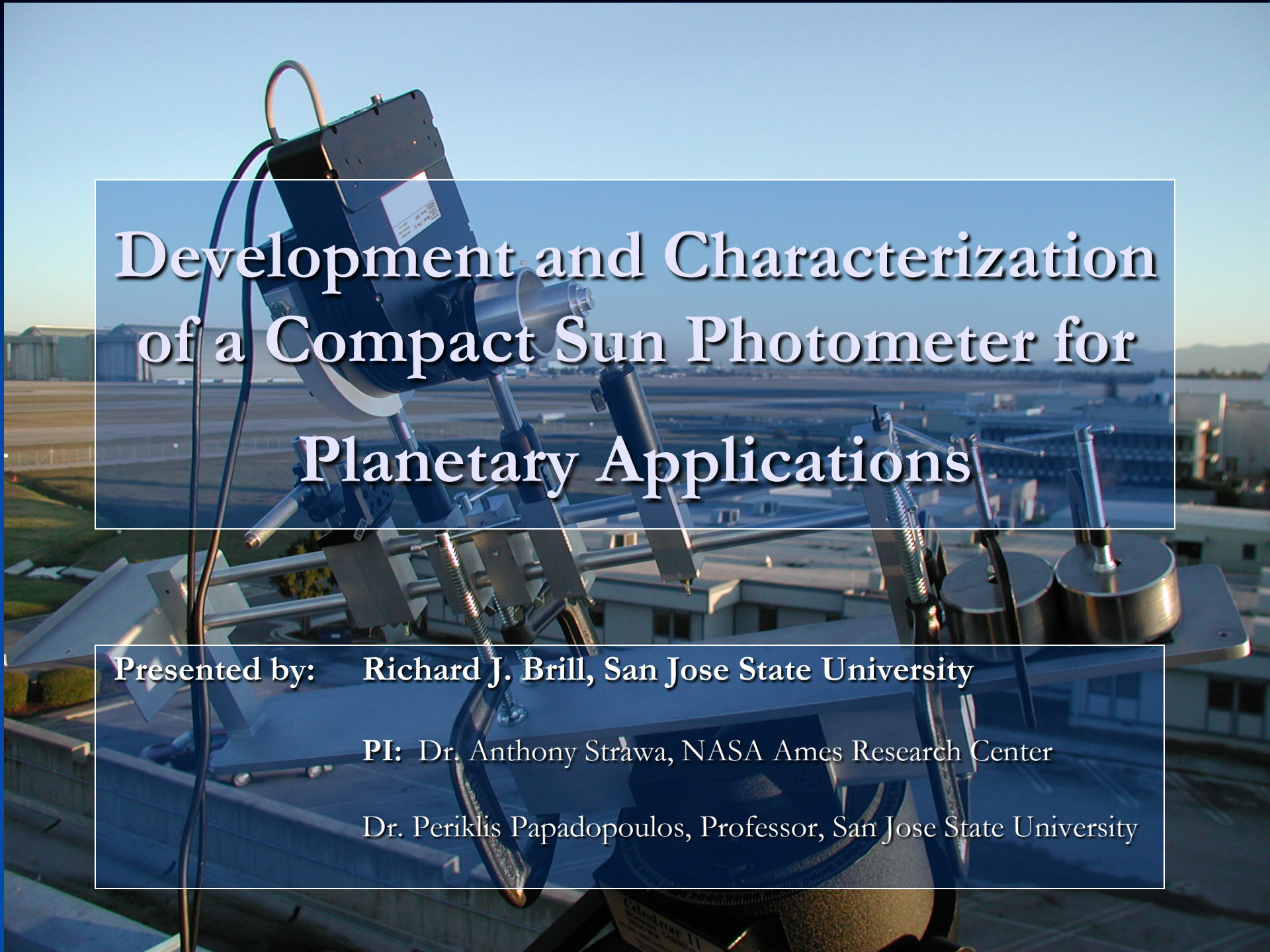


Development and Characterization of a Compact Sun Photometer for Planetary Applications

Presented by: **Richard J. Brill, San Jose State University**

PI: Dr. Anthony Strawa, NASA Ames Research Center

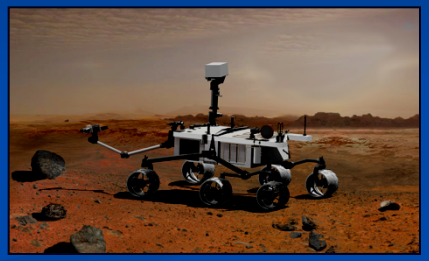
Dr. Periklis Papadopoulos, Professor, San Jose State University

Motivation

- Aerosols Important to Radiative Balance
- Characterization and Distribution of Aerosols in Planetary Atmospheres
  - **Dust in the Martian Atmosphere**
- Aerosols/Dust Vary Temporally and Spatially
- Ground Measurements are Complimentary to Satellite Measurements
- Sun Photometry is an Efficient Method to Measure Aerosols from within an Atmosphere

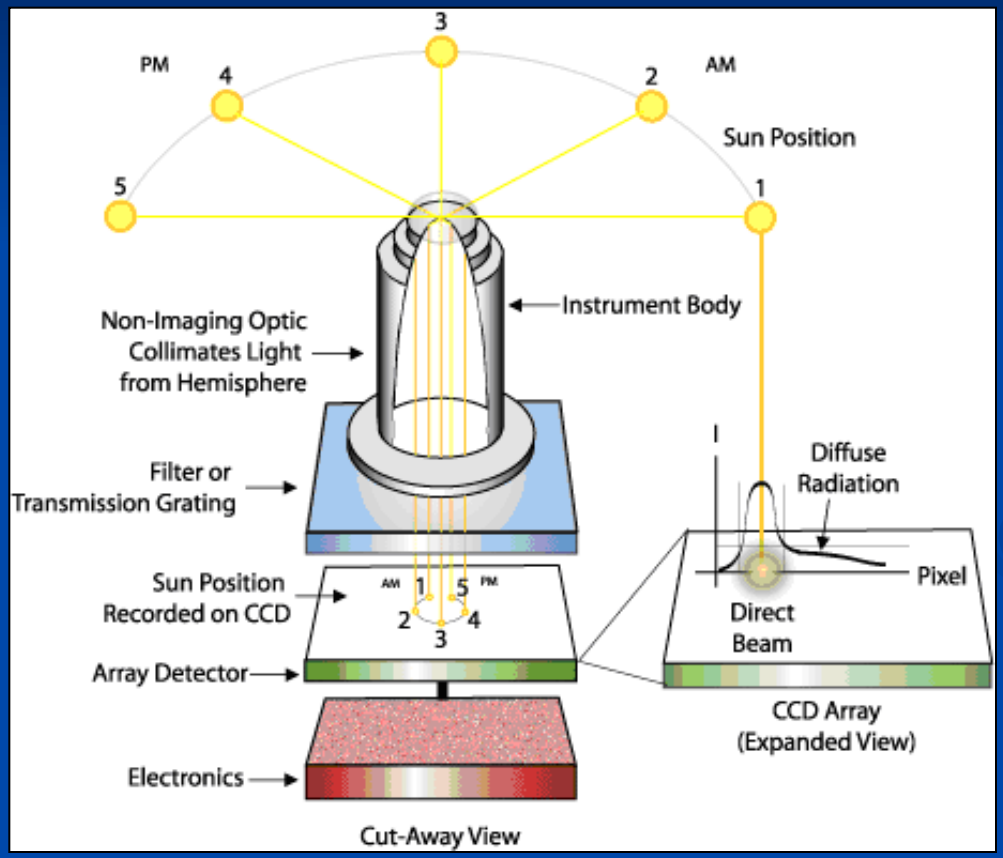
Objective

Dedicated Instrument for the Measurement of Planetary Atmospheric Aerosols - Dust Particles



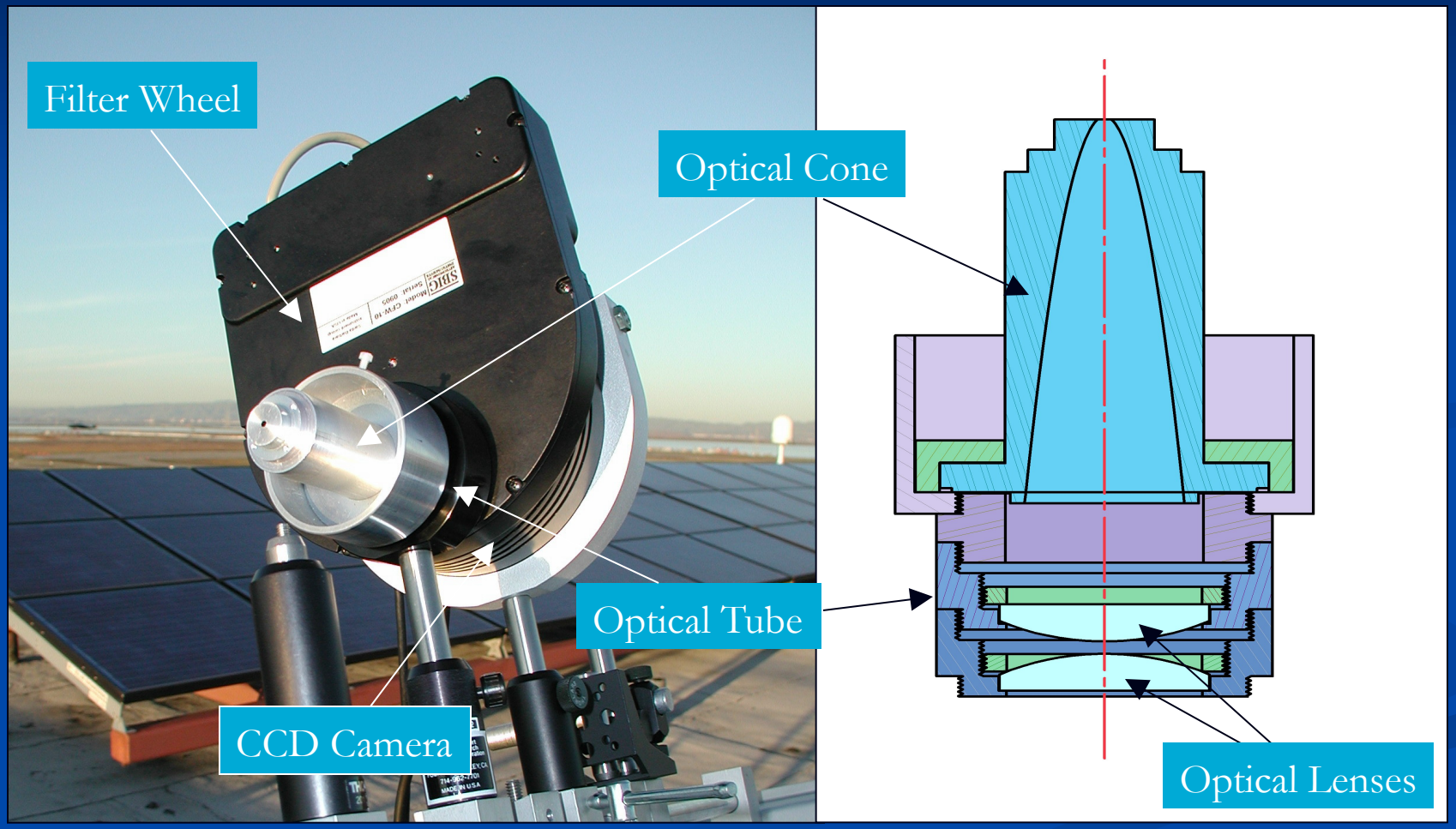
- Reliable
- Small size
- Light Weight
- Low Cost
- Low Power Consumption

Implementation

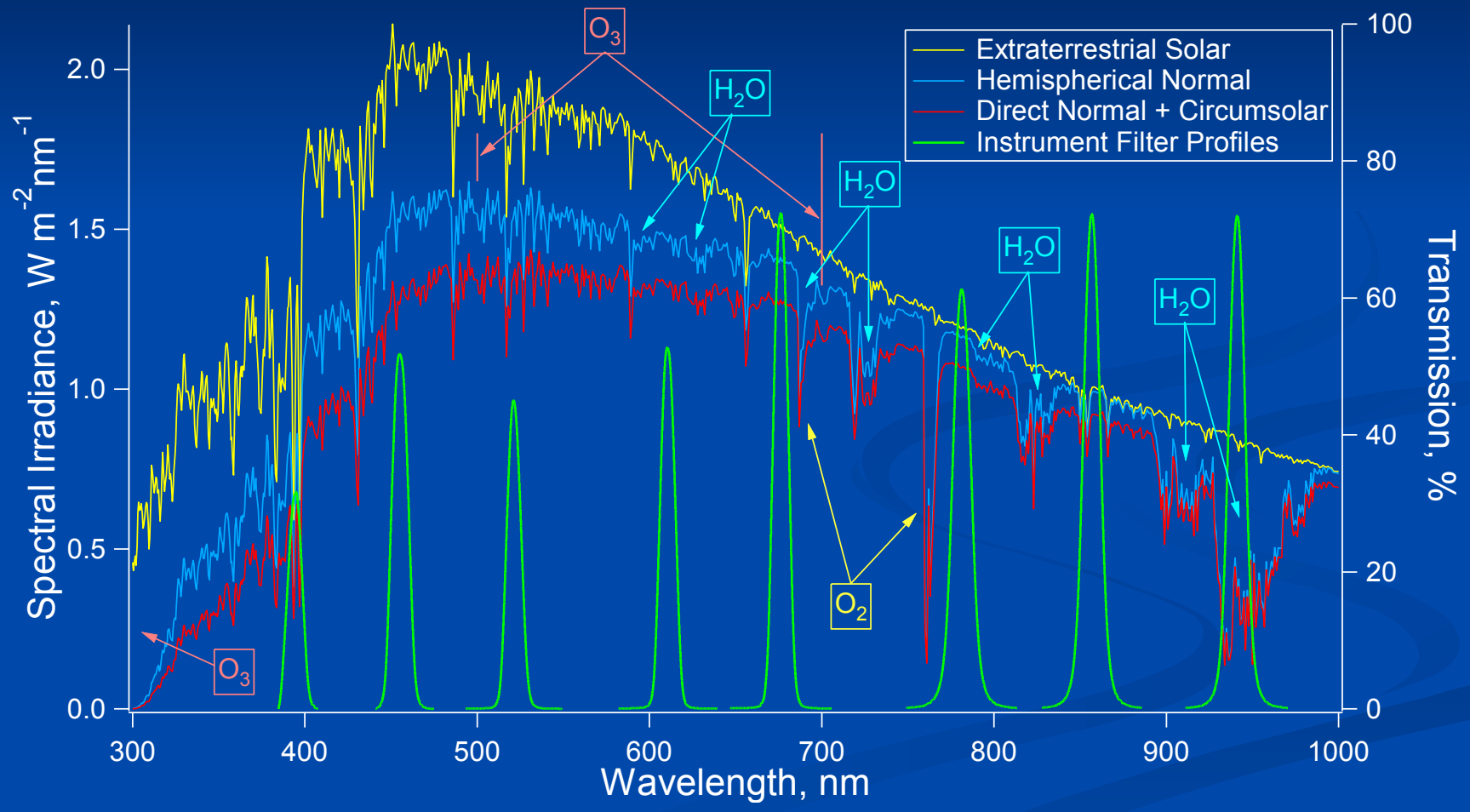


- Hemispherical FOV
- CCD Array Detector
- No Moving Parts to Track the Sun
- Multiple Filters

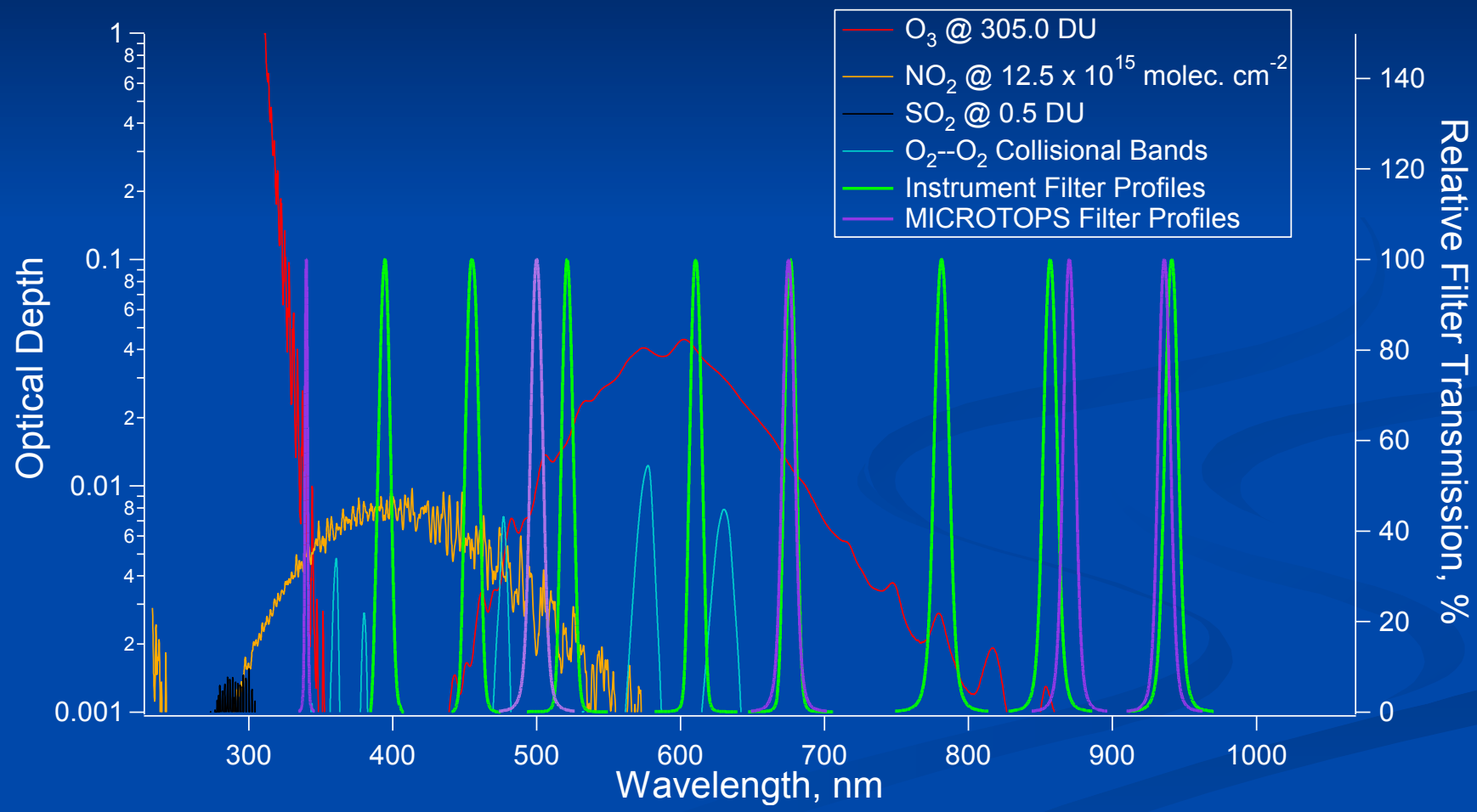
Instrument Prototype



Instrument Filter Bandpass



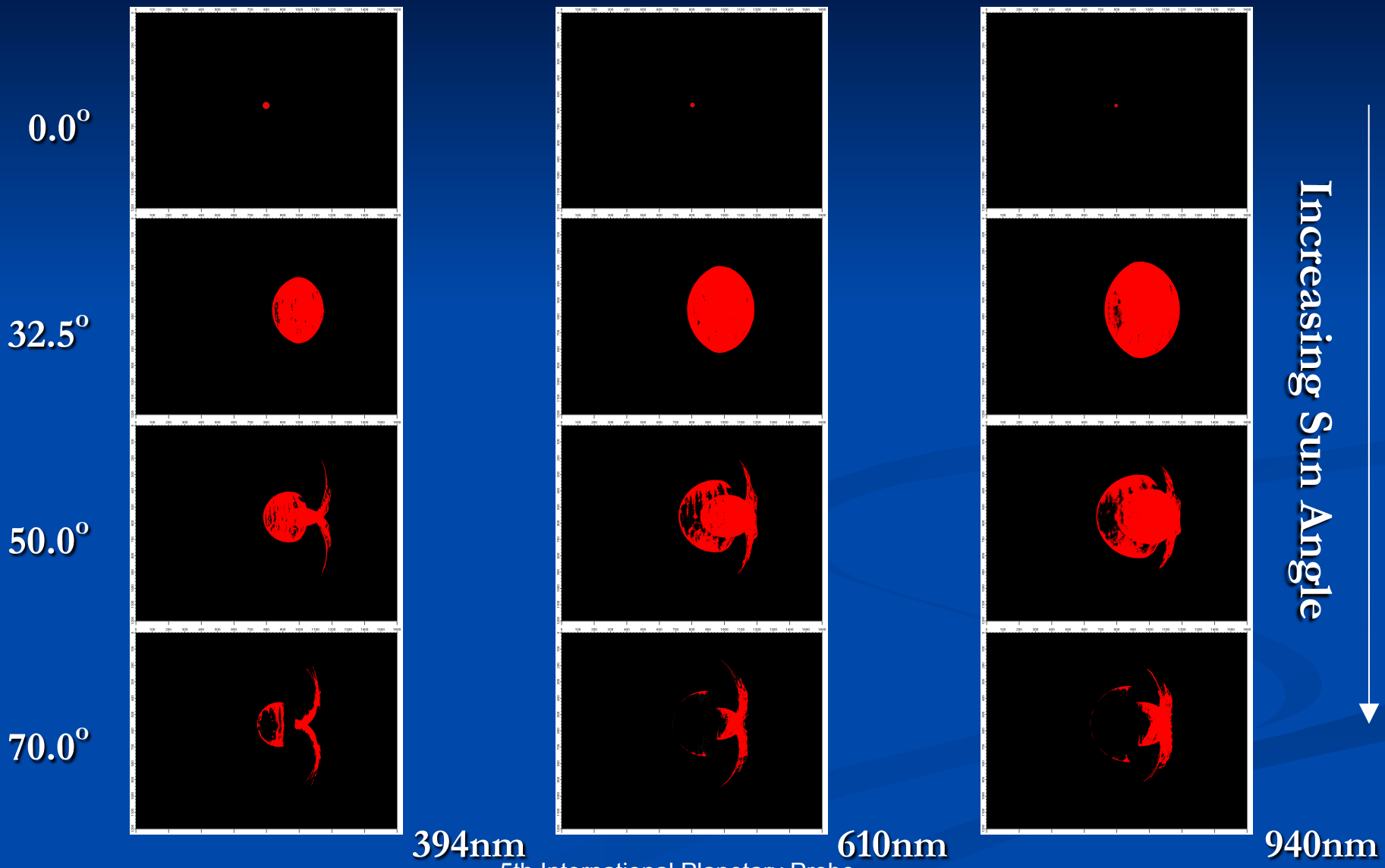
Trace Gas Optical Depth



Data Products

- Aerosol Optical Depth (AOD) as a Function of Wavelength and Scattering Angle
- Column Abundance of Gasses
- Distribution of Aerosol/Mars Dust Particle Size, Shape, and Composition
- Diffuse and Direct Down welling Flux
- Direct to Total Ratio

Increasing Wavelength



Future Work

- Short Term
  - Optical Density as a Function of Wavelength
  - Improved Measurement Optical Depth
  - Automate Data Acquisition Process
- Long Term
  - Develop a Ray-Tracing Model
  - Develop Improved Mirror/Lens Optics
  - Develop Additional Aerosol Data Products

Acknowledgements

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  - P.I. from NASA Ames Research Center
- Dr. Periklis Papadopoulos
  - Professor at San Jose State University
- Patrick Grant and Ted Hildum
  - Science Applications Int. Corp.
- Tuyet Le
  - Student at San Jose State University

Questions?

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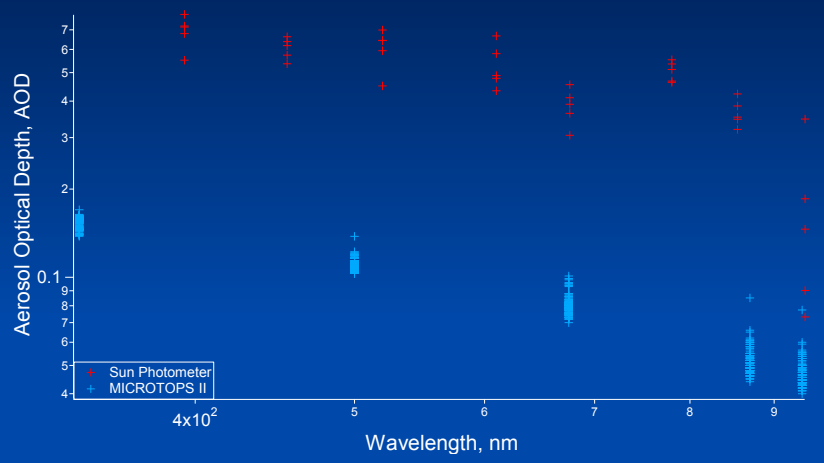
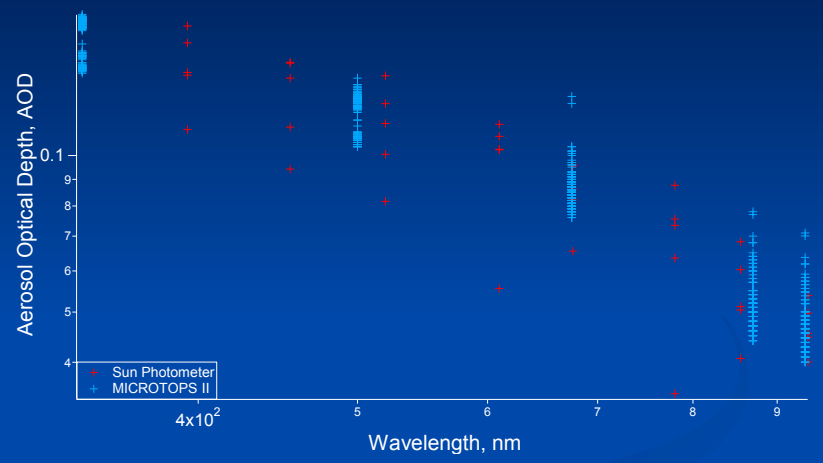
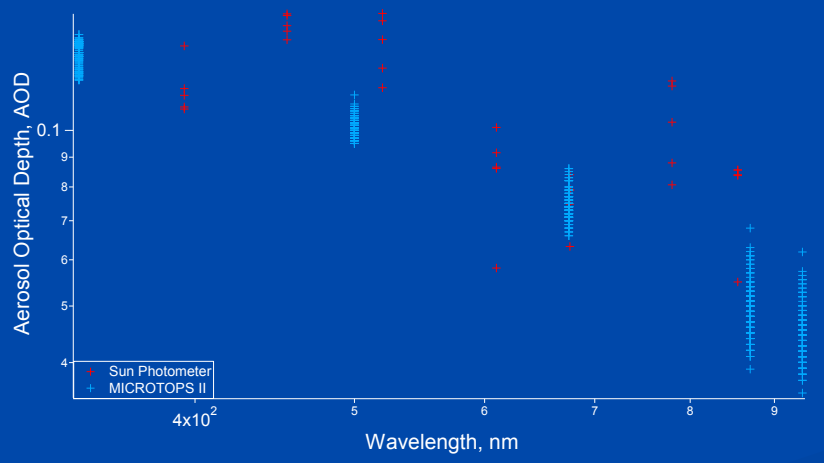
Solar Angle = 15.5 deg



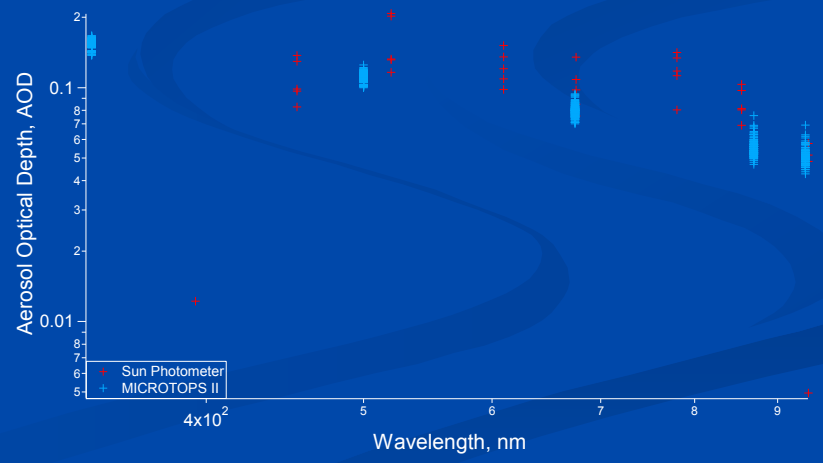
Solar Angle = 31.0 deg



Solar Angle = 46.5 deg



Solar Angle = 62.0 deg



Beer-Bourguer-Lambert Law

$$I_\lambda = \frac{I_{0\lambda}}{R^2}\exp\left(-m\tau_\lambda\right)$$

where, for each channel (at wavelength λ)

- I_λ is the intensity measured by the instrument,
- $I_{0\lambda}$ is the zero-air-mass, solar, spectral intensity,
- R is the Earth-Sun distance in AU at time of observation,
- m is the optical air mass,
- τ_λ the is total optical depth $\left(\tau_\lambda = \tau_{a\lambda} + \tau_{R\lambda} + \tau_{O_3\lambda} + \tau_{tr\lambda}\right)$,
- $\tau_{a\lambda}$ is the aerosol optical depth (AOD) ,
- $\tau_{R\lambda}$ is the Rayleigh (air) optical depth,
- $\tau_{O_3\lambda}$ is the ozone optical depth, and
- $\tau_{\mathrm{tr}\lambda}$ is for any other trace gas optical depths.

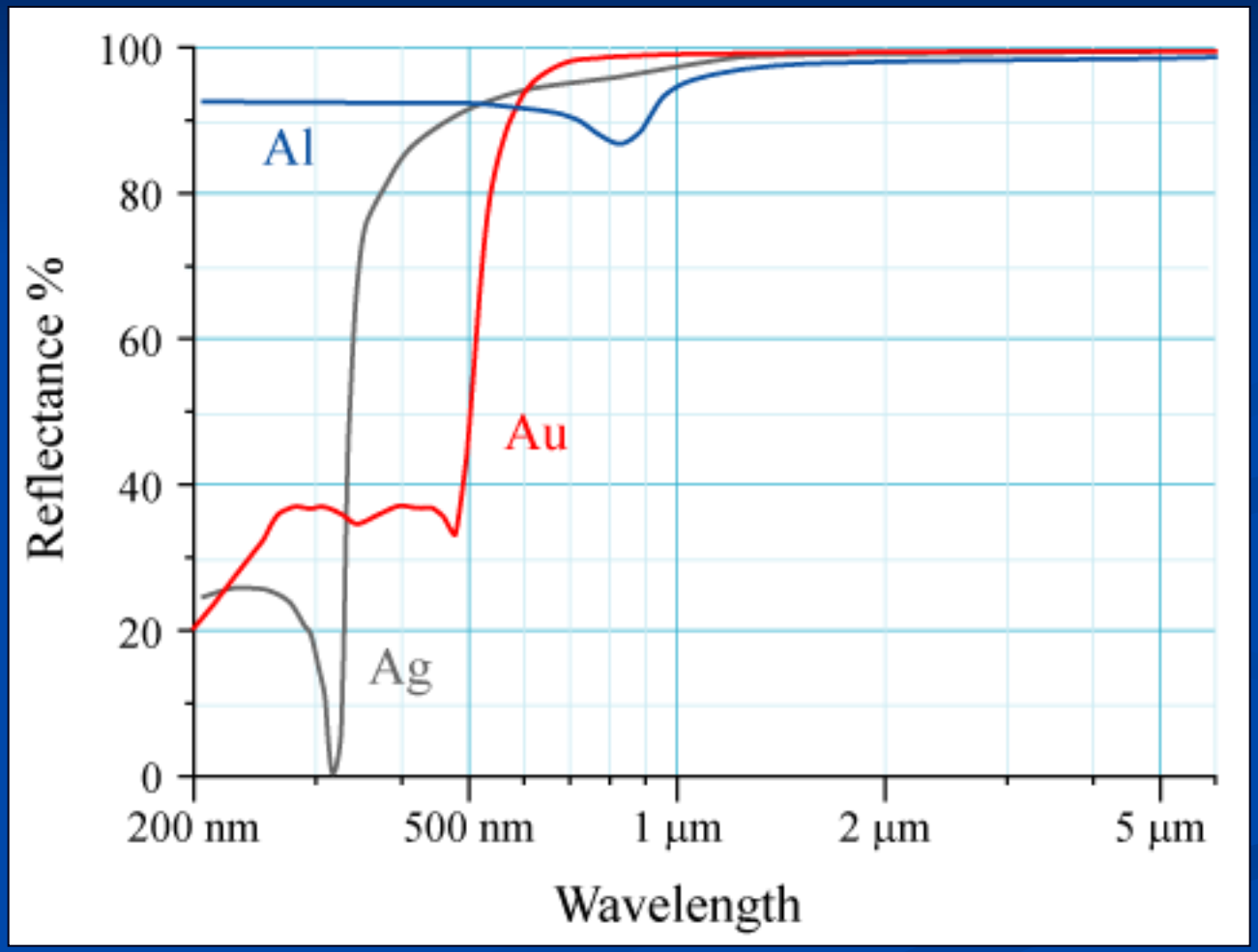
Modified Equation for Water Vapor

$$I_w = \frac{I_{0w}}{R^2} \exp\left[-m\tau_w - k\left(mW\right)^b\right]$$

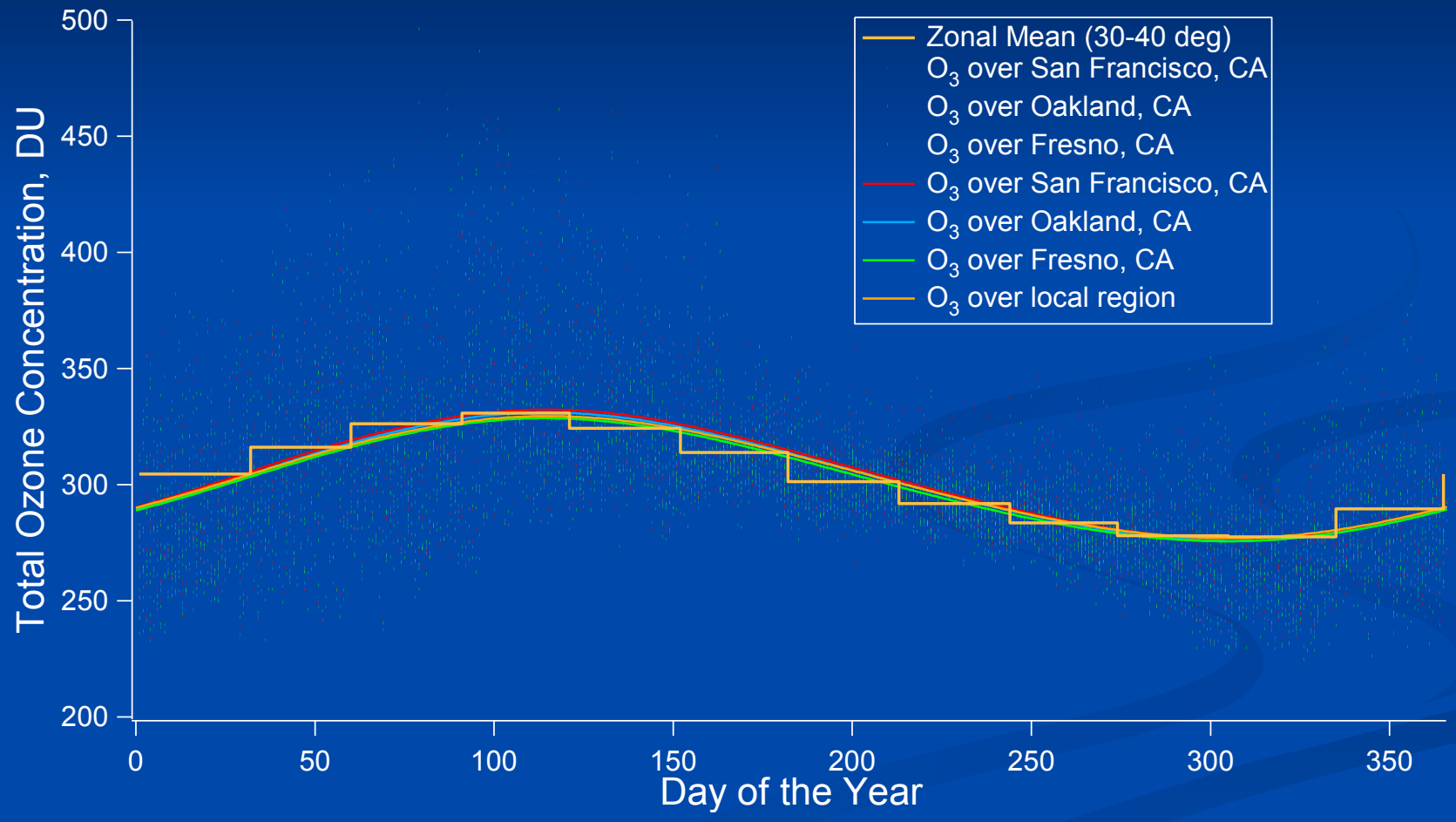
where for water vapor channel (at 936/940 nm),

- I_w is the intensity measured by the instrument,
- I_{0w} is the zero-air-mass, solar, spectral intensity,
- R is the Earth-Sun distance in AU at time of observation,
- m is the optical air mass,
- τ_w is the total optical depth $\left(\tau_w = \tau_{aw} + \tau_{Rw} + \tau_{trw}\right)$,
- τ_{aw} is the aerosol optical depth (AOD),
- τ_{Rw} is the Rayleigh (air) optical depth,
- τ_{trw} is for any other trace gas optical depths,
- W is the vertical water vapor column depth, and
- k, b are constants numerically derived for the 936/940 nm filter.

Mirror Surface Reflectance



Local Annual Ozone Variation



Instrument O_3 Optical Depth

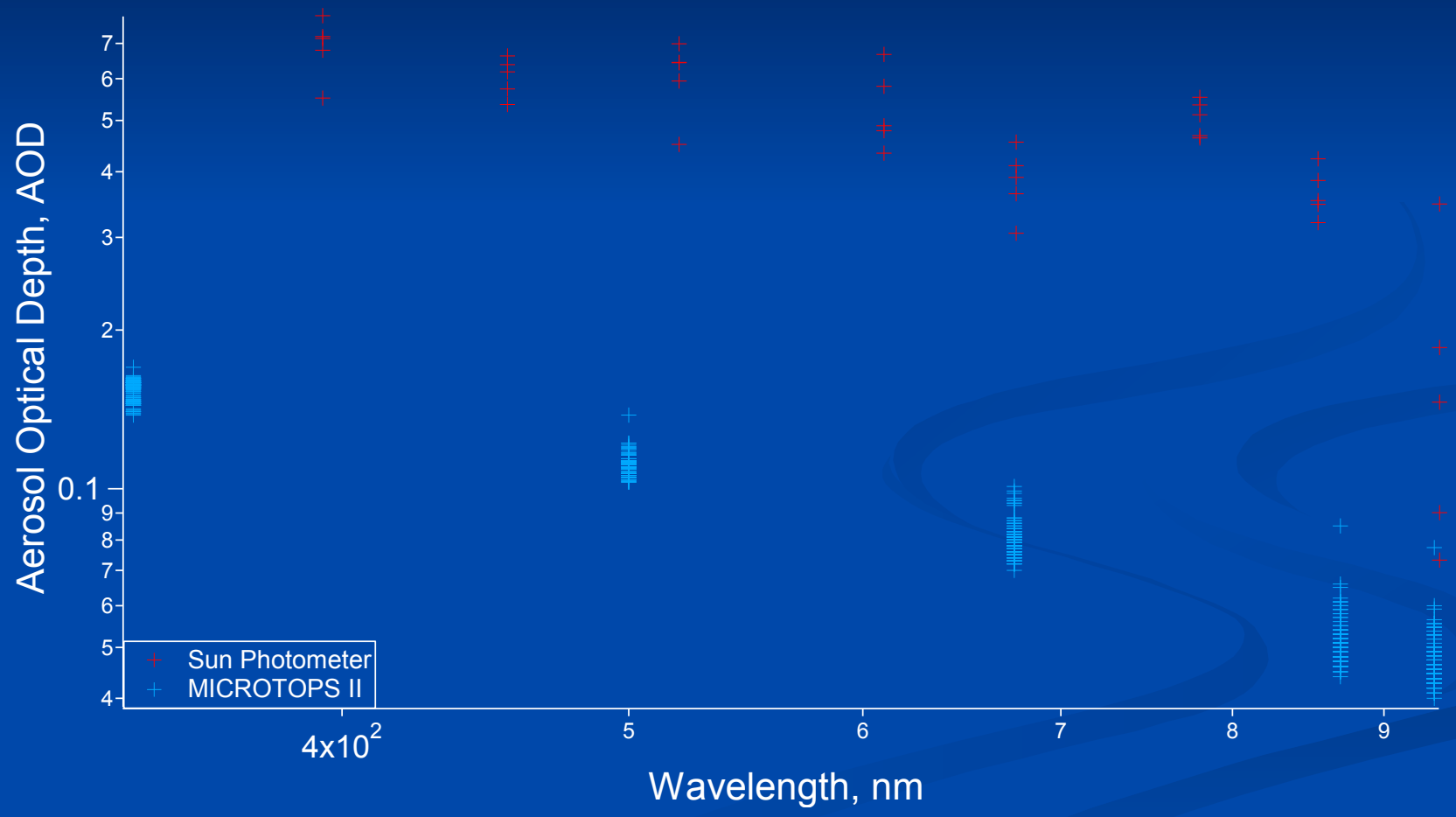
	394 nm	455 nm	520 nm	610 nm	676 nm	780 nm	855 nm	940 nm
Jan	0.000	0.002	0.016	0.040	0.012	0.002	0.001	0.000
Feb	0.000	0.002	0.017	0.041	0.013	0.002	0.001	0.000
Mar	0.000	0.002	0.017	0.043	0.013	0.003	0.001	0.000
Apr	0.000	0.002	0.018	0.043	0.013	0.003	0.001	0.000
May	0.000	0.002	0.017	0.043	0.013	0.002	0.001	0.000
Jun	0.000	0.002	0.017	0.041	0.013	0.002	0.001	0.000
Jul	0.000	0.002	0.016	0.039	0.012	0.002	0.001	0.000
Aug	0.000	0.002	0.016	0.038	0.012	0.002	0.001	0.000
Sep	0.000	0.002	0.015	0.037	0.011	0.002	0.001	0.000
Oct	0.000	0.002	0.015	0.036	0.011	0.002	0.001	0.000
Nov	0.000	0.002	0.015	0.036	0.011	0.002	0.001	0.000
Dec	0.000	0.002	0.015	0.038	0.012	0.002	0.001	0.000
Year Mean	0.000	0.002	0.016	0.040	0.012	0.002	0.001	0.000
Day Max	0.000	0.003	0.027	0.066	0.020	0.004	0.002	0.000
Day Min	0.000	0.002	0.012	0.029	0.009	0.002	0.001	0.000

Microtops II O_3 Optical Depth

	340 nm	380 nm	440 nm	500 nm	675 nm	870 nm	936 nm	1020 nm
Jan	0.007	0.000	0.001	0.011	0.012	0.000	0.000	----
Feb	0.007	0.000	0.001	0.012	0.012	0.000	0.000	----
Mar	0.007	0.000	0.001	0.012	0.013	0.000	0.000	----
Apr	0.007	0.000	0.001	0.012	0.013	0.000	0.000	----
May	0.007	0.000	0.001	0.012	0.013	0.000	0.000	----
Jun	0.007	0.000	0.001	0.012	0.012	0.000	0.000	----
Jul	0.007	0.000	0.001	0.011	0.012	0.000	0.000	----
Aug	0.006	0.000	0.001	0.011	0.011	0.000	0.000	----
Sep	0.006	0.000	0.001	0.011	0.011	0.000	0.000	----
Oct	0.006	0.000	0.001	0.010	0.011	0.000	0.000	----
Nov	0.006	0.000	0.001	0.010	0.011	0.000	0.000	----
Dec	0.006	0.000	0.001	0.011	0.011	0.000	0.000	----
Year Mean	0.007	0.000	0.001	0.011	0.012	0.000	0.000	----
Day Max	0.011	0.000	0.002	0.019	0.020	0.001	0.000	----
Day Min	0.005	0.000	0.001	0.008	0.009	0.000	0.000	----

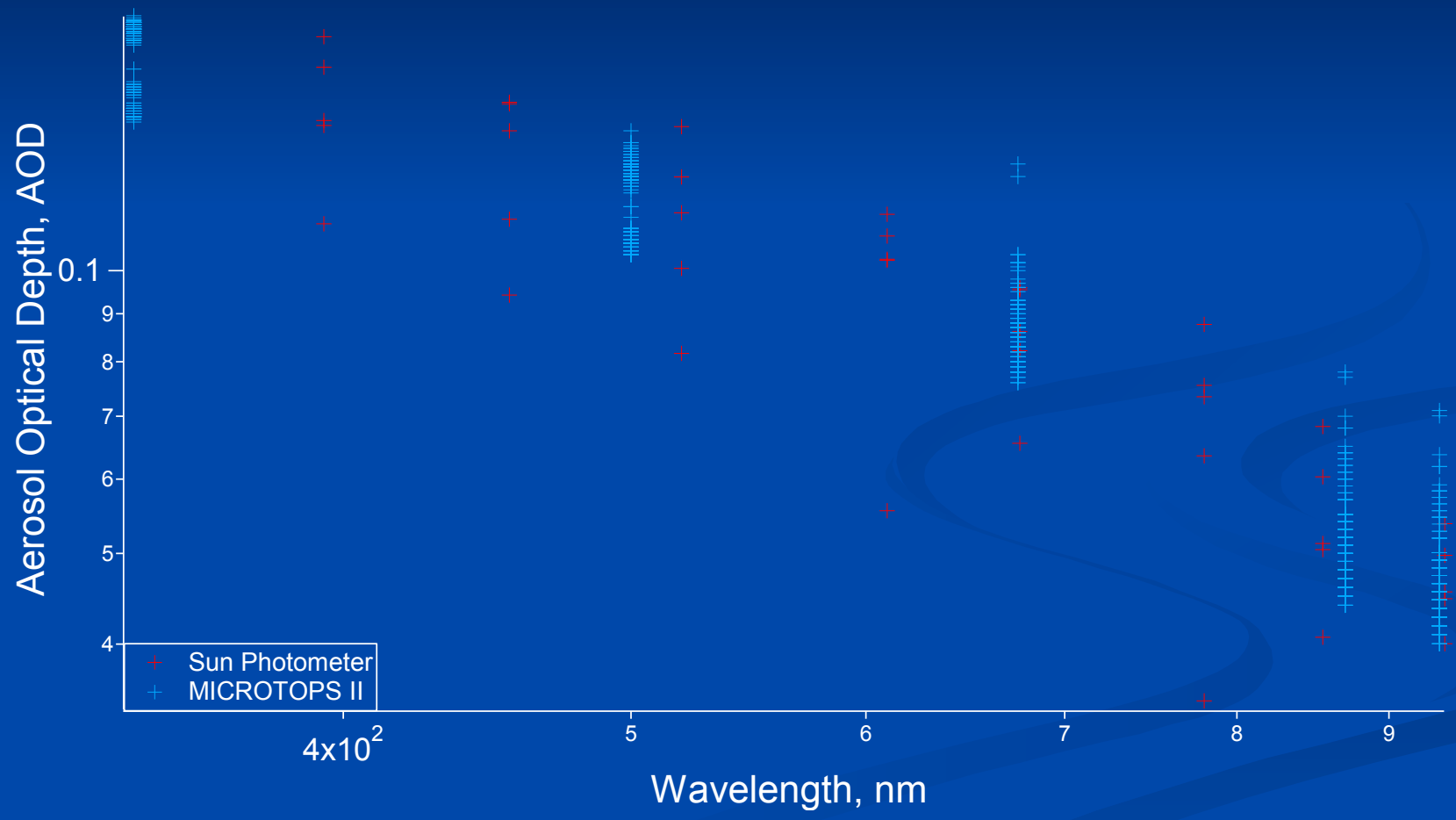
Recent Results

Solar Angle = 15.5 deg



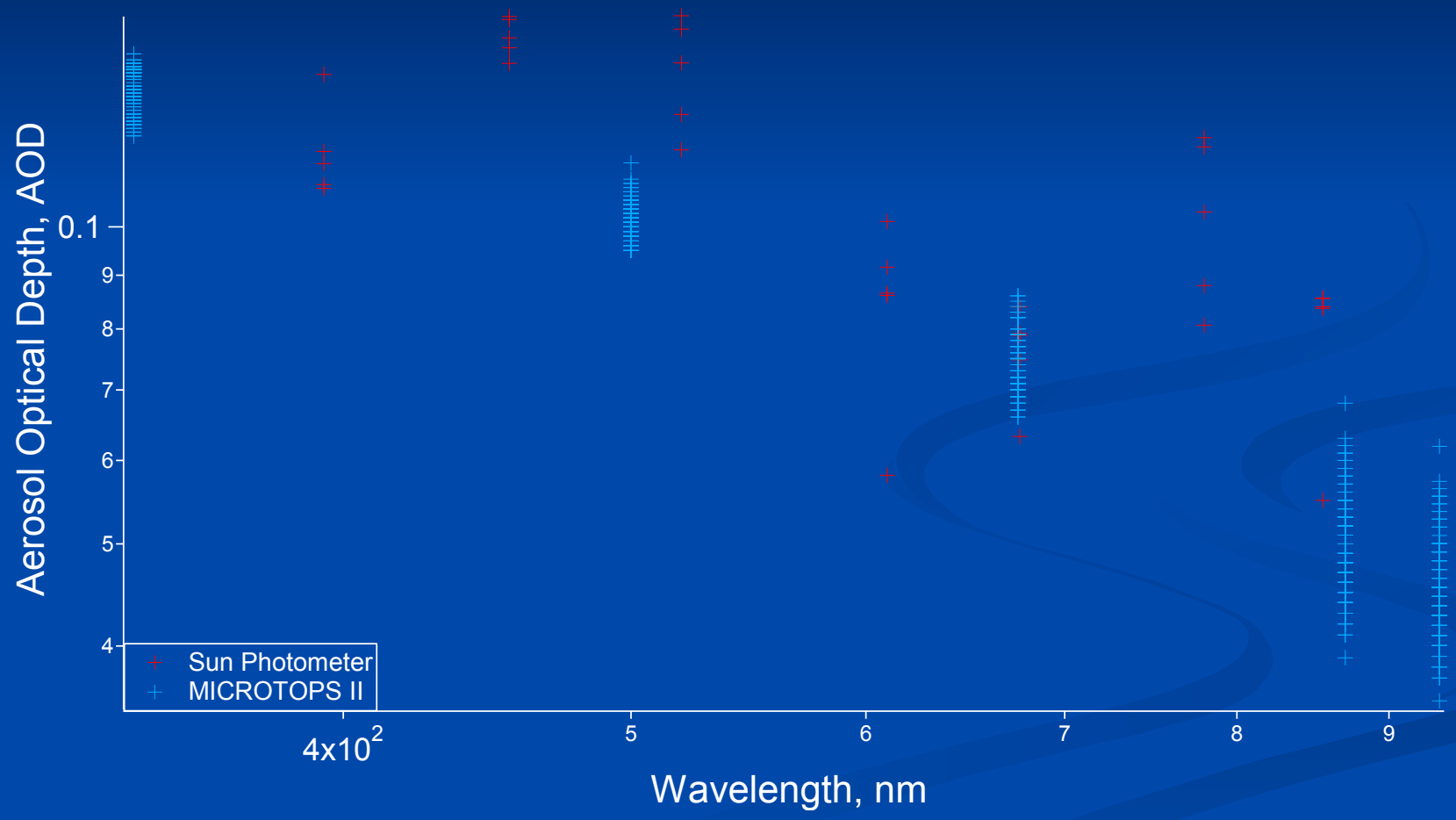
Recent Results

Solar Angle = 31.0 deg



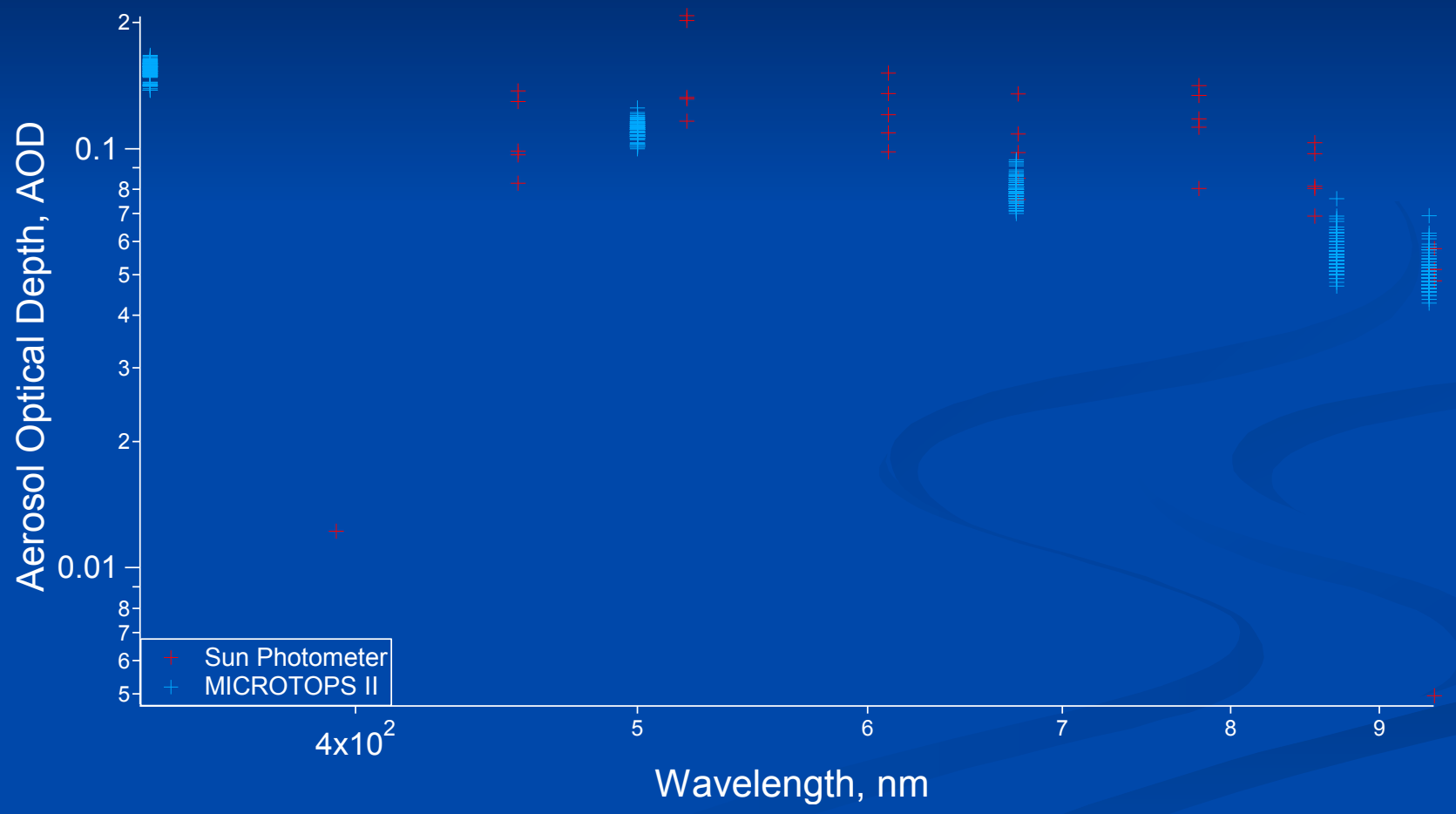
Recent Results

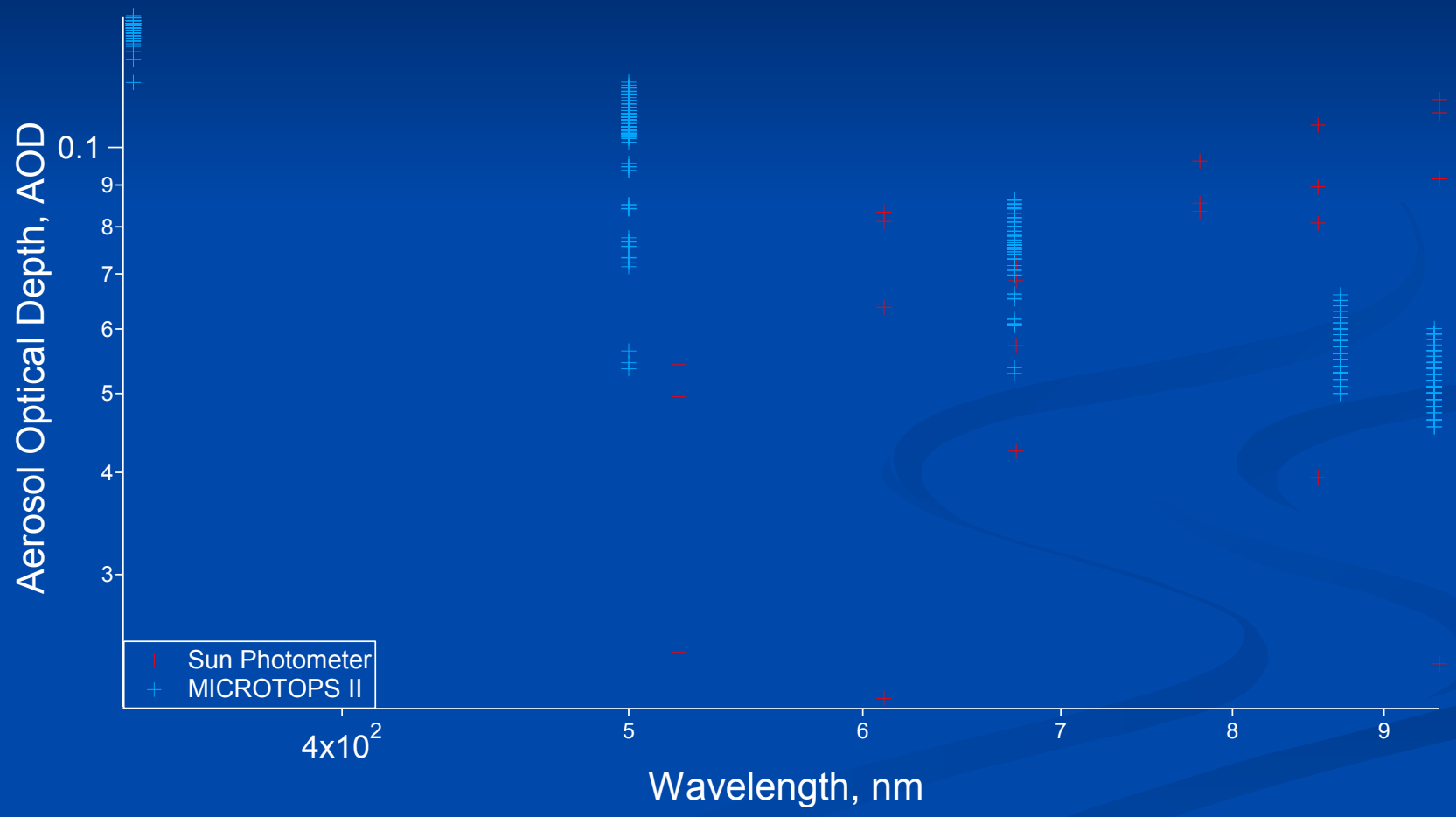
Solar Angle = 46.5 deg



Recent Results

Solar Angle = 62.0 deg



Recent Results

Solar Angle = 77.5 deg