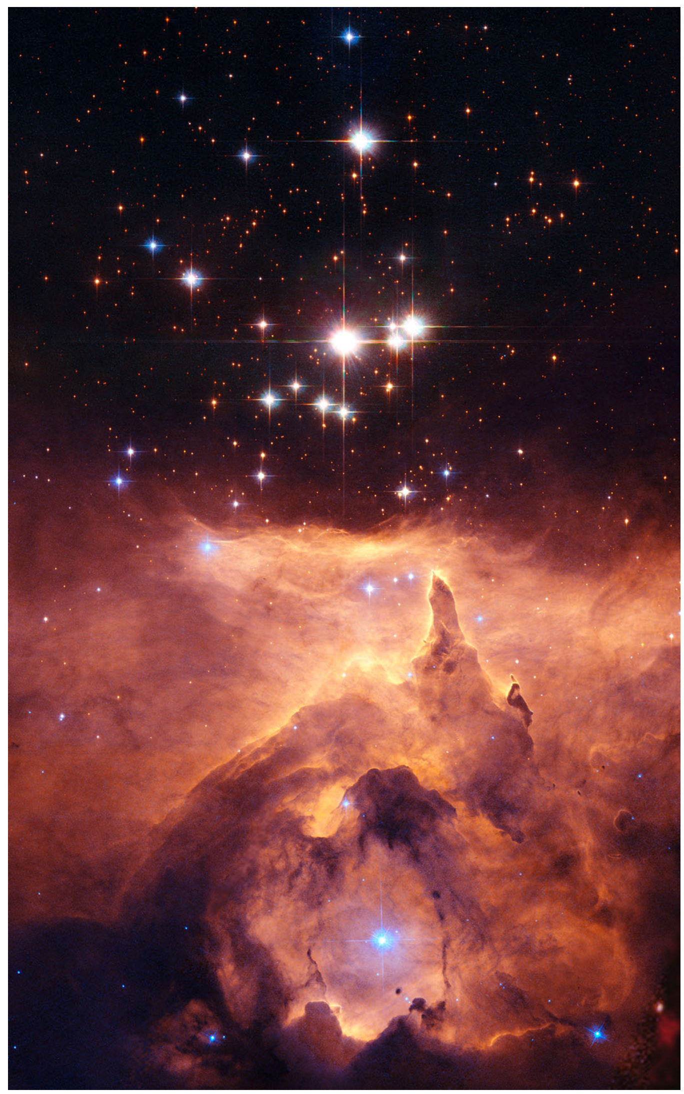
As mentioned previously, the hot gases within a star emit particles of light called photons, and each photon has an energy and momentum associated with it. As such, photons can exert a pressure on the matter with which it interacts via absorption, scattering, and re-emission. This form of pressure is known as "radiation pressure", and depends simply upon the temperature of the gas, $P_{rad} \propto T^4$. In most stars radiation pressure contributes very little to the total pressure exerted within a star, despite unsubstantiated claims to the contrary. In our Sun, it's about 1 part in 1500 (teachers of science: just do the math!). And the photons involved in this pressure are those emitted by the local gases – again, nothing to do with photons emitted in some fusion reactions.

The contribution of radiation pressure to the total pressure does become significant in massive stars – they are hotter and less dense, favoring photons over matter particles in exerting pressure. But only in the most massive stars does P_{rad} begin to compete with P_{gas}, and it is this very fact that helps set an upper limit to the masses of stars (~150 solar masses). As P_{rad} becomes an appreciable fraction of P_{gas} within a particular star, the star becomes ever less tightly bound by the force of gravity. Thus the role of radiation pressure is irrelevant in most stars, and to the extent it is relevant in massive stars, its role is to act toward destabilizing the star – to push it apart!

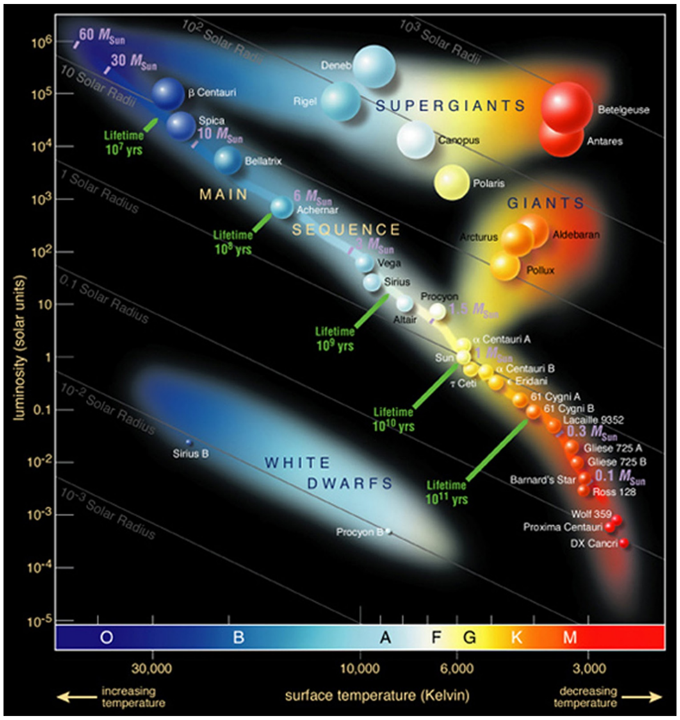
To sum up: In massive stars radiation pressure is better described as a disruptor, not a supporter of stars against the force of gravity, and in all other stars it is largely irrelevant.

How *do* stars become so hot?

The story of star formation begins with an external pressure disturbance of a giant molecular cloud orbiting within a galaxy, consisting of, as the name implies, mainly molecular gases (e.g., H_2, H_2O, CO, CO_2, etc.) plus helium, as well as condensed solids, often called dust grains. These are the densest (~10^{11} molecules per m^3, which is yet a profound laboratory vacuum) and coldest (T = 10 - 30 Kelvin) gas clouds in any galaxy, and as such exert the strongest gravitational field and weakest gas pressure (given its density). A spatially large external pressure disturbance destabilizes a portion of the cloud, and it undergoes rapid gravitational *collapse*. That collapse fragments into a fine



Stars form within giant molecular clouds of dust and gas when dense cores become unstable and collapse under the influence of their own gravity. Pictures above is the emission nebula NGC 6357 in Scorpius with the open cluster Pismis 24, as imaged by the Hubble Space Telescope in 2006.



The Hertzsprung-Russell Diagram of stars plots the star's luminosity vs. its surface temperature. Stars spend 80-90% of their lives on the main sequence (the diagonal band) fusing hydrogen into helium. Giants and Supergiants are stars in old age.

spray of 100s or 1000s of collapsing globules, each of which is eventually to become a star or two. As in any fragmentation process (smash a cookie on a table), a lot more low mass globules arise than high mass ones. As the collapse within a globule proceeds, the density of the gas increases, and potential energy of gravity is converted into various forms of kinetic energy. (This presented story of star formation is a greatly simplified, yet hopefully useful, overview of a complex process, which isn't yet entirely understood.)

As the density becomes high enough for the globule to become opaque to photons emitted by the gas, the gas temperatures rise dramatically – and eventually, a *proto-star stabilizes in pressure-gravity balance*. Initially the proto-star's central temperature is about 150,000 K, its mean temperature about 80,000 K, the surface temperature is approximately 4000 K, and the proto-star of mass M has a radius $R \approx 50\ (M/M_{sun})$ in units of our Sun's present radius. (For comparison, our Sun's central and mean temperatures are 100× higher, its surface temperature 50% higher and its size 50× smaller.) Fusion involving hydrogen isn't possible until the core temperatures rise above ~2 million Kelvin, and generally isn't energetically important until the central temperature rises above several million Kelvin.

So here we have a star, usually referred to as a proto-star, shining with great luminosity – all without fusion taking place within the star. It is for this reason that these objects are also referred to as *pre*-main sequence stars, the Main Sequence being the major portion of a star's life spent fusing hydrogen into helium in the central core. It is the fact that this proto-star is losing energy in the form of light into the cold vacuum of space at a rate set by its luminosity L_* that it *slowly contracts* in a shifting force balance of pressure-gravity. That is, pressure-gravity balance is maintained – the star *does not* collapse – despite the lack of a fusion energy source! Instead, sufficient gas pressure is maintained as approximately half of the potential energy drop goes into continuously raising the kinetic energy (temperature) of the gas particles. Note the curious situation that a star with a net energy leak *becomes hotter*! (This remains true as long as the kinetic energies of the gas particles are related to the temperature.)

Here is another common misconception related to a star's pre-main sequence contraction phase: the proto-star of a particular mass and radius contracts at a rate dictated by its finite L_*, and *not the other way around*. The proto-star's luminosity does *not* physically originate in its rate of contraction. Rather, the proto-star has a luminosity – and thus a net energy leak – the consequence of which is quasi-static gravitational contraction of the star at a rate determined by the rate of the net energy leak from the star (L_*).

The reader may have noticed the use of two distinct words and their adjectives in describing an object becoming smaller/denser under the force of gravity: rapid *collapse* and slow *contraction*. The former is what happens in the absence of *pressure-gravity balance,* with gravity having the upper hand. The latter is what happens in the absence of *energy balance* – there is a net loss of energy to space in the form of the star's luminosity, and little or no energy generated by fusion in the star's core. Collapse, contraction….You say potato, I say potahtoh….right? I mean, what's the difference?

In the case of a star like our Sun, the *contraction* (energy imbalance) time scale is about *25 million years*. Recall that our Sun's time scale to *collapse* (force imbalance) is about *25 minutes*. So despite the nearly universal laziness of astronomy textbook authors, these two phenomena really are different in process and in time scale over which they act. Doesn't a factor of *500 billion* differ sufficiently to merit being careful and consistent in terminology? I think so.

In fact if Dr. Evil used his ray gun to shut off nuclear fusion in our Sun, *very little* would measurably happen to our Sun for ~100,000 years. (Well, the astrophysicists measuring particles known as neutrinos emitted in some of the nuclear fusion reactions in our Sun would become alarmed.) Eventually, our Sun would begin undergoing very gradual, *slow* gravitational contraction.

Fusion is neither responsible for the star's luminosity, nor the ability of the star to be in pressure-gravity balance. **And in the absence of the energy produced by fusion, stars not only *gradually* become smaller, they *become hotter* and their *pressures increase*!** These are in direct contradiction to the mantra of the virus.

Attaining stardom & what determines a star's luminosity?

(It's not fusion.)

Continuing our story, the proto-star continues to slowly contract in a shifting force balance, becoming both denser and hotter along the way, converting potential energy of gravity into the thermal kinetic energy of the particles. As the temperatures in the center of the protostar reaches several million degrees, energy from nuclear reactions associated with the fusion of hydrogen into helium begins entering the star from its central regions. As this energy source ramps up, the *net* rate of energy leakage from the star (energy out minus energy in) diminishes. The proto-star then makes final *slow* adjustments in its structure to accommodate this new, centrally located source of energy – and as it does so, the star's luminosity *decreases*. Yes, you read that correctly. As the energy production rate from the fusion of hydrogen into helium ramps up within the star's core toward matching the star's luminosity, the star's luminosity goes down!

Finally, the rate of energy production via fusion, L_{fusion}, comes into balance with the star's luminous power, L_*, and the star attains the state of *energy balance*. Gravitational contraction stops, and the star is then said to have arrived onto the *Main Sequence* of stars, fusing hydrogen into helium in its central core. Such a star now evolves on the *much slower nuclear time scale*, that which is dictated by the rate at which 4 hydrogen nuclei are fused into 1 helium nucleus. This is about 10^{10} years for stars of our Sun's mass, and is shorter/longer for stars more/less massive than our Sun, roughly in proportion to the star's mass to its luminosity, M_*/L_*.

Clearly, the rate of energy released from fusion, L_{fusion}, does not determine a star's luminous power L_*. So what does? The brilliant astrophysicist, Sir Arthur Stanley Eddington (the same who led the 1919 total solar eclipse expedition that ushered in Einstein's new theory of gravity/space-time) had worked out the first physical structure of stars by **1920** (*On the Internal Constitution of Stars*) – 100 years ago(!). His model predicted many of the important physical characteristics of stars – including their luminosities, L_*. While he suspected that interacting atomic nuclei are somehow involved in converting matter into energy at a rate matching a star's luminosity, the first quantitative determinations of thermonuclear fusion of hydrogen into helium had to wait another 18 years (Hans Bethe and others). In any case his model prediction of a star's luminosity had nothing to do with fusion. Eddington's model, however, initially lacked knowledge of one key ingredient – the star's elemental composition. When Cecelia Payne demonstrated in her 1925 Ph.D. dissertation that stars are composed almost entirely of hydrogen and helium, Eddington's model then correctly predicted the luminosities of the stars as a function of their mass.

Here is Eddington's 100-year old model in a nutshell.

1. Stars are self-gravitating objects in pressure-gravity balance composed of a gas whose particle average kinetic energies are set by the temperature T, which declines from center to surface, emitting thermal radiation.
2. The energy content in the radiation field is transported via interactions with matter (radiative transport), moving downhill in temperature – from hot to cold (just as we're all familiar).
3. The opacity, matter's tendency to interact with photons through scattering or absorption, opposes and *slows* this flow of energy through the star.
4. The star's luminosity is then proportional to the total energy of photons within the star in ratio to the time over which this energy slowly leaks out:

$$L_* \propto \frac{< avg.\,mass.per.particle >^4 \;\; M_*^3}{< opacity >}$$

The star's mass M_* contains the thermal energy that emits the thermal radiation. The average mass per particle sets the temperature scale. A greater value means fewer particles for given mass density, requiring higher T to provide the required gas pressure. All else being equal, a star composed mainly of helium, with a consequent larger average mass per particle, is more luminous than one composed of mostly hydrogen or a standard hydrogen/helium mix. The gas opacity opposes and slows the flow of radiation through the star (just as a thermal insulator slows the rate of energy transfer by conduction), and generally diminishes with increasing temperature. Thus more massive stars, possessing higher average temperatures, *more quickly leak out their larger stores of radiative/luminous energy*.

→ The more massive the star, the greater its luminosity!

> *Details, details:* Eddington's model includes a correction factor, not shown in the above luminosity relation, for the contribution of radiation to the pressure exerted within a star. As radiation's contribution to the total pressure becomes

British astrophysicist Sir Arthur Eddington published *On the Internal Constitution of Stars* 100 years ago.

significant, the gas temperature required by pressure-gravity balance is lowered. In brief, lower temperature gas emits fewer photons per cubic meter, and thus another role of radiation pressure is to reduce a very massive star's luminosity. This becomes an important and growing correction in stars with masses exceeding roughly 30 solar masses.

Finally, stars within which either convection or conduction, rather than radiation, dominates the flow of energy downhill in temperature, or whose particle kinetic energies are set by density rather than temperature, will have a different set of rules governing the determination of their luminosities. Eddington was generally unaware of such stars in 1920. And of course, I paint here a simplified, yet scientifically useful picture of stars.

Summing up: L_* vs. L_{fusion}

To the extent that there is a direct causal relationship between L_* and L_{fusion}, it is that L_{fusion} is what it is because the star has a luminosity L_* – and *not the other way around*, as is so often wrongly presumed or misleadingly implied in textbook/webpage discussions. In other words, **it is the star's luminosity L_* that sets the power generated by fusion L_{fusion}**. More massive stars' higher average temperatures demanded by *pressure-gravity balance* allow them to attain *energy balance* at their greater luminosities L_*, because the fusion reactions run more quickly at higher temperatures, and thus L_{fusion} is correspondingly greater.

Most introductory educational resources have misinterpreted the condition of energy balance, which they nearly always describe as $L_* = L_{fusion}$, as a statement that a star owes its luminosity to and/or is set by the energy generated per second by fusion. I prefer, instead, to write the condition of energy balance as $L_{fusion} = L_*$, which more naturally and correctly directs one's thinking that L_{fusion} is set by L_*, *if and only if* the equality holds. More generally, **L_* and L_{fusion} are two distinct physical processes** in stars, whose energy rates can be the same (they are in main sequence stars), but can also be wildly (many powers of 10) different from one another during various stages in a star's life.

Unfortunately, nearly all of the more advanced discourses of stars discuss in some detail what's going on with nuclear fusion and the energy per second it generates, and then – without informing the reader – use that as a proxy for telling the reader what L_* is doing(!). This presumes, of course, that energy balance ($L_{fusion} = L_*$) holds, which is *not* always the case over a star's life. Obviously, this approach can leave readers with confused ideas of what's going on. Very few advanced sources discuss **what's going on in the star's structure, state of the gas, or energy transport mechanism(s) to inform the reader of what's going on with the star's luminosity**. And even the sources that do will fall back into the trap of discussing what's happening to nuclear fusion (sigh) to inform the reader that the star's luminosity is changing.

Why all the fuss?

For 100s of thousands of years, human beings have looked to the skies with their sharp eyes and large brains and wondered about those points of light (and our Sun!) – what are they and how do I fit in with all of this? In the 20th century, the human scientific endeavor allowed us to tell a beautiful story that finally answers these profound questions. Science seeks to illuminate, clarify, and unify the workings of the universe. This is one of science's great gifts to humanity – our human cosmic perspective. We owe it to our students *and to humanity* to tell the right story. Science and astronomy educators unite!

Dr. Kirk Korista has been a KAS member since 1998 and is a WMU Professor of Astronomy. He says this issue has been nagging at him for several years, now, and the coronavirus internment has allowed him to scratch that itch.

KAS Member Astrophoto Highlight

Dave Garten shares this image of the Jellyfish Nebula (IC 443) in Gemini. It's a nearly 6-hour total exposure through H-alpha, OIII, and SII narrowband filters. Dave processed this image with PixInsight and using the "Hubble Palette" scheme. Equipment used includes a Takahashi FSQ-106 and ZWO ASI1600MM camera on a Losmandy G-11 German equatorial mount. It was taken over the course of 5 nights in late-February and early-March from his backyard observatory in Portage.

The Jellyfish Nebula is the remnant of a supernova lying 5,000 light years from Earth. The latest research points to an estimate for the age of the supernova remnant to be tens of thousands of years. This agrees with previous work that pegged IC 443's age to be about 30,000 years. However, other scientists have inferred much younger ages of about 3,000 years for this supernova remnant, so its true age remains in question.

View more KAS member astrophotography in our recently update gallery:

http://www.kasonline.org/gallery/astrophotos/

HUBBLE SPACE TELESCOPE 30 ANNIVERSARY IMAGE

This image is one of the most photogenic examples of the many turbulent stellar nurseries the NASA/ESA Hubble Space Telescope has observed during its 30-year lifetime. The portrait features the giant nebula NGC 2014 and its neighbor NGC 2020 which together form part of a vast star-forming region in the Large Magellanic Cloud, a satellite galaxy of the Milky Way, approximately 163,000 light-years away.

Learn more about this image and download high resolution versions at:

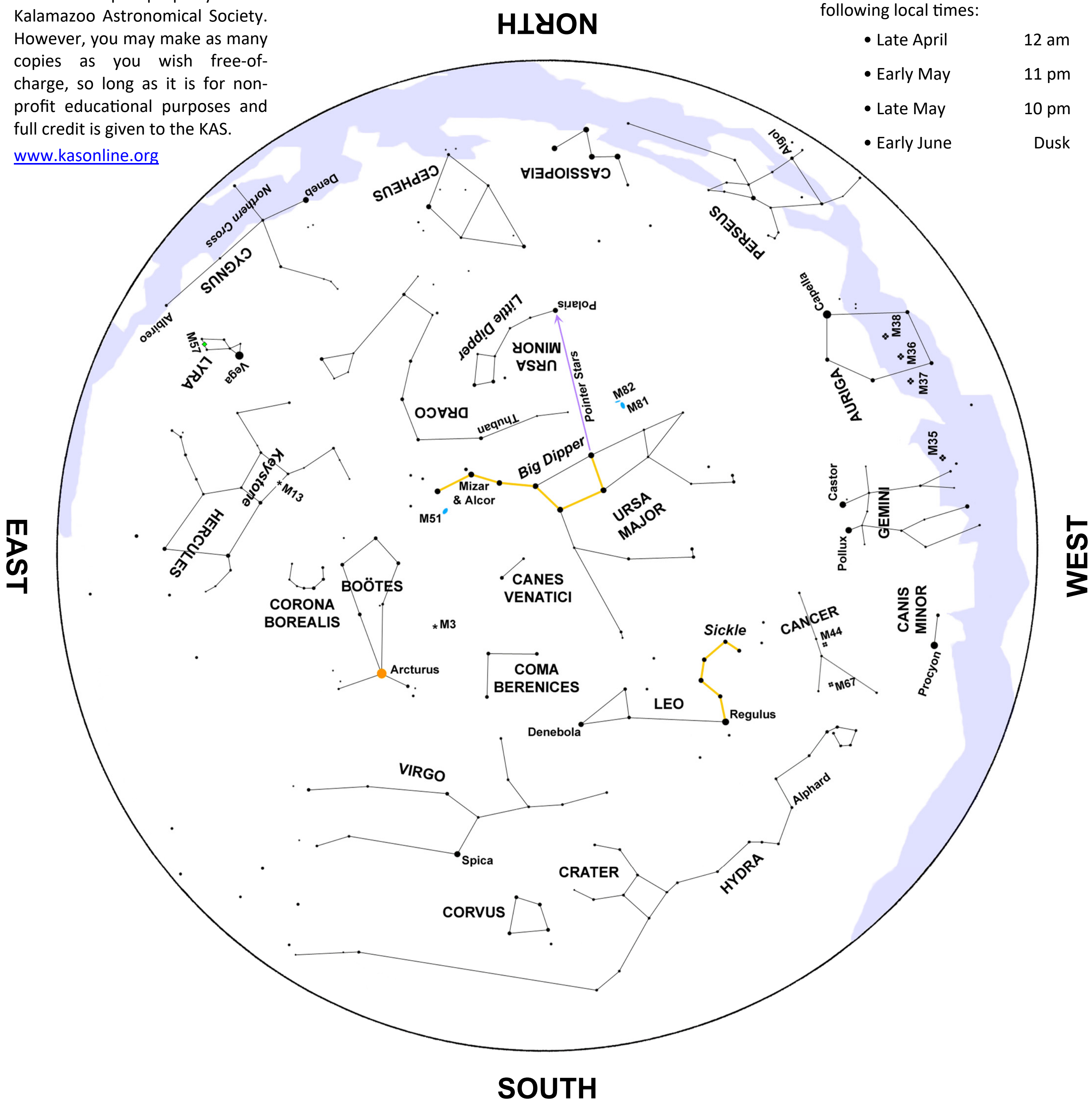
https://www.spacetelescope.org/news/heic2007/

STScI

— May Night Sky —

This map represents the sky at the following local times:

- Late April 12 am
- Early May 11 pm
- Late May 10 pm
- Early June Dusk



Earth crosses paths with debris from Halley's Comet on the morning of May 5th, bringing us the Eta Aquariids meteor shower. Moonlight will interfere and the shower is best from southern skies anyway.

A waning gibbous Moon, Jupiter, and Saturn form a right-angle triangle during the hours before dawn on May 12th. Jupiter will be 3° north of the Moon, with Saturn about 6° to the Moon's southeast. The Moon, now a wide waning crescent, will be found 4° to the lower left of Mars before dawn on May 15th.

Inferior planets Mercury and Venus move to within 1° of each other after sunset on May 21st. The brilliant evening star, Venus, will be a cinch to spot low above the west-northwest horizon. Mercury will be to Venus' lower left.

A very thin waxing crescent Moon, only one day past new, Mercury, and Venus form a slightly curved line nearly 12° long shortly after sunset on May 24th.

KAS BOARD

PRESIDENT

Richard S. Bell

VICE PRESIDENT

Jack Price

TREASURER

Don Stilwell

SECRETARY/ALCOR

Roger Williams

PUBLICITY MANAGER

Joe Comiskey

MEMBERS-AT-LARGE

Dave Garten

Scott Macfarlane

Aaron Roman

E-MAIL a BOARD MEMBER

PST Available for Checkout!

The Kalamazoo Astronomical Society's Coronado Personal Solar Telescope (PST), mounted on the light and ultra-portable Tele Vue Tele-Pod, is available for loan.

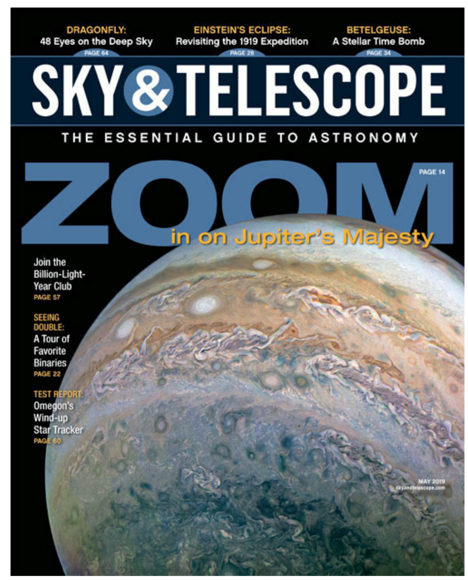
If you'd like to observe the Sun in hydrogen alpha and see prominences dance along the solar-limb and filaments crisscross its surface then contact the KAS Equipment Manager, **Arya Jayatilaka**, today:

http://www.kasonline.org/loanscopes.html

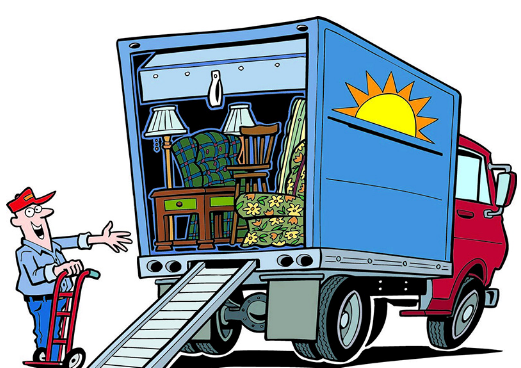
S & T Subscription Discount

One of the many benefits of KAS membership is a **$10 discount** on a one year subscription to the premiere astronomical magazine, *Sky & Telescope*. A regular one year subscription costs $42.95; you pay only **$32.95**. It's like receiving two free issues!

To take advantage, bring a check (made payable to Sky Publishing) to the next general meeting or contact KAS Treasurer **Don Stilwell** for more information. First-time subscribers must pay through the KAS to receive the discount.



Moving? New E-mail?



Have you recently moved and/or changed your e-mail address? If so please let us know ASAP.

If you are moving out of town before your membership expires please contact us anyway. You paid for a years worth (or more) of newsletters and that's what you'll get!

General Meeting Preview

Observing Mars

Then & Now

presented by Richard Bell

Mars has been a tantalizing telescope target for centuries. Its fiery-red planetary surface is the only such one that can be easily viewed from Earth. Thanks to its smaller size and great distance, it’s usually difficult to observe. However, the Red Planet comes relatively close to us every 26 months. The next time this occurs is this October. KAS President Richard Bell will explore the colorful history of observing this neighboring world. He will also provide advice and guidance on topics such as proper equipment, observing techniques, and the top Martian features to see for yourself this Fall.

Friday, May 1 @ 7:00 pm

Online Using the Zoom App

Kalamazoo Astronomical Society
c/o KAMSC
600 West Vine, Suite 400
Kalamazoo, MI 49008

STAMP