

# First results from The Gattini South Pole UV Experiment

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# Collaborators

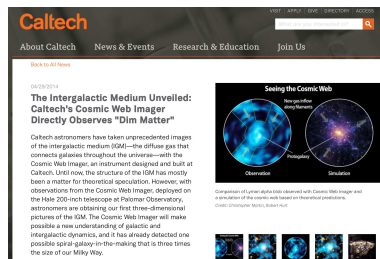
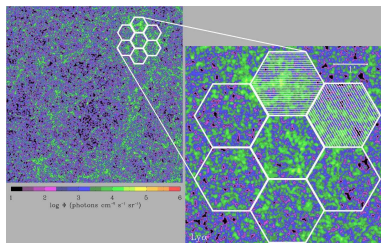
- Sara Ahmed (Caltech Optical Observatories, SURF student, detector characterization)
- Michael Ashley (University of New South Wales, control system)
- Yichen Chen (UCLA, Caltech SURF student, data reduction)
- Ernest Cromer (Caltech Optical Observatories, EE)
- Alex Delacroix (Caltech Optical Observatories, ME)
- Yusuke Ebihara (Nagoya University, All sky imager data)
- Jason Fucik (Caltech Optical Observatories, I&T)
- Chris Martin (CIT)
- Anna Moore (Caltech Optical Observatories, PI)
- Viswa Velur (Caltech Optical Observatories, I&T)
- Allan Weatherwax (Siena College, All sky imager data)
- Yi Yang (TAMU, data reduction)

# Overview

- 1 Why Gattini South Pole UV Experiment
- 2 Instrument design & performance
- 3 Data reduction and preliminary results
- 4 Summary & Future works

# Why Gattini South Pole UV Experiment

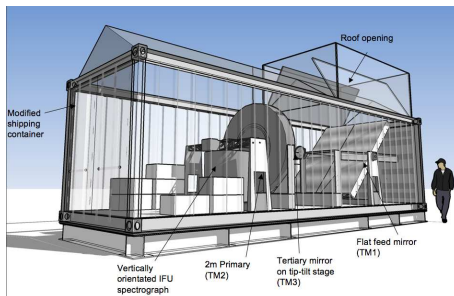
The Gattini SPUV pathfinder will characterize the South Pole winter sky from 2011 onwards in the Astronomical U and B bands to provide a foundation for future larger-scale experiments such as the Antarctic Cosmic Web Imager (direct detection of Ly $\alpha$  fluorescence from the Intergalactic Medium (IGM)). Moore et al 2008, SPIE



Left panel: Predicted Lyman  $\alpha$  emission line distribution for a simulation (S. Furlanetto),  $z \sim 2.5$ ,  $\Delta z \sim 0.07$ , ( $\sim 10$  nm, 1/3 of the ACWI band-pass)  $17 \times 17$  arcmin<sup>2</sup> area (1/16th of the total area of the Wide Lyman  $\alpha$  survey).  
Right panel: Comparison of Lyman  $\alpha$  blob observed with Palomar Cosmic Web Imager (Martin et al. 2014, AJ 786:107)

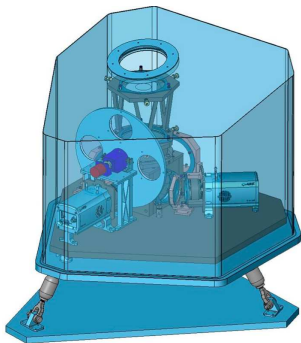
# ACWI observing rationale

- Ly 121.6nm, CIV 155nm, and OVI 103nm. IGM,  $z=2\sim3$
- IGM emission detection requires exceptional sky subtraction (simultaneous spectral imaging with IFS over a wide field at high enough resolution will separate sky emission from source)
- Less systematical effects (const target elevation + long integration periods)
- $\sim 2\text{m}$ -class telescope aperture required for deep survey



# Gattini UVSP Objectives

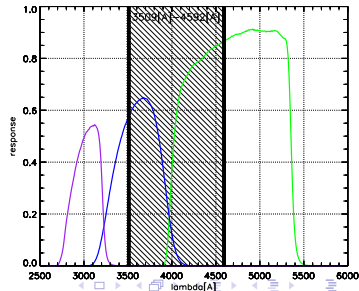
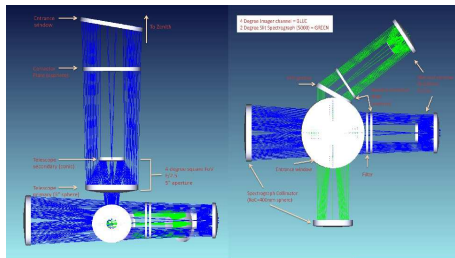
- Characterize the South Pole winter sky brightness in the Astronomical U and SDSS g bands for the first time
- Quantify effect of at least two of the brightest aurora and airglow lines in the U and g bands
- Produce light curve dataset in U and SDSS g to compliment 6 inch CSTAR g/r/i at Dome A



This is the MAPS building in the Dark Sector. We can clear the debris from this roof and put your instrument here. Does this look like a reasonable location for what that groundshield could your view? There is a lab directly below this location where your computer can be set up.

# Optical design

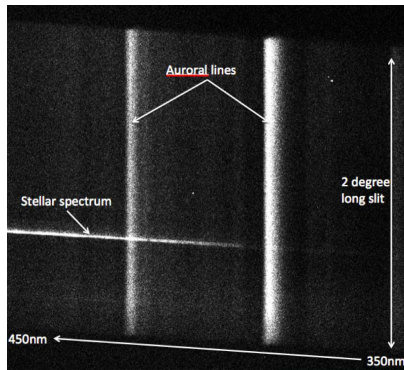
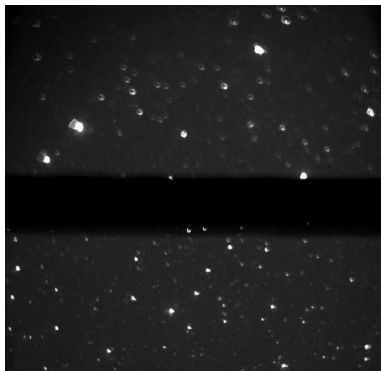
- 6 inch aperture, 4 degree FoV imager with blue side filters:
  - Bessel U (  $< 345\text{nm}$  short pass filter)
  - SDSS  $g'$  (modified to completely exclude 557nm line)
  - 'Super U'
- 2 degree long slit spectrograph
  - 350 - 450 micron bandwidth
  - $R \sim 400$  (capable of  $R \sim 2000$  with narrower slit)
- Both are stationary, transit systems, FOV centered on South Pole, operating continuously through winter season



# Observation and Data reduction

- Typical imager exposure sequence (spectrograph exposed simultaneously)
- SDSS g' 30s, SDSS g' 100s, SDSS g' 300s,
- Bessel U 30s, Bessel U 100s, Bessel U 300s,
- Super U 30s, Super U 100s, Super U 300s,
- Dark, Bias, then REPEAT

Data downloaded via satellite within 24 hrs, 4GB/day download

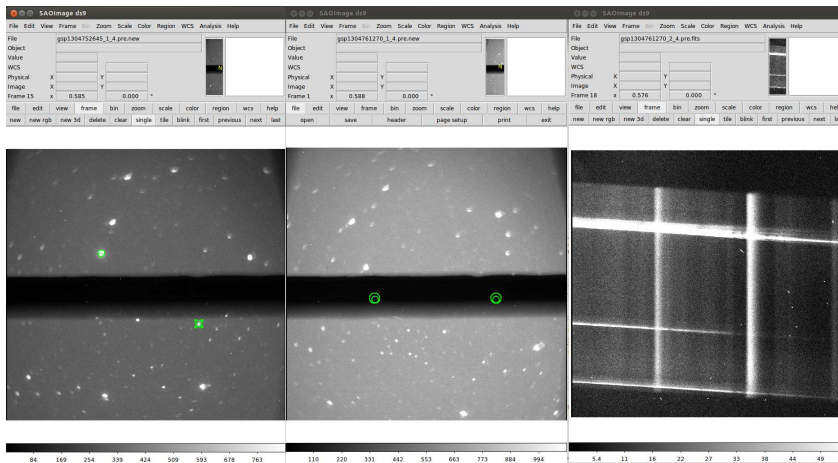




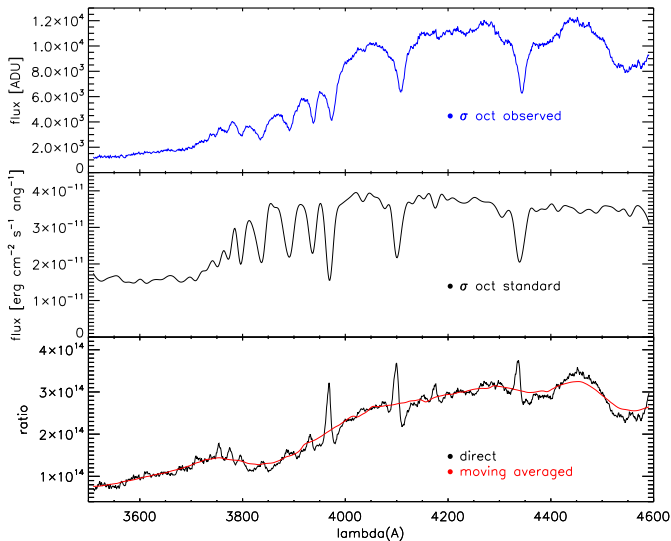
# Observation and Data reduction

- Pre-processing
  - Bias (dark) subtraction
  - Image: Astrometry through *Astrometry.net*, Lang et al 2010
  - Spectrum: Cosmic-ray rejection
  - Spectrum: Stellar spectrum masking
  - Spectrum: Raw sky spectrum: median along spatial direction (vertical)
- Wavelength calibration:  
compare twilight/moon spectrum with solar spectrum
- Flux calibration:  
Image: Aperture photometry, catalogue magnitude  
Spectrum: stellar spectrum ( $\sigma$  Oct)
  - Response function along wavelength direction(horizontal)
  - Response function along spatial direction (vertical)
  - When does a star pass through the slit
- Image: U and g' through May 6 to Sep 9, 2011
- Spectrum: 300s, through Jun 22 2011 to Jul 03, 2011

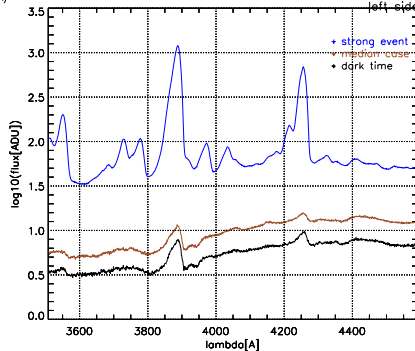
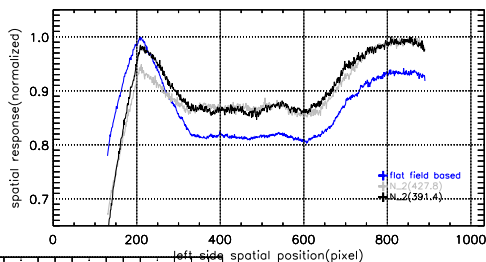
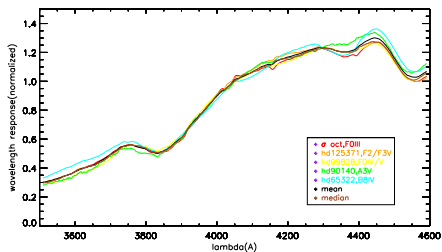
# Star passing through the slit



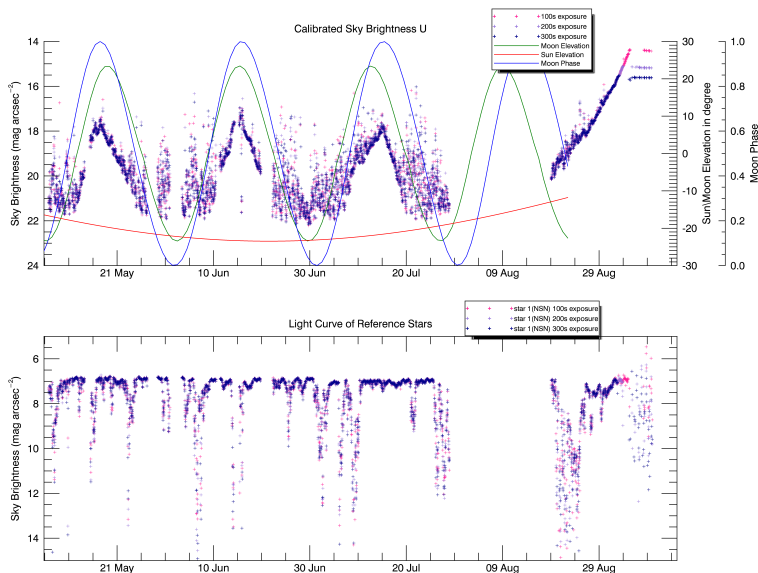
# Wavelength response function



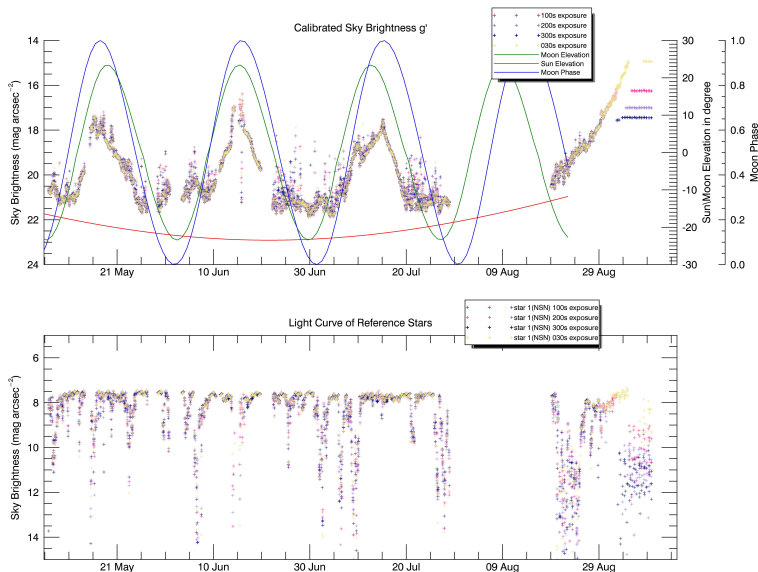
# Wavelength response function



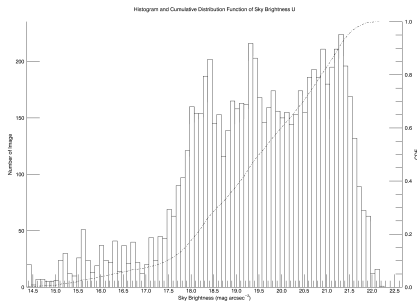
# Results: photometric



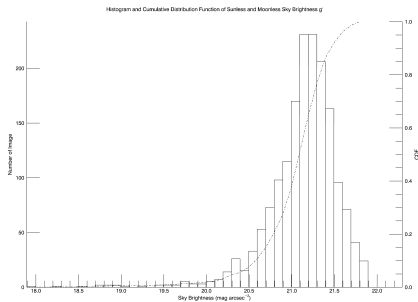
# Results: photometric



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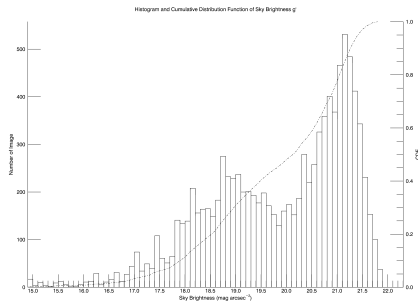
U: Whole season  
median = 19.6 mag arcsec<sup>-2</sup>



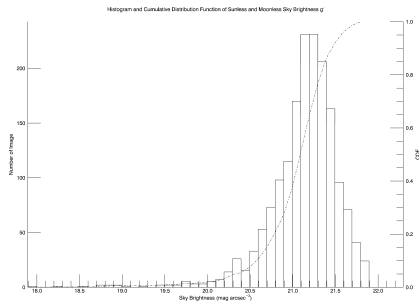
U: Sunless and moonless days  
median = 21.0 mag arcsec<sup>-2</sup>

U: dark = 22.2 mag arcsec<sup>-2</sup>

# Results: photometric



$g'$ : Whole season  
median = 20.2 mag arcsec<sup>-2</sup>

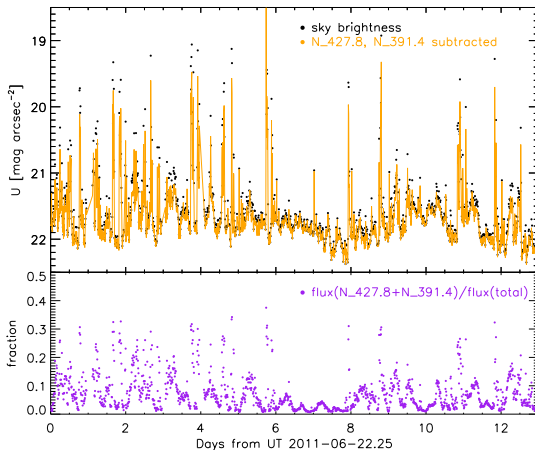


$g'$ : Sunless and moonless days  
median = 21.2 mag arcsec<sup>-2</sup>

$g'$ : dark = 21.9 mag arcsec<sup>-2</sup>



# Results: spectroscopic



Jun 22 - Jul 05, 2011 (Sun  $< -18^\circ$ , Moon  $< -5^\circ$ )

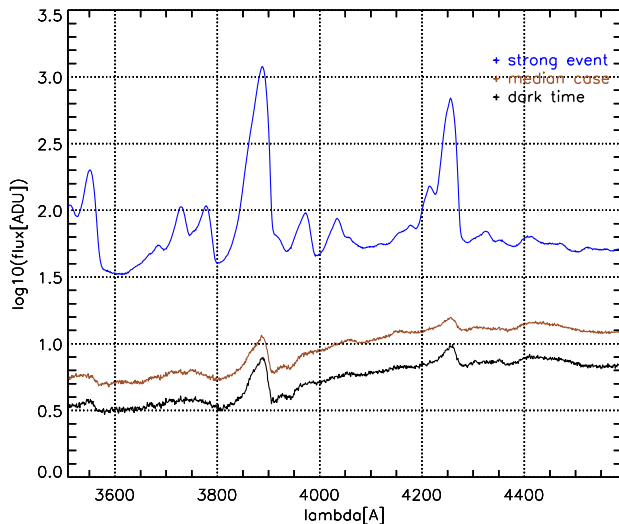
U: median = 21.8 mag arcsec<sup>-2</sup>, darkest = 22.4 mag arcsec<sup>-2</sup>

Cerro Tololo 22.0 mag arcsec<sup>-2</sup>, 1987, Walker (1987, 1988a)

La Palma 22.0 mag arcsec<sup>-2</sup> 1994, Benn & Ellison (1998)

Paranal 22.3 mag arcsec<sup>-2</sup> 2000, Patat (2003)

# Results: spectroscopic



# Summary and Future works

## Summary

- Gattini-UVSP characterizes the sky brightness at South Pole during 2011 winter season
- Photometric and spectroscopic calibrations agrees
- Bright aurora events contribute more to N 427.8nm and N 391.4nm lines, but also continuous sky spectrum

## Future works

- Reduce all the data
- Quantify the number of days that are strongly affected by aurora
- More concerning to Super U? Another palomar test?
- Light curves for variables continuous sky spectrum

## Working with SCAR AAA

(From the perspective of students)

- Expand research interest, science & technology
- Chance to visit
- More frequent collaborations and meetings as more established facilities and science.

## Acknowledgements

- National Science Foundation
- United States Antarctic Program

# Phase-flux plot

