Astronomy on Mars Hill

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'Though parted by a gulf more impassable than any sea, the telescope lets us traverse what otherwise had been barred and lands us at last above the shores we went forth to seek.'

Percival Lowell, *Mars and Its Canals* (1906)

The Lowell Observatory, 1400 West Mars Hill Road, Flagstaff, Arizona, is 100 years young. This evening I will tell you a little of its past, present and immediate future. Today the observatory remains a private institution, managed by William Lowell Putnam, the latest in a line of distinguished Trustees dating back to Percival Lowell's death in 1916. My Address will not be comprehensive, rather more of a personal travelogue, as it records my impressions during a recent visit.

Sunday July 24 1994

Tom Cave and I arrive in Flagstaff, altitude 7250 feet, after a 500-mile drive from Long Beach, California, having crossed the Mojave desert and visited the Grand Canyon en route, along Interstate Highway 66, the old Santa Fe road. There in the distance is a small rise: not a mountain but a hill dotted with trees, capped by the white wooden dome of the 24-inch (60-cm) Clark refractor and dwarfed by a distant view of the San Francisco Peaks. Our first night is cloudy; the monsoon season is starting here and the weather is unsettled. Through the kindness of Director Robert Lowell Millis and astronomer Leonard Martin we have the use of the well-appointed cabin, known as 'the Chalet', amidst the Ponderosa pines. The building's name derives from its alpine appearance, part of it originally housing a 24-inch reflector, the roof opening along its ridge against large protruding counterweights. After supper we swap astronomical stories, and Tom tells me of his previous visits here. He knew several of the resident astronomers: the two brothers Vesto Melvin Slipher (1875–1969) and Earl Charles Slipher (1883–1964), Carl Otto Lampland (1873–1951) as well as Lowell's mechanical wizard Stanley Sykes (1865–1956). On several past trips Tom had sketched Mars in the company of E.C. Slipher, but none of the present staff knew the founder himself: Percival Lowell.

Figure 1. The founder of the Lowell Observatory, Flagstaff, Arizona: Percival Lowell, 1855–1916. *Lowell Observatory photograph*

Lowell (1855–1916) was a wealthy Bostonian who had studied the family business and who had travelled extensively in Korea and Japan, and had in fact brought the first Korean Trade Mission to the USA in 1884. The story goes that upon his return from the Far East, Lowell heard of Schiaparelli's failing eyesight, and the latter's intention to stop observing Mars. Already having an interest in astronomy, Lowell resolved to carry on the observations himself. To the present staff Lowell is affectionately known as 'Uncle Percy', and his ghost is said to haunt the Observatory periodically, though we didn't see it. In 1894 Lowell sent Andrew Ellicott Douglass (1867–1962) site-testing with a 6-inch refractor. Several sites in Arizona were tried. According to a story told by Tom, although Flagstaff did have the best seeing amongst the places tried, Douglass had another reason for favouring the town: it had the best saloon bars. An apocryphal story, but perhaps a true one!

We take a walk around the observatory grounds, and pay homage to Percival Lowell in his glass and stone mausoleum, just beside the Clark. His widow Constance put up this little building at a cost of $40,000. Percival had married late in life, and although his Will made clear provision for the maintenance of his Observatory, Constance tried to grab his entire fortune for herself. A legal battle continued for the next decade, by which time a legacy of $2.3 million had been whittled down to just $1.1 million... But we are quickly brought back to the present by the squat, low pressure sodium lights which illuminate the pathways for both visitors and astronomers. From the hill, the lights of Flagstaff

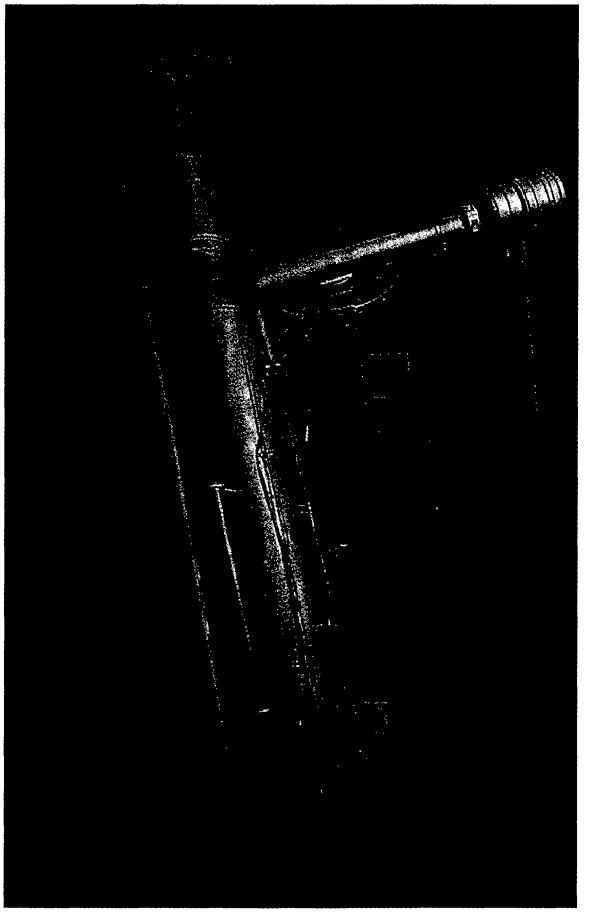

Figure 2. The 60cm (24-inch) Clark refractor, installed 1896. *Lowell Observatory photograph*

are not as bright as I had expected. Full cutoff legislation is in force for new lighting in the city. Our cabin lies amidst the 200 acres of pine trees covering the hill, and naturally trees had to be felled in the Observatory's early years. Fascinated by the information stored in the tree rings, Douglass later went on to found the science of Dendrochronology. Like the trees, he lived to a ripe old age.

Monday July 25

Leonard Martin shows us the famous 24-inch refractor, which arrived in 1896. It is still used most nights for public viewing sessions. The floor is tiered, and there is a ladder for viewing objects at low altitude, but no rising floor. Martin was working on the mapping of the Moon in the 1960s prior to the manned landings, and one of the areas he surveyed was the one finally chosen for Apollo 11. After their historic voyage it was to be at the eyepiece of the Clark refractor that the returning astronauts had their first close-up views of the Moon.

In one of the cupboards we see E.C.'s historic photographic equipment. There is more of it on display in the 'Rotunda', now named the Slipher Building, which combines an historic library with memorabilia. It was Lampland, and later E.C. Slipher who obtained, against the odds of excessive grain and low light levels, the first good ground-based photos of Mars. On this occasion it is me who has trouble with low light levels: my flashgun is of little use in the big dome!

Martin's office is in the Planetary Research Centre, a cool retreat from the hot Sun, with thick stone walls. We meet English-born astronomer (and BAA member) Ted Bowell. Bowell maintains a database containing the orbital parameters of all asteroids, which can be used to predict asteroid occultations. He has also discovered a great many of these little bodies himself. Tom elects to explore the library, where Librarian Martin Hecht makes us welcome, while I am shown the 'vault' in which are kept Lowell's and E.C.'s observing records. On a single shelf, their life's work preserved in red quarto notebooks. E.C.'s rough notes are filed, too. Slipher's office was notoriously untidy, and his notes were often so; Martin shows me a photo of how E.C.'s office looked when he was alive: I pitied the archivist who had to sort it all out! In one of his books, the late Robert S. Richardson told the story of how E.C. always kept his best Mars pictures in a cigar box on his desk, so that no-one could remove them without his knowledge from their proper place in the plate vault! E.C. had come to Flagstaff in Lowell's day, and hero-worshipped Lowell. Like Lowell's, nearly all his sketches portray fine geometrical canals, although he later preferred a natural to an artificial origin for them.

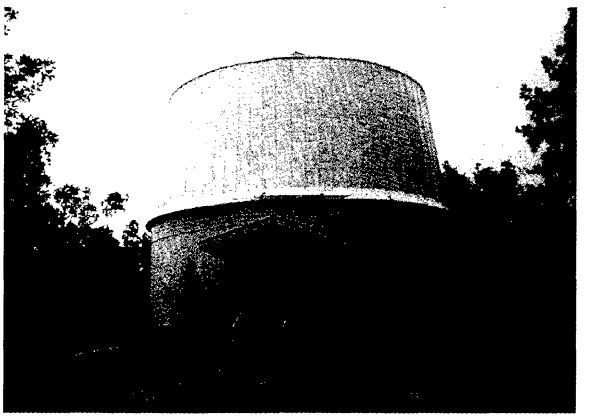

Figure 3. The dome of the 60cm Clark. *R. J. McKim*

Figure 4. Percival Lowell's mausoleum, near the Clark dome. *R. J. McKim*

It is always fascinating to get under the skin of an observer. Although he was a professional, I have no doubt that E.C. had a sense of wonderment about what he saw. He *liked* observing. He published little, and with his brother V.M. had strong business interests outside the Observatory. These outside interests grew up in the years following Lowell's death, when the Observatory v. Constance dispute was raging. On the defensive throughout the final years of Lowell's reign, the astronomers had become withdrawn and now published only what they felt could be readily defended. Turning the pages of Slipher's notes was fascinating: here is a view of the Great Red Spot covered by numerous microscopically small white flecks seen in moments of super-seeing. Here a detailed view of Mercury. And here Saturn's ring divisions in great detail. One scientific purpose in visiting Lowell Observatory is to correlate E.C.'s Mars notes with my own notes on dust storms culled from BAA work, in preparation for a final listing of terrestrially-observed dust storms. Here, some confirmation, here a BAA-suspected dust storm refuted by a better view from Arizona. And so it goes on, till I have turned every page. In E.C.'s last years, Director John Hall got him to write up his two books: *Mars – The Photographic Story,* and *Atlas of the Brighter Planets,* which contain many fine photographs.

Slipher paid a good deal of attention to the martian 'Violet Clearing', a phenomenon that he himself had discovered during the 1937 apparition. Curious how E.C. personally believed the best evidence for canals on Mars was in his photos. His later drawings sometimes show the canali less sharply; here a doubt expressed about his own eyesight, dispelled by switching to Jupiter. Had he begun to shake off the yoke of Lowell's ideas? But he never became a 'soft-pencil' observer. Whatever the case, if Slipher had not died of a heart attack soon after retiring in 1964, his realisation of the true nature of the martian surface as revealed by *Mariner 4* the following year, must surely have killed him. Slipher's superb images will long remain his monument.

Like its counterpart at Meudon Observatory, the Planetary Research Centre holds a unique collection of planetary images, duplicates of historical photos from elsewhere and images from the International Planetary Patrol. From 1954 onwards, E.C. had been instrumental in fostering international cooperation in the observation of the planets. The building was built from NASA funds in the 1960s.

It is late afternoon when we tire of our work and drive down to the town for dinner. Martin recommends a Mexican place, and an astronomers' guide to the best eating places was given to participants in Lowell's Centenary conference this June. At 8pm the sky is clouded over, but this has not deterred the visitors, several hundred of whom arrive. Most are on vacation, just passing through Flagstaff. They get to see the Steele Visitors' Centre, then queue outside the 24-inch to view a double star or nebula. The Centre is a modern building opened this year, with many working models covering all aspects of astronomy and optics, and also has some historical exhibits. Tonight the visitors must be content with a look at the Clark's silvery tube. Later, we are

Figure 5. The historic observatory gates. *R. J. McKim*

only a little more fortunate, a gap in the cloud bringing Leonard Martin in to open up for us. We see Albireo in near-perfect seeing, good enough to demonstrate the optical excellence of the Clark. Tom glimpses the central star in M57. Clouds still cover Saturn and the Moon, and Jupiter is too low. The Clark is a pleasure to use, but the ropework used to open the dome shutter seems more suited to a sailing ship! The dome is now designated a National Monument.

Tuesday July 26

We begin the day with a tour of Oak Creek Canyon, very scenic and much to be recommended, more so than Meteor Crater perhaps. Its weathered red sandstone creates spectacular vistas and photo-opportunities. In the early days, 'Uncle Percy' would bring the Observatory staff on trips such as this a couple of times a year.

After lunch we stop by the Slipher Building to see the historical displays. One can blink the Pluto discovery plates, and see historical letters and photos, Mars globes and photographic equipment. All very impressive. In the corridor we meet Director Robert Millis, who has kindly given us the use of rooms in the cabin on the hill. Millis came to Lowell in 1967, and has been Director since 1989. Back in 1977 he was a member of the Kuiper Airborne Observatory team that discovered the rings of Uranus from a stellar occultation predicted by our own Gordon Taylor. Millis and other

Figure 6. The 'rotunda' or Slipher building. *Lowell Observatory photograph*

Figure 7. V. M. Slipher with the spectrograph on the 60cm Clark. *Lowell Observatory photograph.*

Figure 8. E. C. Slipher at the eyepiece. C. O. Lampland stands at the left. *Lowell Observatory photograph*

Lowell observers have also worked on the structure of the atmosphere of Pluto and on the shapes and sizes of asteroids, all by means of the stellar occultation method. We return to the library for the rest of the day.

The evening is clear. Before the visitors arrive, the Clark is opened to view Jupiter. Days earlier Tom and I (together with several hundred other members of the public) had been at Mount Wilson on July 16, the night of the impact of the first fragment from Comet Shoemaker–Levy 9, and later had some fine visual and CCD views of the complex dark impact scars as they peppered the planet. We had used telescopes from 15 to 45cm aperture. Through the 24-inch (60cm) OG the nearly black spots and rings are well-marked, with some of the darker material already starting to redistribute itself around the planet. Happily the Shoemakers themselves are here tonight, and we meet Gene as he steps down from the eyepiece, suitably excited about the whole thing. I make a rapid sketch of the southern hemisphere, but there is no time to draw the rest. Much later, when the visitors have all gone, Brian Skiff kindly stays up with us to view Saturn, which some of the other staff also come in to see. Saturn is really too low, but the pallor of Cassini's division on the acutely open rings is striking enough. Seeing here can be very good, but apparently it can also be ruined by the presence of the San Francisco Peaks.

Naked eye astronomy is not to be forgotten here. There, just over the trees, is the characteristic 'teapot' shape of Sagittarius, the centre of our own Milky Way galaxy. Over there, the tail of Scorpius. We are at latitude 35° north, some 20° south of Great Britain. Time to reflect that it was on this spot in 1912, with a brand new spectroscope purchased by Lowell, that V.M. Slipher first measured the radial velocities of the closer galaxies. He found that the Andromeda Nebula was moving towards the Sun at 300 km per second, the highest velocity then measured for any astronomical object. Other galaxies showed a redshift and were receding from the Solar System. In 1914, V.M. even managed to measure some of their rotational rates. They could no longer be thought of as nascent Solar Systems within our own Milky Way, but must represent more distant galaxies in their own right. Later these findings were interpreted by Edwin Hubble in terms of the expansion of the Universe.

A thought strikes me: it was in 1911, just one year before Slipher's first results, that Ernest Rutherford had interpreted the results of certain experiments made in his laboratory in England by H. Geiger and E. Marsden, concerning the scattering of alpha particles by metal foils. It was through this work that it was found that almost all the mass of an atom is concentrated in a tiny volume of space, the nucleus, around which the electrons orbit like planets about a star. But if Rutherford was shocked by the new revelations of Inner Space, astronomers were equally shocked by Outer Space, and all that it implied.

Wednesday July 27

An early morning walk before breakfast, followed by a photographic spree, watched with curiosity by the local birds and squirrels. On the road down from the Chalet, near the workshops, is the sunken (and empty) dome of the 42-inch reflector, that was never very easy to use. Lampland had regarded it as his personal telescope and did important work on the infrared emission from planets, opening the way to measuring their temperatures. The mirror was accidentally broken years later in an attempt to convert it into a Cassegrain. Further ahead, the low Sun illuminates the blue glass of the mausoleum at just the right angle, and I take a

Figure 9. Clyde Tombaugh, discoverer of Pluto, at work at the blink microscope. *Lowell Observatory photograph*

Figure 10. An aerial photograph of Anderson Mesa, Lowell Observatory's dark-sky substation. *Courtesy Lowell Observatory and the Peter Rosenthal Collection*

panoramic view which includes the Clark dome. Lowell's old 'Baronial Mansion', a rambling property near the Clark, is long gone, having been removed as a potential fire-risk. There are several other working 'scopes on the hill besides the Clark, but it is the largest. Near the Rotunda, the 'Pluto Walk' starts, its signs comprising a scale model of the Solar System ending 350 feet later at the dome in which the 13-inch Cogshall camera used to reside. This telescope can now be seen in the Visitors' Centre. The name of the planet found by Clyde Tombaugh in 1930 under V.M. Slipher's supervision happily starts with Lowell's initials, PL, for it was Lowell's brilliant mathematical work and predictions that led to the search. Years later, Henry Giclas would use the thousands of search plates in conjunction with more modern ones to conduct a stellar proper motion survey, in which 12,000 nearby and high velocity stars were identified and catalogued. Many of the reminiscences of this Lowell astronomer – who joined the staff in 1931 – can be found in the excellent book by trustee William Lowell Putnam, *The Explorers of Mars Hill.*

After a final morning's work in the archives, Leonard Martin drives us to Anderson Mesa. This is Lowell's substation, opened in the 'sixties, with several large domes at this dark site on National Forest land some 10 miles SE of Flagstaff. We view the impressive Perkins 74-inch reflector, on its Warner and Swasey mounting. It is easy to forget that Lowell Observatory is a thoroughly modern institution, and although much of its research is still devoted to a study of the Solar System, a great deal of work is of an astrophysical character. Next we meet astronomer Nat White to tour the observatory's most ambitious project yet: the Navy Prototype Optical Interferometer, under construction by the Naval Research Laboratory and the Naval Observatory, Washington DC in contract with Lowell Observatory. The total construction cost will be of the order of $15 million. The Anderson Mesa astronomers are justifiably proud of it. It is one of the most impressive things in Arizona – the Grand Canyon included! Tom Cave, whose former company Cave Optical made over 50,000 telescopes, is equally impressed. An interferometer works by forming an interference pattern of light and dark areas, and this pattern is interpreted by computer to yield an image of the object. An interference pattern is produced by combining two beams of light from two separate mirrors: the further apart they are, the higher will be the resolving power, but so too will be the technical difficulties involved in ensuring that the paths travelled by each beam are exactly the same.

The NPOI comprises a Y-shaped array of plane mirrors on rigid piers, and the means to direct the light beams under high vacuum to an optical laboratory where the beams are combined. Operations will be directed from a separate control building because vibrations caused by footsteps in the optical laboratory would be troublesome. Each arm of the array is 34 metres long, but under Phase II of the construction this will be increased to 251 metres. Eighteen piers provide imaging and four perform astrometric functions. Considerable technical difficulties are being overcome, and preliminary tests were due a few weeks after our visit. The combination of the light from the telescope arms effectively leads to the same resolving power as a telescope of several tens of metres aperture. When complete, it should beat the resolving power of the 10-metre Keck telescope (the world's largest) by a factor of 44! This puts it into the sub-milliarcsecond resolution range, although its effective field of view will be below one arcsecond. It will be used to follow the pulsations of the smaller Mira variables, to measure the sizes and shapes of stars, and to search for starspots on other stars. The NPOI will also look for periodic oscillations in the proper motions of stars due to the presence of planetary systems. This last aspect was the most exciting for me, for it will be orders of magnitude more sensitive than existing astrometric techniques, and could indirectly detect quite small planetary bodies.

As we contemplate our final evening on Mars Hill, where so many momentous discoveries have been made, I wonder what Lowell himself would have made of the new techniques and equipment? Of the Optical Interferometer I have no doubt that he would have been fascinated. The chance to know something of the planets circling *other* stars... ? Yes, he would have approved, and he also liked to use the latest equipment, if possible the best available. Here are Lowell's own words, describing the planets and stars slowly appearing in the dusk, from *The Evolution of Worlds.* Imagine, if you will, the observer waiting quietly within the dome of the 24-inch refractor, peering up through the open shutters. Here we see so clearly Lowell's poetic fascination with the subject, perhaps his real reason for founding his Observatory: 'In the hushed quiet of the gloaming Earth holds her breath, prescient of a revelation to come. Then as the half-light deepens, the universe appears. One by one the company of heaven stand forth to human sight. Venus first in all her glory brightens amid the dying splendor of the west, growing in lustre as her setting fades. From mid-heaven the Moon lets fall a sheen of silvery light, the ghostly mantle of her ghostlike self, over the silent Earth. Eastward Jupiter, like some great lantern of the system's central sweep, swings upward from the twilight bow to take possession of the night. Beyond lies Saturn, or Uranus perchance dim with distance, measuring still greater span. All in order in their

several place the noble cortège of the Sun is exposed to view, seen now by the courtesy of his withdrawal, backgrounded against the immensity of space. Great worlds, these separate attendants, and yet as nothings in the void where stare the silent stars, huge suns themselves with retinues unseen, so vast the distances 'twixt us and them. No less a revelation awaits the opening of the shutters of the mind. If night discloses glimpses of the great beyond, knowledge invests it with a meaning unfolding and extending as acquaintance grows. Sight is human; insight seems divine. To know these points of light for other worlds themselves, worlds the telescope approaches as the years advance, while study reconstructs their past and visions forth their future, is to be made free of the heritage of heaven.'

If Lowell was wrong in his interpretation of his martian observations, he was also the founder of the science of comparative planetology. His calculations led to the discovery of Pluto, and it was at his Observatory that evidence for the expanding Universe was first obtained. He has left us with several wonderful books, written in his free, popular style. And as we remember his Observatory's work since 1894, we look forward to another century of great discoveries from his successors on Mars Hill.

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I have not tried to compile a complete list. Here are some sources, all of which give more detail about the history of the Lowell Observatory and its astronomers, or their interactions with others, especially 'Uncle Percy' himself.

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