Temecula Valley Astronomer

The monthly newsletter of the Temecula Valley Astronomers Feb 2021

Events:

Virtual meeting via Zoom on 1 February at 7PM. Join your fellow astronomers for a Gallery assembled by Clark Williams followed by a talk "The History of Mount Wilson" by Tim Thompson, Senior Docent at that observatory. Watch your club email for meeting ID and password.

Until we can resume our monthly meetings, you can also interact with your astronomy associates on Facebook or by posting a message to our mailing list.

Mars 2020 and Perseverance - coming to a planet near you - February 18th 2021

WHAT'S INSIDE THIS MONTH:

Send newsletter submissions to Mark DiVecchio <markd@silogic.com> by the 20th of the month for the next month's issue.

Like us on Facebook

General information:
Subscription to the TVA is included in the annual $25 membership (regular members) donation ($9 student; $35 family).

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Cosmic Comments
by President Mark Baker

“The Stars Are Calling, So We Must Go”!!!

Of course, for now this is meant vicariously by Looking Up in awe and wonder… and pondering as well!!!

I am so glad we have at least the South Coast Winery Star Parties to provide that vicarious opportunity for many others, but I REALLY miss the school events… where we got to point a child’s eyes skyward and instill a desire for answers, often to questions not even asked yet!!!

I’m thankful, therefore, that a few of us take part in virtual events in our communities, and even worldwide… it may not be the same as “being there”, but it’s something at least!! And we often touch an adult mind in such a way that they too are inspired to get involved, often going so far as to obtain the necessary equipment to enhance that experience…

So, TVA Abides… maybe not in the sense we were used to, or even prefer, but we continue to play a key role in our communities. And for that, I thank you all…

Clear, Dark Skies my Friends…

Editor’s Note
by Mark DiVecchio

After many years of assembling the Temecula Valley Astronomer, it is time for me to step away. I have told President Baker that the April 2021 newsletter will be my last.

This is your chance to step in and make the newsletter better than it was. But more importantly, to give back to the TVA and to make its future bright.

Mark DiVecchio

Editor’s Note 2
by Mark DiVecchio

Long time contributor to the TVA, Clark Williams will be doing his last “Looking Up Redux” column in the April TVA. Here is another chance for you to give back to the group and become a magnitude zero star.

Looking Up Redux
compiled by Clark Williams

from these sources:
SeaSky.org
Wikipedia.com
in-the-sky.org
The American Meteor Society, Ltd.
cometwatch.co.uk
NASA.gov
TVA App (2.0.1296)
FullAndNewMoon App (2.0)
Starry Night Pro Plus 7 (7.6.3.1373)
SkySafari 6 Pro (6.1.1)
Stellarium (0.18.2)
timeanddate.com/astronomy
https://www.fourmilab.ch/earthview/pacalc.html

ALL TIMES ARE LOCAL PACIFIC TIME UNLESS NOTED OTHERWISE

Times are given in 24-hour time as: (hh is hours, mm minutes, ss seconds)
- hh:mm:ss or hhmmss
- hhmm+ (time of the next day)
- hhmm− (time of the previous day)
- hhmm (seconds not shown)
- yyyymmddThhmmss (Full date as: year month day Time separator hours minutes seconds)

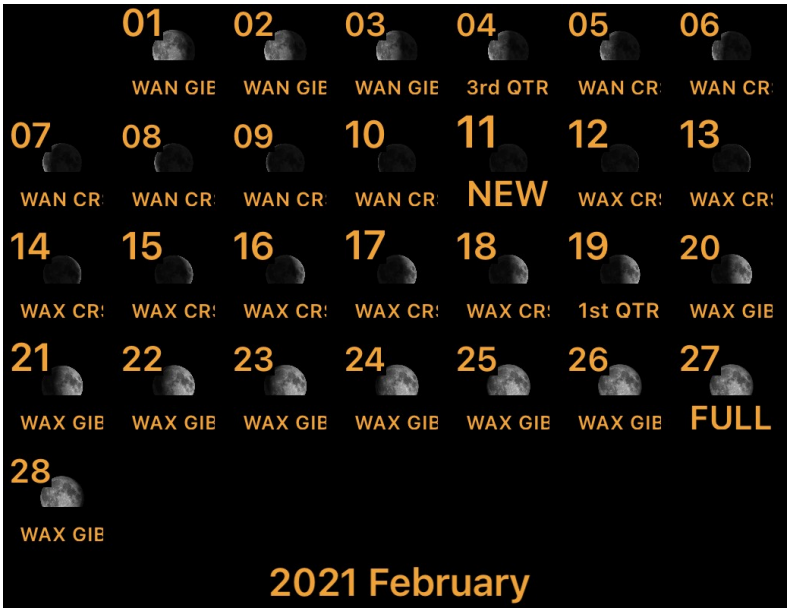
Moon Phases for the month by phase:

Friday	**the 19th**	**@ 1048 FIRST QTR in TAURUS**
Saturday	**the 27th**	**@ 0018 FULL in LEO**
Thursday	**the 4th**	**@ 0938 THIRD QTR in LIBRA**
Saturday	**the 11th**	**@ 1106 NEW in CAPRICORNUS**

Apogee comes on 2021-02-18 @ **0223 – 404,465 km (251,323 mi)**
Perigee comes on 2021-02-03 @ **1131 – 370,126 km (229,986 mi)**

2021 has: (12) new moons, (12) 1st Qtr moons (12) Full moons, (13) 3rd Qtr moons (0) Blue moon and (0) Black moons

Daylight Savings:
Starts: 2021-Mar-14 : Ends: 2021-Nov-07



Luna: Luna is Waning gibbous on the 1st of the month. Luna rises at **2038**, transits at **0306+** and sets by **0930+**. Luna by mid-month is a Waxing Crescent, 12% illuminated. Rising at **0829** and setting in the evening at **2035**. By the-end-of-the-month Luna is Waning Gibbous, 98% illuminated rising at **1822**, transiting at **0058+** setting by **0728+**.

Highlights: (distilled from**: SeaSky.org** and **Clark's planetary Orrey** program[s]**)**

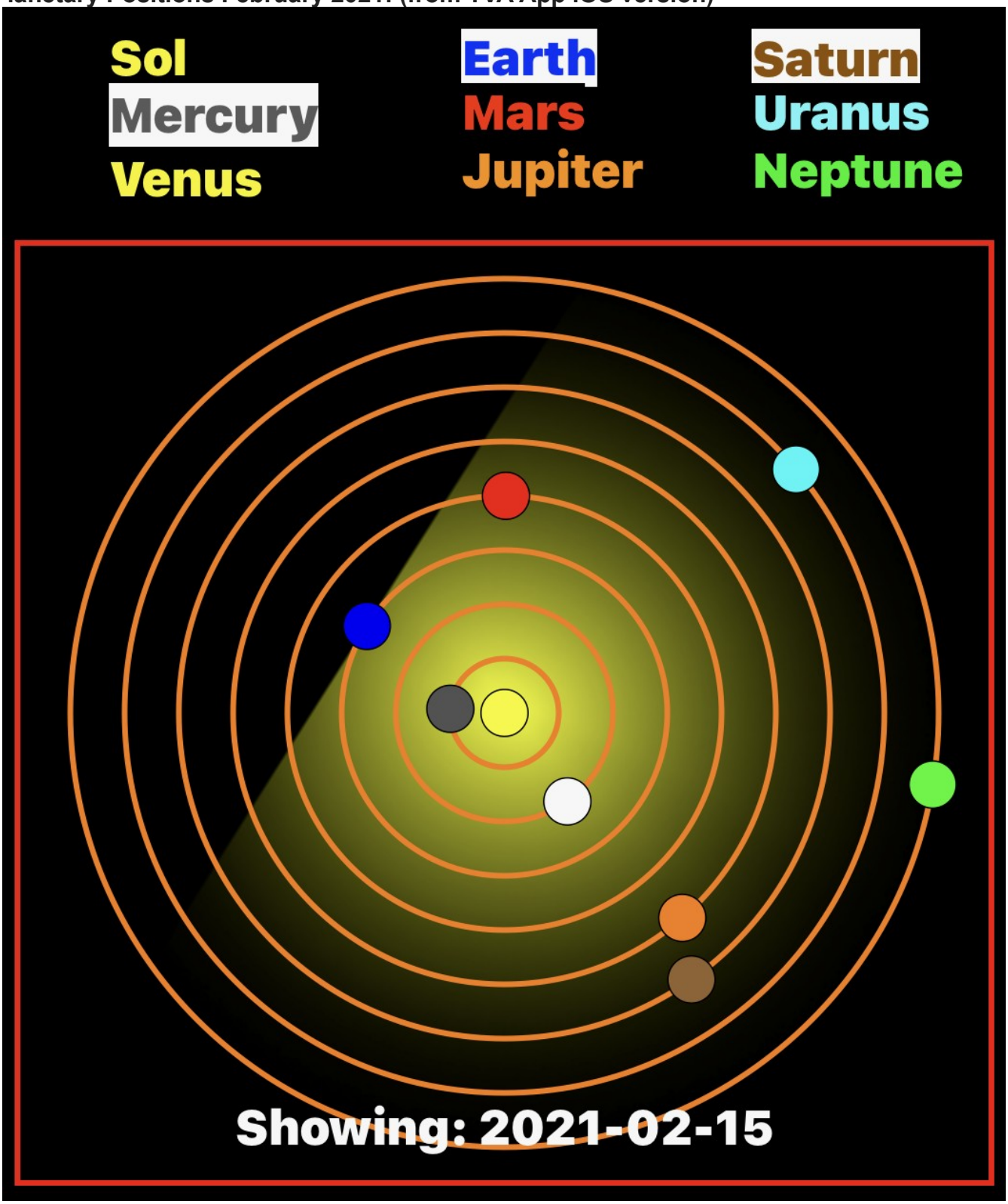
February 11 - New Moon. The Moon will located on the same side of the Earth as the Sun and will not be visible in the night sky. This phase occurs at 19:08 UTC. This is the best time of the month to observe faint objects such as galaxies and star clusters because there is no moonlight to interfere.

February 27 - Full Moon. The Moon will be located on the opposite side of the Earth as the Sun and its face will be will be fully illuminated. This phase occurs at 08:19 UTC. This full moon was known by early Native American tribes as the Snow Moon because the heaviest snows usually fell during this time of the year. Since hunting is difficult, this moon has also been known by some tribes as the Hunger Moon, since the harsh weather made hunting difficult.

Algol minima: (All times Pacific Time)

02/01/2021	**0407**
02/04/2021	**0057**
02/06/2021	**2146**
02/09/2021	**1835**
02/12/2021	**1525**
02/15/2021	**1214**
02/18/2021	**0903**
02/21/2021	**0553**
02/24/2021	**0242**
02/26/2021	**2331**

Planets:
Planetary Positions February 2021: (from TVA App iOS version)



- **Mercury:** Mercury is an evening object in the beginning of the month. Hiding behind the Sun by the 7th-9th of the month and becoming a morning object by the 10th. You're pretty much in luck if Mercury is your thing.Especially in the latter art of the month. Mercury mid month will be rising at **0536** followed by sunrise at **0631**.
- **Venus:** Is the Morning Star in the beginning of the month, rising at **0604** preceding sunrise at **0643**. Venus is approaching the Sun during February. By mid-month Venus rises at **0608** followed by Sol at **0631**. By the 28th Venus is rising at **0605**. followed by sunrise at **0616.**
- **Mars:** Mars is rising during the late morning on the 1st of the month, but should be visible by about **1750**. Mars will set at **0031+**. There will be a waning gibbous moon rising by **2144**. By mid-month Mars is rising during the morning hours, transiting at **1715** and setting at **0014+**. End-of-month finds the Warrior rising at **0951**, transiting at **1655 and** setting by **2359**.
- **Jupiter:** On the first of the month is lost to the glare of the sun. This will hold true though the 21st. Come the end of month Jupiter is rising at **0512** but only 11° above the horizon. Don't look for much of an improvement until June.
- **Saturn:** Saturn is leading Jupiter and the two are close to the sun. By the 11th you may be able to spot Saturn is low on the horizon (only 7°) and within 20° of the sun by mid-month. Not good for viewing. By end-of-month Saturn rises at **0445** followed by the Sun at 0616. So you may be able to catch a glimpse of Saturn. Otherwise wait until June.
- **Uranus:** If Jove and Saturn are gone from the night sky this month Uranus is a perfect jewel. On the first Uranus transits at **1717**, and sets by **2357**. The apparent magnitude is 5.78 so we're on the ragged edge of being naked-eye visible. The Astronomer's Bane will be to the east but doesn't rise until **2144**. By the ides Uranus is visible around **1918** and setting by **2304**. End of the month and the “sky god” is visible about **1845**, and setting by **2215** while a Waning gibbous 95% illuminated Moon glares away but doesn't rise until **1931** giving you some time to spend marveling at Uranus.
- **Neptune:** Neptune is leading Uranus. Neptune is rising midmorning in the beginning of the month, transiting at **1422**, setting by **2011**. The Moon doesn't rise until **2144**. By the 15th Neptune should be visible by about **1800** and setting at **1918**. By the end of the month Neptune is low on the horizon and getting too near the sun to pick out of the solar glare.
- **Pluto:** Is lost to the Sun in the beginning of the month. By the 27th and 28th you may be able to see Jupiter, Mercury, Saturn and Pluto making a nice line on the ecliptic. Sunrise will come quickly though at **0617** so you need to be prepared. Also to see Pluto you will need a scope as it is at mag 14.42.

Asteroids:

- Still a dearth of asteroids. I searched for asteroids in 2021 with a reasonable magnitude; say less than or equal to +10 in February there are a few beyond the regulars: Juno, Vesta. Hebe, Eros and Herculina. So consult your local planetarium software for more or try: https://www.asteroidsnear.com/year?year=2021

(4) Vesta Asteroid in Leo 1st -- 28th rising: mag 6.9 – (4 Vesta) is the brightest asteroid visible in the night sky, and the third-largest asteroid in the main belt.
(16) Phyche Asteroid in Taurus 1st – 28th rising: mag 10.8 – Psyche is one of the ten most massive asteroids in the main belt, and is the most massive M-type asteroid.
(14) Irene Asteroid in Cancer 1st – 28th rising: mag 9.4 – a large main-belt asteroid.

Meteors:

- See Highlights above for more details. (SeaSky.org**)** (American Meteor Society)

Comets: come in various classifications:
  - 1) Short Period comets – further broken down into:
    - Halley Type: The Halley Types are believe to come from the Kuiper Belt and have periods in excess of 20-years.
    - Jupiter Type: The Jupiter types have a period less than or equal to 20-years.
    - Short period comets have a near circular orbit or an elliptical orbit. The latter being far more common.
  - 2) Long Period comets – thought to originate from the Oort cloud these comets have periods of over 200 years and have random inclinations around the celestial sphere.

Deep Sky:

Notes:

L/Z abbreviation for ALT/AZ
R/D abbreviation for Right Ascension/Declination
α is right ascension
δ is declination
In each case, unless otherwise noted, you should look for the following on or about the 15th Day of February 2021 at 2100 PDT and you will have about 20 minutes of viewing time total.

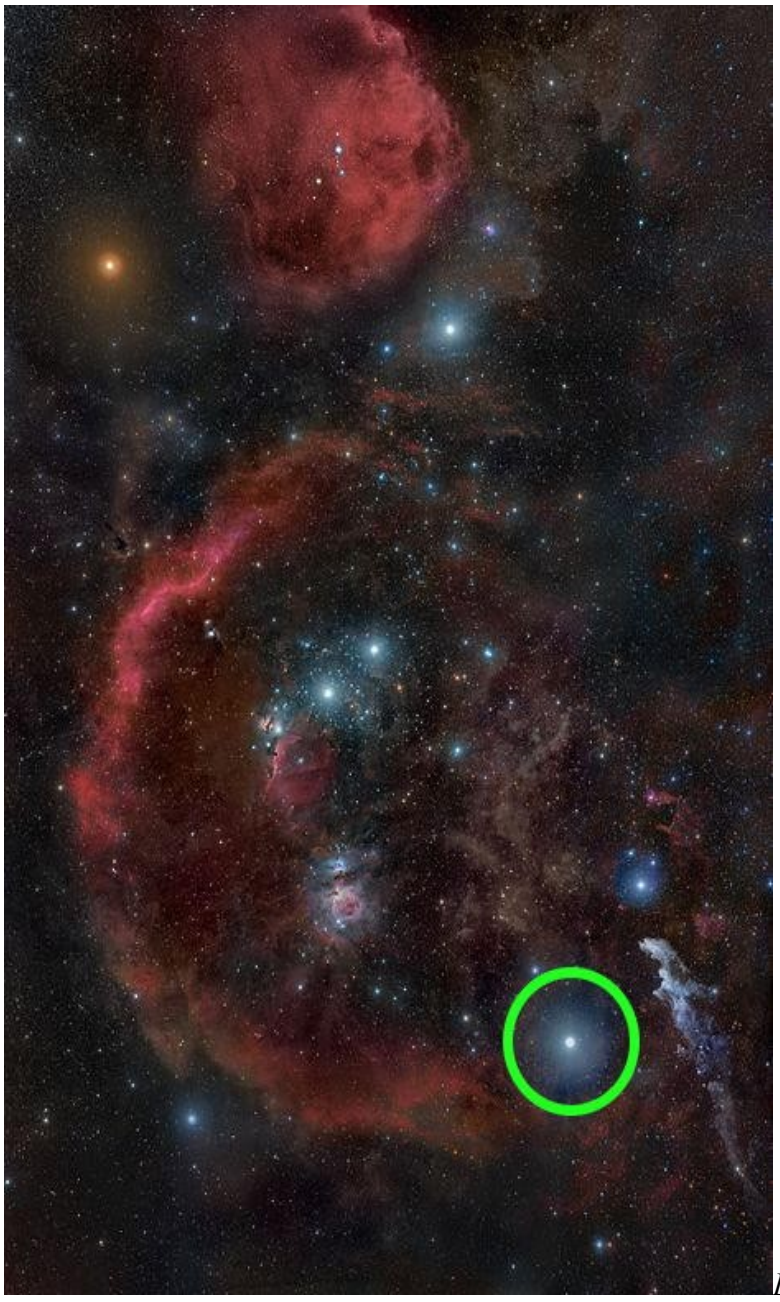
- Regulus

By Drew Farwell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=25051355

Regulus UK: /ˈrɛgjʊlʊs/ US: /ˈrɛgjʊlʊs/, designated α Leonis (Latinized to Alpha Leonis, abbreviated Alpha Leo, α Leo), is the brightest object in the constellation Leo and one of the brightest stars in the night sky, lying approximately 79 light years from the Sun. Regulus appears singular, but is actually a quadruple star system composed of four stars that are organized into two pairs. The spectroscopic binary Regulus A consists of a blue-white main-sequence star and its companion, which has not yet been directly observed, but is probably a white dwarf. HD 87884 is separated from Regulus by 176″ and is itself a close pair.

Regulus, along with 5 slightly dimmer stars Zeta Leonis, Mu Leonis, Gamma Leonis, Epsilon Leonis and Eta Leonis have collectively been called 'the Sickle', which is an asterism that marks the head of Leo. (Wikipedia)

- **Rigel**



By Rogelio Bernal Andreo - http://deepskycolors.com/astro/JPEG/RBA_Orion_HeadToToes.jpg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20793252

Rigel, designated β Orionis (Latinized to Beta Orionis, abbreviated Beta Ori, β Ori), is a blue supergiant star in the constellation of Orion, approximately 860 light-years (260 pc) from Earth. Rigel is the brightest and most massive component – and the eponym – of a star system of at least four stars that appear as a single blue-white point of light to the naked eye. A star of spectral type B8Ia, Rigel is calculated to be anywhere from 61,500 to 363,000 times as luminous as the Sun, and 18 to 24 times as massive, depending on the method and assumptions used. Its radius is more than seventy times that of the Sun, and its surface temperature is 12,100 K. Due to its stellar wind, Rigel's mass-loss is estimated to be ten million times that of the Sun. With an estimated age of seven to nine million years, Rigel has exhausted its core hydrogen fuel, expanded, and cooled to become a supergiant. It is expected to end its life as a type II supernova, leaving a neutron star or a black hole as a final remnant, depending on the initial mass of the star. (Wikipedia)

February is great for both viewing and imaging. Spend some time outside with your scope. Winter objects are here.

For now – Keep looking up.

Random Thoughts – Brother Astronomer

by Chuck Dyson

I saw above a sea of hills,
A solitary planet shine,
And there was no one, near or far,
To keep the world from being mine.

Sara Teasdale

As December and January seemed to be the months of multiple planetary viewing events I decided to lead off with a poem by a person whose writings I am quite the admirer of. Although I usually happily go to club outings and help introduce members of the public to the wonders of the night sky; occasionally I like to go on a solitary telescopic voyage of discovery, accompanied only by a thermos of hot coffee, to a planet of my choosing.

Brother Astronomer

First I must admit and acknowledge that “Brother Astronomer” is not my original work but is a pilfered book title from Brother Guy Consolmagno’s book whose full title is *Brother Astronomer, Adventures of a Vatican Scientist*.

Brother Consolmagno is the latest in a long line of Papal appointed astronomers who both do astronomical research, advise the Holy See on scientific matters, and communicate to the public the Churches position on astronomical scientific matters. Brother Consolmagno is a prolific writer of popular science outreach books and one book for new astronomers titled “*Turn Left at Orion*”. The book is in it’s fifth printing and is a great introduction to astronomy for people with a small telescope (I know this because I have owned three copies of the book and I keep lending them out to people just getting started and never seem to get them back, definition of a slow learner). But, as I said, Brother Consolmagno is the latest and not the first or the earliest; so, lets take a look at some of the principal people that have interacted with the church over the centuries.

The first and probably the major source of the feelings that the Church is antagonistic towards science is Giordano Bruno who was ordained as a priest but harbored serious doubts as to whether Christ was truly the son of God and immortal. He questioned the status of Mary, and generally trashed Church authority, and oh yes, he loved Copernicus and his theories as facts not as convenient mathematical solutions to orbital problems.

Bruno also harbored and continuously voiced concerns that virtually everyone in the Church was an idiot - on their good days which he opined were few and far between. The self-professed goal of the Inquisition was to “admonish and persuade” other words to get people to recant heretical views and to accept and hold the standard views of the Church. The “trial” of Bruno lasted from 1592 to 1600. There was no way Bruno was going to ever change any of his views or opinions; so, in 1600 Cardinal Robert Bellamine ordered his execution.

Today one could, with some assurance, say that Bruno had oppositional defiant disorder (ODD) as he argued constantly and with vigor both disputed and belittled everyone who held opinions different from his own; however, by his execution the Inquisition did fail completely in their stated goal.

Our next encounter between the Church and science is a case of science helping the Church keep people from eternal damnation. In the 1600's it was well known that if one failed to attend mass and celebrate the Easter holiday on the proper day, well, it was eternal damnation for you.

The problem was Easter was the first Sunday after the first full moon after the spring equinox; I ask you who had a calendar that accurate? One answer to this problem was to establish a meridian line in a large dark room. Enter Gian Domenico Cassini, he was tasked with establishing a meridian line in the Basilica di San Petronio. A meridian line is a line that runs exactly north and south so that at noon the light of the sun from a pinhole source will always shine on the line at exactly local noon and because the sun moves up and down in the sky over the course of a year it will be on the line at a different place every day of the year.

Once you identify the place on the meridian line where the sun shines on the day of the spring equinox just mark it and you have just solved your Easter problem. Cassini's problems were to identify a true north south line, where on the basilica's south wall could he create a hole for his beam of sunlight that would not be obstructed by one or more of the pillars in the basilica for the proposed length of his meridian line, and as the floor was not perfectly level how to level the meridian line in the floor. When the problems were solved what the Church got was a meridian line almost 220 feet in length that was the most accurate solar calendar on the planet, period. What Cassini got was a solar disk almost a foot in diameter (pinhole camera), it needed to be that large to be visible over the entire length of the meridian line, and because the disk was so large Cassini was able to measure its diameter over the period of a year.

Over the period of a year the disk got larger and smaller; Cassini has just provided the world with experimental proof of Kepler's first law of planetary motion, yes Virginia the planets do travel around the sun in ellipsis. If you are any type of amateur or professional astronomer and you are in Bologna Italy you must go to the Basilica di San Petronio and see this marvelous meridian line.

Our next person of interest, as we say today, is Laurent Cassegrain (1629–1693) . Father Cassegrain was a teacher at a high school in France who published a letter in 1672 on megaphones and coincidentally a design for reflecting telescopes. The only other thing that we have on Father Cassegrain is a letter by Christiaan Huygens in the same year, 1672 is also the year that Newton presented his design for a reflecting telescope to the Royal Academy of Science, recommending the Newtonian design and trashing the Cassegrain design. In 1997 two astronomers researching old manuscripts of this time were able to reasonably conclude the first name of Father Cassegrain was Laurent. Other than this we know nothing at all about the man who designed one of the worlds most popular reflecting telescopes.

Angelo Secchi is not a well known astronomer in America and yet he really should be. Father Secchi was a force to be reckoned with in both science and politics. Secchi started working at

the end of the observational era and became an early adopter of the spectroscope and observing the different spectroscopic signatures of stars. Secchi most notable observational work was to describe what he thought were channels on Mars when the paper was translated into English from Italian the Italian word for channels which was canali was translated as canals and old you-know-who goes completely nuts with his telescope in Flagstaff Arizona.

Secchi's work with spectrographs is groundbreaking and he starts it in 1848 by photographically recording the spectra of different stars this marks the end of astronomers asking what are the stars exact locations for better maps, although we still make star maps, to the questions what are stars made out of and how do they work. After looking at hundreds of stellar spectra Secchi begins to see patterns and starts assigning stars to groups based on spectral similarities. Secchi groups stars into five different groups and this becomes known as the Secchi stellar classification system and it makes its way to Harvard and naturally they modify it and it becomes the Harvard-Secchi system.

But wait, this is the era of Charles Pickering using women as computers and one of the gals working on the stellar classification project is Annie Jump Cannon; she thinks that both the Secchi and the Harvard systems stink and comes up with her own system of seven stellar groups that is the O.B.A.F.G.K.M. and this is the classification system that we use today; GO Annie.

Secchi was at least as interested in the sun as George Ellery Hale and was the first to observe spicules he studied and recorded sunspot movement, organized solar eclipse expeditions, was able to prove the corona was part of the sun and not an atmospheric artifact associated with the eclipse, and is generally considered to be the inventor of the heliospectrograph, the instrument that a young Hale was to fall in love with and modify several times. Father Secchi's final act with the sun was to quietly and respectfully inform the Church authorities after 250 years had passed that Giordano Bruno had been correct, and our sun was a star and all those points of light in the night sky were stars just like our sun. Oops! Our bad! Sorry Bruno!

I mentioned that Secchi was a fair hand at managing political situations and this was no small feat in Italy in the 1870's as the place was changing from an assembly of city states and papal states to a unified country, there were uprisings all around. Eventually a national government took shape and gained control of all of the traditional Italian lands and that is when government officials showed up at the Vatican observatory. The observatory had been moved, by Secchi, off of the Vatican grounds on to what is now known as the Roman College and the government officials informed Secchi that the college and observatory were now under government control. Secchi was informed that if he didn't renounce the Pope and swear allegiance to the new national government he would have to go.

Secchi immediately started packing his bags as he already had several offers from other prestigious programs, the government realizing that they were bluffing and Secchi was not immediately backed down and Secchi was to remain director of the observatory and loyal to the Pope until his death. After Secchi's death the government did take over and the official Vatican observatory was moved back on to the Vatican grounds.

In the 1880's the Vatican observatory agreed to become part of the Carte du Ciel program that was to map the northern sky using photographic plates to create a photographic reference catalogue to be used as a standard reference for astronomical research. This project was a massive undertaking considering the goals and the equipment of the time. Twenty observatories each agree to photograph an assigned area of the sky in both short and long exposure times and in red and blue color and to move the long exposure plate three times in a triangular pattern to identify defects in the plate so they would not be counted as stellar objects, remember each observatory is making its own plates from its own (hopefully filtered) chemicals. The two directors who were the guiding hands through most of this program were Father Francesco Denza 1890 to 1906 and Father Johann Georg Hagen 1906 to 1930. The telescope used was an f/10 refractor that produced a 2 square degree image on a 10X14inch plate at the focal plane, the entire sky is over 40,000 square degrees. Hagen realizing that Pickering at Harvard with his female "computers" was on to a really good idea had four nuns assigned to work on the project cataloging the stars that were on the plates, in the decades that the nuns worked they cataloged 481,215 stars, I told you that this was a big project.

Unfortunately, because of the time required in just one section of the sky to produce all of the plates required by the protocol the work dragged on for decades, long after the passing of both Father Denza and Father Hagen, and in 1948 at the Palomar observatory a new type of photographic telescope came online. The Schmidt camera was a f2.5 telescope that captured 3.75 square degrees per photo and was much faster that the older telescopes used in Europe for the Carte du Ciel project. In 1958 the Palomar Observatory Sky Survey (POSS I) was complete and released the Carte du Ciel survey data was also released even though the survey was still not completed, time and technology had rendered their equipment and photographic plates obsolete.

If Father Angelo Secchi was the Vatican's powerhouse astronomer for the 1800's then Father George Lemaître was the Vatican's powerhouse astrophysicists of the 1900's. Einstein considered him to be one of the 15 or 20 people on Earth who really understood space time. Lemaître and Alexander Friedmann both worked on Einstein's field equations. Friedmann to see what universe dynamics can be described by the equations (mister theoretical); Lemaître to see if the equations can explain the universe's past (Mister practical application).

At Powell's Mars Hill observatory Powell has hired a young astronomer, Vesto Slipher, newly trained in spectroscopy. Powell wants Slipher to measure the rotational rate of Venus, which he is certain has a solid surface, it does not and Slipher never succeeds, but when he, Powell, is away Slipher can use the equipment as he wishes. Slipher measures the spectral shifts of 25 spiral nebula and finds that 24 are receding and one Andromeda is heading toward us. Slipher gives a talk on his findings, listing Powell as coauthor, and two of the people in the audience are Lemaître and Edwin Hubble. Hubble runs home to Mt. Wilson and immediately starts working on the spectral shifts of other spiral nebula and starts to desperately try and prove that these nebula have stars in them, at this time galaxies were called spiral nebula and there was fierce debate as to whether these nebula are star systems forming in our galaxy or separate galaxies in their own right. Hubble finds stars in the nebula, hooray, the nebula are galaxies in their own right, and finds all galaxies are moving away from us. Lemaître realizes that the galaxies are not moving away from us but that the space time between the galaxies is expanding and carrying

the galaxies with it and this means that the universe once had a beginning, those field equations can explain it all.

Lemaître called the blob of stuff that popped into being at the moment of the universes birth by two names: the primal atom or the cosmic egg. Another astrophysicist, Fred Hoyle, who is completely committed to the idea of a steady state universe, no beginning and no end, is absolutely incensed at the idea of a finite universe and hates the atom and egg description of the universes beginning. On a radio program in 1949 Hoyle tries to disparage the idea of a finite universe by suggesting that rather than calling the beginning the egg or atom why not just say "The Big Bang!". Unfortunately for Hoyle the name resonated with the public and became a popular description. Hoyle would spend the rest of his life trying to prove the steady state hypothesis to be correct, he died in 2001, a frustrated person. Lemaître is remembered as the guy who combined Einstein's equations and Hubble's observations to answer one really big question.

The history of the observatory is also interesting as it was moved four times within the Vatican, bigger facilities, exiting crumbling buildings, or just as part of a general restructuring of the grounds. In 1827 the observatory was moved out of the Vatican to a college site nearby. In 1870 the new mostly national government of Italy claimed the property as a state school, back to the Vatican. In 1930 because of light pollution the observatory is moved to the papal summer residence Castle Gandolfo 16 miles from Rome. In 1981, again because of light pollution, a new observatory is started on Mt. Graham in Arizona and the observatory sees first light in 1993. Today the papal astronomers are called the Vatican Observatory Research Group (VORG). The VORG group has offices, outreach programs, and seminars at Castle Gandolfo; offices and teaching responsibilities at the Stewart Observatory at the University of Arizona, and an observatory with the Vatican Advanced Technology Telescope on Mt. Graham. All of this is headed up by our old friend Father Guy Consolmagno who studies meteors to try and understand how our solar system asteroids were formed. And, oh yes, he has just finished his latest book. The book answers questions written to the astronomy staff at the observatory and takes its name from one of the actual questions. "Would You Baptize an Alien?" Well would you?

Cheers, Chuck

Landing on Mars : A Tricky Feat!

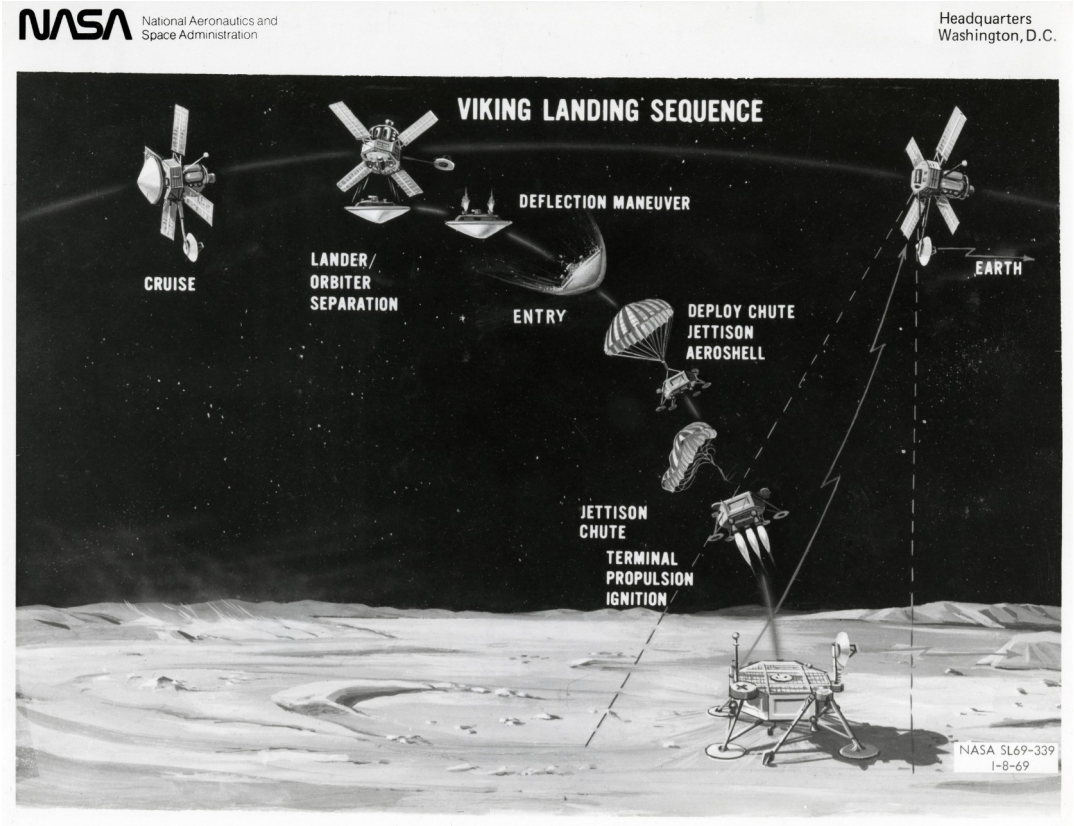
by David Prosper

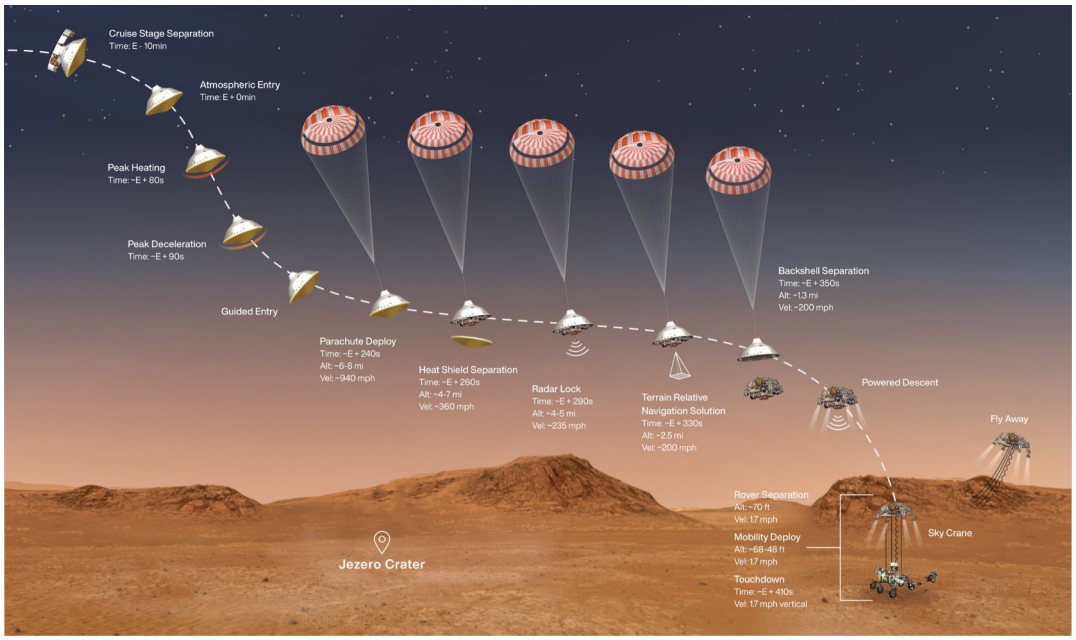
The Perseverance rover and Ingenuity helicopter will land in Mars's Jezero crater on February 18, 2021, NASA's latest mission to explore the red planet. Landing on Mars is an incredibly difficult feat that has challenged engineers for decades: while missions like Curiosity have succeeded, its surface is littered with the wreckage of many failures as well. Why is landing on Mars so difficult?

Mars presents a unique problem to potential landers as it possesses a relatively large mass and a thin, but not insubstantial, atmosphere. The atmosphere is thick enough that spacecraft are stuffed inside a streamlined aeroshell sporting a protective heat shield to prevent burning up upon entry - but that same atmosphere is not thick enough to rely on parachutes alone for a safe landing, since they can't catch sufficient air to slow down quickly enough. This is even worse for larger explorers like Perseverance, weighing in at 2,260 lbs (1,025 kg). Fortunately, engineers have crafted some ingenious landing methods over the decades to allow their spacecraft to survive what is called *Entry, Descent, and Landing (EDL)*.

The Viking landers touched down on Mars in 1976 using heat shields, parachutes, and retrorockets. Despite using large parachutes, the large Viking landers fired retrorockets at the end to land at a safe speed. This complex combination has been followed by almost every mission since, but subsequent missions have innovated in the landing segment. The 1997 Mars Pathfinder mission added airbags in conjunction with parachutes and retrorockets to safely bounce its way to a landing on the Martian surface. Then three sturdy "petals" ensured the lander was pushed into an upright position after landing on an ancient floodplain. The Opportunity and Spirit missions used a very similar method to place their rovers on the Martian surface in 2004. Phoenix (2008) and Insight (2018) actually utilized Viking-style landings. The large and heavy Curiosity rover required extra power at the end to safely land the car-sized rover, and so the daring "Sky Crane" deployment system was successfully used in 2012. After an initial descent using a massive heat shield and parachute, powerful retrorockets finished slowing down the spacecraft to about 2 miles per hour. The Sky Crane then safely lowered the rover down to the Martian surface using a strong cable. Its job done, the Sky Crane then flew off and crash-landed a safe distance away. Having proved the efficacy of the Sky Crane system, NASA will use this same method to attempt a safe landing for Perseverance this month!

You can watch coverage of the Mars Perseverance landing starting at 11:00 AM PST (2:00 PM EST) on February 18 at nasa.gov/nasalive. Touchdown is expected around 12:55 PM PST (3:55 PM EST). NASA has great resources about the Perseverance Rover and accompanying Ingenuity helicopter on mars.nasa.gov/mars2020 . And of course, find out how we plan to land on many different worlds at nasa.gov.





Illustrations of the Entry, Descent, and Landing (EDL) sequences for Viking in 1976, and Perseverance in 2021. Despite the wide gap between these missions in terms of technology, they both performed their landing maneuvers automatically, since our planets are too far apart to allow Earth-based engineers to control them in real time! (NASA/JPL/Caltech)

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