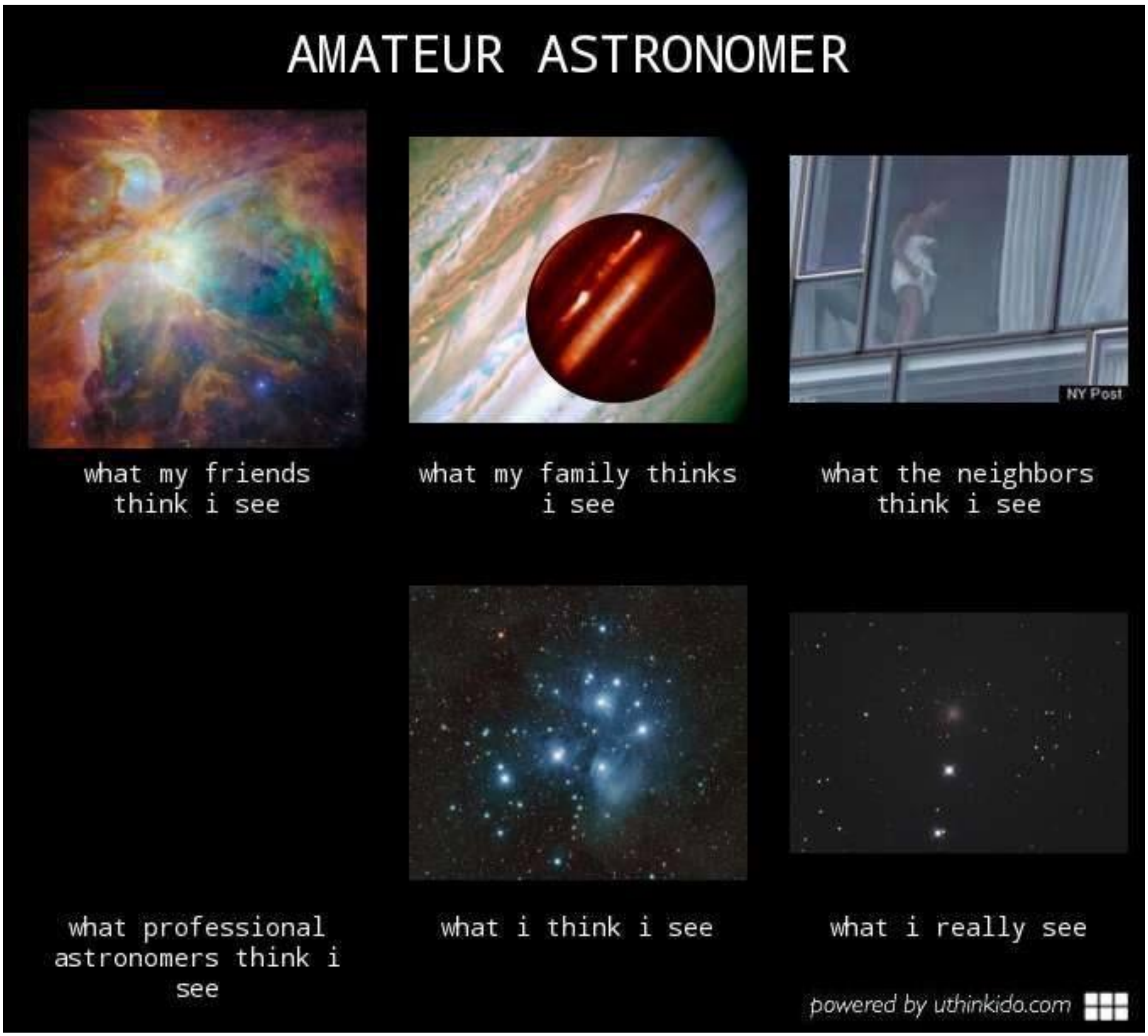
SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

April 2021



WAA April Meeting

Friday, April 9, 7:30 p.m. via Zoom

Discovery at Lowell: The Past, Present, and Future of Lowell Observatory

Kevin Schindler, Lowell Observatory

The wealthy Bostonian Percival Lowell established Lowell Observatory in 1894 in Flagstaff, Arizona. Through the years, the Observatory has been home to many discoveries, including the first detection of the expanding nature of the universe, the discovery of Pluto, moon mapping for the Apollo program to the moon, the rings of Uranus, atmosphere of Pluto, and scores of others. Lowell is also one of the most active astronomy outreach organizations in the world.

Kevin Schindler has been associated with Lowell for more than twenty years. He is its official historian, and has written several books about the observatory, its history and its scientific output.

Pre-lecture socializing with fellow WAA members and guests begins on-line at 7:15 pm!

WAA Members: Contribute to the Newsletter!
Send articles, photos, or observations to
waa-newsletter@westchesterastronomers.org

Editor: Larry Faltz
Assistant Editor: Scott Levine
Almanac Editor: Bob Kelly
Editor Emeritus: Tom Boustead

Also In This Issue

WAA May Meeting

Friday, May 14, 7:30 pm via Zoom

The Space Race in Review

Andy Poniros, NASA Solar System Ambassador

Call: 1-877-456-5778 (toll free) for announcements, weather cancellations, or questions. Also, don't forget to visit the WAA website.

Starway to Heaven: April

Meadow Parking Lot
Ward Pound Ridge Reservation, Cross River, NY

April 10 (Rain/cloud date April 17)
Pandemic safety requirements will be in effect.

Event (Times are p.m. EDT)	4/10	4/17
Sunset	7:29	7:37
Nautical twilight ends	8:34	8:43
Astronomical twilight ends	9:09	9:19
Moon: 4/10 none all night. 4/17: 5-day crescent 23% illuminated, sets at 12:11 a.m. 28° altitude at 9:19 p.m.		

New Members

Greg Alexopoulos	Rye
Joel Bender	New York
Ingrid & Tracy Ehrensbeck Edwards	Binghamton, NY
Louise Gantress	Mt. Kisco
Jeff Gershgorn	Wappingers Falls
Barbara Levine	Mt. Kisco

Renewing Members

Winston Archer	Yonkers
Steven Bellavia	Mattituck
John Benfatti	Bronx
David Butler	Mohegan Lake
Joseph Depietro	Mamaroneck
Howard Fink	New York
Robbins Gottlock	Sleepy Hollow
Garth Landers	Stamford
Robert Rusinko	Tarrytown
Anthony Ortega	Scarsdale
Anthony Sarro	Brooklyn
Alexandr Zaytsev	Holtsville

Current as of March 21, 2021

ALMANAC for April 2021

Bob Kelly, WAA VP for Field Events

Planet Summary

Mars is still the only planet getting lots of love in April. Jupiter and Saturn are getting farther out from the Sun, but still not very high in the morning sky. Venus and Mercury are lost in the solar glare.

Dawn Patrol

The crescent Moon points the way to Saturn, Jupiter and Mercury in early April. On the 6th, the Moon slides about five degrees below Saturn. On the 7th, the Moon jumps to five degrees below Jupiter. The Moon is all but invisible as it passes by Mercury on the 11th, only nine degrees from the Sun.

More About Jupiter

There was a report in a Canadian publication that we'd see two of Jupiter's moons casting shadows on the giant planet at the same time several times this month. In reality, the first of these double shadow transits that we can see in Westchester will be in late June. Jupiter's four brightest moons are wonderful to spot anytime as they slowly shuttle from one side of the planet to the other.

Planets Hiding in the Solar Glare

Mercury and Venus appear about the same elongation on opposite sides of the Sun on the 14th. They'll only be visible in the Solar and Heliospheric Observatory's C3 viewer. Uranus may be faintly visible in the SOHO C3 view starting after the 22nd; it reaches solar conjunction on the 30th.

Mercury reaches solar conjunction on the 17th. Mercury passes by Venus on the 26th as they exit the C3 scene. They are both on the far side of the Sun from us as we all move counter-clockwise around the Sun. Mercury is on its way to the evening sky. Its greatest eastern (evening) elongation this year is in mid-May.

M35 Gets Visitors

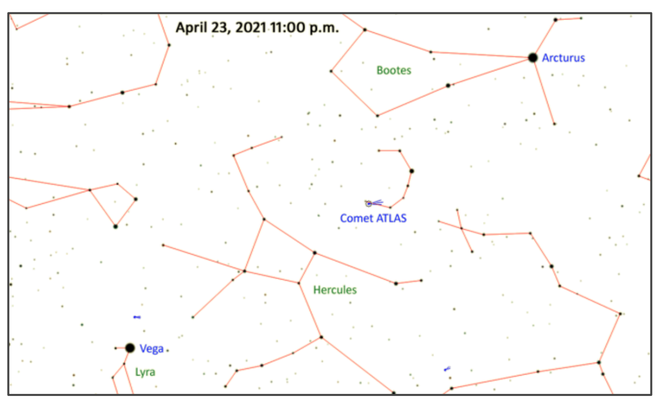
The open cluster M35 gets a visit by the crescent Moon on the 17th, and by Mars on the 25th. It will be a nice surprise for anyone aiming binoculars at the Moon or Mars on those particular days. The Moon passes the faint stars of Cancer about eight Moon diameters above the Beehive Cluster on the 20th.

Evening Constellations

The end of astronomical twilight moves from about 9 p.m. EDT in early April to 9:30 p.m. at the end of the month. At the WAA March star party, Sirius was visible half-an-hour after sunset, but the Dog Star will be getting lower in the southwest this month, seeming to push Orion and Taurus toward the solar glare. Uranus is low in the evening sky, but may be visible through mid-month. Mars and the Moon are together on the 16th with Betelgeuse to the left and Aldebaran below.

Comet ATLAS

C/2020 R4 ATLAS will be hanging well above Jupiter and Saturn in the morning sky before twilight starts. As it makes its closest approach to Earth (at a social distance of 43 million miles) it will swing into the circumpolar sky in Corona Borealis, thus becoming a night object. The present light curve, with only a few recent observations since it made it closest approach to the Sun in early March) predicts it will be no brighter than magnitude +9, but comets can sometimes brighten unexpectedly. Its distance from the Sun is rapidly increasing, as will its distance from the Earth in late April, so earlier in the month may be the best time to catch it.



Supermoon

This month's full Moon occurs on the 26th at 11:32 p.m. The Moon is closest to Earth 12 hours afterwards. Be aware of extreme tides for a few days afterwards.

Member Profile: Emily K Dean DVM

Home town: Pelham NY 10803

Family: Mother, 81, brother and assorted aunts and cousins

How did you get interested in astronomy? I was living in Florida for a short period and took and online astrophysics course just for fun. That got me hooked.

Do you recall the first time you looked through a telescope? What did you see? The Moon.

What's your favorite object(s) to view? The Moon, because it's close and Jupiter because it's big.

What kind of equipment do you have? I have an Orion Space Probe 130 STEQ reflector telescope and a set of basic filters.

What kind of equipment would you like to get that you don't have? A Sun filter.

Have you taken any trips or vacations dedicated to astronomy? Tell us about them. Not yet.

Are there areas of current astronomical research that particularly interest you? The cosmic microwave background, bubble theory and black holes- specifically the event horizon.

Do you have any favorite personal astronomical experiences you'd like to relate? Mostly book-learning as of now, but the two-dimensional representation of the black hole was nifty.

What do you do (or did you do, if retired) in "real life?" I am an equine veterinarian (horse doctor). In addition to western veterinary medicine I am also trained in eastern medicine and acupuncture and spinal manipulation (chiropractics for the horse).

How did you get involved in WAA? We were looking for something different to do with our time and found WAA.

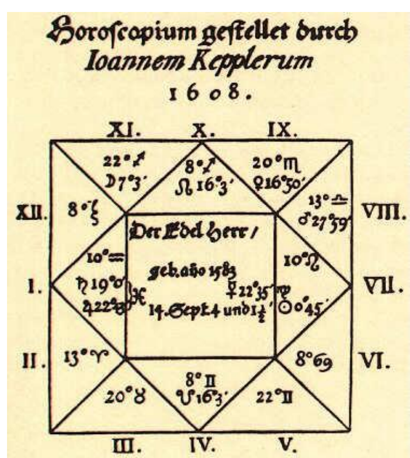
What WAA activities do you participate in? Mostly lectures up to now. We had been planning on a star party this year but have high risk family members with respect to Covid 19. Hopefully that will abate in 2021.

Besides your interest in astronomy, what other avocations do you have? Funnily enough, astrology and Tarot interest me. I ride horses, have dogs, cats and a dove. I do some crafts and have a penchant to play darts when the occasion allows. And somehow we have been to a large number of the aquariums of the eastern seaboard.....

Provide any other information you think would be interesting to your fellow club members, and don't be bashful! It's been such a strange year, it's hard to say. Be safe and well.

Editor's Note

Astrology and astronomy evolved together and were indissolubly linked until the scientific revolution of the 17th century. Among the most famous and accomplished of all astrologers was Johannes Kepler, discoverer of the laws of planetary motion. Kepler was at heart a true Pythagorean, and as such he saw the entire universe, including human behavior, as ultimately being linked by mathematical principles and relationships. His 1619 work *Harmonia Mundi* sought to link geometry, arithmetic, music, astrology and astronomy into a coordinated whole, an overarching "theory of everything."



This is the horoscope cast by Johannes Kepler for General Albrecht von Wallenstein, supreme commander of the armies of the Holy Roman Empire during the Thirty Years' War in the 17th century.

LF

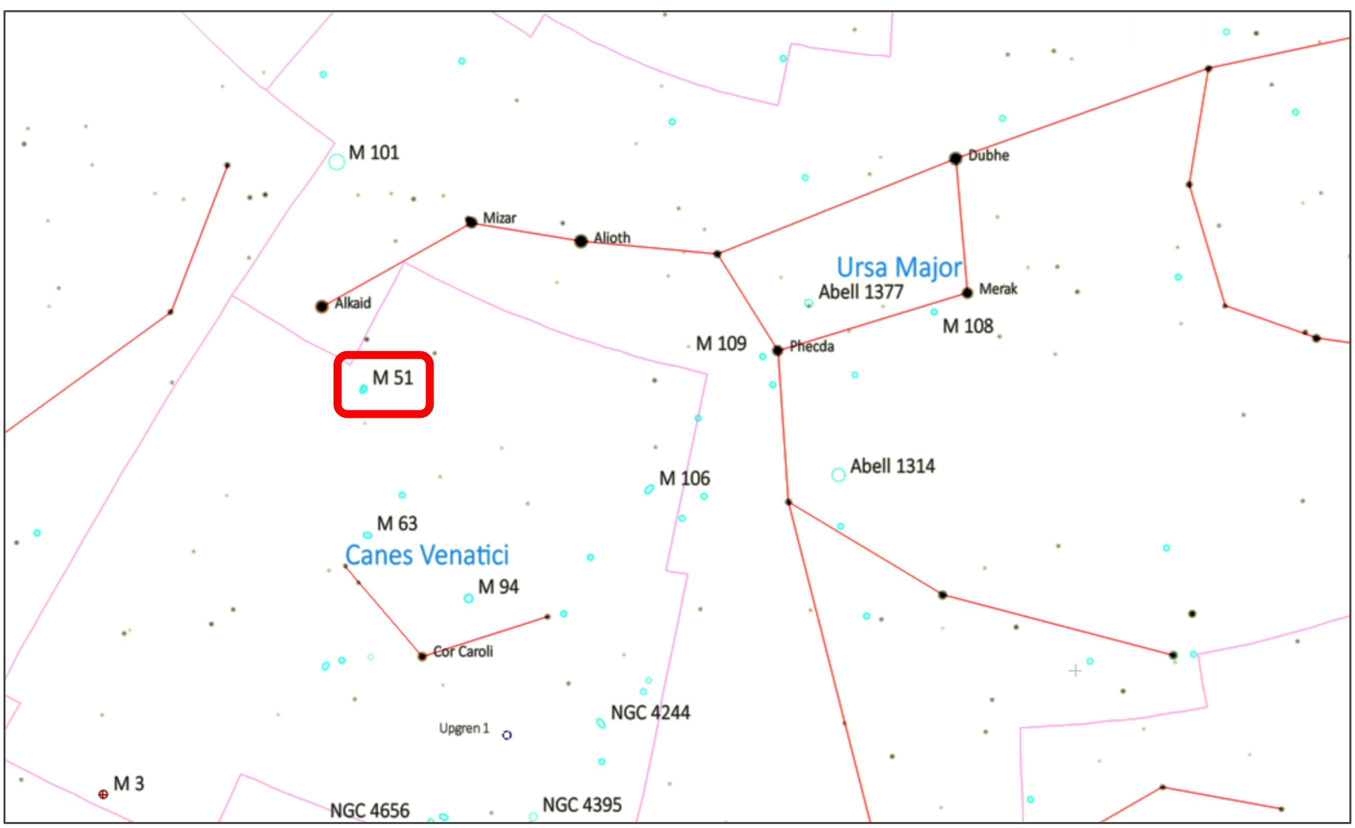
Deep Sky Object of the Month: Messier 51

Messier 51	
Constellation	Canes Venatici
Object type	Galaxy
Right Ascension J2000	13h 29m 54.0s
Declination J2000	+47° 12’ 00”
Magnitude	8.4
Size	11.2 x 6.9 arc-minutes
Distance	7.1±1.2 Mpc
NGC designation	5194
Nickname	Whirlpool Galaxy

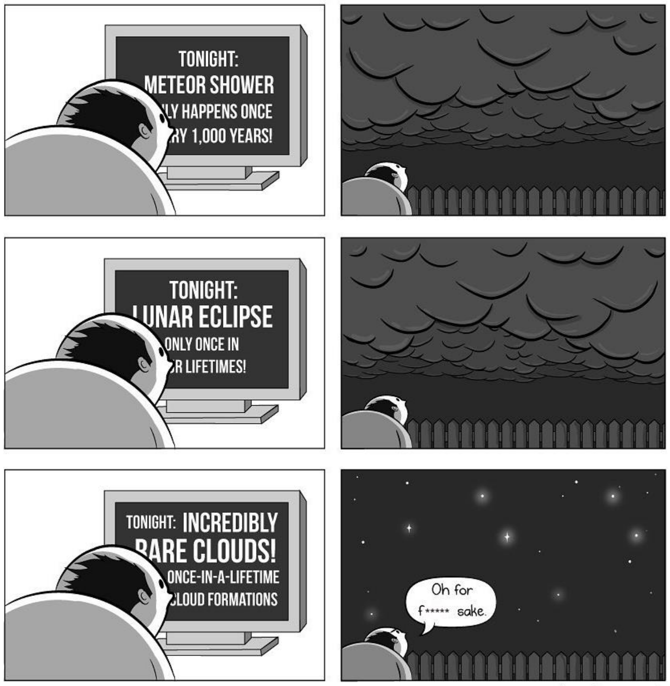
One of the glories of the spring sky, this pair of interacting galaxies (the smaller component is NGC 5195) is seen in small telescopes as two fuzzy nuclei. With a larger instrument, spiral arms can appear as a homogenous patch surrounding the nucleus, and in really dark skies they can be resolved. The pair is easy to find, one-quarter of the way between Alkaid, the tip of the Big Dipper’s handle, and Cor Caroli, the brightest star in the large area below the handle. For more on this important object, see “The Wonderful Whirlpool” in the June 2016 SkyWAAtch.

Visibility for Messier 51			
10:00 pm EDT	4/1/21	4/15/21	4/30/21
Altitude	50° 31’	59° 47’	69° 50’
Azimuth	67° 07’	64° 33’	64° 03’

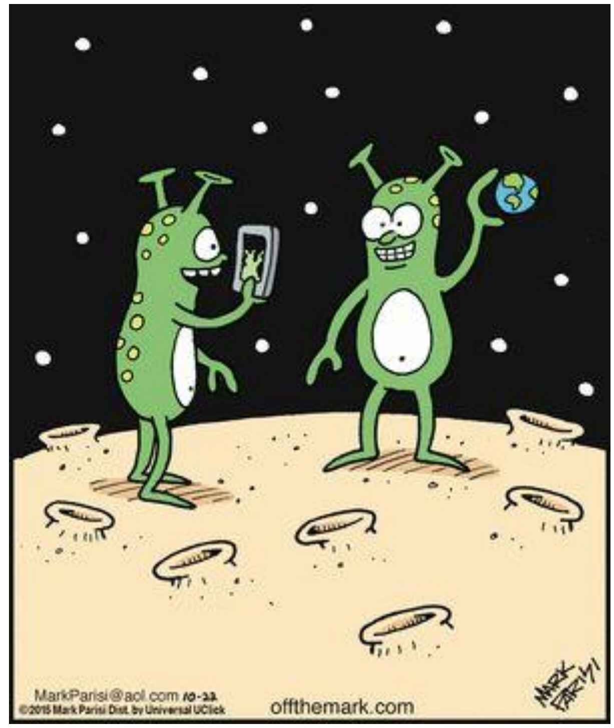
While you’re in galaxy-rich Canes Venatici, look for M63, the Sunflower Galaxy (magnitude 9.4) and M94, a magnitude 8.99 face-on barred spiral, closer to Cor Caroli. Aperture and averted vision will help.

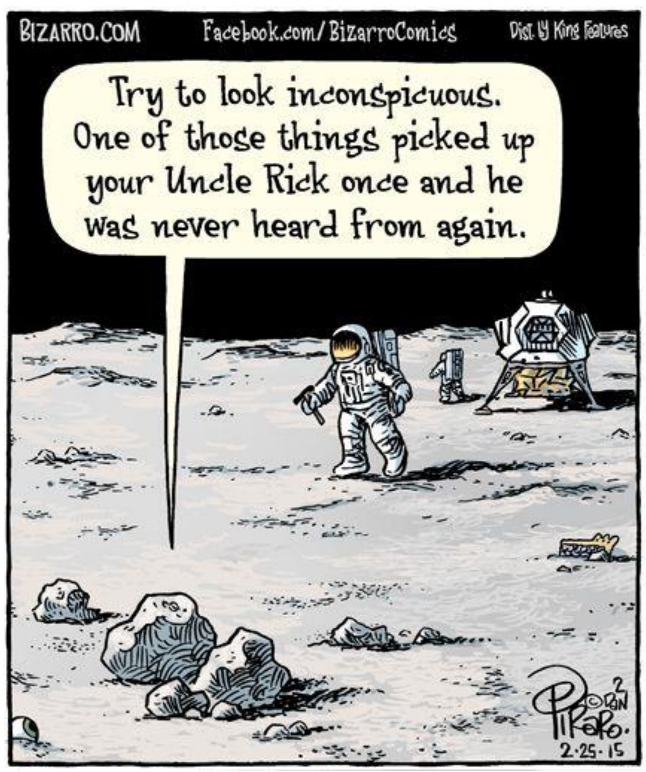


A Little April Astro-Humor



The Oatmeal





Quiz: Telescopes in the Movies

Telescopes make their appearance in movies from time to time, sometimes important to the plot, sometimes just as decoration. Many of the films in which scopes appear are a bit obscure (sorry about that, but there's no telescope in *The Godfather* and there are a whole lot more obscure movies than blockbusters) but a couple of these films might be considered classics, or at least "genre classics." Can you recognize the film, and perhaps name a few of the actors? There are of course many more examples; perhaps you can recall other cinematic scope appearances. The films and actors are identified on page 31.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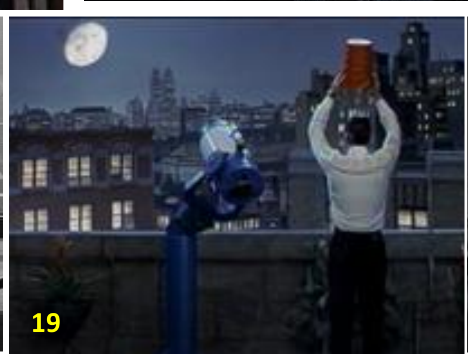
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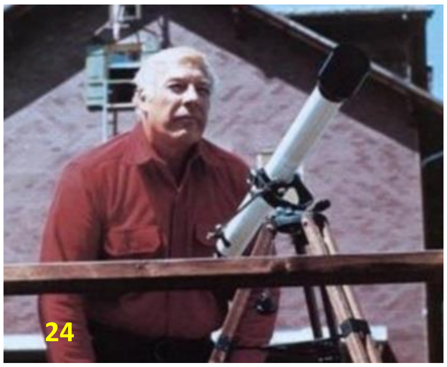
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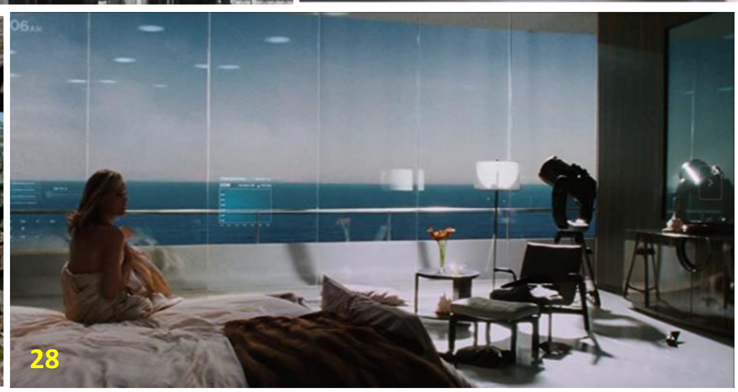
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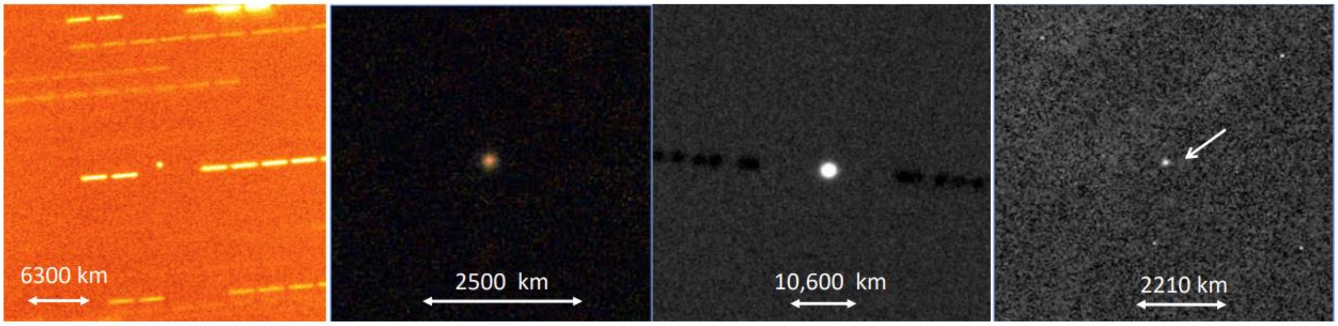
Answers on page 31

Review & Commentary: *Extraterrestrial* by Avi Loeb — Larry Faltz



Images of ‘Oumuamua showing its point-like unresolved appearance, with no hint of detectable cometary activity. From left to right: 0.4-hr r-band integration with the Nordic Optical Telescope; “true color” image simulated from grizY-band images with a total integration of 1.6 hr with the Gemini South telescope in Chile, 3.6-hr r-band composite image obtained with the Gemini North telescope (Mauna Kea); and an F350LP image from Hubble Space Telescope. Images from October 26-28, 2017.

Are we alone? For most of us, the Search for Extra-Terrestrial Intelligence (SETI) provokes an image of Jody Foster on the hood of her truck listening to bleeps in the movie *Contact*. The first (albeit erroneous) claim of evidence of alien intelligence might have been Percival Lowell’s telescopic observations of “canals” on Mars in 1897. Continued fascination with the possibility of intelligent Martian life resulted in "National Radio Silence Day" on August 21–23, 1924, a 36-hour period when all radio transmissions were to be halted for five minutes on the hour, every hour. The US Naval Observatory used a dirigible-mounted receiver in an attempt to receive signals from the Red Planet during those quiet periods.

In 1959, Giuseppe Cocconi and Philip Morrison published “Searching for Interstellar Communications,” in the journal *Nature*.[1] It suggested a methodology that could detect ET’s radio signals. Frank Drake’s first attempts to do so with Project Ozma in 1960 used radio telescopes at Green Bank, West Virginia, and almost all of the other projects we’ve heard about, from SENTINEL at the Harvard-Smithsonian’s Oak Ridge Observatory in Massachusetts to SERENDIP at Green Bank and Arecibo to the Allen Array in California and to the Breakthrough Listen project, also search in the radio region of the electromagnetic spectrum. Not long after Charles Townes invented the maser, he suggested that aliens might use masers more efficiently for communication. Their optical-band equivalent, lasers, would be easier to detect on Earth. Oak Ridge Observatory initiated an “optical SETI” program in 1998 using the now-mothballed 61-inch Wyeth reflector (see “On the Fate of Telescopes” in the January 2021 SkyWAAtch); a smaller detector is still operating remotely at the site. While the detection of electromagnetic signals seems to be the most logical way of looking to the skies for evidence of alien intelligence, what about the possibility that we could simply stumble across an object that could not be explained by anything other than alien technology? It worked for Stanley Kubrick in *2001: A Space Odyssey*, so maybe life can follow art.

By now you are surely aware that Abraham (Avi) Loeb, the Chair of Astronomy at Harvard, has suggested that the first interstellar body ever detected, 1I/’Oumuamua, is just such an object. His papers on the arXiv.org server over the past few years address a wide range of unique topics that relate to SETI. He and his Harvard colleagues and students calculate all sorts of interesting possibilities from the existence of primitive alien life to the detection of the products of evolved alien technology. They include the motility of microorganisms in planetary environments, whether Earth-grazing long-period comets and interstellar objects could export life from Earth by collecting microbes from the atmosphere, how humans or aliens might propel light sails using powerful lasers, and whether chemical energy (rocket fuel) is sufficient to allow space vehicles to achieve escape velocity from Proxima Centauri b. He even proposed building a telescope that would orbit the Moon and could pick out impacts from alien space junk on the lunar surface. This is hardly science fiction, of which he is not a big

[1] Nature 1959; 184: 844-846, available at http://www.coseti.org/morris_0.htm

fan: his proposals are always supported by calculations based on reasonable, if somewhat outré, assumptions and he properly acknowledges the limitations of his data, as all good scientists must do. He's astonishingly prolific: a look at his web site shows that he is turning out interviews, podcasts, popular articles and presentations almost daily, in addition to the amazing fecundity of scientific papers posted to arXiv, some 60 in 2020 and seven in January 2021, many of which are subsequently published in leading astronomy journals. His scientific bibliography lists nearly 800 items.

Extraterrestrial is a simplified exposition of Loeb's argument that the best interpretation of the observational data is that 'Oumuamua is an alien light sail, the product of an advanced intelligent race, not a comet or asteroid.[2] His thesis is simple: the object's trajectory and velocity strongly suggest it did not arise in the Oort Cloud, upon which almost every astronomer agrees. It's more reflective than expected for a comet or asteroid. It's not a spheroid because of its peculiar light curve. It's not a comet since no coma, outgassing, heat release or radio signals were detected, and the exact shape of its trajectory after perihelion suggests that it was responding to solar radiation pressure. The "establishment" view of 'Oumuamua is that it is a peculiar but nevertheless natural object, but Loeb somewhat vehemently pokes holes in that assessment. He reserves his greatest ridicule for the proposals that it might be a coherent mass of low-density material or something called "hydrogen ice," although these are also minority views. On more than one occasion, Loeb invokes Sherlock Holmes's dictum that "When you've eliminated the impossible, whatever remains, however improbable, must be the truth"[3] to suggest that the only objectively supportable interpretation is that it is a disk-like object most likely made for even interstellar travel.

Extraterrestrial is a simplified evaluation of the scientific evidence regarding 'Oumuamua, and someone interested in details will need to go to the primary sources and evidence summaries that are available on line to get the full flavor of the problem.[4] Loeb uses 'Oumuamua as a stepping-stone (while arguing it's not a stone!) to larger issues about scientific orthodoxy, curiosity, creativity, mentorship and even research funding. He facilely connects to his other research interests. Recently he's been active in Yuri Milner's Breakthrough Starshot initiative, which wants to send thousands of nano-craft to Proxima Centauri b, an Earth-sized planet in its star's habitable zone. The craft will be propelled to 20% of light speed by giant lasers on Earth, reaching their target in 20 years, presumably to report something back to us 4.25 years later. You can think of it a swarm of reverse nano-'Oumuamuas.

Loeb's writing is clear and informative, as would be expected from someone who is in demand as a communicator of astrono my to the general public. He uses the book to tell us about his family's history as emigres from Germany to Israel in the early 1930s (his father saw the coming troubles early, but most of his relatives died in the Holocaust), his upbringing on the family farm, his initial academic interest in philosophy, his training in the Israeli military and then his transition to physics and astronomy. He had a long stint at the Institute for Advanced Study before moving on to Harvard. He's proud of his wife and two daughters. He has a nice house in Lexington, Massachusetts. He was amazed by the night sky in Tasmania. He has a lot of graduate students, and he encourages them to think outside the box. Of course, if you write something that's a bit strange, the likelihood that the field will react to it positively (or at all) increases by orders of magnitude if your co-author is the Chair of Astronomy at Harvard.

In this relatively short (200 pages) book, Loeb covers a lot of ground. He even discusses the impact on humanity if proof of alien life were to be found, intelligent or otherwise. He's fairly optimistic but I think too much so. In our bizarre intellectual climate, where all sorts of proof-resistant fantasies claim the allegiance of a substantial proportion of the population, I expect that evidence of alien life would be immediately and loudly countered by conspiracy theories. It would take the actual arrival of aliens to dispel those notions. Yet we know the public is fascinated

[2] https://arxiv.org/abs/1810.11490

[3] Holmes didn't say it exactly this way, but this is how it's always quoted.

[4] A good place to start is "The Natural History of 'Oumuamua" https://arxiv.org/pdf/1907.01910v1.pdf

by aliens: just look at the success of movies featuring them. At least 36% of Americans believe UFOs exist, and 10% claim they've actually seen one.[5] There are a few books and articles on how the discovery of alien life might impact humanity, for good or ill, and for many the mere idea of aliens has already had an impact. A very fine examination of SETI and our reactions to (so far only imaginary) extraterrestrial life is Joel Achenbach's *Captured by Aliens* (Simon & Schuster, 1999). Achenbach surveys the scientific and cultural aspects of SETI through a clever conceit: he frames his story around the evolution of Carl Sagan's thinking about astrobiology and SETI. We're shown some real science but we're also entertained (and at times shocked) by some of the odder and more disquieting events that belief in actual aliens has provoked, like the Roswell incident and the Heaven's Gate mass suicide. Achenbach is a senior writer at the Washington Post, and the book is first-rate reportage. A more academic survey is *The Impact of Discovering Life Beyond Earth*, edited by Steven J. Dick (Cambridge University Press, 2015).

We have to quote Holmes again: "It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts."[6] It was quite an accomplishment to gather as much data on 'Oumuamua as astronomers did in the two or three weeks or so it was in a position to be effectively observed, but many of the instruments were working near the limit of their sensitivities. They did not get all the data that was needed to reach a "five sigma" level of certainty for any model. Everyone trying to make 'Oumuamua into a plausibly concrete object faced the same limitations and in a sense had to parse the facts. Loeb's claim that the data supports alien technology more strongly than a natural object has few adherents among professional astronomers, but it can never be refuted with certainty. Establishment analyses use the same data to dismiss his proposal, if they address it at all. All we can do is be on the lookout for more strange interstellar objects, using the capabilities of the Vera Rubin Telescope and the super-sized instruments coming in the next decade (Giant Magellan Telescope [24.5 meters], Thirty Meter Telescope, and the Extremely Large Telescope [39 meters], if all those Starlink satellites don't blind them.

Loeb tells us that we should *want* to interpret the data to show that 'Oumuamua is of alien origin. He provides an analogy to Pascal's wager: A rational person should live as though God exists. If God does not actually exist, such a person will have only a finite loss (some sinful earthly pleasures), whereas if God does exist, he stands to receive infinite gains (eternity in Heaven) and avoid infinite losses (eternity in Hell).[7] It's a peculiar argument to cite but it does apply, in a sense. Loeb argues that we have nothing to lose and everything to gain if we opt to consider 'Oumuamua a piece of alien technology out of all the possible identities that it might have. To believe so might energize us to make progress in astrobiology and SETI, and even justify sending our own signals and technology into space.[8] Another rock or frozen ice-ball is just another rock or frozen ice-ball, hardly worthy of the public's interest and maybe not even astronomy's, no matter where it comes from.

Theirs is no downside risk to believing one thing or the other about 'Oumuamua: its true nature is simply indeterminate within a range of possibilities. Loeb is espousing a unique view, but it is one that appeals to popular culture. That in turn sells more books and gets more media exposure than someone's less fantastic assertion that it's just a weird space rock. Loeb chafes at the scientific establishment's relative disinterest in SETI research, noting that considerable financial support and tenure-track faculty appointments are given for far more arcane and equally unproven theories like the multiverse, string theory and supersymmetry. Why are they deemed credible and supportable while SETI is disdained? To the extent that we might need a lever to move intellectual energy and funding in order to achieve more SETI research, why not agree to endow 'Oumuamua with an alien provenance? ■

[A new study published on March 16, after this review was written, suggests that 'Oumuamua is made of frozen nitrogen, and is a fragment of a Pluto-like body. See https://is.gd/1IOumNit.]

[5] Study by *National Geographic*, 2012

[6] "A Scandal in Bohemia" (1891). Not quoted by Loeb.

[7] This is best encapsulated in Woody Allen's dictum that "I don't believe in the afterlife, but I'm taking a change of underwear just in case."

[8] "We're all so curiously alone, but it's important to keep making signals through the glass." John Updike, in reference to something else, but still apt.

Moonlight

Robin Stuart

My high school library housed a copy of the *Flammarion Book of Astronomy* (Danjon and Flammarion 1964). This nearly 700-page tome contains a wonderful survey of the state of astronomical knowledge as it stood at the time of its publication and I spent countless hours immersed, wide-eyed, in its pages. The chapter entitled, *The Planet Venus*, shows plots of the *scattering indicatrices* for the Earth, Venus, Mercury and the Moon, noting "... that the full moon sends us 12 times as much light as we receive at the quarters." Although surprising, I felt sure this could be explained by simply treating the Moon as a diffuse reflecting sphere, but lacking a sufficient level of calculus at the time, I was unable to confirm it. The sought-after analysis can be found online (Dawson 1919) but predicts that the full Moon is just a little over 3 (actually π) times brighter than the quarters. What explains this large difference?

A diffuse or *Lambertian* reflecting surface scatters an incoming beam of light uniformly or *isotropically* in all directions. Figure 1 simulates the appearance of a diffuse reflecting sphere with the light coming from behind the observer. The surface is obviously much brighter near the center. Contrast this to the image of the nearly full Moon (solar phase angle $\alpha \approx 10°$) taken by the author on March 8, 2020 (see also WAA Newsletter May 2020, p.17) which has the appearance of a flat uniformly-illuminated disk. Clearly the surface of the Moon is not a Lambertian reflector, but then how does it actually behave?

When imaging the phases of the Moon there can be a very large difference in brightness between the limb and terminator regions. To correct for this a gamma or curve adjustment can be applied to compress the dynamic range and enhance the visibility of both areas in the same image. While the adjustment might approximate the logarithmic response of the human eye it will modify intrinsically dark regions near the limb in the same way as bright regions near the terminator and hence does not produce a true representation of the lunar surface. An understanding the Moon's reflecting properties would allow position-dependent brightness adjustments to be made that show the Moon as it really is. Can this be done in practice? This article attempts to provide answers to these questions.

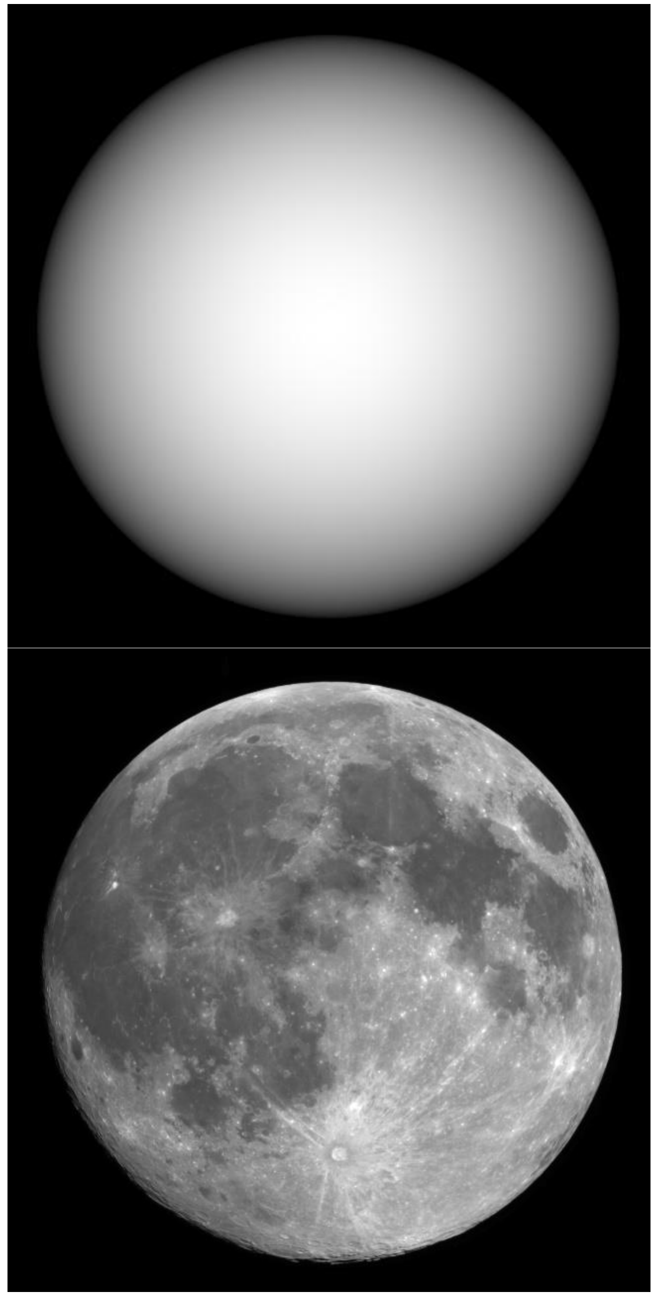


Figure 1: A Lambertian reflecting sphere at phase angle, $\alpha = 0$, compared to the Full Moon.

Lunar Photometry

A complete description of the reflectance properties of the Moon ideally requires measurements to be made over the full range of angles that the incoming and reflected beams make perpendicular ("normal") to the surface. These are referred to as the *incident and emergent angles*. As the Moon always presents the same face to the Earth, for any point on its surface, the emergent angle is roughly fixed. The scope of Earth-based measurements may seem very limited, but appealing to the *Helmholtz Reciprocity Principle* extends the range of observable angles (Minnaert 1941). The principle states that sum total of the modifications that a beam of light experiences are the same if the positions of the source and observer are switched. This requirement constrains the form that physically allowable reflectance functions can take.

An account of the history of lunar photoelectric photometry has been given by Kapral (2006).

Photometric Models

Lunar observations are described by a *photometric function* that gives the intensity or brightness of each point on the lunar surface. The photometric function, I(α, *b*, *l*), is conventionally written as the product of a solar phase function, A(α), and disk function, d(α, *b*, *l*).

$$\mathrm{I}(\alpha,b,l)=\mathrm{A}(\alpha)\times\mathrm{d}(\alpha,b,l)$$

Here α is the (solar) phase of the Moon ranging from 0° at full and 180° at new. The location of a point on the Moon's surface is specified by its latitude, *b*, and longitude, *l*.[1] The disk function describes the variation in the intensity of reflected light across the Moon's face. The phase function increases the brightness of all points on the surface by the same scale factor. Popular choices for A(α) and d(α, *b*, *l*) are summarized by Golish *et al.* (2021). Absent from the list is the Oren-Nayar reflectance model (Oren and Nayar 1994) that was ubiquitous in computer-generated imagery (CGI) and has been used for the Moon (https://www.youtube.com/watch?v=aMIvrfvNj5Y). It is, however, comparatively complicated and produces intensity profiles that make sharp transitions from one form to another. It is therefore not suitable for the type of quantitative analysis which is the focus here.

A technical overview of lunar photometry can found in an article by Shkuratov, *et al.* (2011).

Disk Functions

In this article the *Lommel-Seeliger* and *Azimov* disk functions will be considered. Their mathematical details can be found in the Appendix. Like the Lambert disk function, Lommel-Seelinger and Azimov are universal in the sense that they contain no free parameters that can be adjusted to fit observations. The Lommel-Seeliger has been known since the 19th century and is derived from *radiative transfer theory,* assuming that light rays partially penetrate the reflecting surface and experience a single isotropic scattering event. The Azimov disk function is a semi-empirical formula that dates from the latter part of the 20th century and can be obtained by assuming a fractal structure for the scattering surface. Both of these disk functions produce flat constant intensity distributions across the face of the full Moon.

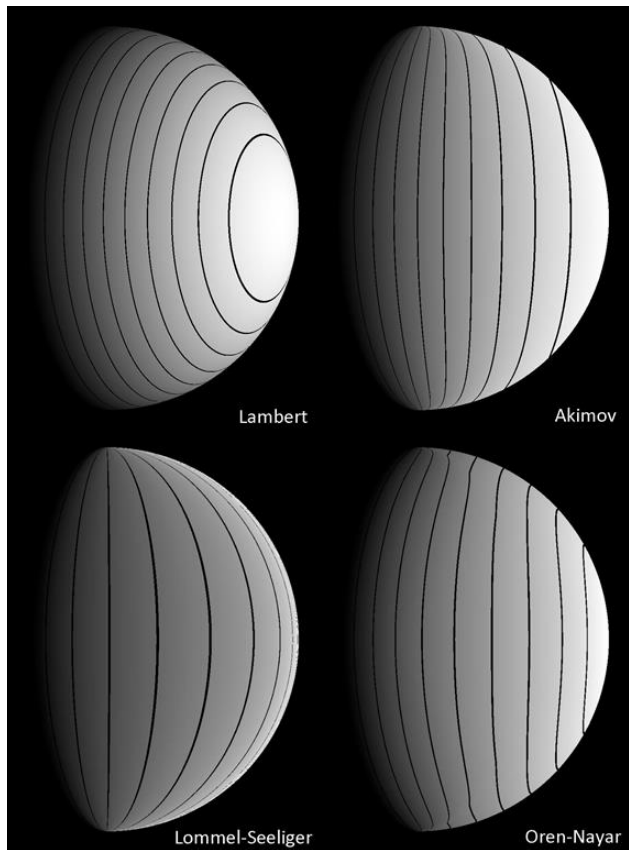


Figure 2; Disk Functions and their isophotes for the photometric models discussed in the text. The formulas used to generate the first three images can be found in the appendix.

Figure 2 shows the intensity distribution on the surface of a sphere generated by the Lambert, Lommel-Seeliger and Azimov disk functions for a solar phase

[1] In this context *b* and *l* are strictly the *photometric latitude and longitude* but for the Moon they roughly correspond to the selenographic latitude and longitude (see the Appendix, page 16).

angle, $\alpha = 65.4°$. The images are all normalized so that the brightest visible pixel has a value of 1. Contours or *isophotes* are drawn for pixel values 0.1 to 0.9 in steps 0.1.

In the case of the Lommel-Seeliger disk function, the isophotes are simply lines of longitude or *meridians*. Overall the surface appears comparatively dim due to the fact that its brightest pixels are concentrated in a small region close to the limb.

The Oren-Nayar disk function, with a roughness parameter $\sigma = 40°$, is also shown. Note that the contours are kinked near the limb. It does nevertheless satisfy the requirements of the Helmholtz Reciprocity Principle.

Phase Functions

After including some geometric factors the photometric function may be integrated over latitude and longitude to yield the photometric function for the Moon as a whole.

$$\tilde{\mathrm{I}}(\alpha) = \mathrm{A}(\alpha) \times \tilde{\mathrm{d}}(\alpha).$$

The integrated disk functions, $\tilde{\mathrm{d}}(\alpha)$, are plotted in Figure 3. By comparing points at $\alpha = 0°$ and $90°$ it can be seen that these only produce a ratio in brightness of the full to quarter Moon in the range 2.36 to 3.14. The remainder needed to account for the observed factor of 12 is attributed to the phase function.

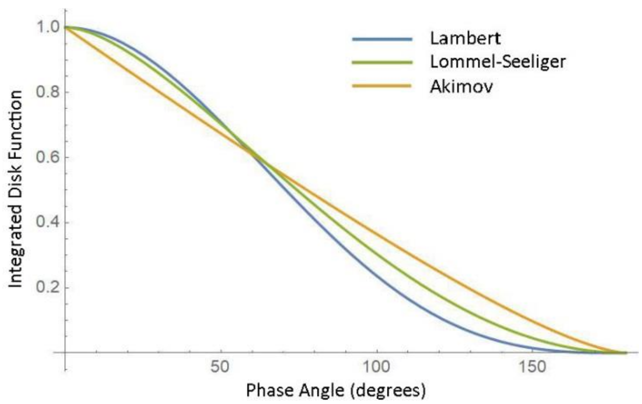


Figure 3: Integrated Disk Functions for Lambert, Lommel-Seeliger and Azimov photometric models plotted using formulas given in the appendix.

Since $\tilde{\mathrm{d}}(\alpha)$, is known, a measurement of the overall brightness, $\tilde{\mathrm{I}}(\alpha)$, of an object is a measurement of the solar phase function, $\mathrm{A}(\alpha)$. It may depend on parameters that relate to the structure and physical properties of the reflecting surface. Such models can produce a good fit to observations and may provide information on the properties the regolith, at least within the context and model's applicability for the body in question. Many phase function models, however, are simply empirical in nature.

The Opposition Surge

Figure 4 shows a fit of a semi-empirical photometric model to observations of the high albedo asteroid, 64 Angelina, for phase angles below 20°.

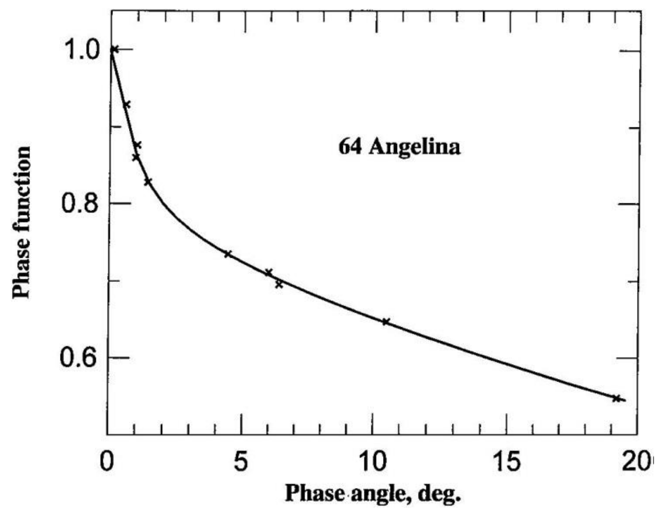


Figure 4: Fit of a modelled phase function to photometric observations of the asteroid, 64 Angelina (Shkuratov *et al.* 1999).

Note the strong uptick in the phase function near zero phase angle. This is the *opposition surge*. At small scales a rough surface consists of illuminated areas and shadows. When the light source is in the same direction as the observer the shadows disappear and the surface brightens. The effect is known as *shadow hiding*.

The other phenomenon contributing to the opposition surge is *coherent backscattering*. Near zero scattering angle the source and observer lie close to the same direction. The Helmholtz Reciprocity Principle tells us that the role of the source and observer can be reversed, and it follows that there will be two possible paths of equal optical length, one the reverse of the other, that a beam of light can follow from the source back to the observer. Light beams following these two paths interfere constructively.

From the Earth it is not possible to observe the Moon's opposition surge for scattering angles below about 1½° since the radius of the Earth's penumbral shadow and that of the Moon subtend 1¼° and ¼° respectively. If the Moon approaches within about 1½° of the anti-solar point it enters eclipse. The opposition surge can be seen potentially any time your shadow falls on a rough surface such as ploughed field. It is something to look for from an airplane window seat during final approach. A terrestrial manifestation of the phenomenon is shown in Figure 5.

Figure 5: Opposition surge in the light reflected from a field of crops viewed from a hot air balloon.

For over six years up to 2003 the USGS Robotic Lunar Observatory (ROLO)[2] operated out of Flagstaff, Arizona. Every clear night a pair of coaligned 20-cm Ritchey-Chrétien telescopes on a common mount made photometric measurements of reference stars and the Moon itself between first and last quarters. The stated aim of the project was to turn the Moon into an on-orbit calibration standard for spacecraft instrumentation, which often experience changes in responsivity from their pre-launch states and may undergo degradation in the space environment over time. The result is the ROLO Irradiance model (Kieffer and Stone 2005) plotted in Figure 6. The model consists of a function representing the Moon's *disk-equivalent reflectance*, $A_k(\alpha)$, which is an empirical fit to the observations that describes the brightness for phases between first and last quarter. The model accounts for variations due to librations and the Sun's selenographic latitude.

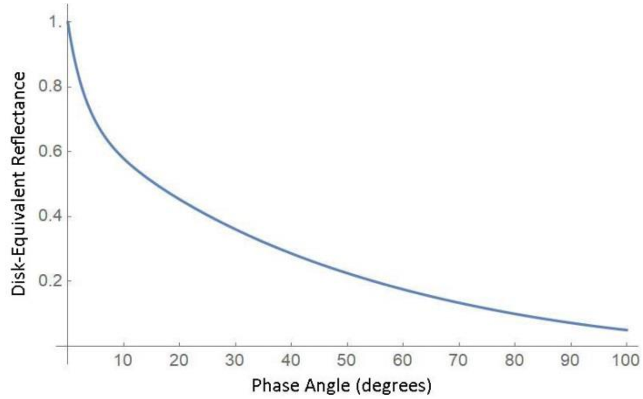


Figure 6: ROLO irradiance model disk-equivalent reflectance for the Moon plotted against the solar phase angle, α, with librations and selenographic latitude of the Sun set to zero. Values outside the range of $1.55° < \alpha < 97°$ are extrapolated. The plot has been normalized to 1 at phase angle $\alpha = 0$ for comparison with Figures 3 and 4.

The ROLO model confirms that the brightness ratio between full and quarter moon is

$$\frac{A_k(1.5°)}{A_k(90°)} = 12.0$$

as noted in the introduction.

Application to Lunar Imaging

At the time and location of Figure 7, below, the center of the Moon's disk was at selenographic latitude 0.99°S and longitude 4.95°W. The sub-solar point was 1.50°S and longitude 62.42°E giving a solar phase angle $\alpha = 65.36°$. With this information and calibrating by carefully measuring the pixel locations of prominent surface features, the brightness was adjusted, using code written in Mathematica, according to the Lommel-Seeliger disk function. At least for this phase angle this disk function gave a somewhat better result than the Azimov disk function, particularly near the poles.

The final image is a stack of 38 frames taken through a Televue NP127 using a Meade LPI-G monochrome camera. Each image covered the entire illuminated portion of the Moon. Light wavelet sharpening at the finest scale was applied using RegiStax.

The true appearance of the mare is displayed. Mare Imbrium (Sea of Rains) shows fairly uniform shading except where it is dusted with ejecta from the craters Copernicus and Aristillus.

[2] https://astrogeology.usgs.gov/moon-cal/index.php

Figure 7: Image of the Moon taken from Valhalla, NY on February 21, 2021 at 18:53 EST when the solar phase angle, α, was 65.4°. The entire illuminated portion of the Moon was captured in a single frame (not a mosaic) and the image was enhanced by applying position-dependent brightness adjustments based on the Lommel-Seeliger disk function.

There is an artefact that can be seen running parallel to the terminator. In the original image that region was very dim and therefore occupied a narrow dynamic range. When scaled up in brightness, the limited number of pixel values introduces some visible non-uniformity. It would probably have been better to combine separate images of the limb and terminator regions.

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Appendix

This appendix gives the formulas that were used to generate the images and plots in Figures 2 and 3 and perform the adjustments to the image in Figure 7. All angles are in radians. Further technical information on the Lommel-Seelinger model can be found in Muinonen and Lumme (2015) and for the Azimov model in Shkuratov et al. (1999)[3].

[3] Note that this reference has a typographical error in equation (31) in the argument of one of its Gamma functions. This error has been corrected in Table 1.

Rather than writing photometric disk functions in terms of incident and emergent angles it is convenient to specify them in terms of the photometric latitude, b, and longitude, l and the phase angle, α. For the Moon the photometric latitude and longitude are just like their selenographic equivalents except that the origin is at the center of the Moon's disk as seen by the observer and the Sun sits at zero latitude directly over the photometric equator. The phase angle corresponds to the phase of the Moon and is 0° at full Moon and 180° at new Moon.

Let (x, y) be Cartesian coordinates of a point measured from an origin at the center of a disk of radius r. Provided $x^2 + y^2 \le r^2$ the corresponding photometric latitude and longitude are

$$b = \sin^{-1}\left(\frac{y}{r}\right); \quad l = \sin^{-1}\left(\frac{x}{\sqrt{r^2 - y^2}}\right).$$

These are then used in the formula for the disk function, d(α, b, l), which returns the pixel value at that point. The longitude, l, should fall in the range

$$(\alpha - \pi/2) \le l \le \pi/2$$

otherwise it does not lie on the illuminated part of surface and the pixel value is zero.

The results in the second and third columns of the table are related by

$$\tilde{\mathrm{d}}(\alpha) = k\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos b\, db \int_{\alpha-\frac{\pi}{2}}^{\frac{\pi}{2}} dl\, \mathrm{d}(\alpha, b, l) \cos\varepsilon$$

where k is a normalization factor such that $\tilde{\mathrm{d}}(0) = 1$, and ε is the emergent angle with $\cos\varepsilon = \cos b \cos l$.

Model	**Disk Function** $\mathrm{d}(\alpha, b, l)$	**Integrated Disk Function** $\tilde{\mathrm{d}}(\alpha)$
Lambert	$\cos b \cos(l - \alpha) \times \begin{cases} 1 & ; \alpha \le \frac{\pi}{2} \\ \csc\alpha & ; \alpha > \frac{\pi}{2} \end{cases}$	$\frac{1}{\pi}\left(\sin\alpha + (\pi - \alpha)\cos\alpha\right)$
Lommel-Seeliger	$\frac{\cos(l - \alpha)}{\cos(l - \alpha) + \cos l}$	$1 + \sin\frac{\alpha}{2} \tan\frac{\alpha}{2} \ln\tan\frac{\alpha}{4}$
Akimov	$\frac{\pi - \alpha}{\pi} \cos\left[\frac{\pi}{\pi - \alpha}\left(l - \frac{\alpha}{2}\right)\right] \frac{(\cos b)^{\alpha/(\pi-\alpha)}}{\cos l}$	$\frac{2}{\sqrt{\pi}}\left(1 - \frac{\alpha}{\pi}\right) \frac{\Gamma\left(\frac{3\pi - 2\alpha}{2(\pi - \alpha)}\right)}{\Gamma\left(\frac{4\pi - 3\alpha}{2(\pi - \alpha)}\right)}$

Table 1: Photometric disk functions and their integrals for the models discussed in the text. The disk functions have been normalized to have a maximum value on the visible surface of 1. The integrated disk functions are normalized to 1 at α = 0.

Much Ado about Nothing, or, Who Stole Messier's Space? Larry Faltz

It was only with the invention of the telescope that astronomers realized that the universe contained objects besides stars and planets, excepting perhaps for the confused view of the ancients about comets and meteors and the misconception that the Milky Way was something utterly fantastic (Hera's milk, spilled embers from a fire, a river, the abdomen of a dolphin, a canoe). Galileo dispelled that fantasy in 1610, but it wasn't until better lenses became available in the 18th century that non-stellar objects and peculiar congeries of stars began to be noticed, catalogued and wondered about.

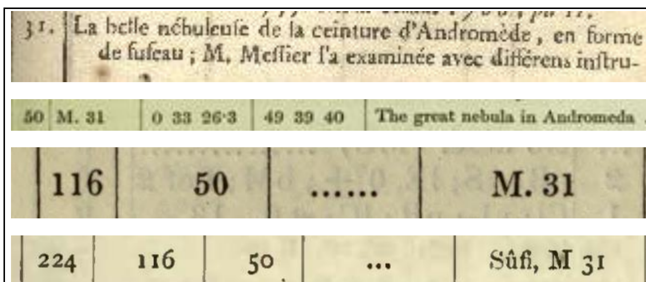
Charles Messier's catalogue of celestial entities that astronomers must not confuse with comets was the first major collection to be published, and it is still the primer of deep sky observing for amateur astronomers. Messier's initial list of 45 objects was published in 1771, and a larger list arrived in 1781 (the version on line is a republication from 1784)[1]. This list contains 103 objects, but it was expanded to 110 by later astronomers who found the seven additional objects in Messier's notes. In 1786, William Herschel published a list of 1,000 objects,[2] none of which were in the Messier catalogue. Although Herschel was apparently inspired to look for deep sky objects by Messier, he doesn't mention Messier by name in his publication, instead noting

> In the same manner these nebulae have been compared with those that are contained in the two volumes of the *Connaissance des Temps*, for the years 1783 and 1784, of which none have been inserted in this catalogue. It was indeed easy enough to distinguish the nebulae of that excellent collection from those of mine which in several places are very near them: The quantity of good light in my telescope having enabled me, even in bright moonlight nights, to see occasionally some of the most feeble of the former, when the latter could not by any means be perceived.

William's son John Herschel, a major figure of 19th century British science, compiled a catalogue of 2,306 northern hemisphere objects in 1833.[3] He then went to South Africa, observed several thousand southern hemisphere objects and included them in his *General Catalog* of 5,079 objects in 1864.[4]. All the additional objects were nebulas and clusters that neither his father nor Messier could have seen from their observatories in England and Paris, respectively. The *General Catalogue* begins

> The study of the Nebulae has, within the last quarter of a century, attracted much more of the attention of observers than heretofore as well on account of the singularity of the phenomena presented by many of these objects, as in consequence of the increased optical power of the telescopes which the skill and industry of modern inventors and artists have placed within their reach.

This catalogue was the basis for John Louis Emil Dreyer's 1888 *New General Catalogue*[5] with 7,830 objects and its extension, the two *Index Catalogues* (1895 and 1908), containing 5,386 objects between them. All but four of the Messier objects appear in the NGC. [6]As an example of the entries, the "Andromeda Nebula" is object 31 in Messier, 50 in John Herschel's 1833 catalogue, 116 in the *General Catalogue* and 224 in the *New General Catalogue*.


31. La belle nébuleuſe de la ceinture d'Andromède, en forme de fuſeau ; M. Meſſier l'a examinée avec différens inſtru-

50	M. 31	0 33 26·3	49 39 40	The great nebula in Andromeda ..

116	50	......	M. 31

224	116	50	...	Sûfi, M 31

Original catalogue entries for the Andromeda Nebula, from top to bottom: Messier's 1781 catalogue (edition of 1784, decription runs to the next page), John Herschel's 1833 catalogue, his *General Catalogue* (1864) and Dreyer's *New General Catalogue* (1888). Dreyer, a historian of astronomy as well as noted observer, often credited the discoverer, here the famous Arabic astronomer 'Abd al-Rahman al-Sufi. In each catalog, additional columns to the right of those shown here give coordinates and other information.

In both of John Herschel's catalogues the Messier's objects are cross-referenced as "M." with a space before the object number, as in "M. 31." The *New General Catalogue* is explicitly a continuation of John

[1] https://www.messier.seds.org/xtra/Mcat/mcat1781.html
[2] https://tinyurl.com/HerschelCat
[3] https://is.gd/jhersh1833

[4] https://tinyurl.com/JHGenCat
[5] https://tinyurl.com/NGCOrig
[6] Missing are the Small Sagittarius Star Cloud (M24), the Pleiades (M45), the double star M40, and M72, an asterism of four stars.

Herschel's work (he had died in 1871). It dispenses with the period, but keeps the space, as in "M 31." In modern published versions of the NGC, cross references to Messier objects are usually without spaces, as in "M31". In everything else I've read for the past several decades, the space-less abbreviation has been consistently observed, while an NGC reference always has a space between letters and number. The difference is a little peculiar and maybe trivial enough to be tantalizing. Where did it come from?

I started tracking down the answer by looking in the NASA Style Guide[7] to see whether they offered any direction, but there was nothing about it among a vast number of seemingly arbitrary grammatical rules. For example, if you want to use the abbreviation NACA (for the National Advisory Committee for Aeronautics, NASA's predecessor), for which I think most of us would say "nakkah," the NASA style guide tells us to "Treat it as though saying each letter. Hence, 'the NACA,' 'an NACA program'." In other words, don't ever say "nakkah," say "N-A-C-A." But one says "NASA" as a word, "nassah", and we would write "a NASA program" and not "an NASA program" (as if spoken as "N-A-S-A"), so where does this difference come from? Just somebody's idea of being grammatically righteous, I suppose.

But maybe NASA (not "the N-A-S-A") has some unpublished information, so I wrote to the Style Guide office about it. I got the following response from Sarah LeClaire, Contract Archivist in the History Program Office at NASA headquarters in Washington.

> Karen Northon, who knows the NASA Style Guide inside and out, did a little research and came up with the info below. We really don't have an answer and it's not our call, but take this for what it's worth!
>
> The NGC was compiled in the 1880s by John Louis Emil Dreyer. The IC (of which there are two parts – IC I and IC II) is the first major update to the NGC, which is probably why they use the same format. There's also a Revised NGC (RNGC), which also uses the same format. The Messier Catalogue, compiled by the French astronomer Charles Messier, uses a different nomenclature, e.g., Messier 1 or M1.
>
> So, my guess is the format of each was a preference of the creator of the catalogue.

I thanked Ms. LeClaire and Ms. Northon for their responses, but I felt obligated to point out that they can't be correct. Messier never referred to his objects with the prefix "Messier" or the abbreviation "M." In the original NGC catalogue, the objects are listed in a table with heading for the number column simply labeled "No." And we know that the space after "M" was there in the GC and NGC.

So I reached out to my friend J. Kelly Beatty, Senior Editor of *Sky & Telescope*. He replied that,

> In principle, both M objects and NGC objects should include a space. I think the current usage dichotomy isn't so much a formality as it is subjectivity. Here's some crude speculation on my part:
>
> Let's take NGC first: since any NGC object has a three- or four-digit ID, then it's easy to imagine that NGC5128 creates visual confusion and is easier to pick up as NGC 5128 (or just "5128," because these 3/4-digit designations are pretty much unique to NGC objects).
>
> Messier objects: I found that the very earliest issues of S&T did indeed include a space (e.g. M 45), and personally I try to always use "Messier" at least once when I'm writing about such objects. That said, I think the VCC (visual-confusion coefficient) is low when M is appended directly to the object's digits. Visually it's easy to subliminally ignore the M in M101. And, typographically, using a concatenated ID limits the chance of having M appear on one line of text and 101 on the next. S&T doesn't allow splitting of either M or NGC designations, BTW.[8]

The argument that we need the space because NGC objects have three or four digits is only partially true, of course: nine of them have one digit and 90 have two. And if it's good for 3- and 4-digit objects, what about the eleven 3-digit Messier objects? But the elimination of the space during *S&T*'s publication history (it was founded in 1941 with the merger of *The Sky* and *The Telescope*) was intriguing. When, and by whom? And what about other astronomy publications?

Kelly forwarded my email to Roger Sinnott, a Senior Contributing Editor at *S&T* who has been associated with magazine since 1971. I had first met Roger at the 1991 Hawaii solar eclipse (we were clouded out) and we renewed our acquaintance at a NEAF about ten years ago. I told him about my first probes into the professional astronomy literature using the NASA

[7] https://www.history.nasa.gov/styleguide.html

[8] *SkyWAAtch* also tries to adhere to this convention.

ADS web site. Roger had some inside information that proved quite valuable. He wrote:

> I have the original *S&T* Style Book, a handwritten log that was in use from the 1940s through about 1978. Most of the entries were made by Charlie Federer, but in later years Bill Shawcross and Joe Ashbrook contributed to it. Oddly enough, it doesn't have anything to say about the style to be used with M and NGC objects!
>
> However, this old style book does have an entry made on Sept. 27, 1977, and signed by both Joe and Bill: "3C 273 (not 3C-273). JA + WES Sept. 27, 1977 (to get us in step with the rest of the world!)."[9]
>
> I found that, in *The Sky*, spaces were used after both M and NGC. As Kelly noted, Charlie carried this over into the earliest issues of *S&T*, starting with the November 1941 issue. But I just discovered that the switch was made in the May 1942 issue, page 20, without any fanfare, in a News Note titled "The Spiral M33." The article begins with "Messier 33, a beautiful spiral galaxy …." Later, in the in the same text, M33 is used. In subsequent issues, Leland S. Copeland also closed up Messier designations in his deep-sky column, although before May 1942 he had used a space.

The only way to trace the history of the space and to try to find its earliest usage was to look at the literature prior to S&T's adoption. The NASA ADS web site has hundreds of thousands of articles and references. One has to be somewhat arbitrary about searching. I figured a good place to start was with Vesto Slipher and Edwin Hubble. Slipher, the discoverer of the galactic red shift, used the space in both title and text in "The spectrum and velocity of the nebula N.G.C. 1068 (M 77)" in the *Lowell Observatory Bulletin* of 1917. It looked at first that Hubble always used the space (and I looked at almost all of his papers on ADS) until I found "The Nature of the Nebulae" in the 1938 *Proceedings of the Astronomical Society of the Pacific*, in which he writes "Except for our own stellar system, the most conspicuous member of the local group is the great spiral in Andromeda, M31, with its two satellites, M32 and NGC 205." But the following year, in his "New Stellar Systems in Sculptor and Fornax," also in the *Publications of the Astronomical Society of the Pacific*, the space reappears in references to "M 81" and "M 82." Whether removing the space in the 1938 article was the author's or the editor's decision, it didn't stick. In fact, the ASP continued to use the space for at least another twenty years. In the *Astronomical Society of the Pacific Leaflet 341* (June 1957), Gerard de Vaucouleurs's article "Classifying Galaxies" still had a space after the M.

But even earlier than this, in his extremely influential book *The Realm of The Nebulae* (Yale University Press, 1936),[10] for which I assume Hubble read the final galleys, the space is not present. He even writes at one point "The great spiral in Triangulum, for instance, is Messier No. 33, or M33." Was the great Hubble the inventor of this convention?

Well, no. I found a paper, "The periods and light curves of the variables in Messier 3" by Jesse Greenstein in the *Astronomische Nachrichten*, volume 257, issue 19, p. 301, which has two space-less M abbreviations. The data-laden paper, in English, ends with a note that it is from "Rutherfurd Observatory of Columbia University, New York, May 1935."

I scanned for more articles in *Astronomische Nachrichten,* trying out a few English and German search terms: "Messier," "galaxy," "nebel," "spiralnebel," and "sternhaufen." The earliest paper with a space-less M that I found in that journal was a 1932 paper, "Helligkeits messungen im Sternhaufen Messier 52 (NGC 7654)" (Brightness measurements in the star cluster Messier 52) by E. Jost, which uses "M52" in the text. Now I had the bit between the teeth, so to speak, and I spot-checked papers from the 1920s and 1930s by E. E. Barnard, Harlow Shapley and Heber Curtis, including "The Scale of the Universe," in the May 1921 *Bulletin of the National Research Council,* summarizing the Great Debate of 1920. The section written by Shapley spells out "Messier" each time. Curtis abbreviates, not only using the space but also the period that Dreyer had removed ("M. 13").

Then I found an unsigned note in the April 15, 1920 issue of *Nature*, "The Parallaxes of Globular Clusters and Spiral Nebulae." It referenced "M3" and "M13."

I didn't find any space-less M's in the many papers between 1900 and 1920 that I checked. The general custom in that era was either to spell out "Messier" every time, to use a common name

[9] I found dashes for Messier objects in Willy Ley's 1963 book *Watchers of the Skies*, where Andromeda is "M-31" for example. I have not seen this usage for Messier objects anywhere else.

[10] https://tinyurl.com/HubbleRealmNeb

(Andromeda Nebula, Beehive) or to employ a space (and frequently the period until the 1920s) after M.[11] So I thought I had nailed it in the 1920 *Nature* note.

But then, thinking I was done, while doing research for an image we'll publish next month, I found a space-less "M11" in a report by E. E. Barnard in an 1894 issue of *Popular Astronomy.*[12] Other articles by Barnard in this journal, earlier and later, used a space, so it wasn't a formal editorial change. This was the absolute earliest space-less M I could find.

How did the space-less M come to dominate? The *Astrophysical Journal* (ApJ), founded in 1895 by Hale and Keeler, is considered the top American astronomy journal. ApJ seems to have started eliminating the space in the 1940s, after *S&T*. I checked a dozen papers in that journal from the early 1940s. If an abbreviation was used, the space was present. However, in "Star Counts in the Andromeda Nebula" by Seyfert and Nassau in March 1945 the galaxy was referred to as "M31." The space still made an occasional appearance until about 1950, after which it disappeared.

Other journals removed the space at a slower pace. The *Monthly Notices of the Royal Astronomical Society* came around at the end of the 1950s, as did *Nature*, but *Science* had an article with the space as late as 1975 and *Astronomy and Astrophysics* continued to employ the space well into the late 1980s.

That the elimination of the space had not completely settled in astronomy brains can be seen in an abstract for a meeting presentation by Gerard de Vaucouleurs, whose many papers in the late 1950s in ApJ were consistently space-less. Prior to the Internet and standardized electronic text formats, if you were presenting a paper or poster at a scientific conference you had to submit a typewritten abstract on a form with a ruled box into which your entire text had to fit, so that it could be photocopied into the program. When I did biochemistry research at the NIH in the mid-1970s, we spent hours wordsmithing our abstracts to pack in as much information as possible in the precious real estate. De Vaucouleurs was invited to give a talk at the 166th AAS meeting in 1985. He submitted his abstract for the program book with the title "The Supernova of 1885 in M 31." The spaced "M 31" also occurs twice in the body of the abstract. We have to assume that his secretary typed this submission, but I'm sure he reviewed it and approved it before it went out. I suspect his brain never registered the space, one way or the other.

There are many scanned 19th and 20th century astronomy books on line at archive.org. Neither Messier's name nor his catalogue are mentioned by authors such as Flammarion, Proctor or Newcomb, or by Hale in *The New Heavens* (1922), which surprised me. H. Spencer Jones's *General Astronomy* (1922) refers to "M 101." Sir James Jeans's *The Universe Around Us* (1930) also uses the space. *Olcott's Field Book of the Skies* (1954), edited by the Mayalls, uses the space, but it's gone in the Mayalls's 1959 *The Sky Observer's Guide: a Handbook for Amateur Astronomers*. It's also absent in my copy of Isaac Asimov's *The Universe: From Flat Earth to Quasar* (1966) and in Burnham's *Celestial Handbook* (1966).

Are there any formal style guides that address the Messier abbreviation? As Roger Sinnott noted, the space-less M wasn't specified in the *S&T* materials even though it was adopted and consistently implemented. The American Astronomical Society, which now publishes ApJ, has a style guide on line. It began during the editorial tenure of S. Chandrasekhar (1952–1971). It's silent about this detail.[13] In 1989, the International Astronomical Union published a Style Manual, which is on-line as a scanned pdf.[14] No specific mention of M, but the introduction refers to something called "The First Dictionary of the Nomenclature of Celestial Objects," from 1983 with a supplement from 1986. So I tracked these documents down on ADS. They list hundreds of abbreviations from the myriad celestial object catalogues that modern astronomy has accumulated since Messier.

The First Dictionary has a table that lists the abbreviation, the source, the accepted enumeration and a reference, but it doesn't set a rule for usage in text. For Messier, the table simply says M in one column and NNN (placeholder for the numbers; use the number of N's you need) in a different column. There's a note that says that the acronym "might be considered as defined once and for all." The refer-

[11] I saw "51 M." in an article by Lewis Swift in 1893, the only time I encountered this form of the abbreviation. He also used "M. 20", "91 of M. Cat." and "51 Messier" in various notes.
[12] https://is.gd/Barn94. This discovery forced a bit of a re-write!

[13] https://tinyurl.com/AASGde
[14] https://www.iau.org/static/publications/stylemanual1989.pdf

ence given is to the Messier publication of 1784 in the version published by Sky Publishing in 1978, *The Messier Album* by Mallas and Kreimer. The *Album* does not use a space. A subsequent article that discusses some of the problems with the "First Dictionary," "Tricks and traps in astronomical nomenclature" refers to "M31," but a formal rule is not elaborated.

The IAU refers to the CDS/SIMBAD astronomical database web site at the University of Strasbourg. If you enter the term "Messier" in their Dictionary of Nomenclature of Celestial Objects, a screen appears that says that the format for a Messier object is M NNN, that is, with a space. You can search for a Messier object in SIMBAD inputting M NNN or MNNN: it will take either. It will also accept inputs for NGC objects with or without a space and will even accept just an "N," as in N224 for M31.

As additional evidence that the elimination of the space is not complete throughout astronomy-dom, Wolfgang Steinicke's extremely thorough 2019 update of the NGC, *Revised New General Catalogue,* is available as an Excel file. It cross-references Messier objects with a space.[15] The 1973 *Revised NGC* by Sulentic and Tifft,[16] upon which Steinicke's revision was based, does not use the space, so in a sense Steinicke has retrogressed!

Did I find, in E.E. Barnard's 1894 article, the absolutely earliest space-less use of "M" for a Messier object? Possibly not, but I must be close. ADS catalogues 119,773 articles from 1850-1893. One can only spot-check. I found nothing earlier. After scanning hundreds of articles, your eyes blur and you just have to stop. For all I know, it was only a typesetting error. All I can say is that the first evidence I found of a space-less M was in 1894, and it was very rare until the 1940s, when S&T and then ApJ adopted it.

"Language, like other important patterns of human behavior, slowly but constantly evolves from older forms into newer ones." So begins the introduction to the *American Heritage Dictionary of the English Language.* Such evolution can even affect minor elements of scientific annotation. The *New General Catalogue* dropped the period after M, but it persisted in the literature for several decades. Then beginning sometime after the turn of the 20th century, the space after M slowly disappeared. Perhaps the increasing frequency of explicit references to Messier object numbers rather than their common names in the proliferating astronomical literature, both professional and popular, earned M a distinction because of the priority and value of the list. The period was already gone, so the space was next. No single person or journal established a rule. Adoption was most likely subliminal, like almost all changes in language.

I think Kelly Beatty is correct that reducing "visual confusion" has everything to do with the now universal acceptance of the space-less M. That conclusion is reinforced by the lack of space in abbreviations for the two other single-letter catalogues in frequent use, Caldwell (Sir Patrick Moore's 109-object extension of the Messier catalogue, published in *Sky & Telescope* in 1995) and Barnard (E.E. Barnard's catalogue of 182 dark nebulae, published in 1919 and extended to 369 objects in 1927). The Caldwell catalogue came out after the space-less M was fully established, so a space-less C was expected. In any case, it's not an abbreviation we would see in professional journals, since all the Caldwell objects except one have NGC or IC designations (the exception is the Coalsack). It was harder to track down the more infrequently used B for Barnard. I found "B 10" and "B 7" along with "M 78" in a 1960 article[17] in *Publications of the Astronomical Society of the Pacific*, but as we've already noted, ASP was late to dance. The space-less B seems to have evolved in parallel with the space-less M (for example, Burnham refers to the Horsehead in Orion as "B33" in 1966).

There were undoubtedly many exchanges among authors, editors and proofreaders during the years of transition, all lost to history. The space is gone in text but persists on-line in at least one important table, Steinicke's NGC Excel file. Considering the specificity of the NASA Style Guide regarding writing terms such as "NACA" and the lengthy and detailed "First Dictionary," I'm surprised we don't find a formal rule somewhere in an authoritative astronomy reference about formatting M for Messier in text. To me, that's a funny omission in a field as precise, organized, data-rich and historically connected as astronomy. ■

[15] The zipped catalog is at http://www.klima-luft.de/steinicke/.
[16] https://cdsarc.unistra.fr/ftp/VII/1B/catalog.dat
[17] http://articles.adsabs.harvard.edu/pdf/1960PASP...72...10J

Images by Members

The Crescent Nebula NGC 6888 in by Rick Bria

Almost as wide in its largest dimension than the full Moon and nominally magnitude 8.8, the Crescent Nebula's low surface brightness makes it a difficult visual object without large aperture and the right filter. The central star HD 192163 (also called WR 136) is magnitude 7.7. It's a Wolf-Rayet star. WR stars are very luminous and have intense stellar winds. They shed mass with velocities as high as 3,000 km/sec. The material smashes into the gas that was previously ejected from the star's outer atmosphere when it was a red giant.

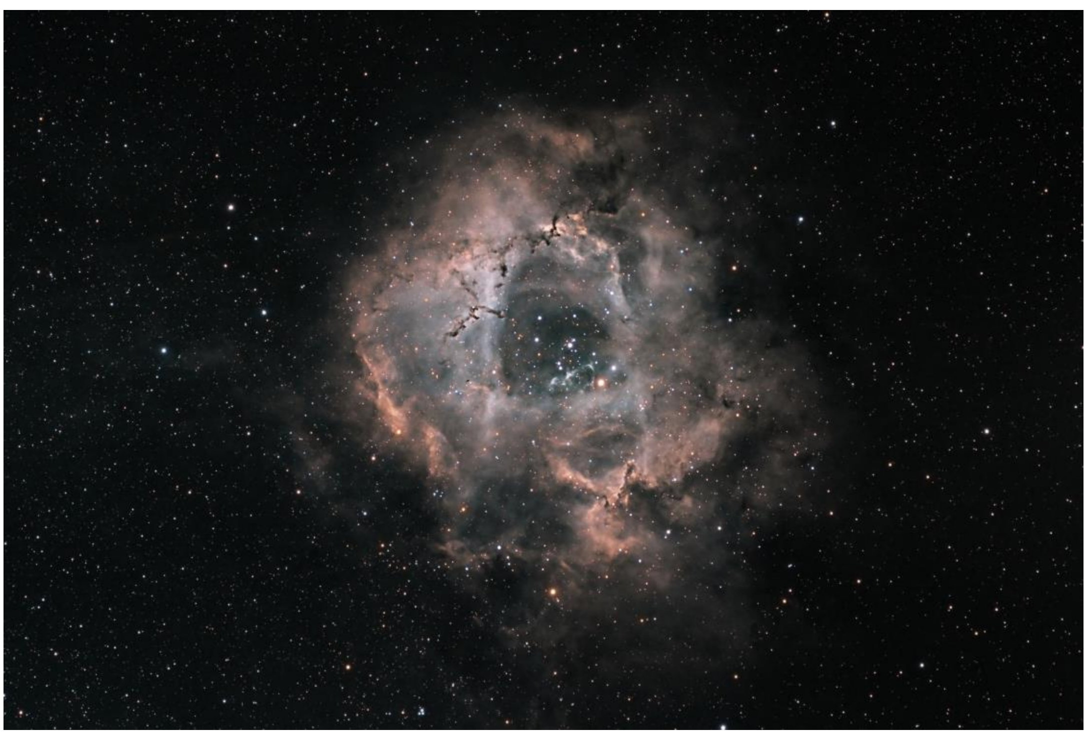
Data from the Infrared Astronomy Satellite (IRAS) satellite published in 1995 (https://is.gd/IRASN6888) shows that there is a second, much larger bubble of material that surrounds the nebula, the detritus of material ejected when HD 192163 was a younger, hot O star. The extent of the larger bubble is 1.7° X 1.4° while the nebula itself, as seen above, is 18 X 12 arc-minutes.

Narrow-band image (hydrogen=red, oxygen=blue) with 14" PlaneWave telescope and STX16803 camera at the Mary Aloysia Hardey Observatory, Sacred Heart School, Greenwich.

Rose and Rosette by Steve Bellavia

The open cluster NGC 7789 in Cassiopeia was discovered by Caroline Herschel in 1783 and is often called **Caroline's Rose**. It shines at an integrated magnitude of 6.7. Distance 7,600 llight years. The field is about three degrees in width.

Steve used two telescopes for the image of Caroline's Rose, a 90-mm Borg f/4 fluorite doublet and a 51-mm William Optics Redcat 51 mm f/4.9 Petzval refractor.



The **Rosette Nebula,** Caldwell 49, is the "official astronomical object" of the state of Oklahoma, having been so designated in a law passed by the legislature and signed by the governor in 2019!
The emission nebula is composed of several separately named NGC objects. The young (5 million years) open cluster 2244 sits in its center. Mag 9, distance 5,200 LY.

The Rosette was imaged with the William Optics Redcat. Field about three degrees across.

Bright Cloud and Dark Cloud by Steve Bellavia

The **Seagull Nebula** (IC 2177) is on the Monoceros-Canis Major border. This HII region is excited by radiation from the Be star HD 53367. The area has wider areas of nebulosity and also includes open clusters NGC 2335 and NGC 2343 (outside the field of this image). This field shown is about 1½ degrees across.

This was the first light image with the TS-Optics Photoline 72mm f/6 FPL-53/Lanthanum doublet APO refractor on December 26, 2020. Monochrome camera, hydrogen alpha and OIII filters.

Kutner's Cloud

450 LY away in Taurus, this dark nebula is composed of interstellar gas and dust. It's also known as Bernard 18 (B18). Within it are Lynds Bright Nebula (LBN) 800, 812, and Lynds Dark Nebula (LDN) 1529, 1531, 1533 and 1535. The field is also about 1½ degrees.

Another image with the -Optics Photoline 72mm f/6 FPL-53/Lanthanum doublet APO refractor. January 6-7, 2021. Monochrome camera, RGB and IR/UV cut filters.

The Bubble Nebula and Friends by Leandro Bento

An area of five square degrees in Cassiopeia and Cepheus shows, diagonally from upper left to lower right, the open cluster M52 (NGC 7654), the Bubble Nebula (NGC 7635) and the large nebula Sharpless 2-157 (sometimes called the Lobster Claw). The bubble is created by stellar winds from the hot O star SAO 20575 within it. On the upper right is NGC 7358, a site of very active star formation. At a distance of 9,000 light years, NGC 7358 contains the largest known protostar, NGC 7538 S, which is embedded in a compact elliptical core of mass between 85 and 115 $M_{\odot}$. The star is surrounded by a rotating accretion disk, which powers a hot molecular outflow approximately perpendicular to the rotating disk. (https://arxiv.org/PS_cache/arxiv/pdf/1004/1004.0643v1.pdf).

Leandro made this image in October 2020 at Ward Pound Ridge Reservation with his usual set-up: William Optics RedCat 51-mm f/4.9 refractor, iOptron SkyGuider Pro and ZWO ASI533mc Pro camera.

Research Highlight of the Month

Galdeano, D, Pereyra, L, Duplancic, D, et. al., Overdensity of VVV galaxies behind the Galactic bulge, arXiv:2103.01865 (posted March 2, 2021, accepted for publication in *Astronomy & Astrophysics*)

The Zone of Avoidance (ZOA), also known as the Zone of Galactic Obscuration, (both of which sounds like something out of StarTrek), is the area of the sky in which objects behind the Milky Way can't be viewed with any confidence. Not only are the objects obscured by dust and stars, there is enough foreground dust to attenuate radiation from local stars, making them easily confused with more distant galaxies. About 20% of the sky is in the ZOA, and optical galaxy catalogues are incomplete as a result. Infrared radiation can penetrate the dust to some extent. The Great Attractor, presumably an enormous galaxy cluster that is pulling other galaxies toward it (while they are still expanding with the Hubble Flow) lies somewhere in the ZOA.

A group of Argentinian and Chilean astronomers looked for optical counterparts of one small area of the VISTA Variables in Vıa Lactea near-infrared survey (VVV for short). This survey utilizes the 4.1-meter ESO VISTA (Visual and Infrared Survey Telescope for Astronomy) instrument on Cerro Paranal in Chile. The group selected an area at the edge of the Milky Way's central bulge, and was able to find 624 galaxy candidates, of which 607 had never been detected before. They were distributed in a manner that suggested an "overdense region," a concentration of galaxies along a strand of the cosmic web often at fairly high red shifts. They were able to separate galaxy candidates from the general distribution of Milky Way stellar sources presenting clearly redder colors. These would be older stars in the central zones of our galaxy.

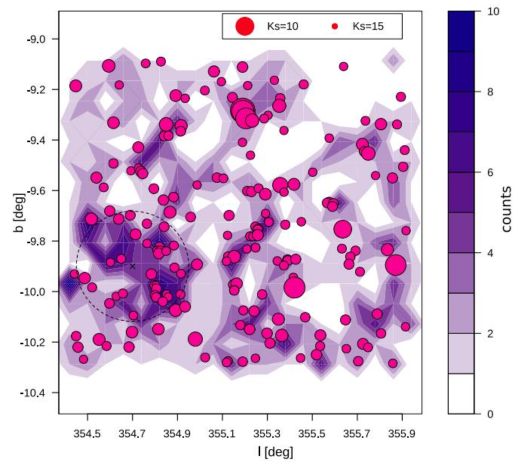


Fig. 12. Density map of confirmed galaxies. Red dots are the brightest galaxies. The dashed circle, 15 arcmin radius, lower left, highlights the overdensity region.

Fig. 5: False-colour J(blue), H(green), and Ks(red) images of eight galaxy candidates detected in the tile b204, as examples. The two more-luminous galaxies in the left panels were also catalogued by 2MASX: 2MASX J18164505-3747263 (left-top) and 2MASX J18172135-3721158 (left-bottom). The length of each box side is 30 arcsec.

Member & Club Equipment for Sale

Item	Description	Asking price	Name/Email
Orion Alt-Az mount	Orion alt-azimuth mount on 4 foot adjustable aluminum tripod. Slow motions on both axes. Accessory tray. Suitable for a small refractor or spotting scope.	**FREE**	Robin Stuart robinstuart@earthlink.net
Ritchey-Chretien 6 inch astrograph	Astro-Tech f/9 imaging instrument. Barely used with original shipping box. These scopes list at $399. See https://is.gd/RCf9scope.	$200	John Paladini jpaladin01@verizon.net
Denkmeier 60-mm spectrum 60 upgrade (OTA) for PST	Unscrew the 40-mm PST tube and screw in the upgrade, and now your PST is a 60-mm solar scope. It does work with newer PST's. Original price $599	$240	John Paladini jpaladin01@verizon.net
ADM R100 Tube Rings	Pair of 100 mm adjustable rings with large Delrin-tipped thumb screws. Fits tubes 70-90 mm. You supply the dovetail. Like new condition, no scratches. See them on the ADS site at https://tinyurl.com/ADM-R100. List $80.	$50	Larry Faltz lfaltzmd@gmail.com
Losmandy G11G mount	Pristine condition observatory-quality yet portable German equatorial mount. 2018 model. 60 lb. weight capacity. Heavy-duty tripod. Includes brand-new Gemini II go-to system new in box (never mounted). See http://losmandy.com/g-11.html.	$2500	Dante Torrese torresedds@optonline.net
Explore Scientific 40 mm eyepiece	68° field of view. Argon-purged, waterproof, 2" eyepiece. New in original packaging, only used once. Lists for $389.	$340	Greg Borrelly gregborrelly@gmail.com
Atco 60-mm f/15.1 refractor	A classic Japanese refractor from the early 1970s. Obtained from the original owner about five years ago. It had been used only a few times, then stored for 40+ years. Current owner used it maybe seven times. Very good condition. Comes with three eyepieces and a 1.25" eyepiece adaptor star diagonal. Straight-through finder. Equatorial mount with slow-motion adjustment knobs (screws). Wooden tripod, metal tube. Everything is original.	$150	Robert Lewis lewis@bway.net

Want to list something for sale in the next issue of the WAA newsletter? Send the description and asking price to ads@westchesterastronomers.org. Member submissions only. Please offer only serious and useful astronomy equipment. WAA reserves the right not to list items we think are not of value to members.

Buying and selling items is at your own risk. WAA is not responsible for the satisfaction of the buyer or seller. Commercial listings are not accepted. Items must be the property of the member or WAA. WAA takes no responsibility for the condition or value of the item, or for the accuracy of any description. We expect, but cannot guarantee, that descriptions are accurate. Items are subject to prior sale. WAA is not a party to any sale unless the equipment belongs to WAA (and will be so identified). Sales of WAA equipment are final. *Caveat emptor!*

Answers to Telescopes in Movies Quiz on page 7 (along with listing a few of the more accomplished directors and some scope notes)

1: Ann Todd and Ralph Richardson in *The Sound Barrier* (1952). (dir David Lean).

2: Russell Crowe in *Master and Commander: The Far Side of the World* (2003).

3: Errol Flynn in *Captain Blood* (1935). (dir Michael Curtiz).

4: Clark Gable in *Mutiny on the Bounty* (1935).

5: Bill Murray in *Scrooged* (1988).*

6: Gregory Peck (left), Robert Beatty (with telescope), James Kenney in *Captain Horatio Hornblower R.N.* (1951) (dir Raoul Walsh).

7: Richard Carlson and Barbara Rush in *It Came from Outer Space* (1953).

8: Craig Wasson (left) and Gregg Henry in *Body Double* (1984) with Questar. (dir Brian dePalma).

9: Colin Blakely as Dr. Watson (left), Genevieve Page (behind window) and Robert Stephens as Holmes in *The Secret Life of Sherlock Holmes* (1970) (dir Billy Wilder).

10: Bruce Dern in *Silent Running* (1972) with an orange tube Celestron SCT.

11: Arthur Franz, Helena Carter and Jimmy Hunt in *Invaders from Mars* (1953).

12: Hunter Carson in *Invaders from Mars* (1986).

13: Jerry Lewis in *Way Way Out* (1966) with a Questar (and Anita Ekberg). There are quite a few telescopes shown in this otherwise forgettable movie.

14: Julie Andrews in *10* (1979) (dir Blake Edwards).

15: Jason Lee and Jennifer Love Hewitt in *Heartbreakers* (2001). Looks like a 102-mm Celestron.

16: Charles Bronson in *The Mechanic* (1972) with a Questar.

17: Kiefer Sutherland, Charlotte Gainsbourg and Kirsten Dunst in *Melancholia* (2011). A Meade LX-75?

18: Lon Chaney Jr. in *The Wolf Man* (1941).

19: Ewan McGregor (his back, anyway) in *Down with Love* (2003) with an original (1960s) blue and white 10" Celestron Pacific!

20: C. Henry Gordon (L) and Robert Barret in *The Charge of the Light Brigade* (1936). (dir Michael Curtiz).

21: Will Hannah (L) and Patrick Dempsey in *Can't Buy Me Love* (1987) with a Meade Schmidt-Newtonian.

22: Leelee Sobieski, Mike O'Malley and Elijah Wood in *Deep Impact* (1998). The two equatorial mounts ought to be pointing in the same direction, but they're not.

23: Angelina Jolie in *Lara Croft, Tomb Raider* (2001).

24: George Kennedy in *The Eiger Sanction* (1975) (dir Clint Eastwood).

25: Rex Harrison in *The Ghost and Mrs Muir* (1947) (dir Joseph L. Mankiewicz).

26: Unknown actors in *Flight to Mars* (1951).

27: George Dzundza and Chuck Aspegren in *The Deer Hunter* (1978) (dir Michael Cimino).

28: Leslie Bibb in *Iron Man* (2008) with Celestron CPC800.

29: James Cromwell in *Star Trek: First Contact* (1996) with Meade LX200.

30: Stellan Skarsgård and Kat Dennings in *Thor* (2011) with Celestron CPC (dir Kenneth Branagh).

31: But Lancaster in *Local Hero (*1983).

32: Jamyang Jamtsho Wangchuk in *Seven Years in Tibet (*1997).

33: Roman Polanski in *The Fearless Vampire Killers* (1967) (dir Roman Polanski).

34: Vincent Price in *The Raven* (1963) (dir Roger Corman).

35: George Sanders, Debra Paget, Joseph Cotton, Don Dubbins in *From the Earth to the Moon* (1958).

36: Richard Dreyfuss in *Close Encounters of the Third Kind* (1977). Orange tube Celestron SCT. (dir Steven Spielberg).

37: Arjun Singh Panam and Joshua Ford in *Cosmos* (2019). A recent British movie about three amateur astronomers, with a very clever ending.

38: Chris Lowell and Allison Janney in *Brightest Star* (2013).

39: Rachel Weisz, Joanna Cassidy and Keanu Reeves in *Chain Reaction* (1996). The scope is a 6" wooden-tube Henry Fitz refractor made before 1863 for Trinity College, now owned by telescope collector John Briggs of Magdalena, NM (near the VLA).

40: Steve Martin, Shelley Duvall and Darryl Hannah in *Roxanne* (1987)

* The building across from Bill Murray is 515 Madison Ave (53rd St.). The antenna (only the base is seen) was the original transmitter for NY's channel 5 TV, and was used by Columbia's WKCR-FM from 1958-1977. I climbed on it once when I was an undergraduate and worked at WKCR. It's still up there.

Thanks to a Cloudy Nights thread for some of the film references. And to John Paladini for the original idea of quizzing me with movie images of telescopes. The images are from CloudyNights, imdb.com or copied from my DVR.

LF