

# Intercomparing Methods of Night Sky Brightness Measurements

Constance Walker, John Kanemoto, Amy Juan & John Barentine



## The Focus of the Research

- Digital Single-Lens Reflex (DSLR) Camera
- Sky Quality Meters - with Lense (SQM-L)
- SQM-UL-DL+H Stations
- Night Sky Brightness Monitor
- Dark Sky Meter (DSM) Application
- Loss of the Night (LoN) Application
- Globe at Night (GaN) Web Application

## Field Test Locations

Sixteen locations were identified throughout the city of Tucson and surrounding areas for taking measurements.

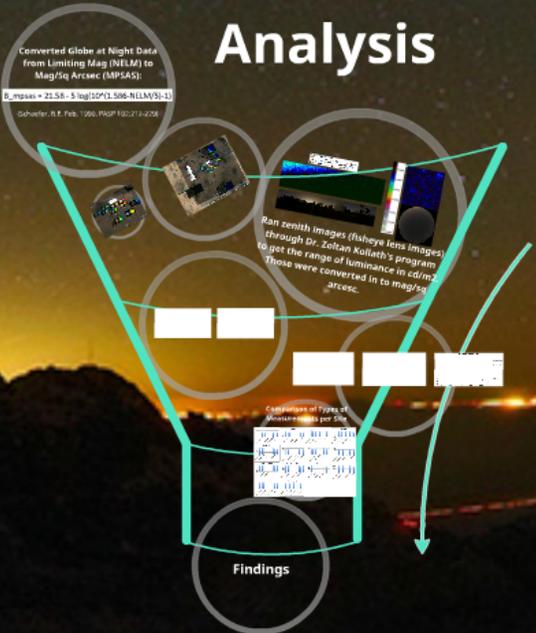
The locations had a complete range of sky brightness conditions, including parks, highly populated areas and observatory mountaintops.



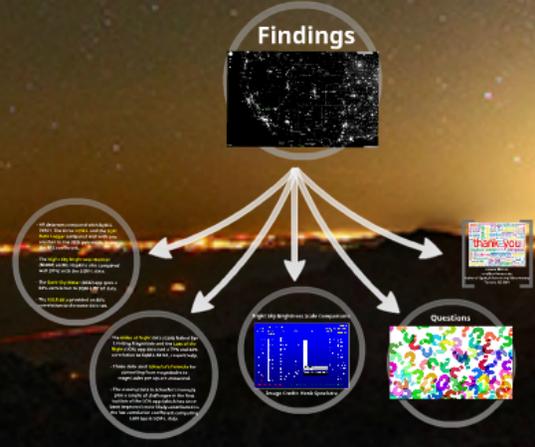
## Data Acquisition



## Analysis



## Findings



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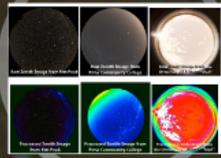


# Data Acquisition

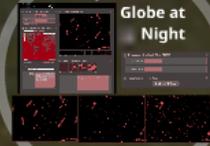
Step One: Panoramas



Step Two: Zeniths



Step Three: Globe at Night



Step Four: Loss of the Night Android Application



Step Five: Dark Sky Meter



Step Six: Sky Quality Meter (SQM-L)



Step Seven: Sky Quality Meter - Data Logger (SQM-DL)



Step Eight: Night Sky Brightness Monitor (NSBM)



Example of Data Collected

Time	Latitude	Longitude	Altitude	Temperature	Humidity	Pressure	Wind Speed	Wind Direction	SQM	SQM-DL	NSBM	Dark Sky Meter	Globe at Night	Loss of the Night
2013-08-01 21:00	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:05	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:10	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:15	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:20	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:25	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:30	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:35	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:40	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:45	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:50	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 21:55	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66
2013-08-01 22:00	34.05	-118.24	1000	15.0	65	1013	10	135	18.66	18.66	18.66	20.15	18.66	18.66

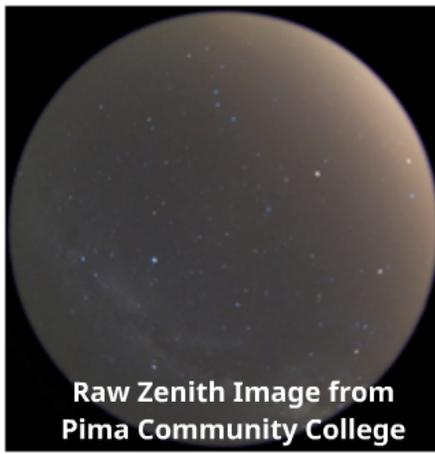
# Step One: Panoramas



# Step Two: Zeniths



Raw Zenith Image from Kitt Peak



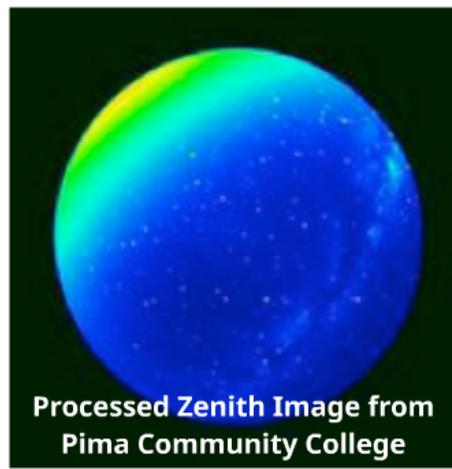
Raw Zenith Image from  
Pima Community College



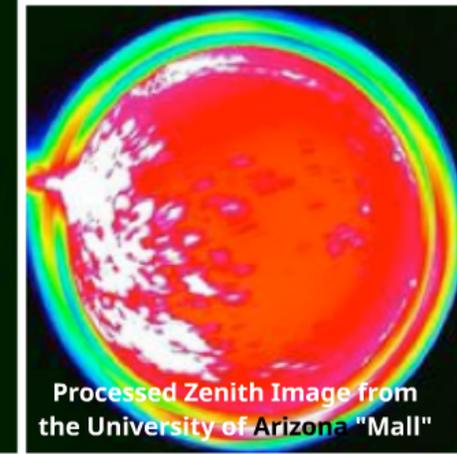
Raw Zenith Image from the  
University of Arizona "Mall"



Processed Zenith Image  
from Kitt Peak



Processed Zenith Image from  
Pima Community College



Processed Zenith Image from  
the University of Arizona "Mall"

# Step Three:

# Globe at Night

**Globe at Night**

1 When did you make your observations?

Observation Date

Observation Time

Switch to Database version

2 Where did you make your observations?

Google

Location sorted:

Latitude:

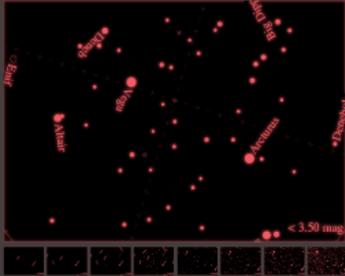
Longitude:

Elevation: meters

Country:

Location comments (E.g., Point, pulsation, or other location; Break cover? Number of observations; nearby light or other light sources [including machines, etc.] in vicinity; Time or otherwise in session)

3 How dark was the sky that night?



Constellation: Hercules

4 What were sky conditions like that night?

Clear  1% of the sky  1% of the sky  More than 1% of the sky

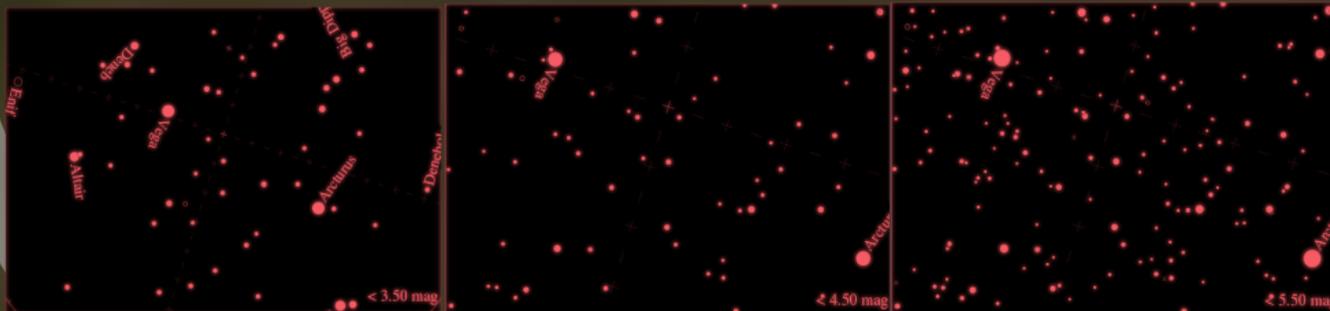
Sky condition comments (E.g., Flow - direction? Clouds - type, amount? sky photo/light dome - direction?)

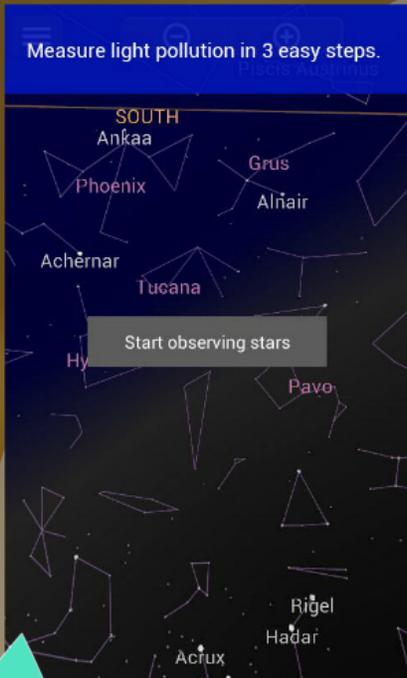
5 Did you use a Sky Quality Meter (SQM)?

SQM reading

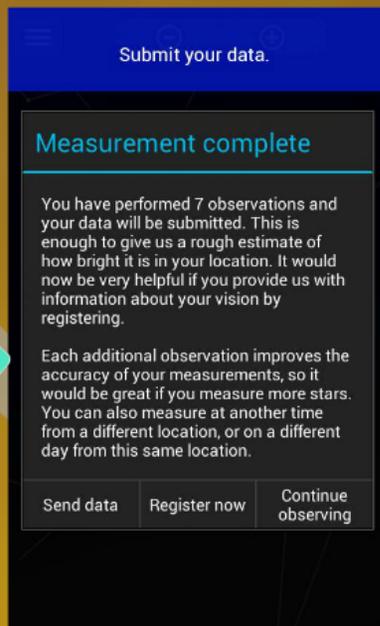
Serial Number

6 Ready to send us your data?





## Step Four: Loss of the Night Android Application



# Step Five: Dark Sky Meter



iPhone App

# Step Six: Sky Quality Meter (SQM-L)



# Step Seven: Sky Quality Meter - Data Logger (SQM-DL)



# Step Eight: Night Sky Brightness Monitor (NSBM)



# Example of Data Collected

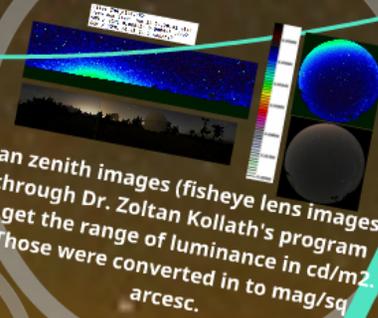
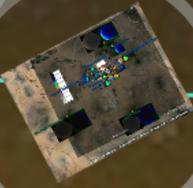
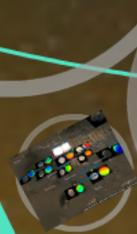
<u>Location</u>	<u>Date</u>	<u>Time</u>	<u>Temp</u> (Degrees Fahrenheit)	<u>Humidity</u> (Percentage)	<u>Calculate d SQM</u> (cd/m2)	<u>Calculated SQM (ALL SKY)</u> (mag/as2)	<u>Calculate dSQM-L</u> (cd/m2)	<u>Calculate dSQM-L</u> (mag/as2)	SQM-L (8161 Hand Held) (mag/as2)	SQM-L (5428 Hand Held) (mag/as2)	SQM-L (3829 Hand Held) (mag/as2)	SQM Data Logger (mag/as2)	NSBM (Mount Hopkins) (mag/as2)	DSM Average (iPhone) (mag/as2)	DSM NELM Value (iPhone) (mag)	LoN Mag. (Andriod) (mag)	GaN NELM (mag)
University Mall	June 17, 2014	8:52 PM	--	--	0.01148	17.6	0.00953	17.81	--	--	--	--	--	--	--	--	--
--	--	9:01 PM	92.00	18	--	--	--	--	17.11	17.41	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	17.09	17.43	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	17.12	17.44	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	17.08	17.47	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	17.12	17.47	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	17.10	17.44	ND	--	--	18.17	5.14	2.83	3
--	--	--	--	--	--	--	--	--	0.02	0.03	ND	--	--	0	0	0	0
NOAO Rooftop	June 17, 2014	10:36 PM	--	--	0.00619	18.28	0.00576	18.35	--	--	--	--	--	--	--	--	--
--	--	ND	85.00	27	--	--	--	--	18.59	18.46	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	18.59	18.45	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	18.55	18.47	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	18.62	18.50	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	18.61	18.47	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	ND	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	18.59	18.47	ND	18.93	--	18.29	5.2	5.12	3
--	--	--	--	--	--	--	--	--	0.03	0.02	ND	0.004	--	0	0	0	0
Camp Cooper	June 18, 2014	8:53 PM	--	--	0.00184	19.59	0.00154	19.78	--	--	--	ND	--	--	--	--	--
--	--	8:55 PM	--	--	0.00181	19.61	0.00152	19.8	--	--	--	ND	--	--	--	--	--
--	--	8:57 PM	--	--	0.00181	19.61	0.00151	19.8	--	--	--	ND	--	--	--	--	--
--	--	9:02PM	ND	ND	--	--	--	--	20.02	ND	20.08	ND	--	--	--	--	--
--	--	--	--	--	--	--	--	--	20.00	ND	20.02	ND	--	--	--	--	--
--	--	--	--	--	--	--	--	--	19.96	ND	19.98	ND	--	--	--	--	--
--	--	--	--	--	--	--	--	--	19.93	ND	19.98	ND	--	--	--	--	--
--	--	--	--	--	--	--	--	--	19.90	ND	19.98	ND	--	--	--	--	--
--	--	--	--	--	--	--	--	--	19.90	ND	20.01	ND	--	--	--	--	--
--	--	--	--	--	--	--	--	--	19.95	ND	20.01	ND	--	19.69	5.9	5.11	4
--	--	--	--	--	--	--	--	--	0.05	ND	0.04	ND	--	0	0	0	0
Gates Pass	June 18, 2014	10:17 PM	--	--	0.00147	19.84	0.00105	20.2	--	--	--	--	--	--	--	--	--
--	--	10:19 PM	--	--	0.00151	19.81	0.00106	20.2	--	--	--	--	--	--	--	--	--
--	--	10:22 PM	--	--	0.00153	19.79	0.00124	20.02	--	--	--	--	--	--	--	--	--
--	--	ND	ND	ND	--	--	--	--	20.30	ND	20.30	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	20.24	ND	20.48	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	20.22	ND	20.45	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	20.40	ND	20.45	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	20.27	ND	20.37	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	20.23	ND	20.35	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	20.28	ND	20.40	--	--	10.46	5.78	4.50	5

# Analysis

Converted Globe at Night Data from Limiting Mag (NELM) to Mag/Sq Arcsec (MPSAS):

$$B\_mpsas = 21.58 - 5 \log(10^{(1.586 - NELM/5)} - 1)$$

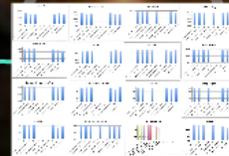
(Schaefer, B.E. Feb. 1990. PASP 102:212-229)



Ran zenith images (fisheye lens images) through Dr. Zoltan Kollath's program to get the range of luminance in cd/m<sup>2</sup>. Those were converted in to mag/sq arcsec.



Comparison of Types of Measurements per Site



## Findings



Step Four: Loss of the Night Android Application

Step Five: Dark Sky Meter



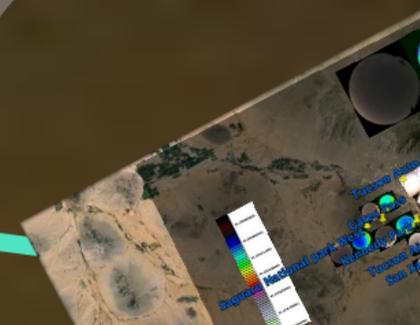
- All data was compared with SQM-L #8161. The three SQM-L and the SQM Data Logger compared well with one another to the 99th percentile, using the R<sup>2</sup> coefficient.
- The Night Sky Brightness Monitor (NSBM) on Mt. Hopkins also compared well (91%) with the SQM-L data.
- The Dark Sky Meter (DSM) app gave a 93% correlation to SQM-L #8161 data.
- The DSLR data provided an 80% correlation to the same data set.

- The Globe at Night data Limiting Magnitude and Night (LON) app data had correlation to SQM-L #8161.
- Those data used Schaefer converting from magnitudes per square arcsecond to mag/sq arcsec.
- The assumptions in Schaefer's formula plus a couple of challenges with the version of the LON app (which has been improved) most likely caused the low correlation coefficient between the LON app & SQM-L data.

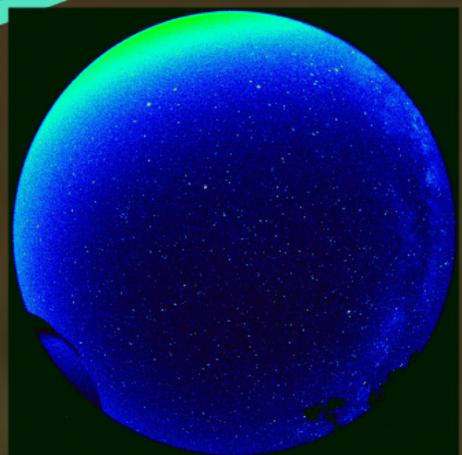
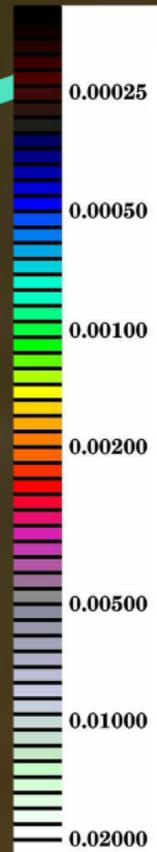
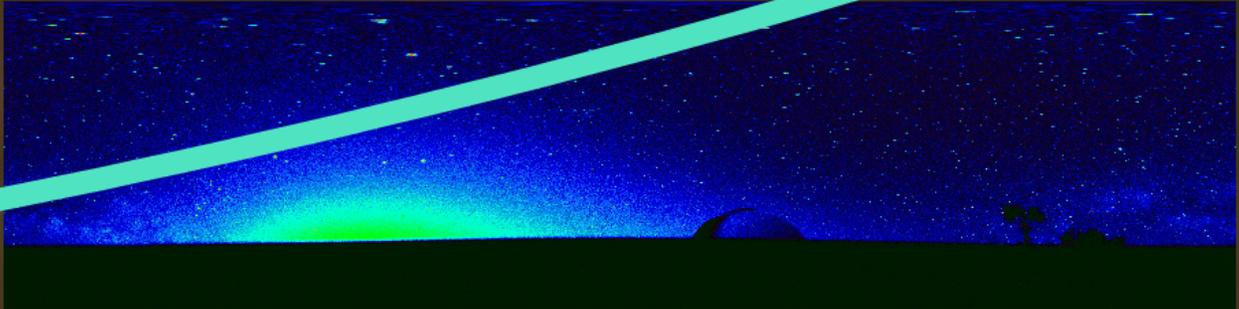
# Converted Globe at Night Data from Limiting Mag (NELM) to Mag/Sq Arcsec (MPSAS):

$$B\_mpsas = 21.58 - 5 \log(10^{(1.586 - NELM/5)} - 1)$$

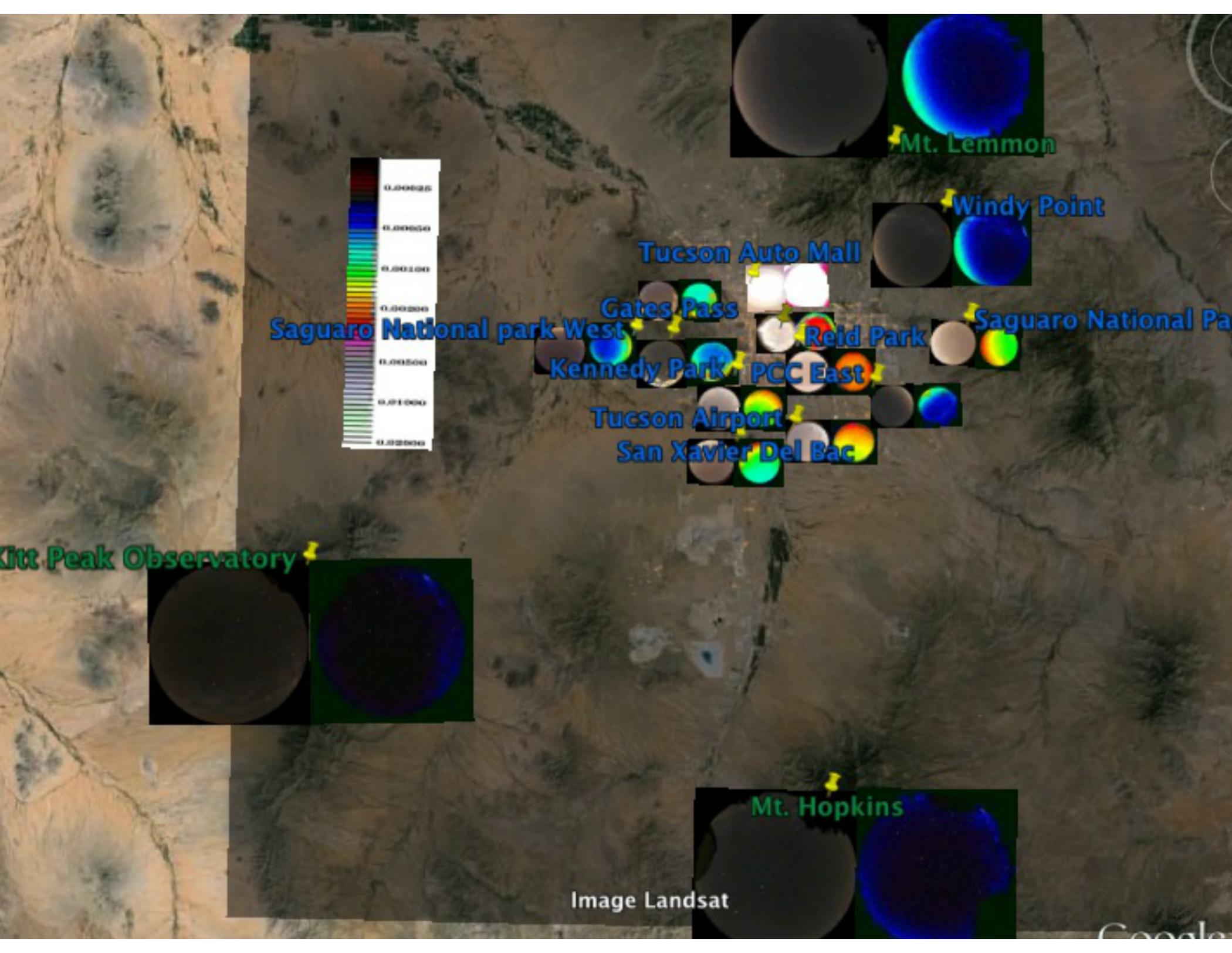
(Schaefer, B.E. Feb. 1990. PASP 102:212-229)

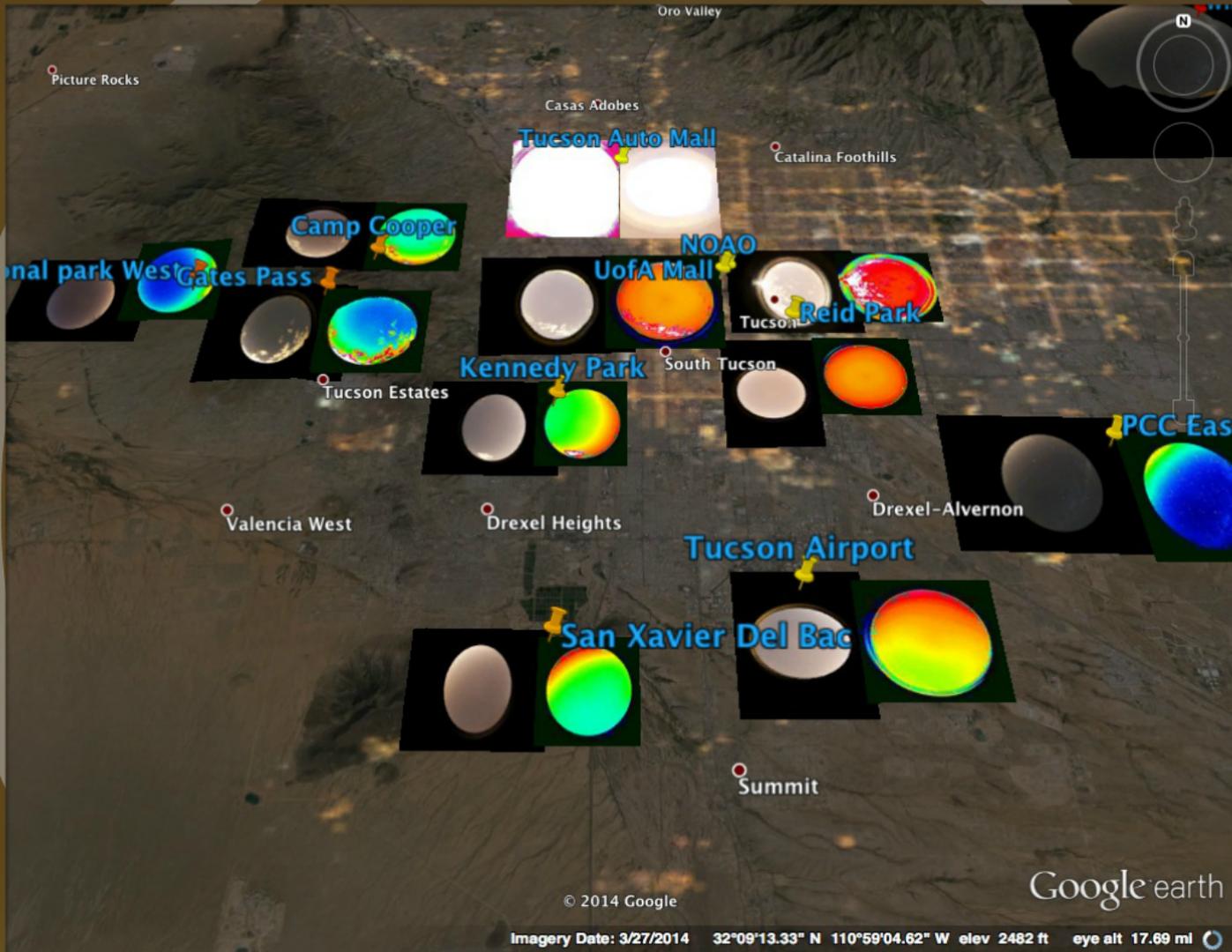


File: IMG\_0174.CR2  
Date and time: Jun 23 21:20:42 2014  
SQM / SQML 0.000526 0.000457 cd/m<sup>2</sup>  
SQM / SQML 20.95 21.1 mag/arcsec<sup>2</sup>

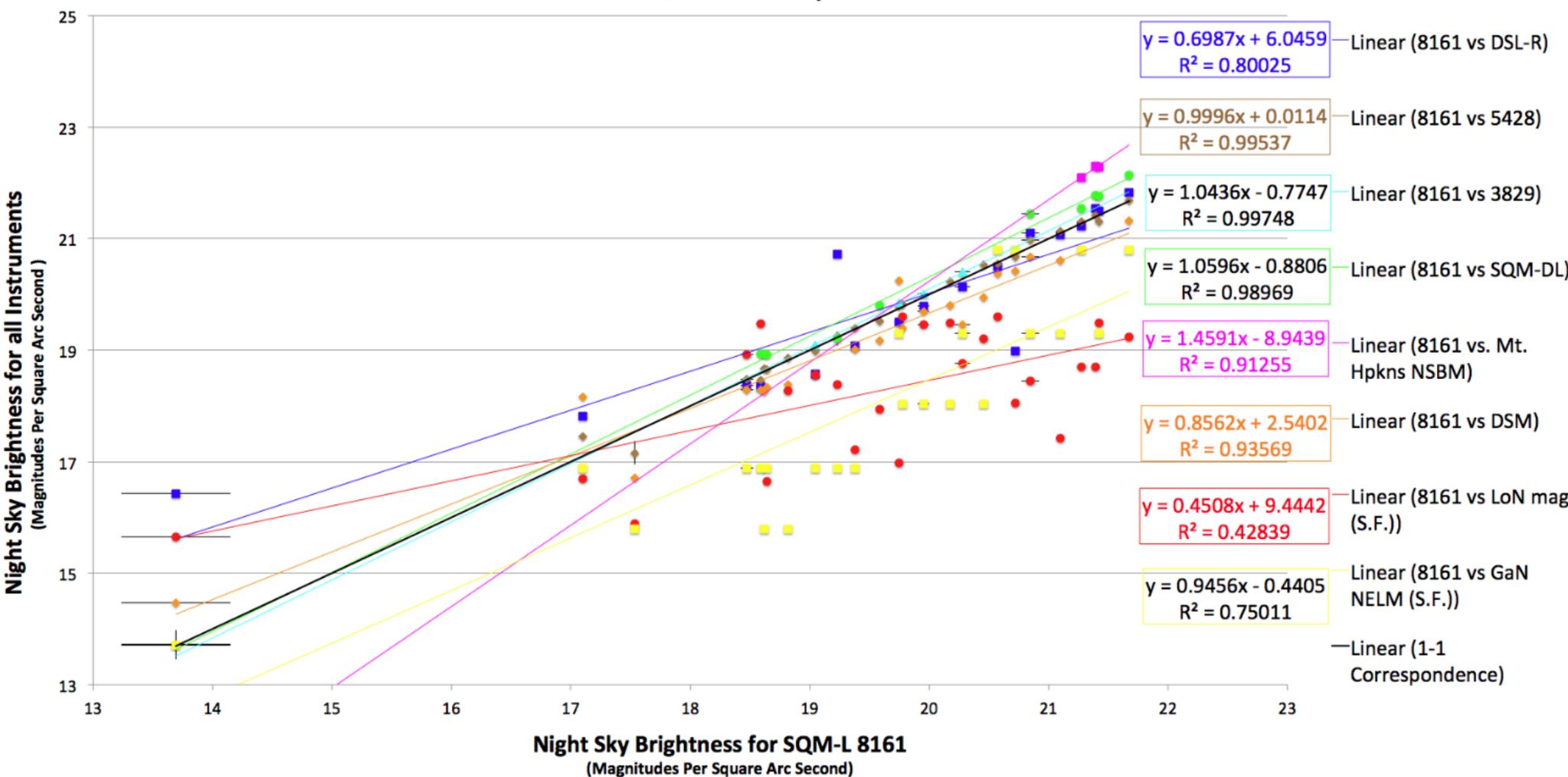


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Those were converted in to mag/sq

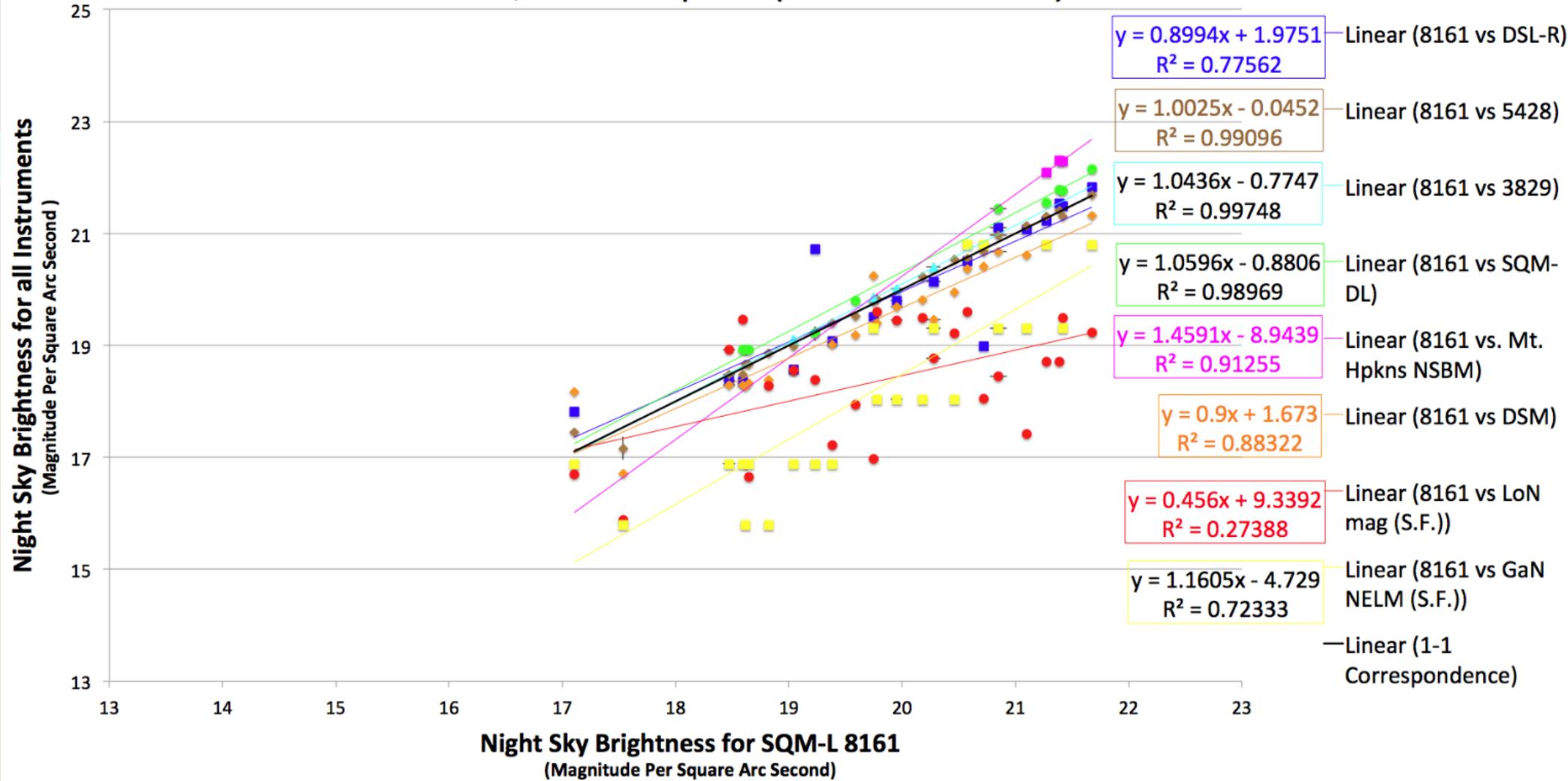




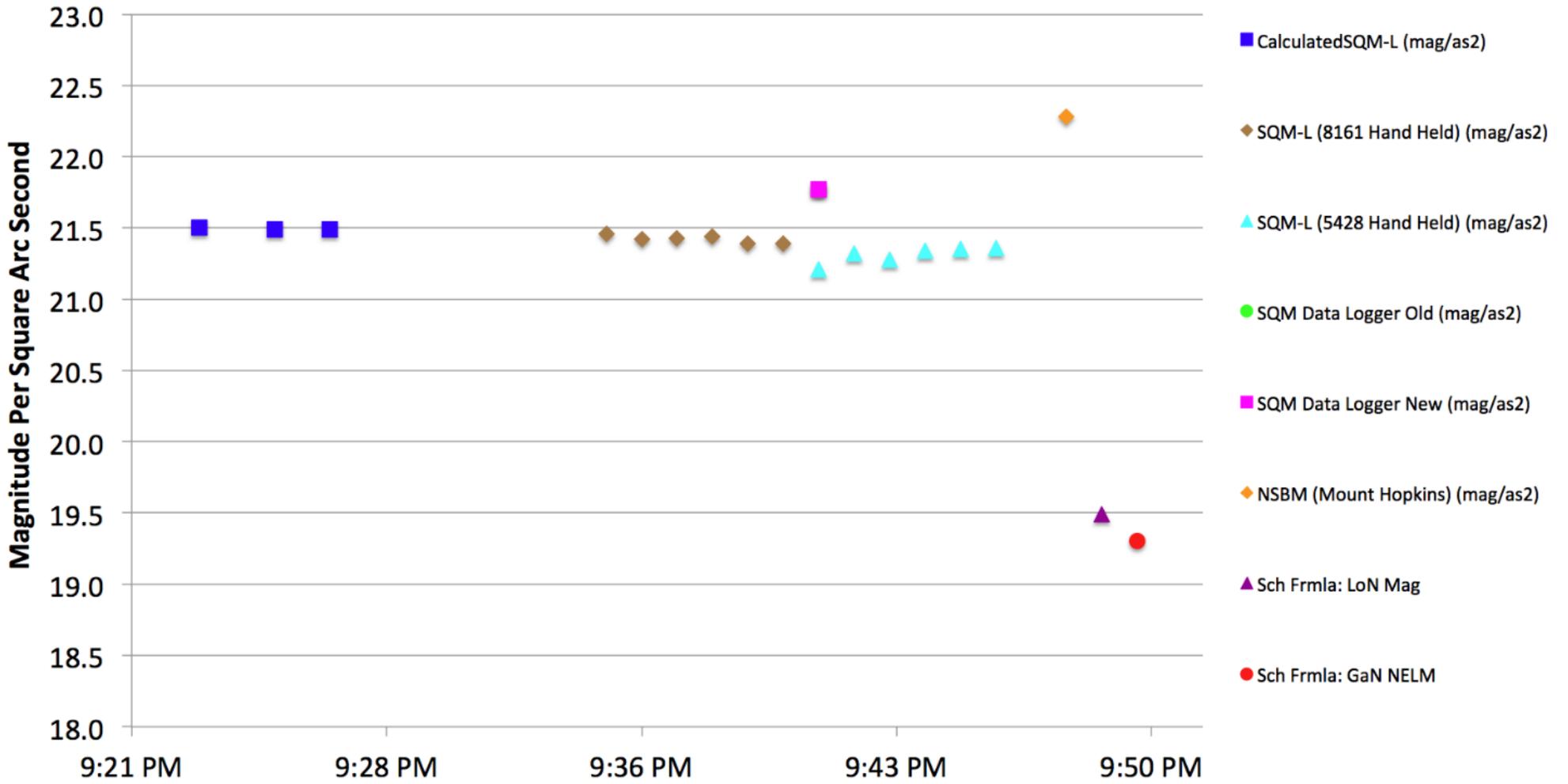
### SQM-L 8161 Comparison



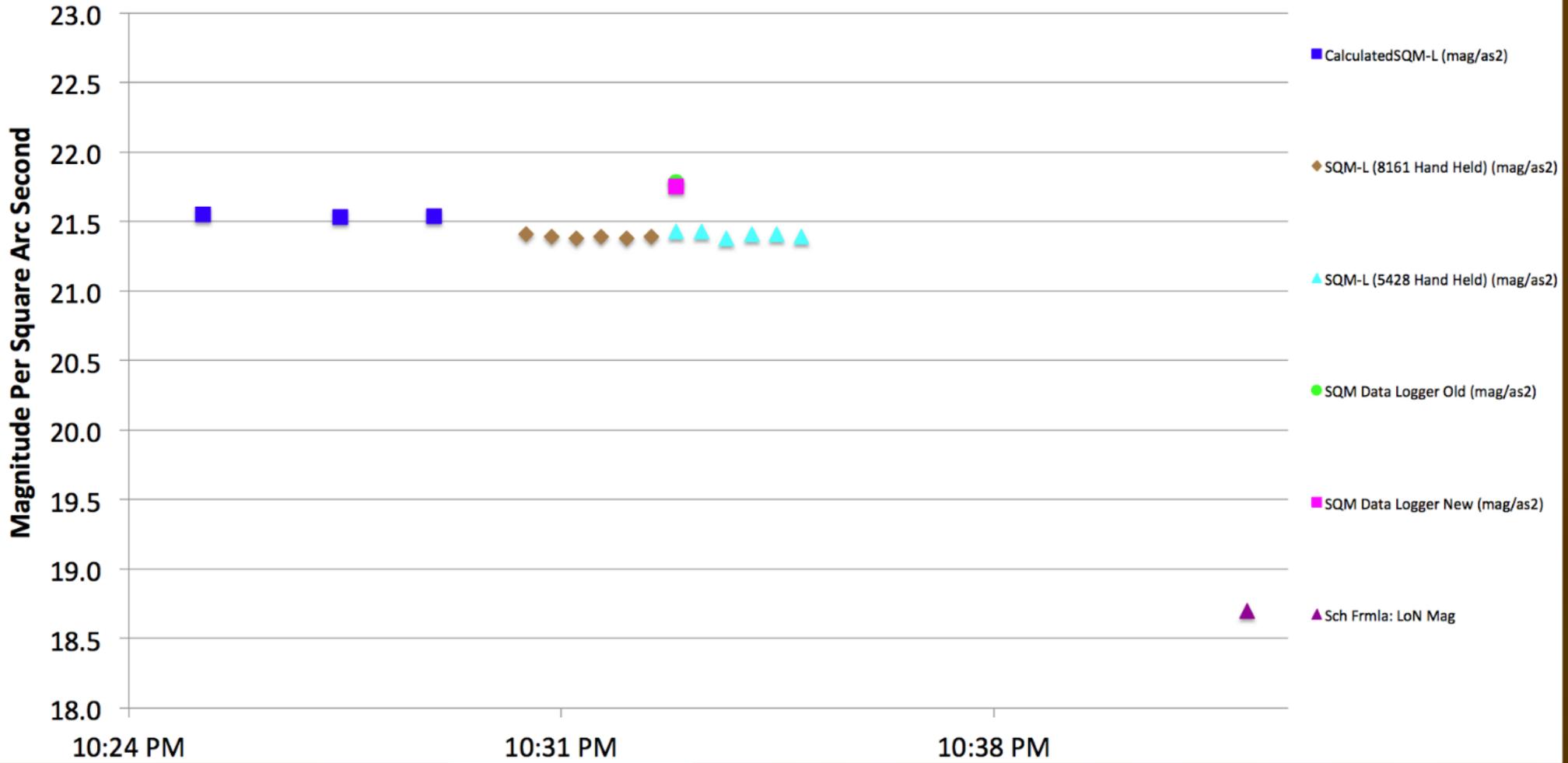
### SQM-L 8161 Comparison (without Auto Mall Data)



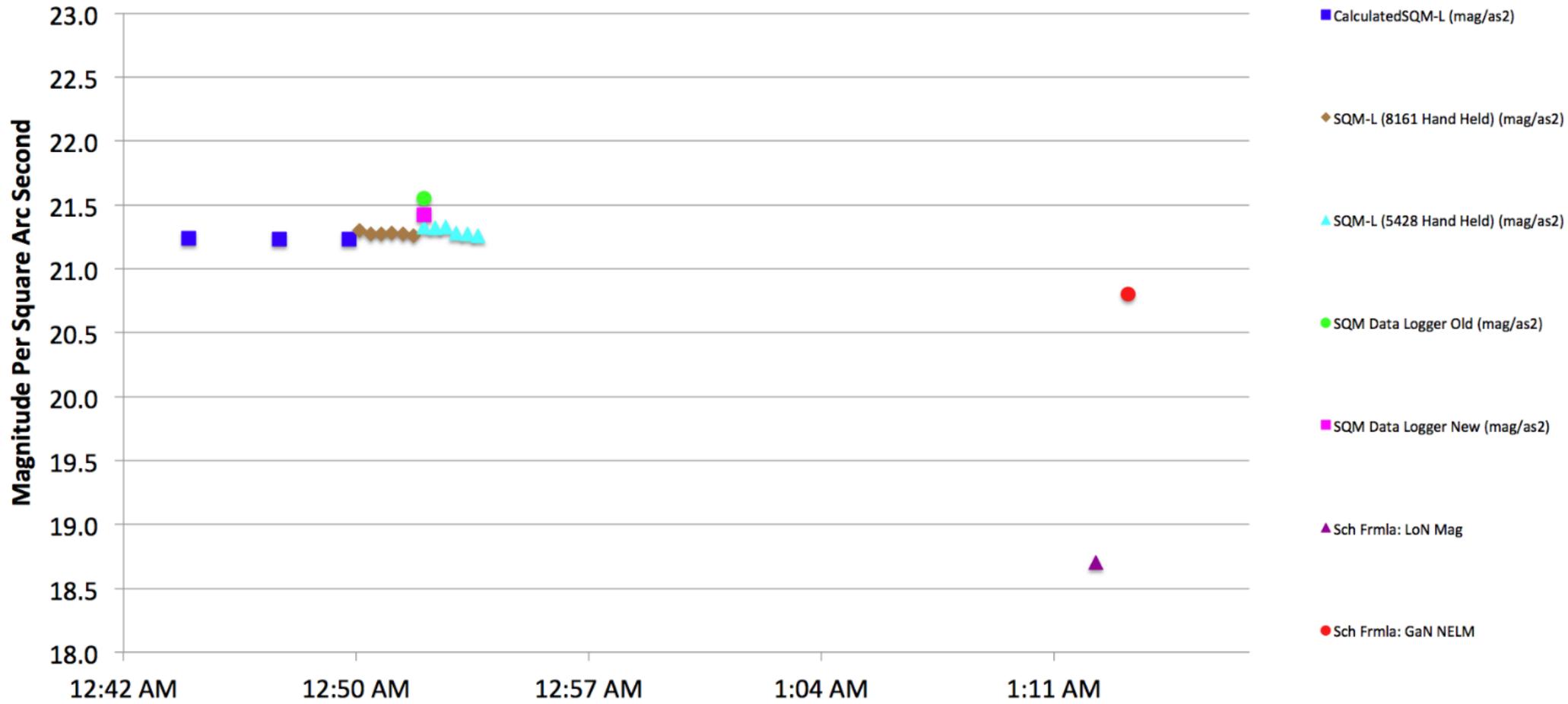
### Mount Hopkins Time Series - 9-10PM Observations



Mount Hopkins Time Series - 10-11PM Observations



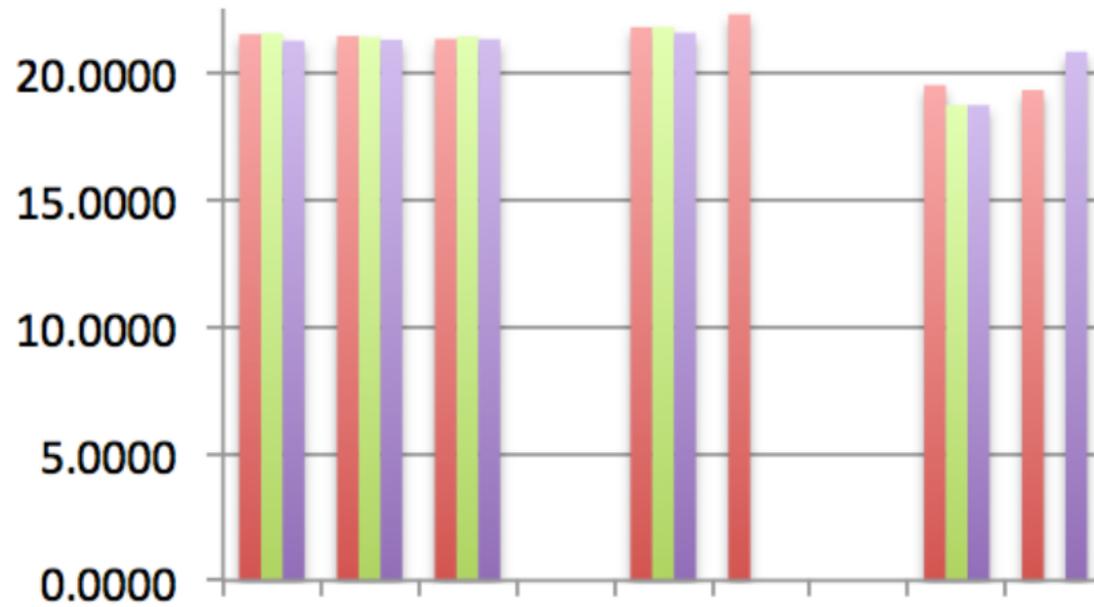
Mount Hopkins Time Series 12:30-1:30AM



# Comparison of Types of Measurements per Site



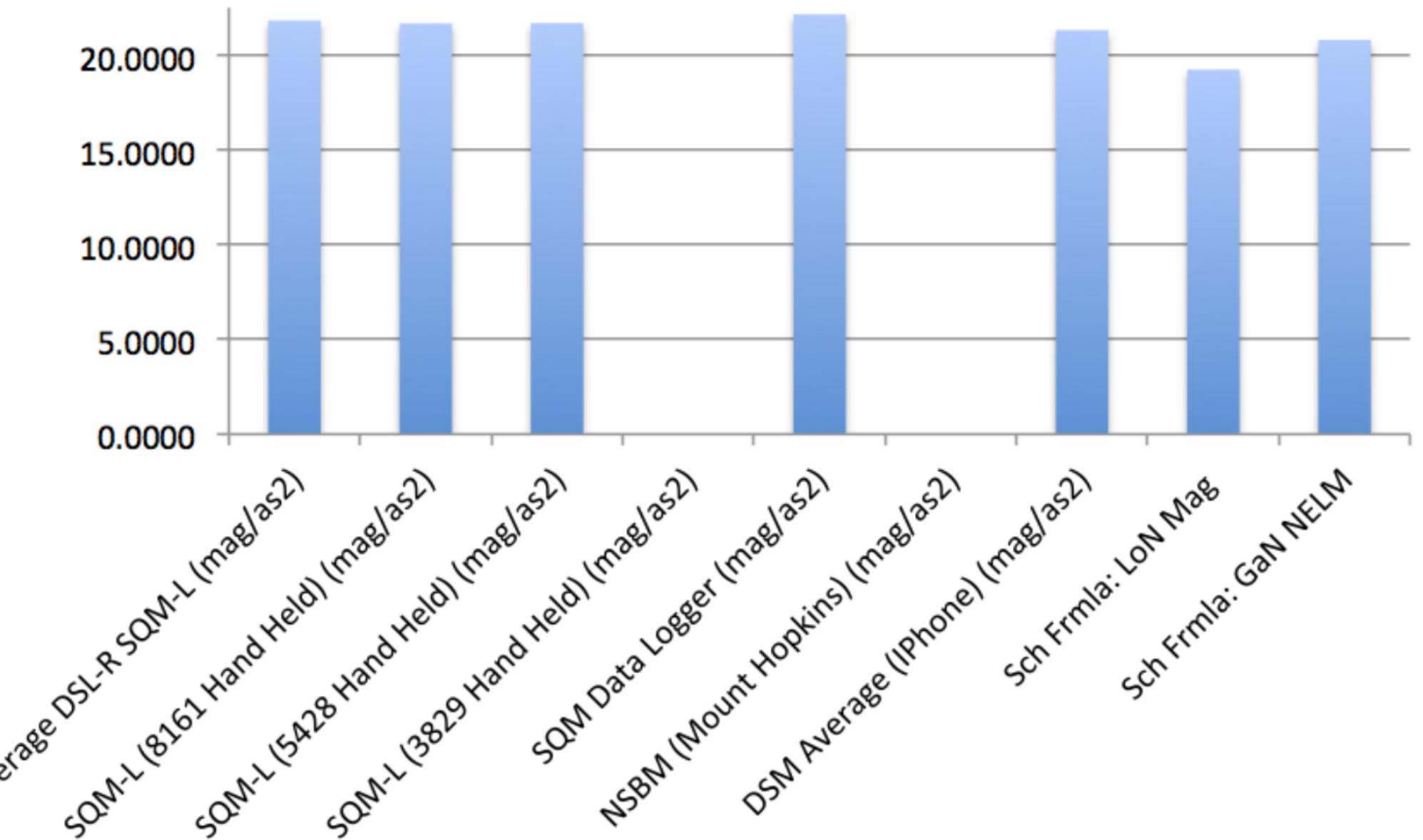
# Mount Hopkins



- Mount Hopkins 9-10pm
- Mount Hopkins 10-11pm
- Mount Hopkins 12:30-1:30am

Average DSL-R SQM-L (mag/as2)  
 SQM-L (8161 Hand Held) (mag/as2)  
 SQM-L (5428 Hand Held) (mag/as2)  
 SQM-L (3829 Hand Held) (mag/as2)  
 SQM Data Logger (mag/as2)  
 NSBM (Mount Hopkins) (mag/as2)  
 DSM Average (Iphone) (mag/as2)  
 Sch Frmla: LoN Mag  
 Sch Frmla: GaN NELM

# Kitt Peak



# Findings



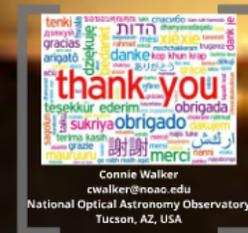
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- The **Dark Sky Meter** (DSM) app gave a 93% correlation to SQM-L #8161 data.
- The **DSLR** data provided an 80% correlation to the same data set.

- The **Globe at Night** data (GaN) Naked Eye Limiting Magnitude and the **Loss of the Night** (LON) app data had a 75% and 43% correlation to SQM-L #8161, respectively.
- Those data used **Schaefer's Formula** for converting from magnitudes to magnitudes per square arcsecond.
- The assumptions in Schaefer's Formula plus a couple of challenges in the first version of the LON app (which has since been improved) most likely contributed to the low correlation coefficient comparing LON app & SQM-L data.

## Night Sky Brightness Scale Comparisons



Image Credit: Henk Spoelstra



Connie Walker  
twalker@noao.edu  
National Optical Astronomy Observatory  
Tucson, AZ, USA

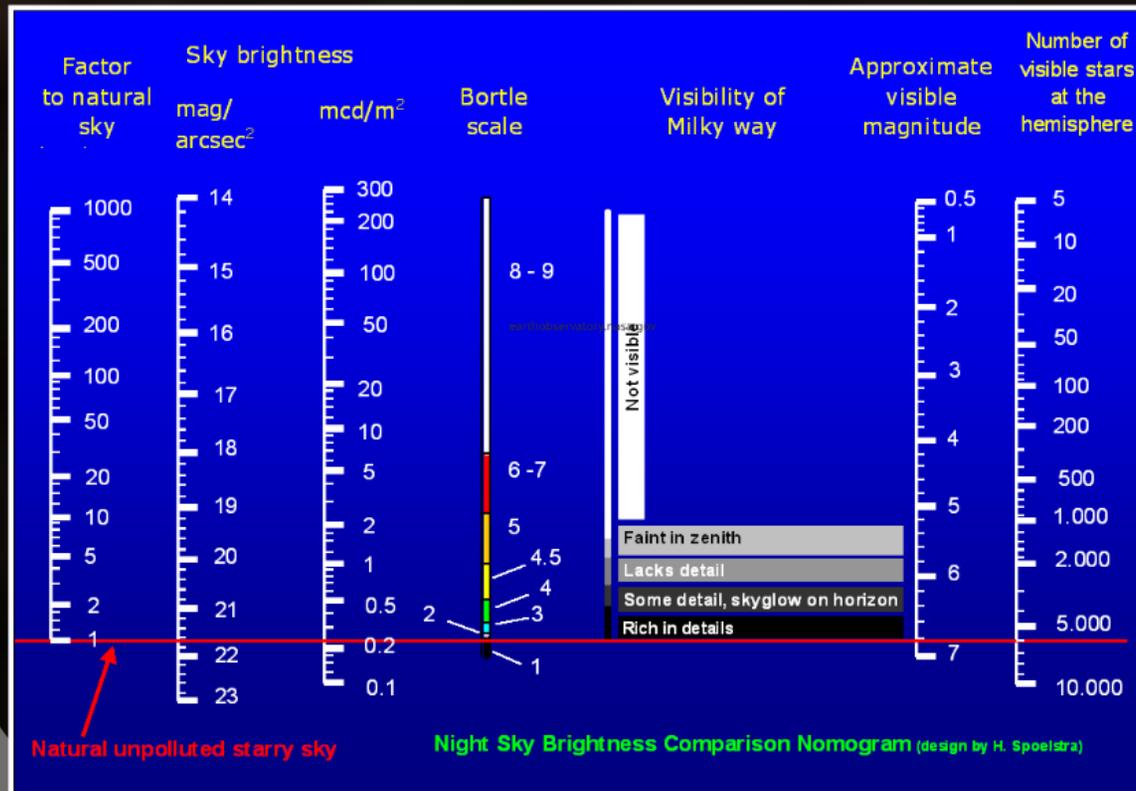
## Questions



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# Night Sky Brightness Scale Comparisons



**Image Credit: Henk Spoelstra**

# Questions



