Robert Frost and the Leonid Meteor Shower

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Abstract. Robert Frost (1874–1963) enjoyed a lifelong interest in astronomy, and a number of his works refer to astronomical phenomena and to our propensity to look for meaning in them. Frost's poem 'A Loose Mountain (Telescopic)', published in 1942, provides an apt—and humorous—description of the Leonid meteor shower. Aspects of the poem suggest Frost was inspired by the complex history of the Leonids, and in particular, the failure of the Leonid 'storm' to appear as predicted in 1899. Like the old constellation myths, the poem tells a story that helps us understand and remember a night-sky phenomenon. It also invites us to think about our relationship to the night sky, and warns us, with references to Milton's *Paradise Lost*, against losing our connection with it.

Art-science connections

Art and science intersect in many ways, including art that is inspired by science, and science inspired by works of art.[1] Chemist and poet Roald Hoffmann has talked about the similarities between his twin interests. Poetry and science, he says, both value economy and intensity:

> They're acts of creation that are accomplished with craftsmanship, with an intensity, a concentration, a detachment, an economy of statement. […] There is an aesthetic at work, there is a search for understanding. There is a valuation of complexity and simplicity, of symmetry, and asymmetry. There is an act of communication, of speaking to others.[2]

Frost's 'A Loose Mountain (Telescopic)', published in 1942 in the collection *A Witness Tree*, embodies the intensity and craftsmanship

[1] Toni Feder, 'Mingling Art and Science Opens Minds', *Physics Today* 74 no. 4 (April 2021): pp 24–29.
[2] Lewis Wolpert and Alison Richards, *Passionate Minds: The Inner World of Scientists* (Oxford: Oxford University Press, 1997), p.23.

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Hoffman speaks about in an artful depiction of the Leonid meteor shower.[3] As we will see, the rhythm and rhyme scheme support the poem's content. The discerning reader may also notice a reference to the Leonid shower's notable history. At the same time, the poem is more than a compendium of scientific facts. It asks us to think about our own, and humanity's, engagement with the natural world, and whether our attachment to artificial light, and all that goes along with it in the modern world, is a form of hubris.

Frost's astronomical background

Frost's attention to astronomy is documented in scholarly biographies and in a number of books and articles.[4] The poet acknowledged his 'bias' toward that branch of science in a 1960 interview with the literary critic Richard Poirier. Poirier noted Frost's evident interest in science. 'Yes', Frost said, 'you're influenced by the science of your time, aren't you? Somebody noticed that all through my book there's astronomy… Many poems, I can name twenty that have astronomy in them'.[5] Poems making use of astronomical themes or images include 'The Star-Splitter', 'The Literate Farmer and the Planet Venus', and 'Skeptic'.[6]

While in high school in Lawrence, Massachusetts, Frost read a popular astronomy book that had come into the family's possession in the early 1880s, when the family lived in California.[7] This was Richard Proctor's *Our Place Among Infinities,* first published in 1874. Frost, wishing to see for himself Saturn and other objects Proctor described, acquired a small telescope. He evidently hoped for better views, for, as editor of his high school newspaper, he advocated for the school's purchasing a large instrument.[8]

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[3] Robert Frost, *Collected Poems, Prose, & Plays*, eds Richard Poirer and Mark Richardson (New York: The Library of America, 1995), p.327.

[4] Lawrance Thompson, *Robert Frost: The Early Years* (New York: Holt, Rinehart and Winston, 1966); Virginia Smith, *A Scientific Companion to Robert Frost* (Clemson, SC: Clemson University Press, 2018); Charles Maynard, 'Robert Frost: Poet of the Night', *Sky and Telescope* (June 1992): pp.692–693.

[5] Robert Frost, 'The Art of Poetry No. 2', *Paris Review* 24 (Summer-Fall 1960): pp.89–120.

[6] Frost, *Collected Poems, Prose, & Plays*, pp.166, 335, 353.

[7] Thompson, *Robert Frost: The Early Years*, p.508 (note 8).

[8] Robert Frost, untitled editorial in the Lawrence, MA *High School Bulletin* of Dec. 1891, p.4. See Edward C. Lathem and Lawrance Thompson, *Robert Frost and the Lawrence, Massachusetts, 'High School Bulletin*' (New York: The Grolier Club, 1966), p.72.

Frost attended Harvard University from the fall of 1897 to the spring of 1899, during which time he studied Latin and Greek and audited a class on geology. He abandoned his university education in part to support his growing family, and by October 1900 was farming on a property near Derry, New Hampshire. We know from his daughter Lesley's notebooks, and from her reminiscences, that he maintained an interest in astronomy during this time. He observed auroral displays and sunspots with Lesley, taught her to recognize stars and constellations, and explained the motions of the sun and moon in the sky.[9] Later still, we know that Frost avidly read *Scientific American* magazine and popular science books by authors such as Arthur S. Eddington.[10] Some of Frost's poems refer to new discoveries and theories in astronomy, such as measurements of the temperature and size of stars and the expansion of the universe.

The Leonid meteor shower

The meteor shower that inspired 'A Loose Mountain (Telescopic)' was that known as the Leonid. To understand this allusion in the poem it is necessary to know a little about the astronomical phenomenon of meteor showers.

Meteors are bright streaks of light in the night sky caused by the passage through Earth's atmosphere of particles of cosmic dust (meteoroids). Surprisingly, given their brilliant trails, these meteoric particles generally are only about the size of a grain of sand. On any given night, an observer in a dark location might see a few meteors per hour (two to eight or so). These are 'sporadic' meteors.

Meteor 'showers' involve a higher rate of meteors than those that fall sporadically. A number of named, regularly-occurring meteor showers may be seen each year, including the well-known Perseid shower in August. A typical meteor shower such as the Leonid or Draconid yields ten or twenty meteors per hour; the Perseid shower often delights observers with about one hundred per hour.[11]

Frost's poem is explicitly about the most prominent mid-November shower. It begins, 'Did you stay up last night (the Magi did) / To see the star shower known as Leonid?' One peculiarity of the Leonid shower is

[9] Lesley Frost, *New Hampshire's Child: The Derry Journals of Lesley Frost* (Albany, NY: SUNY Press, 1969); Lesley Lee Francis, *The Frost Family's Adventures in Poetry: Sheer Morning Gladness at the Brim* (Columbia, MO: University of Missouri Press, 1994).

[10] Smith, *A Scientific Companion to Robert Frost*, pp.4 and pp.285–316.

[11] https://www.imo.net/resources/calendar/ [accessed 26 January 2023].

that, while it normally exhibits ten to fifteen or so meteors per hour, the rate at which the meteors fall can occasionally be exceptionally high, up to about ten per *second*. We refer to this as a meteor 'storm.'

Long-exposure photographs of meteor showers which capture a half-dozen or more on one view show the meteors' streaks of light radiating from one point on the sky. This is how the meteor showers are named; in the case of the Leonid showers, that point from which the meteors seem to come coincides with the direction of the constellation Leo.

As Frost knew from Proctor's book, the cause of the regular meteor showers is Earth's encounter with the ice-and-dust crumbs shed by a comet as it hurtles through space. These cometary crumbs become the meteors. In the case of the Leonid shower, the object generating the trail of debris in space is comet 55P/Tempel-Tuttle. Figure 1 shows the orbit of Earth around the Sun, and a segment of the orbit of the comet around the Sun. The comet leaves behind a trail of cometary debris—particles which themselves continue to orbit the sun. The intersection of these two orbital paths is where Earth travels in mid-November. Each year, then, Earth encounters the cometary dust that produces the regular Leonid shower. The enhanced Leonid storms occur about every thirty-three years, when the trail of cometary debris is freshly repopulated by the approximately contemporaneous passage of the comet, which has a 33-year orbital period.

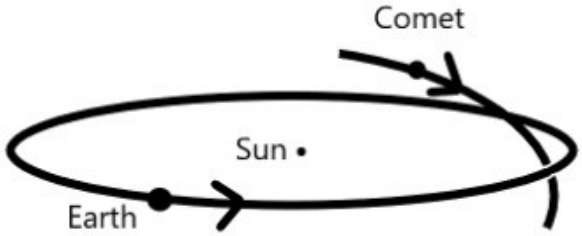

Figure 1. Earth is shown orbiting the Sun anticlockwise, making one orbit each year. (The orbits of other planets are not shown.) The comet 55P/Tempel-Tuttle—on an elongated orbit that takes it above and below the plane of the ecliptic in which Earth orbits—plunges through the inner solar system once every 33 years, leaving fragments of itself in its wake. The comet's debris-strewn orbital path crosses the orbital path of Earth at the position Earth occupies in mid-November. Earth's yearly encounter with the remnants of the comet is what gives rise to the annual Leonid meteor shower. When the comet and Earth reach the intersection point around the same time, the meteor shower may turn into a meteor 'storm.' Copyright attribution: Sketch by the author, made using Microsoft's Paint 3D software.

The poem

'A Loose Mountain (Telescopic)' appears in *A Witness Tree* near a similarly titled poem, 'A Considerable Speck (Microscopic)'.[12] Both are droll in tone; in 'A Considerable Speck (Microscopic)', the narrator, about to put pen to paper, startles a tiny 'living mite' whose intelligence he comes to ponder.

The speaker of 'A Loose Mountain (Telescopic)', uses colloquial and humorous language to deliver a kind of old-timer's lesson on the nature of the Leonid meteor shower. He begins with a question directed to the listener or reader:

> Did you stay up last night (the Magi did)
> To see the star shower known as Leonid
> That once a year by hand or apparatus
> Is so mysteriously pelted at us?

The speaker refers to the meteor shower un-scientifically as a star shower, and amusingly says the meteors are being 'pelted at us'. The rhyme of Leonid and 'Magi did' is playful, too. There aren't many words that sound like Leonid. Frost could have chosen a poetic form or a placement of 'Leonid' within the line that would have avoided the need to find a rhyme or near-rhyme for this difficult word. Instead, he highlights his dexterity. It makes sense to invoke the Magi—albeit off-handedly and parenthetically—in a poem about watching the night sky, and the reference to these biblical priests alerts us to the possibility of a moral theme to the poem.

The shower, the speaker continues, consists of 'fiery puffs of dust and pebbles', a description which emphasizes the small and evanescent nature of the cometary debris burning up in our atmosphere. The speaker suggests in a tongue-in-cheek way that the shower has a meaning: it is 'no doubt directed at our heads as rebels / In having taken artificial light / Against the ancient sovereignty of night'.

Despite the humour, there's a note of menace in this view that the meteors are 'directed at our heads.' And by referring to us as rebels, the narrator calls up associations with Milton's *Paradise Lost*, a text Frost and members of his generation commonly read in high school. In this epic poem about the biblical story of Adam and Eve and a larger confrontation between God and Satan, Satan and his followers are frequently referred to

[12] Frost, *Collected Poems, Prose, & Plays*, pp.324–5.

with such phrases as 'rebel Angels' or a 'Godless crew rebellious'.[13] And although it is not their sin or chief defining feature, these rebels too take artificial light. In their preparations for a great battle with God's warriors, they build a kind of weapons factory where 'starry lamps… yielded light / As from a sky'.[14]

Elaborating on this battle theme, the poem's speaker suggests that although the meteoric ashes falling to earth are minuscule, the 'fusillade' of such particles has its origin as a projectile in weapon of war: The meteoritic outburst 'constitutes a hint / That the loose mountain lately seen to glint / In sunlight near us in momentous swing / Is something in a Balearic sling'.

The Balearic sling was perfected by ancient inhabitants of the Balearic Islands in the western Mediterranean. The Balearic slingers, who are mentioned by chroniclers of Roman wars, would load a slingstone into a pocket attached to two cords, whirl the stone in a horizontal circular motion above their heads (similar to the motion of an object orbiting the sun), and let go of one cord such that the slingstone flew off at a tangent to the circle.[15] The slinger here is the 'heartless and enormous Outer Black', a personification of the forces at work in the unseen depths of the space.

The paradoxical-sounding 'loose mountain' of the poem and its title can be taken several ways. Frost's peers would have been reminded of *Paradise Lost* again, for in Book VI, God's troops extract hills or mountains from the celestial landscape and hurl them at their foes:

> From their foundations loosening to and fro,
> They plucked the seated hills, with all their load,
> Rocks, waters, woods, and, by the shaggy tops
> Uplifting, bore them in their hands. Amaze,
> Be sure, and terror, seized the rebel host,
> When coming towards them so dread they saw
> The bottom of the mountains upward turned […][16]

More literally the loose mountain consists of particles of cometary debris coursing through the solar system prior to their impinging on Earth. The

[13] John Milton, *Paradise Lost* (New York: Crowell, c. 1892), pp.20, 53, 99, 119, 124, 148, 158.
[14] Milton, *Paradise Lost*, p.59.
[15] Edward C. Echols, 'The Ancient Slinger', *The Classical Weekly* 43, no. 15 (27 Mar. 1950): pp.227–30 (p.228).
[16] Milton, *Paradise Lost*, p.158.

poem's narrator tells us the loose mountain was 'lately seen to glint / In sunlight near us'. While individual particles that produce meteors can't be seen, a cloud of such dusty debris particles (not restricted to Leonid meteor producers) orbits the sun and reflects sunlight. This phenomenon is called the zodiacal light, and its glow is in the shape of a cone or mountain extending above the horizon. The zodiacal light was quite commonly seen in the United States and elsewhere through the 1960s, when light pollution was less intrusive than it is now.[17] At least one astro-photographer, Alan Dyer, has captured the zodiacal light at the same time as a Leonid meteor shower, lending credence to the poem's association between shower and glinting cloud.[18]

In the poem's final lines, we learn that the mysterious actor behind the meteor shower is trying to time it so we'll notice it. The cosmic slinger pauses momentarily in winding up the ammunition in his sling. He feels 'irresolution in his back / About when best to have us in our orbit / So we won't simply take it and absorb it'. The message is clear: although the meteor shower may not harm us, it is a warning about the power of the solar system to deliver a potentially destructive rain of impacts, and a call to pay attention to this yearly reminder in the form of the Leonid shower.

Some commentators have suggested that the poem's warning is a sign of Frost's prescience: the poem was published in 1942, before scientists generally accepted that Earth had sustained large impacts from space.[19] While it is true that this idea was not widely accepted until the 1950s, well-reasoned arguments for Earth impacts circulated as early as 1920.[20]

Both the poem's rhyme scheme and its rhythmic structure highlight the line about the slinger's 'irresolution in his back'—a line which, as I'll argue, relates to the history of the Leonids.

The poet draws our attention by setting up a pattern and then altering it. The rhyme scheme, for the first eighteen lines, is simple: it consists of rhyming couplets, such as pebbles/rebels and light/night. At the nineteenth line, where we expect a new rhyme following 'Black/Zodiac', we hear

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[17] J. Kelly Beatty, 'Stalking the "False Dawn"', *Sky & Telescope* (Sep. 2013): p.55.
[18] Alan Dyer, personal communication.
[19] Nancy Lewis Tuten and John Zubizarreta, eds, *The Robert Frost Encyclopedia* (Westport, CT: Greenwood Press, 2001) p.224.
[20] See, e.g., George P. Merrill, 'A Retrospective View of the Origin of Meteor Crater, Arizona', *Publications of the Astronomical Society of the Pacific* 32, no. 189 (Oct. 1920): pp. 259–64; Matt Walton, 'The Arizona Meteor Crater Controversy', *Journal of the Royal Astronomical Society of Canada* 53 (1959): pp. 162–71.

instead a third line rhyming with the previous two: 'But from irresolution in his back'. This is the only triplet in the poem.

Similarly, we hear mostly iambic pentameter (five repetitions of unstressed-stressed syllables) through the poem's first eighteen lines. Appropriately, this rhythmic pattern becomes perfectly regular at the lines about the Outer Black whirling his ammunition in 'momentous swing', the way a slinger setting a stone going in a circle above his head would give it one or more well-timed impulses. Then, abruptly, this regularity is perturbed (to use an astronomical term for a change in the motion of an object due to gravitational forces). 'But from irresolution in his back' scans more like trochee-dactyl-dactyl-iamb. The poem ends, not with an image of a hail of meteors as the slinger completes his action, but with a conditional statement about our possible obliviousness to the meteor shower:

> … the loose mountain lately seen to glint
> In sunlight near us in momentous swing
> Is something in a Balearic sling
> The heartless and enormous Outer Black
> Is still withholding in the Zodiac
> But from irresolution in his back
> About when best to have us in our orbit,
> So we won't simply take it and absorb it.

Thus, using both rhyme and rhythm, the poet underscores something important about the timing of the meteor shower and the uncertainty around it.

Expectations for the Leonid shower in 1899

The slinger's hesitancy as he winds up his missiles, to which our attention has been drawn, does make sense in light of the history of the Leonids and the difficulty astronomers had of predicting the appearance of the shower. This difficulty became apparent in 1899.

The Leonids were expected to 'storm' that year, putting on a dazzling display. At least a year in advance, while Frost was still in Cambridge, newspaper columns devoted to monthly sky-watching highlights began alerting the public to the fact that the 1899 shower would be exceptional. In November 1899, as the date of the shower approached, details emerged of American astronomers' preparations to attempt to record the shower photographically and visually. A *Boston Evening Transcript* article noted

that Harvard astronomers would not be the only ones witnessing the event, as there was 'a good deal of popular interest' in the forthcoming event.[21] In Cambridge, at the request of a local school committee, Harvard College Observatory Director Edward Pickering had agreed to advise the central office of the municipal fire alarm system if the meteor shower, which was not expected to get going until after midnight, was 'good enough to make it worthwhile' getting up. The office would then sound a special alarm of bells and whistles.[22]

As many of the news articles explained, the expectation of a noteworthy Leonid storm was based on a historical pattern of meteor storms, which in turn was related to the association between the meteors and the comet. In November 1833, before the Leonids were identified as a recurring event, observers had witnessed an astonishing display. Theologian Joseph Harvey Waggoner recounted, as an adult, his memories of seeing the meteors when he was about thirteen years old:

> In the eastern part of Pennsylvania, where I was, they began to fall about eleven o'clock in the evening, increasing in frequency until, in a few hours, they became a perfect shower. They could no more be counted than one can count the fast falling flakes of snow in a hard storm. They continued to fall without any diminution of numbers until the dawn of day obscured them. And when the approaching light of the sun paled them in the east, they still covered the western sky. And when the spreading light obscured them in every direction, occasionally one of great brilliancy would leave its trace in the west, showing that they were still falling.[23]

Accounts such as these had fascinated Yale University astronomer Denison Olmsted. Olmsted collected a number of such reports and published them, noting that many observers had noticed that the meteors

[21] 'Shooting Stars Out Tonight', unsigned article in the *Boston Evening Transcript,* 13 Nov. 1899, p.4, column 4.
[22] 'Fire Alarm to Announce Meteors', unsigned article in the *Boston Evening Transcript*, 14 Nov. 1899, p.10 column 4.
[23] Quoted in David W. Hughes, 'The World's Most Famous Meteor Shower Picture', *Earth, Moon, and Planets* 68 (Jan. 1995): pp.311–22 (p.315).

consistently appeared to radiate from a point in the sky in the constellation Leo.[24]

In the years following Olmsted's report, astronomers came to understand the connection between regular meteor showers and the Earth's encounter with streams of cometary debris. They also connected the display of 1833 to a similarly noteworthy one recorded by several witnesses, including the explorer Alexander von Humboldt in 1799, while he was in what is now Venezuela.

By the 1860s another Yale University scholar, the mathematician Hubert Anson Newton, understood the Leonid shower phenomenon well enough to predict the return of a particularly heavy shower or storm in 1866.[25] When the Leonids returned as foretold on 13 November 1866, the show was not as spectacular as it had been in 1799 and 1833, but it was abundant enough to validate Newton's calculations. Observations of the Leonid shower between 1866 and 1868 confirmed the link between the Leonids and the trail of debris from comet 55P/Tempel-Tuttle. Writers of astronomy textbooks in Frost's era began including in their lessons the explanation of the yearly Leonids and their exceptional recurrences roughly every thirty-three years.[26] The shower for 1899 was, then, widely predicted, and expected to be grand.

The failure of the Leonids

What actually happened in the skies in 1899 was a disaster for the public's faith in the astronomers. A meteor shower did occur, but the effect was far more subdued than generally expected. Some Leonid meteors were seen, but there was no sustained blizzard of fire in the sky.

A few days after the expected peak of the meteor shower, the *New York Times* ran an article by Princeton astronomer Charles Young, headlined 'The Fiasco of the Leonid Meteors'. Young explained that the cause was basically twofold. First, the stream of cometary dust and debris is not uniform. Young likened the particles following in the comet's wake to 'an army on the march, traveling on several nearly parallel roads'. This year,

[24] Denison Olmsted, 'Observations on the Meteors of November 13, 1833', *American Journal of Science and Arts* 25 no. 2 (Jan. 1834): pp.363–411, and 26 no. 1 (Apr. 1834): pp.132–74.

[25] Hubert A. Newton, 'The original accounts of the displays in former times of the November star shower […]', *American Journal of Science* S2-37 (111) *(*May 1864): pp.377–89; continued in *American Journal of Science* S2-28 (112) (July 1864): pp.53–61.

[26] Robert S. Ball, *In Starry Realms,* 2nd edn (London: Isbister and Company, 1892).

he wrote, 'the earth may have cut through […] between two brigades, and so have failed to strike any considerable mass of the enemy, meeting only some of the stragglers which are scattered along the whole line of march'.[27]

The second reason for the Leonids' disappointing showing was that the particles originally on a course to meet Earth had been affected by the gravitational pulls not only of the Sun but also, during their trip through the solar system, of Earth, Saturn, and Jupiter. The 'disorderly procession' of particles became even more difficult to keep track of because of these expected but complex gravitational interactions.

In the years following this great failure, the Leonids continued to make their usual modest appearances, and returned with some vigour in the predicted storm year of 1932-33.[28] But in the 1930s astronomers again blamed the gravitational perturbations of the larger solar system planets, especially Jupiter, for nudging cometary dust particles out of the narrow paths where they would encounter Earth in mid-to-late November.[29] These unseen forces were spoiling the opportunity for Earth dwellers to witness the kind of fiery rains of meteors seen in 1799 and 1833.

Art and Science in 'A Loose Mountain (Telescopic)'

By 1942, when 'A Loose Mountain (Telescopic)' appeared in the collection *A Witness Tree*, professional and amateur astronomers alike were familiar with the phenomenon of the 33-year Leonid storms being disrupted by gravitational forces from distant planets. These gravitational tugs changed the timing of meteoric particles' arrival in the vicinity where Earth should have encountered them, or knocked them out of Earth's orbital path. It is fitting, then, that Frost's ode to the Leonids ends not with their fiery display but with the image of a celestial slinger pausing in target-acquiring calculation.

With these lines about the slinger's irresolution, Frost found an effective way to convey the abstract concept of the gravitational perturbations affecting the meteor shower. Any lover of sports might relate to the calculation and vacillation of one about to pitch an object at a target, and the importance of slight changes in timing. By relating the occurrence of the Leonid meteor shower to the skill of a slinger, Frost underscored how

[27] Charles A. Young, 'The Fiasco of the Leonid Meteors', *New York Times*, 26 November 1899, p.23 column 5.

[28] Peter Brown, 'The Leonid Meteor Shower: Historical Visual Observations', *Icarus* 138 (1999): pp.287–308 (p.289).

[29] James Stokely, 'Assert Jupiter Led the Leonids Astray', *New York Times*, 17 Nov. 1932, p.21 column 2.

singular the circumstances are that lead to Earth's encounter with the cometary debris trail and a spectacular display.

Frost was 68 years old at the time 'A Loose Mountain (Telescopic)' was published. As time went on, fewer people remained who, like him, could remember the great expectations for the Leonids of 1899. People of Frost's age might have heard from their elders about the stunning display of 1833 and the lesser but still exceptional one of 1866. The 1833 event was discussed and illustrated in a popular book for home study of the Bible, which was in print from 1888 to 1923.[30] The poem functions in part as a reminder to a younger audience that, once or twice every generation, there is a possibility of witnessing not just the annual spectacle of the ordinary yearly Leonids, but an awe-inspiring spectacle of silent but brilliant Leonid fireworks.

Frost died in 1963 and so missed, by just a few years, the brief but intense return of the Leonid storm in 1966. Astronomer James Young of Table Mountain Observatory in California wrote: 'The shower peaked around 4 a.m., with some 50 meteors falling per second. We all felt like we needed to put on "hard hats"! The sky was absolutely full of meteors'. Danny Ihara, who was then a student at a small college near the California-Nevada border, wrote that the Leonids streaking by reminded him of driving into a snowstorm. He added, 'I felt as if the Earth, itself, were moving through space toward the constellation Leo'.[31] One observer recalled years later, 'We turned on the radio to make sure it wasn't the apocalypse, and the announcer kept shouting and telling people to go outside and see it'.[32]

It's not necessary to know the history of the Leonids to appreciate Frost's poem and its call to pay attention to the night sky. But knowing what most amateur and professional astronomers know about the meteor shower and the way it has surprised witnesses over the past two centuries gives 'A Loose Mountain (Telescopic)' extra depth of meaning. In a mere 21 lines—a short enough poem to memorize—Frost has told a science-

[30] *Bible Readings for the Home Circle*, (Washington, DC: Review and Herald Publishing Association, 1923), pp.283, 287, 317, 321, and illustration p.323.

[31] Young's and Ihara's quotes are from 'Eye Witness Accounts of the 1966 Leonid Storm' collected by staff of NASA Ames's Leonid Multi-Instrument Aircraft Campaign and posted at https://leonid.arc.nasa.gov/1966.html [accessed 29 Jan. 2023]. I confirmed J. Young's account by email with him 29-30 Jan. 2023.

[32] David Guidos on https://www.imo.net/50-years-ago-the-1966-leonid-meteor-storm/ [accessed 30 Jan. 2023]

informed story about a piece of the sky that not only is worth keeping an eye on, but that, he tells us, we *should* keep an eye on.

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