Spotting the elusive star in the Seven Sisters

W P Koorts
wpk@saao.ac.za

Introduction

In Greek mythology there are several tales explaining why only six of the stars in the Pleiades are easily visible to the unaided eye. In one account, Merope marries a mortal whereas her sisters marry gods. In shame, she hides her face, hence her elusive appearance.

Equally elusive is something resembling a bright star visible for a short while on a section of mountain known as the Seven Sisters, behind my hometown of Wellington. And as in the Greek tale, the death of a mortal is involved.

Set in the Hawekwa crags of the Seven Sisters is a granite memorial stone that from time to time reflects the setting Sun. Although numerous old-Wellingtonians can tell you the story behind the so-called "Hawekwa Mirror", for a number of reasons very few have actually seen it.

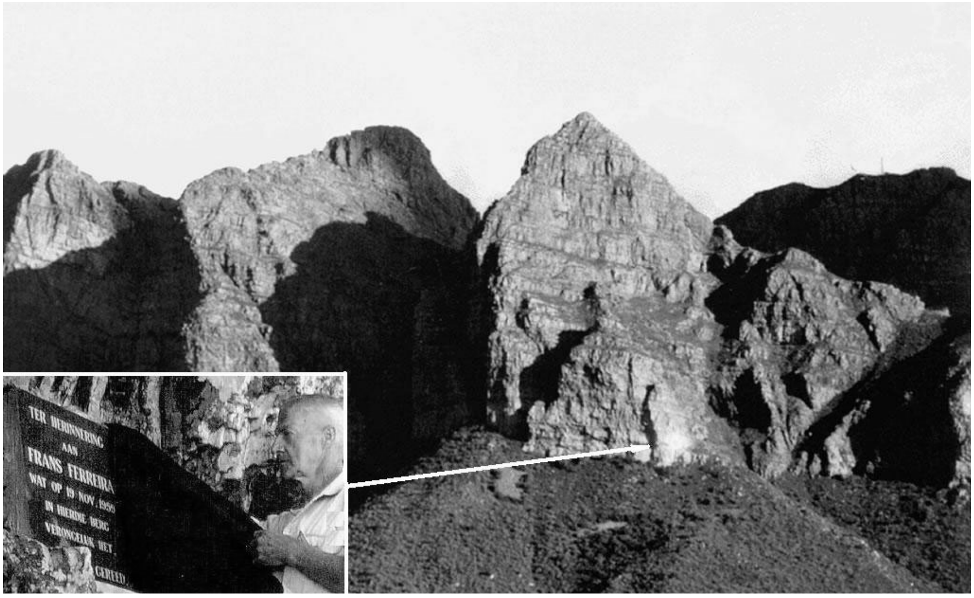
From any particular location it is only visible twice a year for about a week, during which it gradually gets brighter before fading back to invisibility. During this maximum it is visible to the naked eye for about 10 minutes but only gets really bright for a few minutes, putting on quite a show for those who happen to be looking at the mountain at this time. As with astronomical observations, visibility is easily impaired by afternoon cloud, either on the mountain or on the opposite sunset horizon.

On the other hand, its bi-annual visibility spells traverses the most densely populated parts of Wellington that have a good view of the mountain. Each visibility "season" lasts about three months as the "beam" slowly sweeps across town, corresponding to the daily shift in the sunset position on the horizon. It gets about as bright as the total brilliance of the Full Moon, concentrated into a single point source.

Most of these facts about the visibility pattern of the Hawekwa Mirror have not been known until recently, when I took an intense interest in the elusive "mirror". I took a series of measurements, made predictions by applying some astronomical knowledge and confirmed these by observation.

Folklore

The origins of this story goes back to 1959. Two local youths, Piet Hugo, from the farm Hexberg, and Frans Ferreira, the only child of the police chief of Wellington, were on vacation from university. On the morning of November 19 they set off to climb the Hawekwas. Frans' beloved Doberman went along and as the party travelled through the farm Patatskloof, the owner, Sarel van der Merwe, warned them about the danger of taking a dog into the mountain. Frans replied that his dog was used to climbing but Sarel's prediction soon came true when the dog got stuck on a narrow ledge high up on a cliff. In an attempt to lift his dog to safety, Frans lost his balance and fell to his death. Although his heroic deed saved the dog's life, it is said that the dog later mourned itself to death. The Ferreira family were devastated by the tragic death of their only child and decided to erect a headstone, cemented to the rock-face lower down on the mountain (Figure 1 inset and Figure 2).



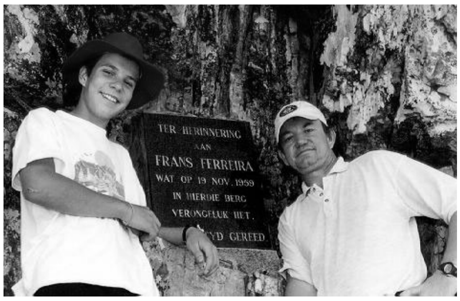


Figure 1 (above). The Hawekwa crags in the Seven Sisters mountain, showing the reflection of the Sun off the granite memorial stone. The photograph was taken on 2002 February 4 at 18:58 from near the Bovlei wine cellar on the Bains Kloof road. The inset picture shows Callie van der Merwe unveiling the stone at the opening ceremony and memorial service. **Figure 2 (right).** The author (right) and his son, Jaco-Chris, at the plaque with the Afrikaans inscription: "In memory of Frans Ferreira who had a fatal accident on this mountain on 19 November 1959. Always be ready." The dark colour of the granite can be seen here.

It is unclear if it was intentional or not, but the highly polished granite stone very effectively reflects the light of the setting Sun, sweeping across the full width of the town of Wellington. Since most people find it hard to believe that an almost black stone can produce such a bright reflection, it is said that a real mirror was placed next to the plaque to produce the reflection. As the story goes, the mirror occasionally gets disturbed by baboons or is overgrown by vegetation, and it needs to be put right from time to time.

I thought it unlikely that a real mirror was installed on the mountain because the strong winds would ruin any chance of a repeatable reflection. Also, no interfering vegetation can grow near it since the stone is surrounded by solid rock. Either way, on a recent outing to the site, no trace of a real mirror could be found, though we did encounter a troop of baboons fleeing past the monument as we approached.

There is no relationship between the date of Frans' accident and the periods of visibility I identified (Table 1), further suggesting that the orientation of the stone was not intentional.

Seeing is believing

I first heard the story of the Hawekwa Mirror from Jacques Retief, incidentally also born and raised on a subdivision of the original Hexberg farm on the outskirts of Wellington. I was immediately interested and asked him to keep an eye on it for me. As soon as he spotted it again he invited us over and we happened to catch it close to its maximum. I was amazed by how bright it became which made me realise why the story of a real mirror is told.

I was so intrigued by this phenomena that I immediately wanted to find out more about its dynamics and the possibility of it being visible from my house, a few kilometres south of Hexberg. A quick mental visualisation suggested that it should be visible. Subsequent detailed calculations, considering the actual shift of the sunset position, confirmed this. Local conditions close to the plaque, like obscuring rocks, vegetation, etc. were still unknown at that time but were later found to be of no consequence.

Finding my bearings

The very next night I was back at Hexberg, this time armed with more than just binoculars. I had since worked out that a lot of the geometry of the "mirror" could be calculated by simply taking a bearing to it. I therefore set up my satellite tracking mount to do just that. This system consists of a 20x80 monocular on an altitude-azimuth mount, fitted with setting circles. A vital aid to setting up and aiming this mount is an old laptop computer running a simple DOS program, ASTRO (downloadable from my website [http://www.saao.ac.za/~wpk/]) that I wrote several years ago. ASTRO uses the laptop's internal clock to continuously calculate the position of a celestial object in real time.

Once the mount was oriented on the Sun, the monocular was simply pointed at the "mirror" and its bearing read off the setting

Figure 3. A sequence of images grabbed from footage taken from my house on 2003 September 28, three days after predicted maximum, using my 9-inch telescope fitted with a CCD surveillance camera. As can be seen from the fuzzy shadows in the first two pictures, the Sun was unfortunately partly obscured by thin cloud. Despite this, the "mirror" put on a good show. (**left**) The almost-square shape of the plaque was very noticeable about ten minutes before maximum. (**centre**) At maximum, the brilliance of the reflection caused blooming of the CCD pixels and some scattering of light in the telescope optics. (**right**) Half an hour later the cloud had mostly disappeared but the show was over with the granite stone blending back to near invisibility into the surrounding rock.

circles. From Hexberg this was found to be az = 134.3° and alt = 6°. At the instant we observed maximum brightness (19:07 on January 26) ASTRO gives the position of the Sun as az = 253°, alt = 8° as seen from Wellington. By stepping ASTRO in time, it was found that the Sun would also be in this position on November 15 at 18:39 each year, on its way back to its winter turning point.

In order to determine when I would be able to see the reflection from my house, I also took a bearing from there. This proved difficult; the biggest problem was finding the monument site because the mountain looks somewhat different from my house compared to the view from Hexberg. Once I managed to photograph the reflection (Figure 1) I could use the picture as a "finding chart" to guide me to it. To verify that I was looking at the right spot, I pointed my 9-inch Newtonian telescope at the mountain. I was quite surprised by how clearly visible the plaque was in the telescope (Figure 3). In fact, at 175 power, with the correct lighting and at moments of good seeing, one could actually make out it has an inscription of some kind.

From my house, the bearing to the stone was measured as az = 113°, alt = 6.7° with reflections calculated to occur on March 18 at 18:54 and again on September 25 at 18:00.

Working out the geometry

Using a 1:50 000 map, the line-of-sight distance from my house was estimated as 8 km. This map was not very helpful in determining the geometry since it was difficult to determine the exact position of the monument site on the map, mainly because of the very steep contours.

To work out the geometry, I separated the problem into its two components by investigating the plan and side views.

The side view is very simple (Figure 4) suggesting that the headstone is tilted back by one degree from the vertical. This result initially surprised me because, judging by the pictures taken at the memorial service and unveiling ceremony (Figure 1 inset) it looks like the stone should lean back more. Measuring this angle was thus specifically done during our expedition to it and found to agree perfectly with the calculation.

Again, by applying the plane mirror reflection law, considering the plan view, the azimuth of the stone's reflecting surface could easily be determined by both calcu-

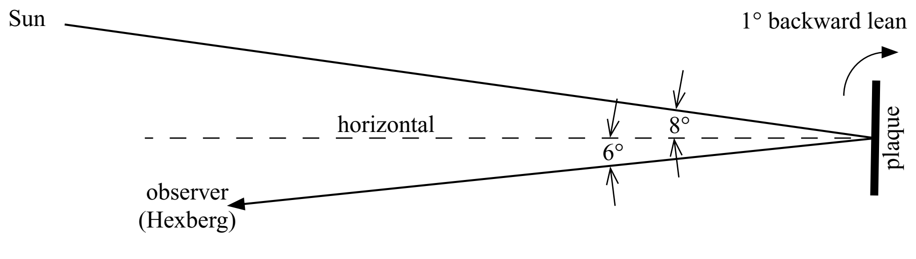


Figure 4. A side view of the geometry of the reflection as seen from Hexberg, yielding the 1° lean-back angle of the stone. This value agreed with a subsequent on-site measurement.

lation and geometry (Figure 5) without the exact distance to the "mirror" being known. Drawing this to scale puts the azimuth of the reflecting surface at 193.66° as shown. From this, a ray-trace using the measured bearing from my house yielded the azimuth of the Sun when producing a reflection for me. Using ASTRO again, the corresponding dates and times could be determined.

By simply constructing lines at the correct azimuth angles from Hexberg and my house on a detailed street-map (similar to Figure 6 but with much more detail), proved to be a very simple, yet effective way of visualising the problem. Lines at the measured azimuth angles, representing the reflections from Hexberg (labelled beam 1 in Figure 6) and my house (beam 6) to the position of the stone were first drawn in on the map. Using ASTRO the azimuth of the Sun was calculated at 10-day intervals and corresponding reflection lines drawn in on the map. This map was then used as a basis for making the observations.

Observations

Since the stone is mounted only 1° off the vertical, the simplified plan view ignores this and was found to be accurate enough for observational purposes. Some uncertainty is introduced anyway by factors such as Wellington stretching over many hills and valleys, the proximity of one's viewing position to the mountain affecting the altitude angle, etc. Further simplification was therefore introduced by calculating with the Sun at a fixed altitude of 8°.

To test my predictions, I followed the beam over a period of two months until the predicted times were too early for me to get

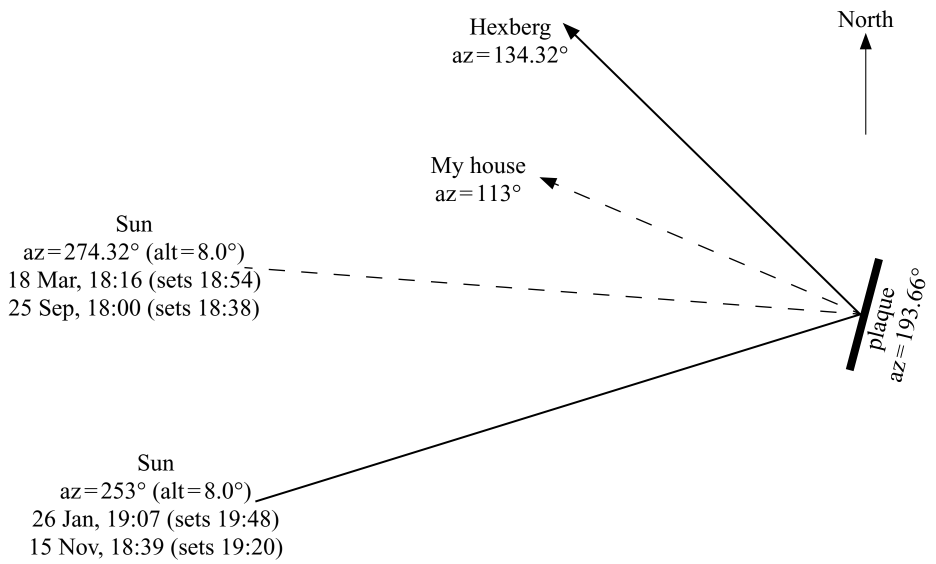


Figure 5. A plan view showing the geometry of the reflections as seen from Hexberg and my house respectively. This was used as a basis to producing Figure 6.

off from work. A few more observations over weekends finally yielded 28 points spread over a wide area of Wellington, some spanning a number of days either side of the predicted ideal dates.

As when observing astronomical objects, making use of binoculars greatly increases visibility. The visibility period of the reflection was increased by at least 10 minutes before and after the naked-eye visibility spell and by a number of days either side of the visibility window for a particular location.

I placed an article in a local newspaper, including Figure 1, sketching the historical background and listing my predictions with a request for observations. Unfortunately,

Table 1. Visibility of the Hawekwa Mirror from various locations in Wellington

Beam no.	Autumn visibility	Spring visibility
1	Jan 27 19:05	Nov 14 18:40
2	Feb 6 19:00	Nov 4 18:30
3	Feb 16 18:50	Oct 25 18:20
4	Feb 26 18:40	Oct 15 18:15
5	Mar 8 18:30	Oct 5 18:05
6	Mar 18 18:15	Sep 25 18:00
7	Mar 28 18:00	Sep 15 17:50
8	Apr 7 17:50	Sep 5 17:45
9	Apr 17 17:35	Aug 26 17:40

The estimated visibility dates are given in 10-day intervals, and times to the nearest 5 minutes, corresponding to the numbered lines or "beams" in Figure 6. The two visibility "seasons" are apparent.

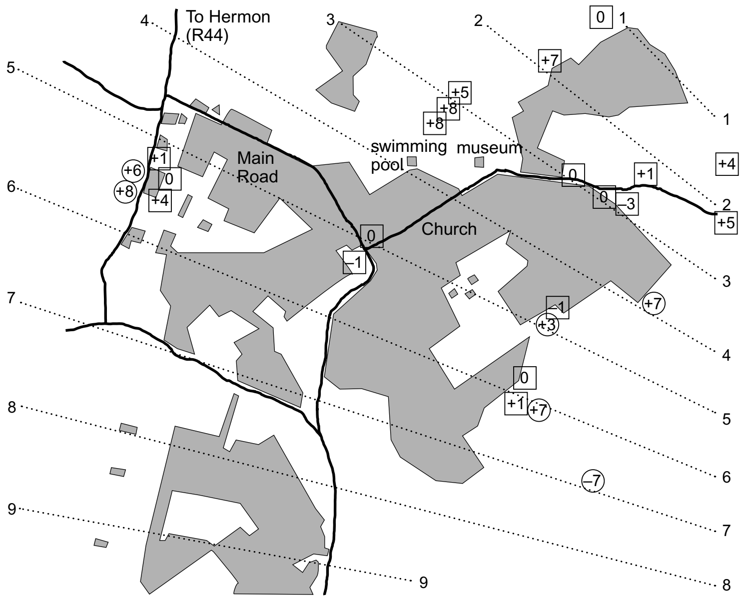


Figure 6. A simplified map of Wellington with numbered "beams" of visibility of the reflection, corresponding to the dates and times in Table 1. Also shown are some of my observations; successful sightings are shown as a square, while circled numbers indicate that no naked-eye reflection was seen, despite conditions being ideal. The numbers inside the symbols indicate the difference in days between the calculated and observed dates. Negative numbers indicate an attempted observation before the predicted date and positive numbers the number of days observed after the prediction.

no useful data was obtained from this. However, some awareness had been generated since on one occasion I noticed people looking at the mountain using binoculars with the newspaper at hand.

A few phone calls were received, mostly giving personal accounts and details of the events surrounding the accident. One very interesting call came from Frans' stepbrother, a boy from the local children's home who was adopted by the Ferreiras after Frans' death. He unfortunately knew very little, since the accident was a very sensitive issue for his step-parents, who hardly ever mentioned the tragic story.

How bright?

I considered ways of doing photometry to try and determine the brightness of the reflection, but no practical way could be devised of doing this against the sunlit background of the mountain which constantly changes brightness as the Sun sets.

To determine the brightness theoretically, I turned to the proven methods devised by the satellite tracking community. Similar situations occur when sunlight is reflected off flat surfaces on satellites. The most famous example is perhaps the Iridium satellites, which produce very predictable "flashes" off their highly reflective door-sized antennae, capable of reaching a brightness of magnitude –8. The solar panels on the Hubble Space Telescope and the International Space Station, to name a few, also regularly produce spectacular glints.

Studying and analysing these reflections from satellites has been fully characterised by the amateur tracking community and in particular by Tony Beresford from Australia, whose help is greatly appreciated in this regard. Satellite reflection brightnesses are easily measured by comparison to the background stars. The geometry of the satellite orbits are well-known, making it easy to calculate the distance to the observer, the solar phase angle, etc. Data on the exact sizes of the antennae and solar panels is freely available for unclassified payloads. It is therefore no surprise that predicting satellite reflection brightnesses has been refined to a fine art.

These calculations are based on the fact that a perfect mirror of one square metre, 1 000 km distant, at near-zero phase angle gives a specular reflection of magnitude –7. The effect of distance is then compensated for by the inverse square law and the reduction in brightness by the percentage reflection compared to a perfect mirror, taking into account the size of the reflecting area.

The brightness calculation depends a lot on the specular reflectivity of polished granite. No exact value for this could be found, so an estimate was made. Taking into account that solar panels are generally 12% reflective in the visible and that the granite surface has been subjected to almost 45 years of weathering, a value of 10% was deemed reasonable. The plaque is about 400 x 400 mm in size and 8 km away.

Using the above methods the brightness was calculated as follows:

A perfect mirror of 1m^2 at 1 000 km produces a brightness of magnitude –7. A reflection area of 0.16 m^2 is 2 magnitudes fainter, and at only 10% reflectivity this drops by a further 2½ magnitudes. However, at a distance of only 8 km the brighteness goes up by 10½ magnitudes, for a resulting estimated brightness of mag –13.

Readers will recognise this as being just slightly brighter than the Full Moon. The reflection is thus equivalent to the Full Moon's light concentrated into a single point.

Conclusion

The derived brightness value seems reasonable considering what has been observed but is difficult to compare because of the difference in observing conditions when seeing the Moon against the sky compared to the tiny reflection against the backdrop of the mountain, lit by the Sun 8° above the horizon.

My visibility predictions, confirmed by observation, is accurate to within about a week and ±5 minutes in time. This is sufficient to use as a guide to find and track the reflection pattern as it traverses the hills and valleys of the town of Wellington or to know when to expect it to shine for your location.

My efforts have hopefully illuminated some of the folklore that has sprung up, mainly as a result of poor knowledge and a lack of understanding of the whole phenomena.

As it has done for the past 40-odd years, the reflection of the Hawekwa mirror is likely to continue, bi-annually, bi-directionally, sweeping the town of Wellington for generations to come. Through the memory of Frans Ferreira, it will keep reminding us of the tragic events of 19 November 1959 while blazing out the eternal warning: "Always Be Ready"!