Measurements of airglow on Maunakea at Gemini Observatory

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Airglow captured over the Atacama Desert (December 2015)
Gemini cloud camera (North)
Gemini cloud camera (North)
Gemini cloud camera (South)
Gemini cloud camera (South)
GMOS-S Hamamatsu CCD Commissioning

- PR imaging of science field previously imaged in excellent seeing in i,z-band with the original EEV detectors.
GMOS-S Hamamatsu CCD Commissioning

- Measured background with EEV $\sim 4200e^{-}$
- Measured background with Hamamatsu $\sim 38000e^{-}$ no gain in sensitivity
- EEV image taken at 2am with no moon, Hamamatsu image taken just after evening twilight in full moon.
  - Does the moon impact i-band imaging? Not at that level
  - Did proximity to Twilight impact the background? No, subsequent images had same levels
  - Must be airglow
Measuring sky background with QAP (Quality assurance pipeline)

- QAP uses instrument/filter zero-points to calculate the measured sky background in imaging data
- QAP not intended to produce scientific quality images or measurements
- Use QAP automatic sky background values measured in 13 years of GMOS and NIRI imaging data to verify
  - How well are we doing - are we delivering data with the expected sensitivity?
  - What could we do better - anyway to improve the scheduling?
Preliminary Investigation

- Currently have run QAP on Gemini North imaging data back through mid 2010
- Correct QAP background values for changes in instrument/filter zero-points
- Empirically determine airmass correction to QAP background measurements
- Look for trends in background values with various parameters (moon phase, time of night, solar cycle, time of year, etc)
- A purely empirical approach
Performance Monitoring: Instrument zero points

- Photometric standards are taken whenever imaging data are taken on photometric nights for both NIRI and GMOS.
- Dedicated “performance monitoring” data are taken in all filters / modes ideally at least once per month.
- Zero points are automatically derived from scripts running in background and results are posted on the web.
- Recent investigations into GMOS zero points have reduced errors and reveal trends with zero point related to various mirror reflectivities.
Airmass Dependence

• Linear fits to QAP background brightness values as a function of airmass.
• In the optical only data with sun and moon below -18 deg elevation considered
• In the infrared no moon restriction is considered, only sun below -18 deg
Airmass

Magnitude

AB / arcsec^2

i-band vs Airmass | Sun/Moon < -18

Z-band vs Airmass | Sun/Moon < -18

Magnitude_{AB} / arcsec^2

Airmass

-0.84 ± 0.04

-0.93 ± 0.09
Time Of Night

- Corrected sky brightness values plotted against percent of night, where evening 12-deg twilight is 0% and morning 12-deg twilight is 100% of night completed.
- Hawaii nights are 8.9 hours long in the summer and 11.4 hours long in the winter
- Some expected results: optical bands see the moon and Twilight
- Unexpected result: all bands except g and K take 20-30% of the night to reach darkest values
Sky brightness (mag/arcsec²) vs % Night in the g-band.
Sky brightness (mag/arcsec²)

% Night

r-band

Moon Phase

Sky brightness (mag/arcsec²)

% Night

16 17 18 19 20 21 22 23 24

0 0.2 0.4 0.6 0.8 1 1.2

0 10 20 30 40 50 60 70 80 90 100
Sky brightness (mag/arcsec²) vs. % Night and Moon Phase for J-band.
Target – Moon distance

• Sky brightness plotted as a function of distance from the moon, sun below -18 and moon above horizon
• Only optical data show a dependence on the moon phase and distance from the moon.
• Strongest correlation in g-band
• z,Y show no correlation unless very close to the bright moon
• J, H, K do not see the moon
Sky brightness (mag/arcsec^2) vs. Distance from Moon. Sun < -18.
Sky brightness (mag/arcsec²)
Sky brightness (mag/arcsec$^2$)

Distance [deg]

H | Distance from Moon | Sun < -18

Moon Phase
Gemini Sky Background Observing Condition

- Sky background combination of Sun and moon position, moon phase, zodiacal light based on visible observations and scattering models
- Gemini PIs use ITC to derive expected sensitivity of their imaging data for a given sky background (20,50,80,Any) between Nautical Twilights
- Gemini queue coordinators use QPT to schedule observations in conditions that do not violate the observing conditions awarded
- In the infrared, QPT and ITC do not attempt to model the sky background
All r-band

Corrected Brightness [mag/arcsec^2]

Predicted V-band Magnitude

ITC SB(20) 21.0
ITC SB(50) 20.3
ITC SB(80) 19.4
ITC SB(Any) 17.5

0.6663 x + 7.009

Moon Phase
ITC	SB	14.6

All K-band

Corrected Brightness [mag/arcsec²]

Predicted V-band Magnitude

20%-ile  50%-ile  80%-ile

0.02791 x + 13.25

ITC SB 14.6

Moon Phase
Other Fun Stuff

• Explore seasonal signature
• Looking for correlations with sun spots
• K-band thermal component correlation with ambient temperature
• Zodiacal Light
R-band measured on the same UT date

Corrected Brightness [mag/arcsec²]

# of Sunspots

-0.0014 ± 0.0001
-0.0010 ± 0.0003
R-band measured on the following UT date

![Graph showing corrected brightness vs. number of sunspots with two linear regression lines: one with a slope of -0.0013 ± 0.0001 and another with a slope of -0.0009 ± 0.0003.]
r-band during Nov, Dec, Jan
r-band during Feb, Mar, Apr

Corrected Brightness [mag/arcsec²]

Percent of Night

Moon Phase
r-band during May, Jun, Jul

Corrected Brightness [mag/arcsec^2]

Percent of Night

Moon Phase
J-band during Feb, Mar, Apr
i-band, Solar & Lunar elevation < -18 deg
Preliminary Conclusions

- $r, i, z, J, H$ and maybe $Y$ band sky background values decrease during the first several hours of the night before reaching their darkest values.
- There may be a seasonal dependence on this decay especially in the optical – under investigation.
- The observing constraints and ITC underestimate the background level in $J$ and $K$. 
Possible scheduling Improvements

• Revise Observatory Constraints and ITC values to match sky background values actually measured.
• Avoid scheduling imaging in the first 2-3 hours of the night for science requiring the darkest background
• More advanced / challenging improvements
  – Revise QPT scheduling software to match optical sky background values actually measured
  – Implement sky background constraints in the infrared, cannot easily be predicted but would require on-sky measurements (similar to water vapor scheduling constraint)