



LGS-AO: Ability to Operate in Twilight

We would like to extend the hours of operation of LGS-AO. Currently we request approval from the FAA for sunset to sunrise, but our current rules restrict us to propagating the laser only within the 12° twilight times. Extending the time into the brighter twilight hours has a number of implications:

- + More time available to observing,
- Longer work hours for spotters,
- Brighter sky.

The potential problem with the brighter sky is that it may be harder to detect aircraft against such a sky. Often just after sunset, aircraft can be “invisible” against the sky, brightening into visibility quite dramatically if they become suddenly lit by the setting Sun. In fact, this is a known source of some UFO reports! In a dark sky we rely on the aircraft anticollision and position lights for visibility. What level of sky brightness can we tolerate?

In the following we assume that we can tolerate a sky at least as bright as that seen during a Full Moon. We do not include area immediately surrounding the Moon, but rather larger angular distances. We will choose some precise numbers to demonstrate below.

Calculation

We follow the formalism of Krisciunas & Schaefer (1991), and refer the reader to that paper for background information and equations, etc. In particular, from their eqs. 20, 21, 3, and 15, we can calculate how bright the sky is during a Full Moon. We use the following parameters: $\alpha = 0$ (Full Moon); $\rho = 90^\circ$ (distance of sky from Moon); $k = 0.113$ (extinction coefficient, typical for the summit of Mauna Kea); $Z = Z_M = 45^\circ$ (zenith distances of sky and Moon). From the equations, $B(\text{Moon}) = 776$ nanoLamberts. Equation 1 converts this to mag/sq. arcsec, giving 19.11 (with a standard background of 21.39, a difference of 2.3 mags).

How does the twilit sky vary with solar altitude? From Patat et al. (2006), the twilit sky at zenith is 2.3 mags brighter than “dark” when the Sun is 8.5° below the horizon.

Using JPL’s *Horizons* software, the time difference between 12° twilight and 8.5° twilight ranges from 15–17 minutes over the course of the year. Since 12° twilight times are tabulated and readily available, we propose using the time period from 15 minutes before evening 12° twilight until 15 minutes after morning 12° twilight.

References

JPL *Horizons* ephemeris software, URL: <http://ssd.jpl.nasa.gov/horizons.cgi>.

Krisciunas, K. & Schaefer 1991, PASP, 103, 1033.

Patat, F., Ugolnikov, O. S., & Postlyakov, O. V., 2006, A&A, 455, 385.



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