Glory, Rainbow, Glints and much more: Learning Atmospheric Radiation from People who made the science and the science history.

J. Vanderlei Martins
University of Maryland, Baltimore County
Department of Physics and JCET/NASA GSFC

Wiscombe's Fest – July 2013

I had Been taught about Wiscombe's work for long time before I met him…

- Institute of Physics - University of Sao Paulo:
  - As undegraduate student I heard about the Legendary work by Moyses Nussenzveig and Warren Wiscombe
  - Only much later I started really using his reference and codes for my PhD work:
    - Mie calculations, Absorption Efficiency with the layered sphere code, Chebyshev particles, DISORT, etc.

Legendary and long lasting Brazilian connection: Warren Wiscombe and Moyses Nussenzveig

Photo Courtesy: M. Nussensveig

Efficiency Factors in Mie Scattering

H. M. Nussenzveig[a]
Cooperative Institute for Research in the Environmental Sciences, Boulder, Colorado 80309, and National Center for Atmospheric Research, Boulder, Colorado 80307

Phys Rev Lett, 1980

and

W. J. Wiscombe
National Center for Atmospheric Research, Boulder, Colorado 80307

(Received 22 May 1980)

Asymptotic approximations to the Mie efficiency factors for extinction, absorption, and radiation pressure, derived from complex-angular-momentum theory and averaged over $\Delta\beta \sim \pi$ (β = size parameter), are given and compare
refractive indices $N = n + i\kappa$ with $1.1 \leq n \leq 2.5$ and 0
from ~(1–10)% to ~(10^{-2}–10^{-3})% between $\beta = 10$ and
duced by a factor of order β, so that the Mie form
the asymptotic ones in most applications.

Complex angular momentum approximation to hard-core scattering

Phys Rev 1991

H. M. Nussenzveig* and W. J. Wiscombe
NASA Goddard Space Flight Center, Code 913, Greenbelt, Maryland 20771

(Received 24 September 1990)

The complex angular momentum (CAM) approximation for nonrelativistic quantum scattering by a hard sphere—a union of the recently developed CAM uniform approximation with a semiclassical WKB-like approximation valid at large angles—is shown to be remarkably accurate over the complete range of scattering angles, and down to size parameters (circumference to de Broglie wavelength ratios) of order unity. The best approximations previously derivable (Fock-type) cannot reach large scattering angles where semiclassical approximations are useful; even at angles where Fock-type approximations are valid, they are typically two or more orders of magnitude less accurate than CAM. The crucial new feature responsible for the high accuracy of the CAM approximation is the treatment of large-angle diffraction associated with (a) tunneling near the edge of the scatterer, and (b) anomalous reflection.

1987: I started my undergrad studies in Physics

Phys Rev Lett 1987

Diffraction as Tunneling

H. M. Nussenzveig[a] and W. J. Wiscombe
NASA Goddard Space Flight Center, Greenbelt, Maryland 20771

(Received 29 April 1987)

A new approximation to the short-wavelength scattering amplitude from an impenetrable sphere is presented. It is uniform in the scattering angle and it is more accurate than previously known approximations (including Fock's theory of diffraction) by up to several orders of magnitude. It remains valid in the transition to long-wavelength scattering. It leads to a new physical picture of diffraction, as tunneling through an inertial barrier.

Merging with the locals in a recent visit…

Photo Courtesy: M. Nussensveig

Warren was instrumental in the career of some of my colleagues in Brazil.

Aline Procopio student scientist award in Goddard

"Warren foi importantíssimo na minha carreira, foi através dele que fui parar na NASA, depois de conhecê-lo num mini-curso de aquecimento global que ele ministrou na UFRJ, quando eu ainda era estudante de mestrado, em 1998! E, é claro, depois disso muitas portas se abriram para mim aqui no Brasil, inclusive meu doutotado na USP! Sem dúvidas nenhuma, além de minha admiração pelo pesquisador, sou muito grata a ele!"

I had been taught about Wiscombe's work for long time before I met him…

- At the University of Washington 1996 I had many classes on Warren's work:
  - Mie calculations, Backscattering Fraction, Phase function, Delta-Eddington, Snow properties, Clouds, Monte Carlo Simulations, etc.

- I visited Yoram Kaufman at Goddard several times 1994-1998 and finally moved to Goddard in December 1999
  - Knocked in Warren's door by the first time because I wanted to meet the guy I had heard so much about
  - I didn't know what to say… but I did it anyway!!! We talked about aerosol absorption and his layered sphere code for Mie calculations

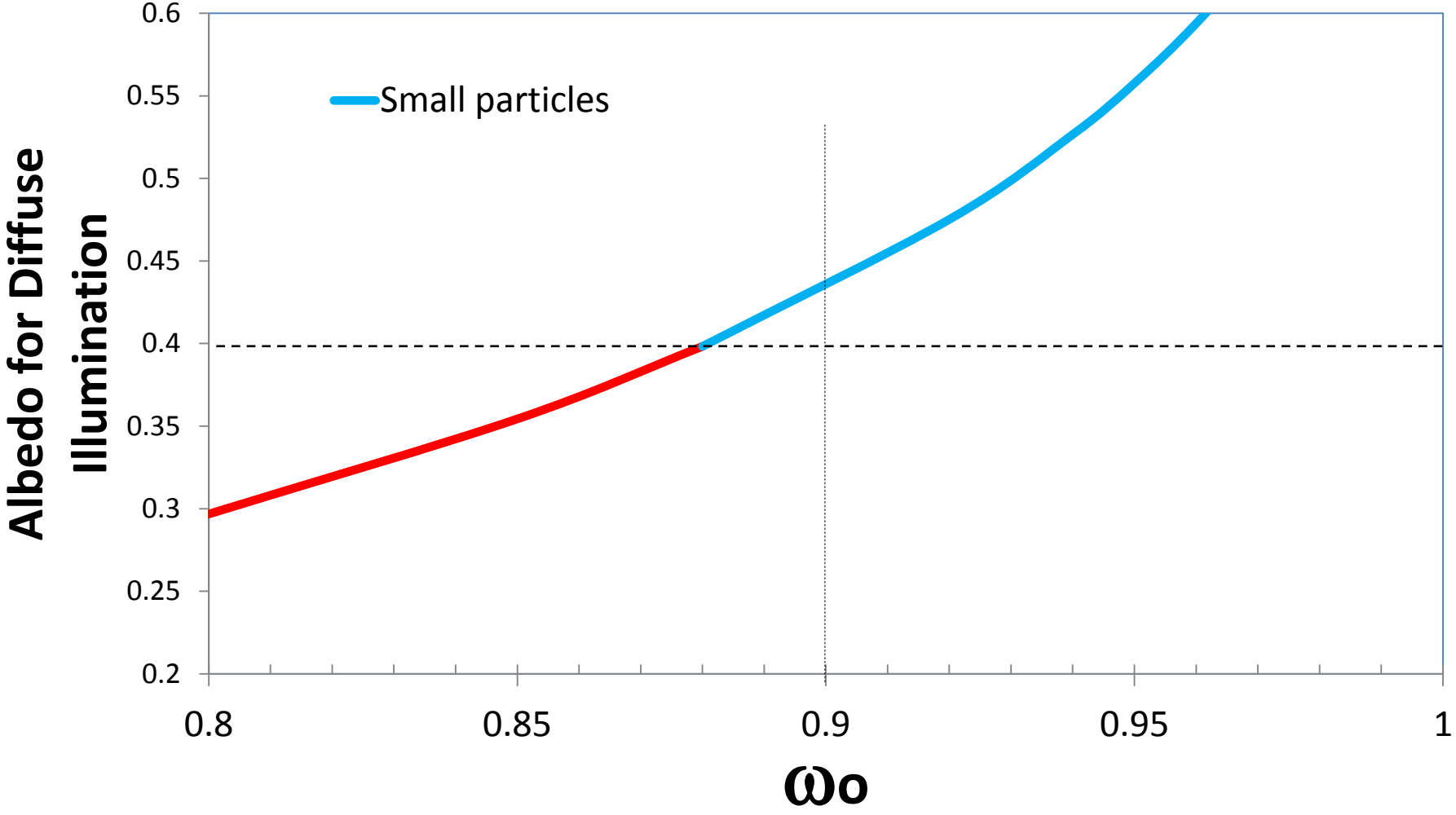
- Several interaction in the corridor with Warren
  - Sunglint, Phase function measurements, Rainbow/Glory Measurements, Cloud 3D properties, Cloud Side Measurements, CubeSats, etc.

Aerosol Critical Albedo

- Inspired by Kaufman's work on critical reflectance and other references on the surface critical albedo and on the critical single scattering albedo we started looking at the "Aerosol critical albedo"
  - Property of aerosol particles that combines absorption and scattering properties in a single quantity
  - Quantity that directly describes the aerosol potential for producing direct radiative forcing

- Back to the basis: Warren's work on the upscatter fraction was instrumental in helping us to make the connection between the intrinsic aerosol properties and the aerosol radiative forcing.

For aerosols over a given surface, single scattering albedo is not enough to determine the sign of the direct aerosol forcing



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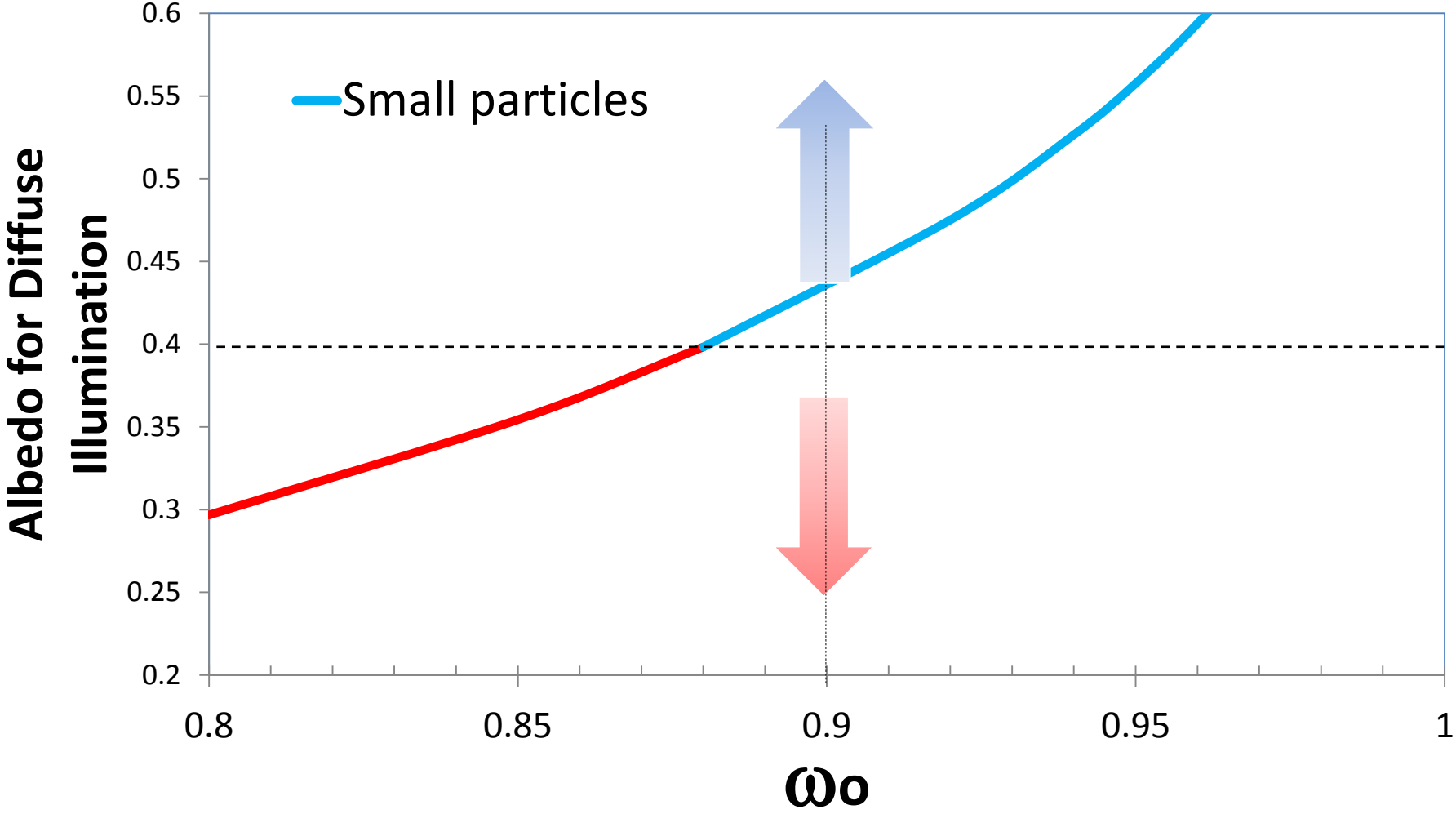

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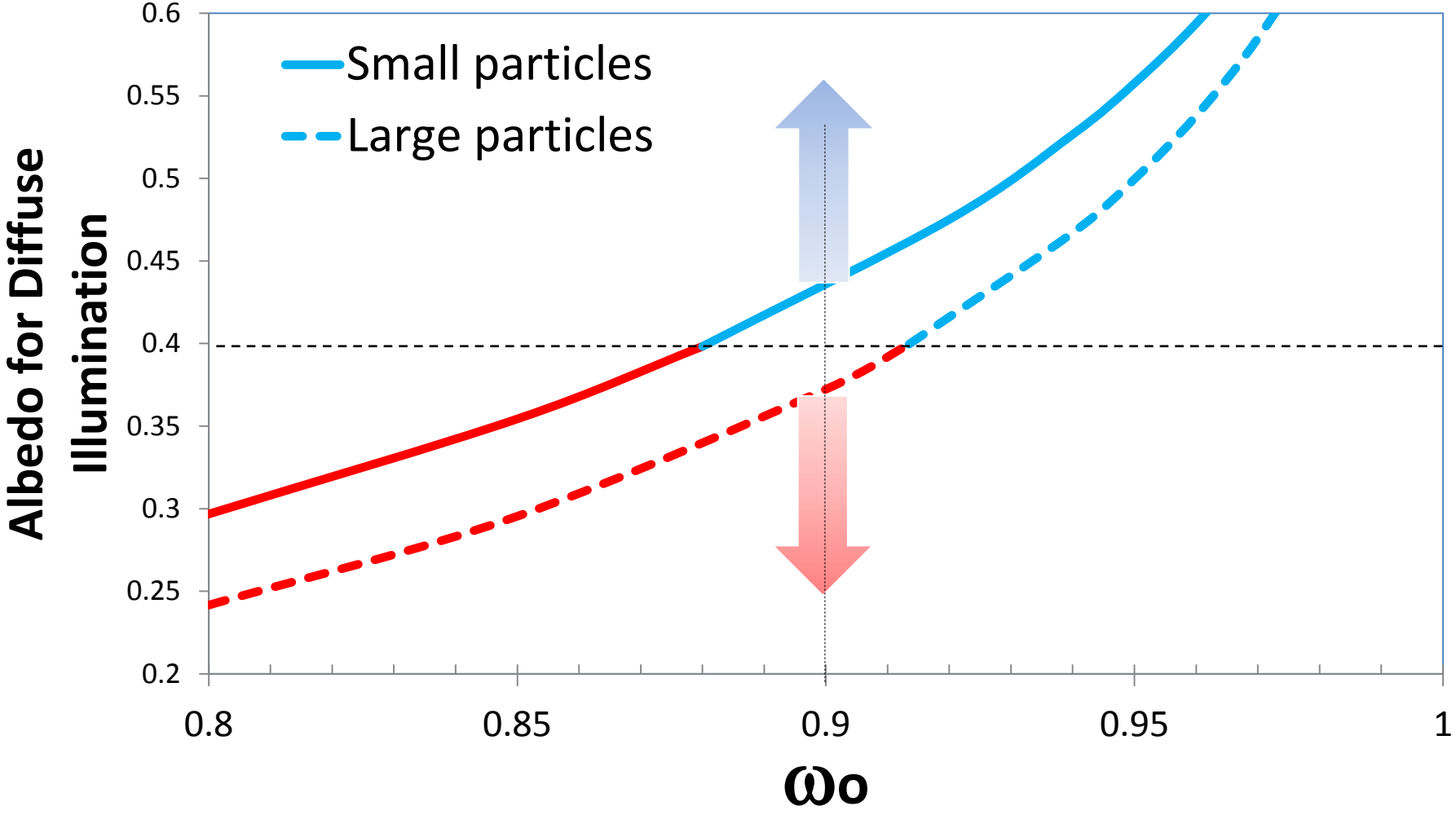
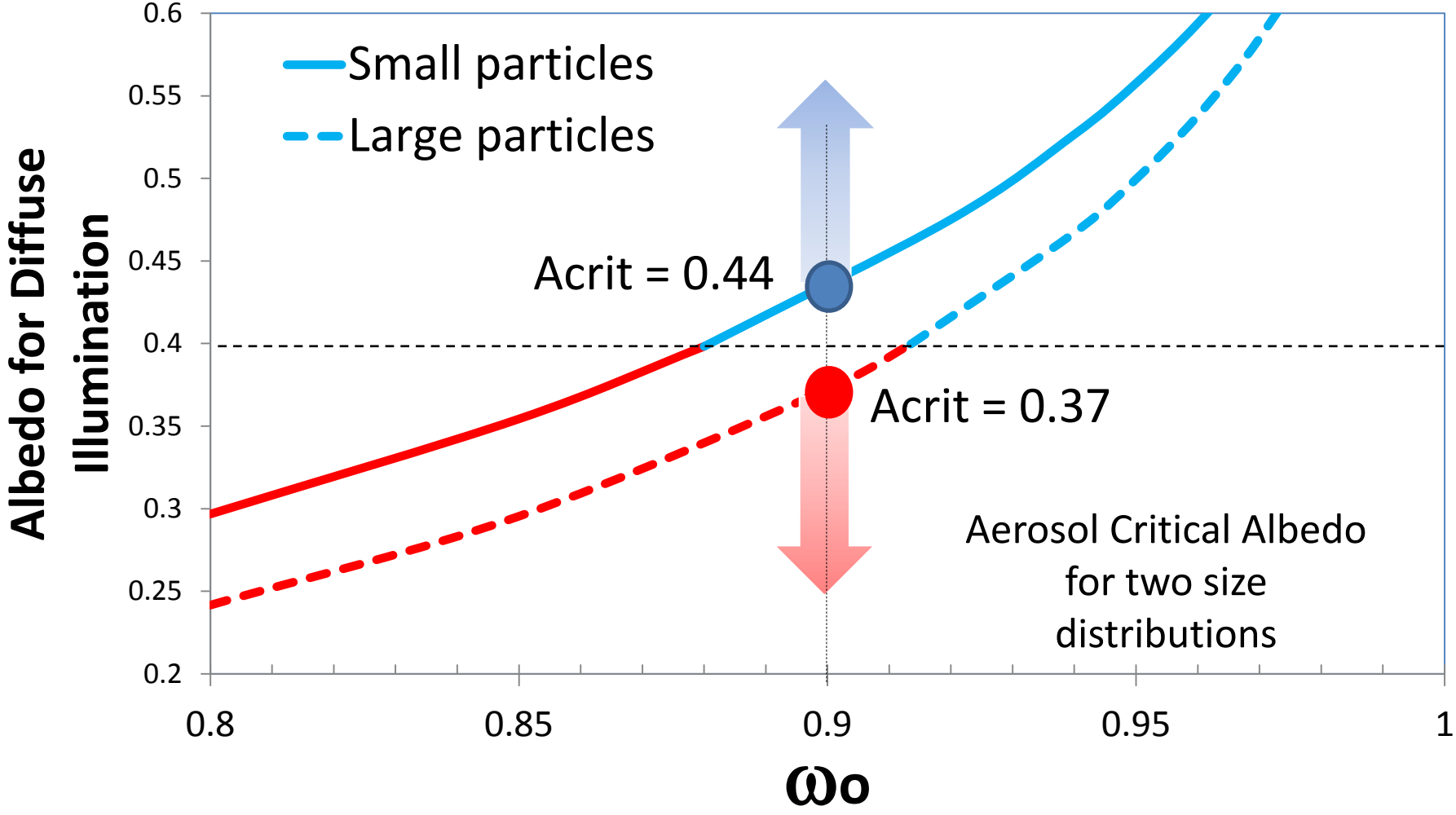


Aerosol Critical Albedo in Single Scattering Approximation:

$$\overline{A_{c,\lambda}^{\tau\to 0}} \equiv \overline{A_{c,\lambda}^{o}} = \frac{[1-\omega_{o,\lambda}(1-\overline{\beta_\lambda})]-\sqrt{[1-\omega_{o,\lambda}(1-\overline{\beta_\lambda})]^2-[\omega_{o,\lambda}\overline{\beta_\lambda}]^2}}{\omega_{o,\lambda}\overline{\beta_\lambda}}$$

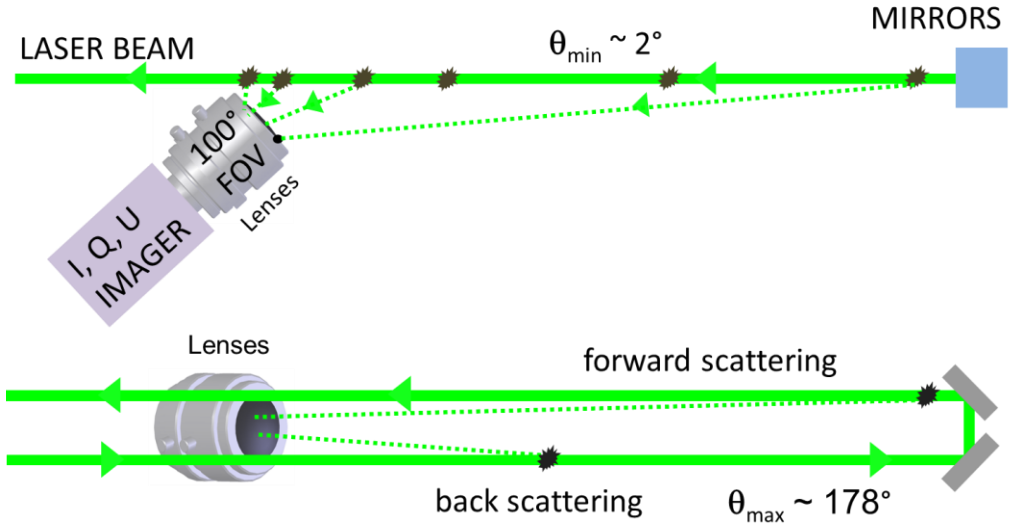


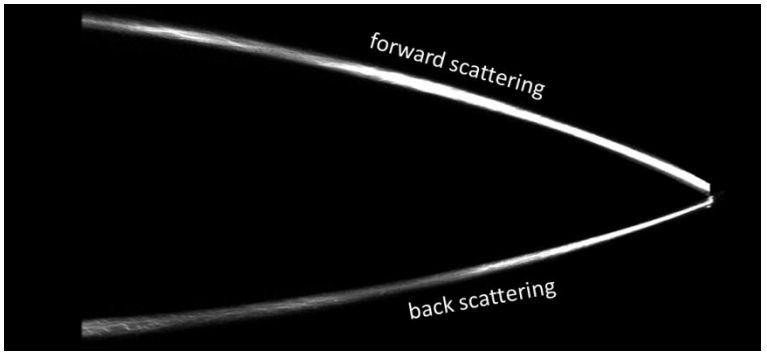
Recent Interaction with Warren on three recent proposal efforts:

Proposal #1 - Under Warren as ARM Chief Scientist (or short after that) I got funded to build the Open Imaging Nephelometer for the measurement of aerosol and cloud particle phase functions

I understand that Warren was a great motivator of this program in order to foster the development of new instrumentation

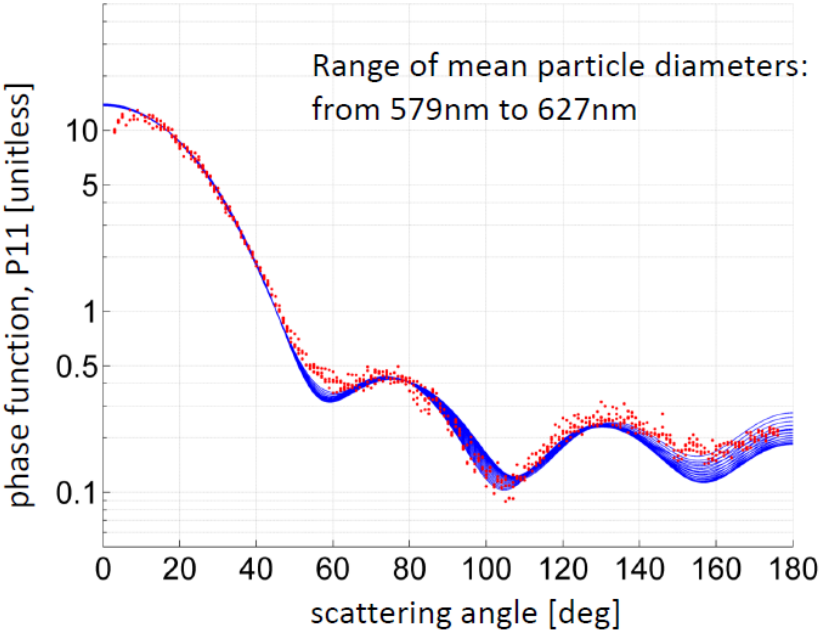
Polarized Imaging Nephelometer Concept



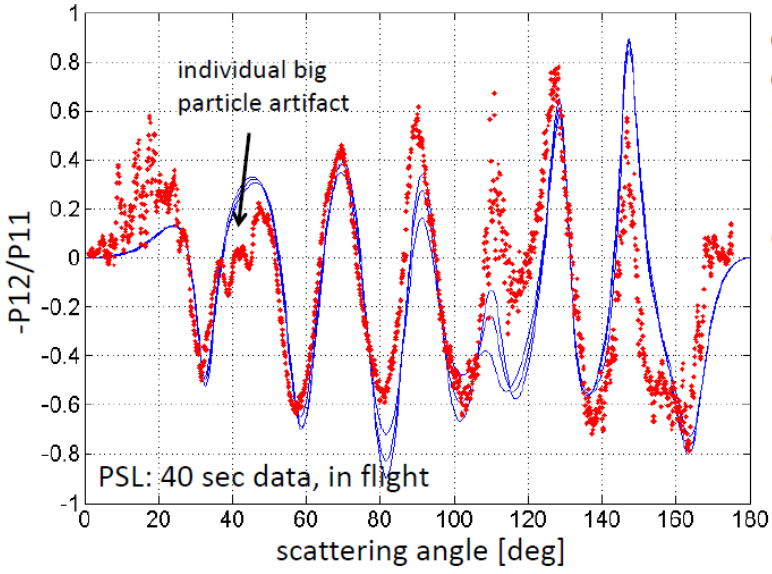


PhD Student: Gergely Dolgos

P11 PSL sphere data vs. Mie theory



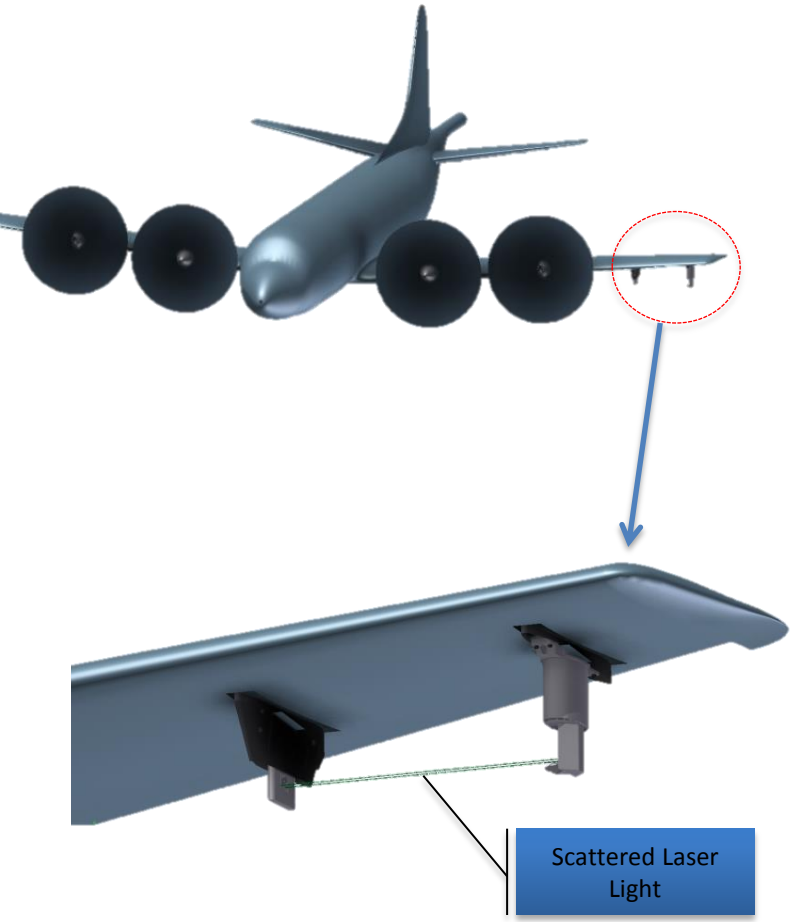
P12 PSL sphere data vs. Mie theory

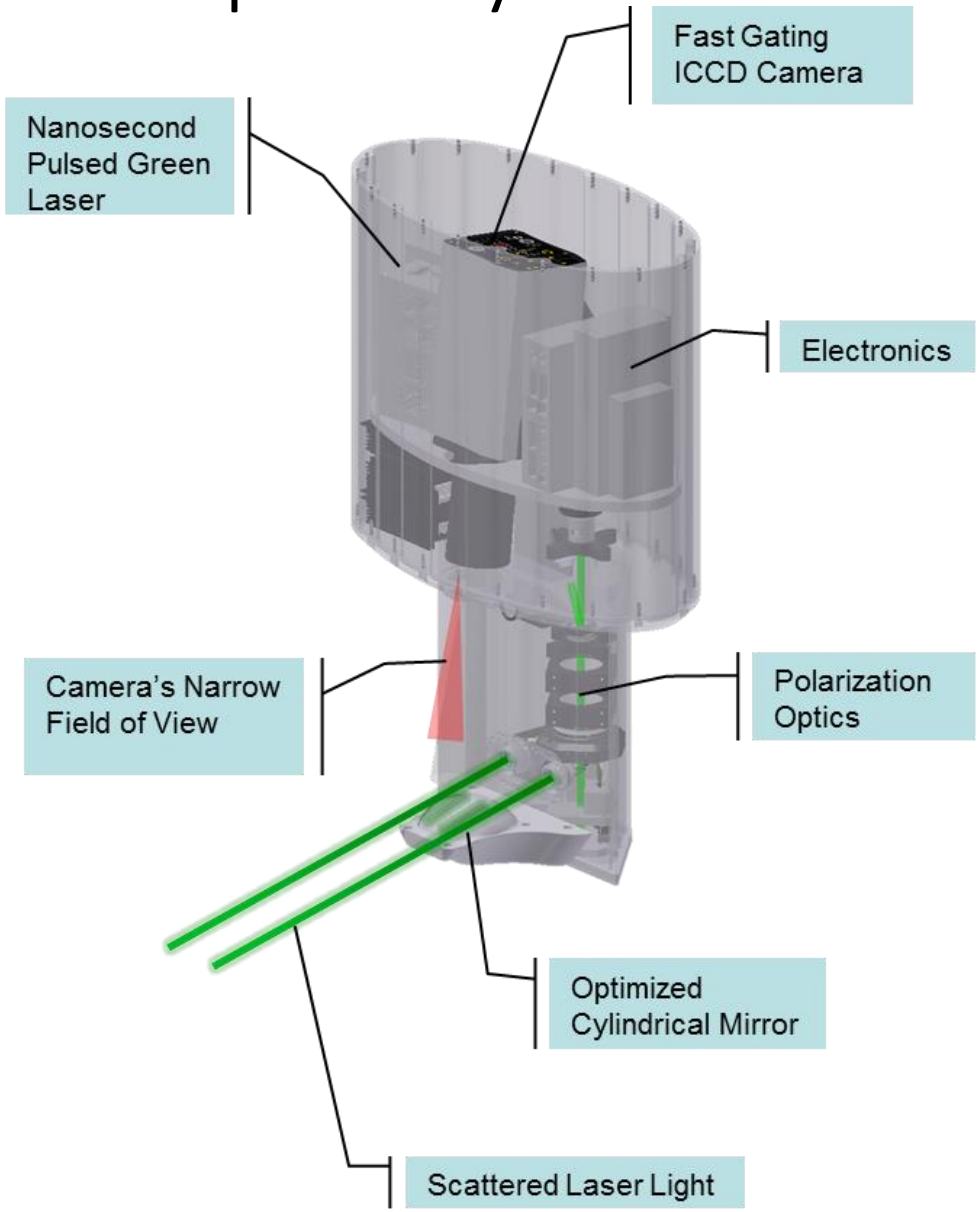


center diameters :
1354 nm
1359 nm
1363 nm
(blue curves)

preliminary results before application of final calibration

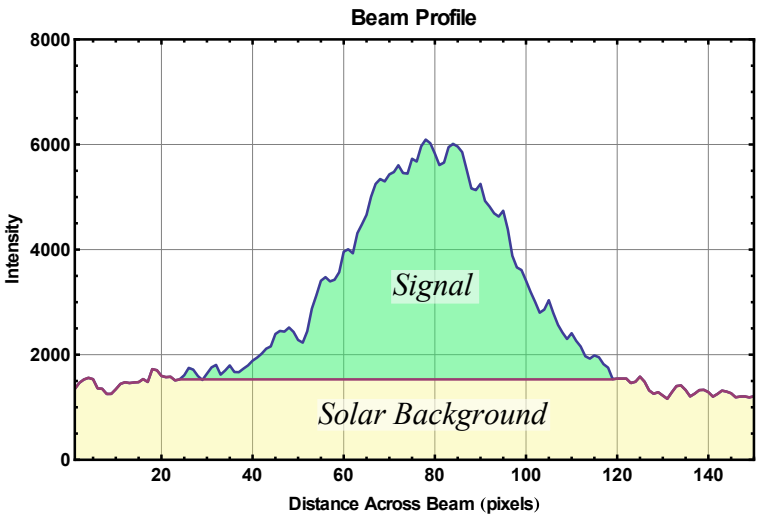
Open Imaging Nephelometer in the NASA P3 Aircraft follows the PI-Neph lead to an open air system

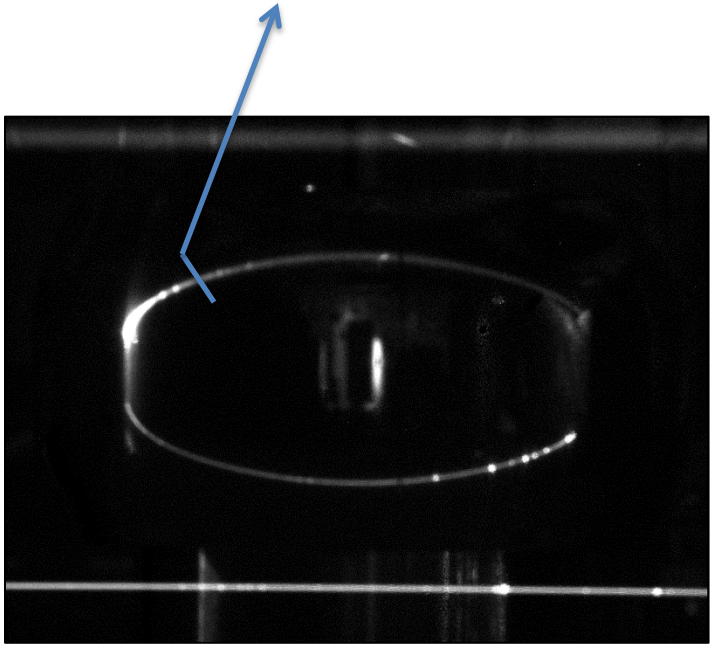




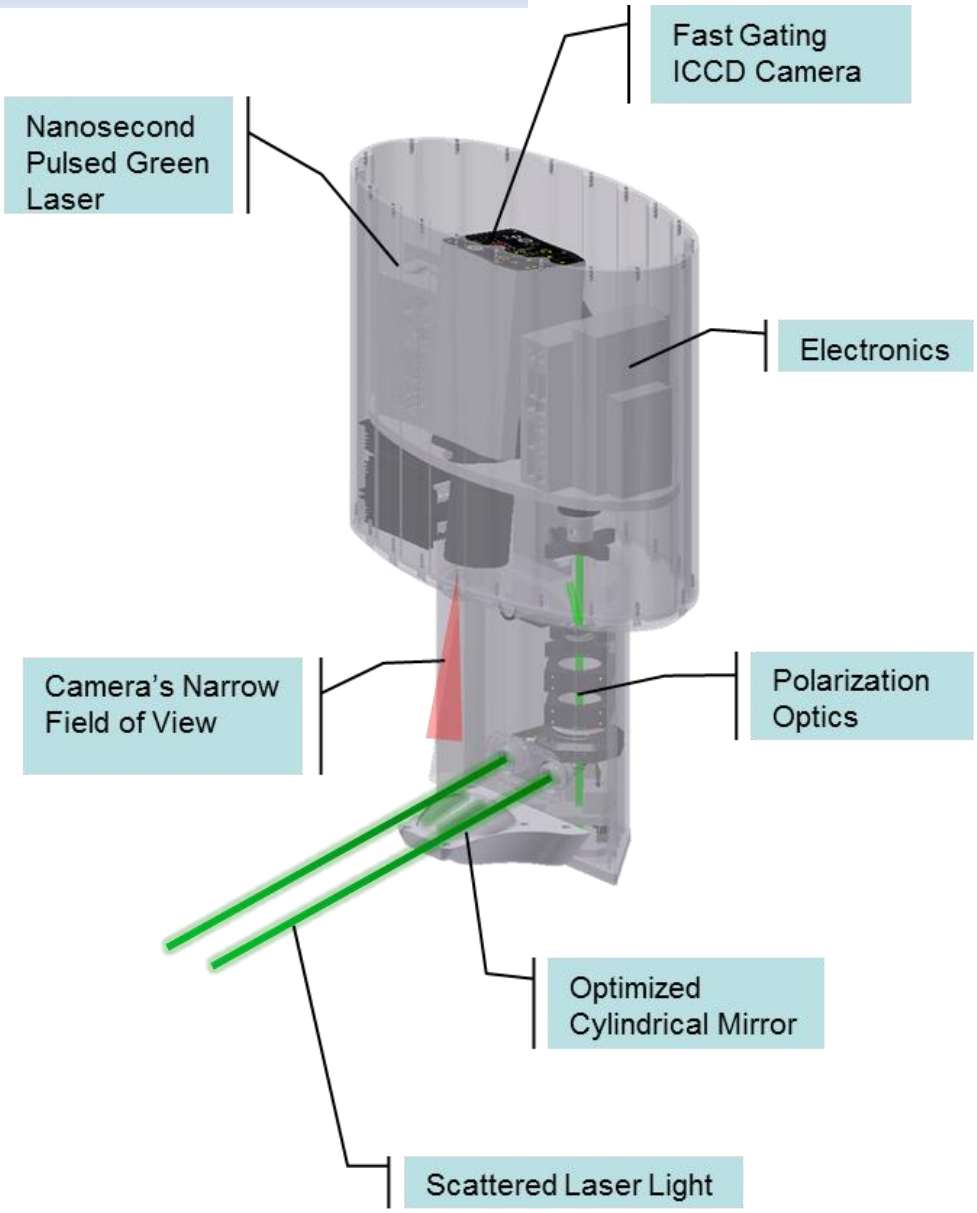
PhD Student: Reed Espinosa

Open Imaging Nephelometer in the NASA P3 Aircraft:





Ready by Summer 2013!!!



Proposal #2 – Lorraine Remer as PI asked the question:

How can we possibly know the 1750 aerosol emissions?

Jeff Pierce and Lorraine tasked me to *"invent a time machine so we can go back and make the measurements ourselves"*

Development of the TimeJumper: A time travel solution for characterization of pre-industrial aerosols

A proposal submitted to

the National Aeronautics and Space Administration

Earth Science Enterprise

by

The NASA/Goddard Space Flight Center

In response to the NASA Research Announcement

NNH08ZDA001N-SFX

Principal Investigator: Lorraine A. Remer
Laboratory for Atmospheres
NASA/Goddard Space Flight Center
Lorraine.A.Remer@nasa.gov
Tel: 301-614-6194

Co-Investigators: José Vanderlei Martins (Physics UMBC)
Jeffrey Robert Pierce (ORAU/NASA GSFC)
Richard Kleidman (SSAI GSFC)

Collaborator: Ilan Koren (Weizmann Institute, Israel)

The TimeJumper concept

Watterson, 1992

Warren Wiscombe 2011

#3 - Two competing Proposals:

NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences
NNH12ZDA001N- ROSES-2012
A.48 In-Space Validation of Earth Science Technologies (InVEST)

Advancing Climate Observation:Radiometer Assessment Using Vertically Aligned Nanotubes (RAVAN)
Lars Dyrud, Johns Hopkins Applied Physics Laboratory

HyperAngular Rainbow Polarimeter HARP-CubeSat

J. Vanderlei Martins,
University of Maryland, Baltimore County

- Both proposals competed and got funded under the NASA InVEST program.
- Warren is a Co-Investigator in the RAVAN proposal.
- Though Warren is not a CO-I in the HARP proposal, his work will be heavily used to make it successful.

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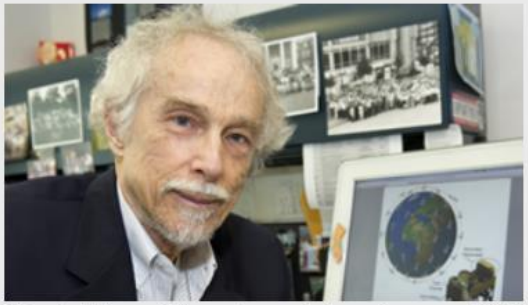
Feature

The Last Frontier
Team to Test Carbon-Nanotube Sensors Measuring Earth's Radiation Budget

A Goddard scientist wants to explore one of NASA's last frontiers in climate studies by launching small, carbon nanotube-based instruments on dozens of satellites to determine with unprecedented accuracy the imbalance in Earth's energy budget and measure the extent to which fast-changing phenomena, like clouds, contribute to the imbalance.



Scientist Warren Wiscombe wants to explore one of NASA's last frontiers in climate studies. He wants to launch small, carbon nanotube-based instruments on dozens of satellites to determine the imbalance in Earth's energy budget.

Last year, scientist Warren Wiscombe and a "virtual" team of climate-studies experts used Goddard Internal Research and Development (IRAD) program funding to flesh out a concept to collect Earth radiation-budget measurements with scores of radiometers installed on massive satellite constellations, such as the one operated by the Virginia-based Iridium Communications, Inc.

Although NASA found the science compelling, Agency reviewers ultimately did not select the concept under its Earth-Venture 2 (EV-2) mission solicitation, saying that the idea considerably exceeded EV-2's $150-million cost cap.

Wiscombe is not giving up, however. And to a certain degree, neither is NASA.

Now Wiscombe and his team, including Lars Dyrud, a scientist at the Johns Hopkins University Applied Physics Laboratory (APL) and principal investigator of the EV-2 proposal, plan to use NASA Space Technology Program funding this spring to test a next-generation detector that Wiscombe believes would be ideal for measuring the amount of solar energy reflected by the Earth and the amount of energy emitted to space as infrared radiation or heat. "I call this detector the roach motel for photons," Wiscombe joked. "Light goes in, but it doesn't come out."

HARP

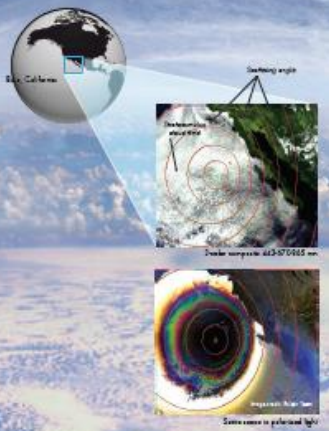
Hyper-Angular Rainbow Polarimeter

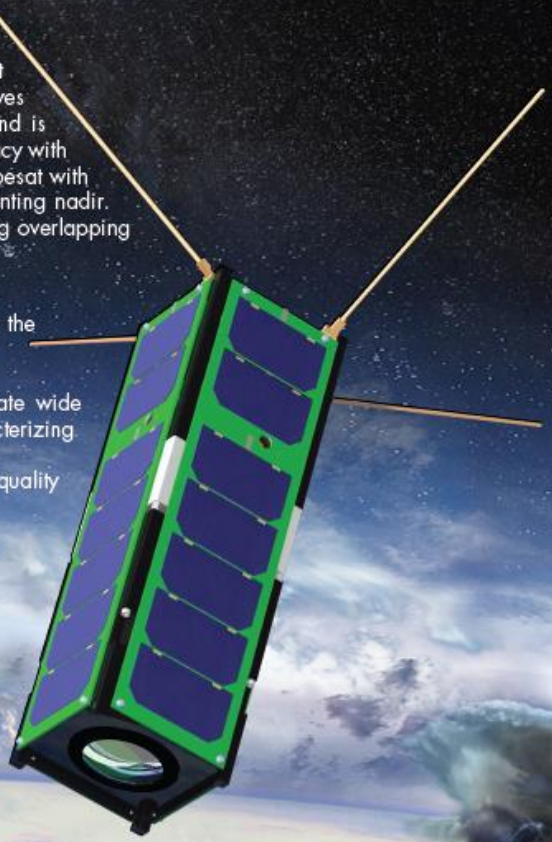
In-Space Validation of Earth Science Technologies (InVEST)

The HARP payload is a wide FOV imager that splits three spatially identical images into three independent polarizers and detector arrays. This technique achieves simultaneous imagery of three polarization states and is the key innovation to achieve high polarimetric accuracy with no moving parts. The spacecraft consists of a 3U Cubesat with 3-axis stabilization designed to keep the imager pointing nadir. The hyper-angular capability is achieved by acquiring overlapping images at very fast speeds.

OBJECTIVES:

- Space validation of new technology required by the NASA Decadal Survey Aerosol-Cloud-Ecosystem (ACE) mission
- Prove the on-flight capabilities of a highly accurate wide FOV hyper-angle imaging polarimeter for characterizing aerosol and cloud properties
- Prove that cubesat technology can provide science-quality Earth Sciences data

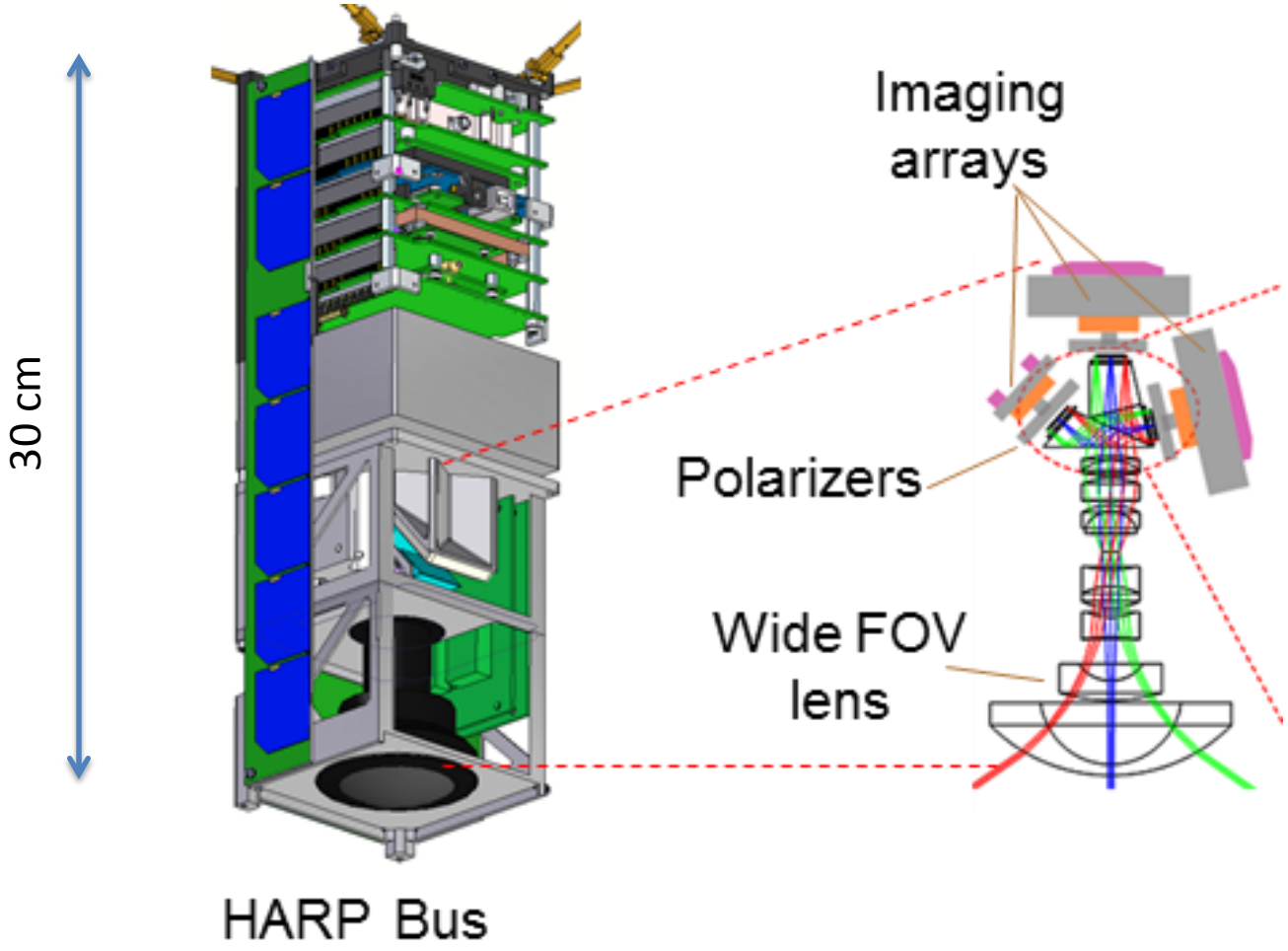




UMBC NASA STC JCET NOAA Space Dynamics Laboratory

HARP CubeSat Mission

HyperAngular Rainbow Polarimeter – Funded by NASA INVest Program
Planned for 2015

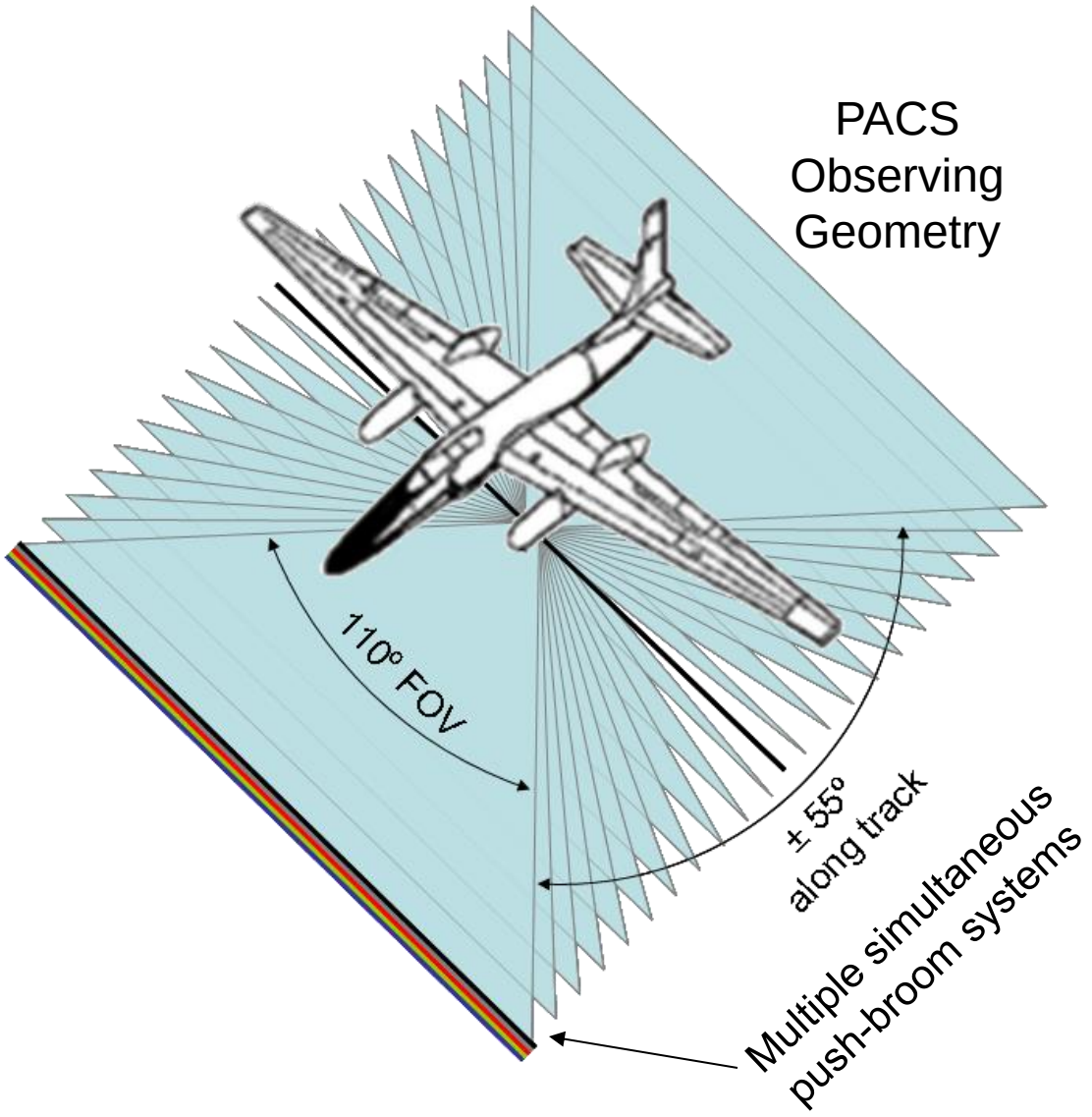


PACS Airborne ER2 Polarimeter

PACS ER-2 Facts

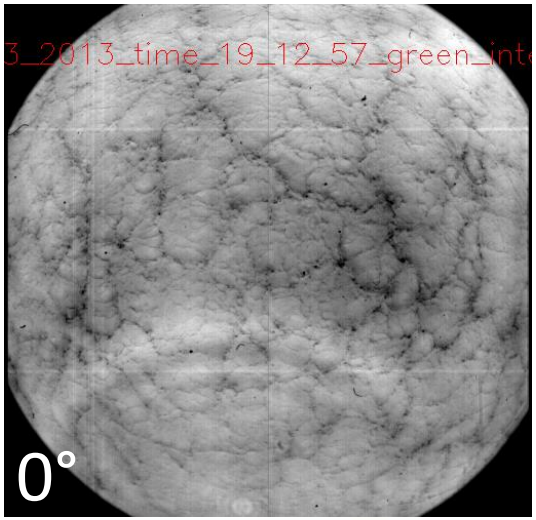
Current VNIR system
- Ground Resolution = 37m
- Swath = 37km
- 470, 550, 670, 766, 870nm
- 1 K pixel X-track
- 65+ angles for all wavelengths
- 130 view angles for 670nm
- 110˚ FOV cross track
- +/- 55˚ FOV along track

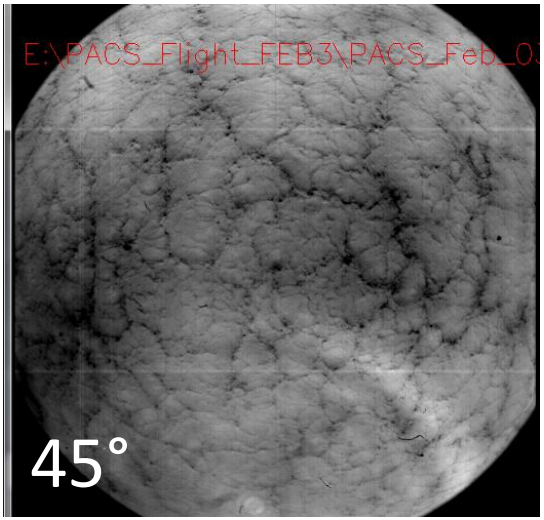
SWIR Under construction:
- 1650, 1880, 2130, 2250nm
- 320x256 pixels
- Adjustable FOV
- Mounted together with PACS VNIR

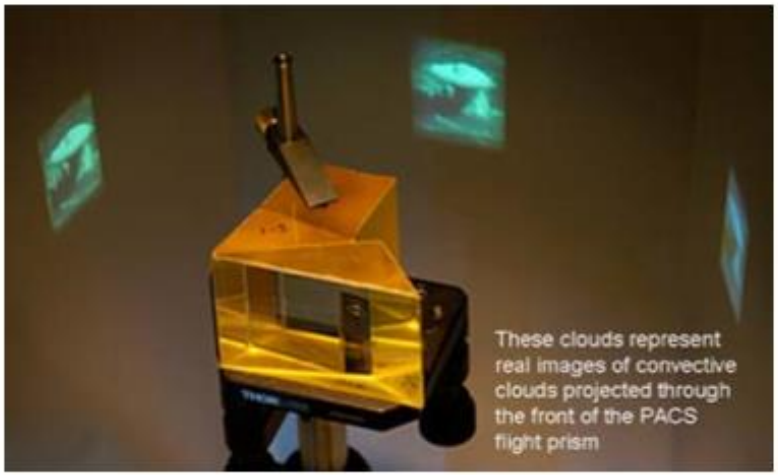


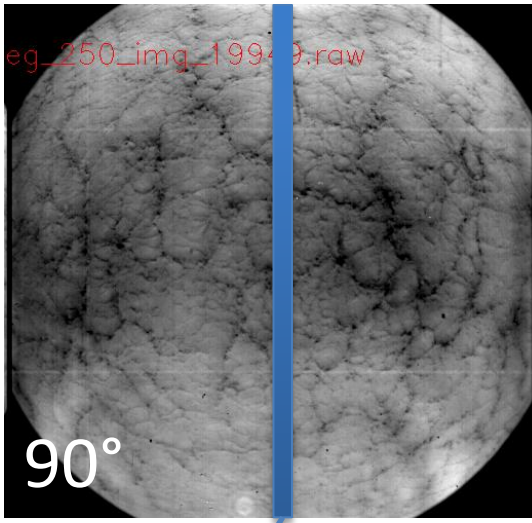
PACS

Three Polarized Images

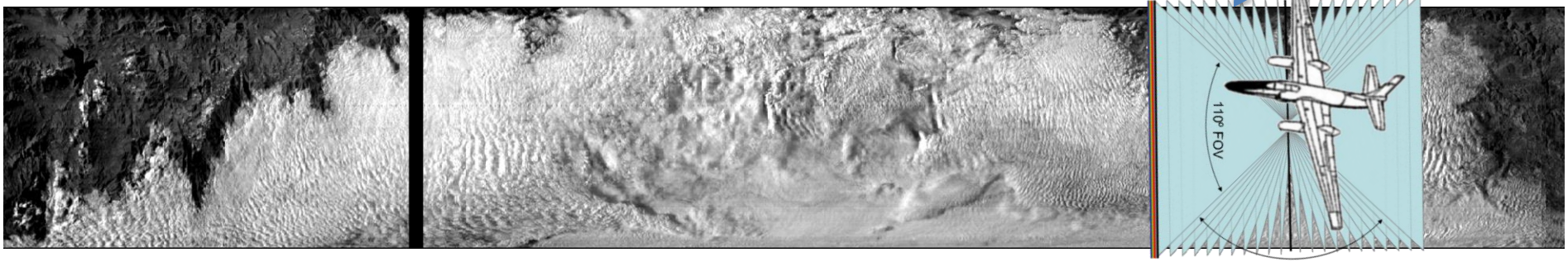




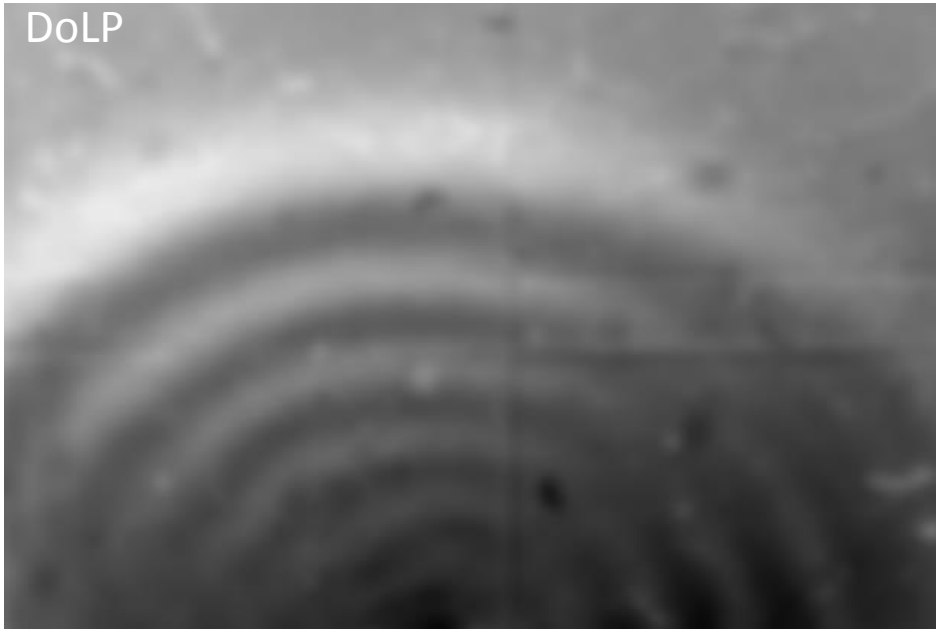


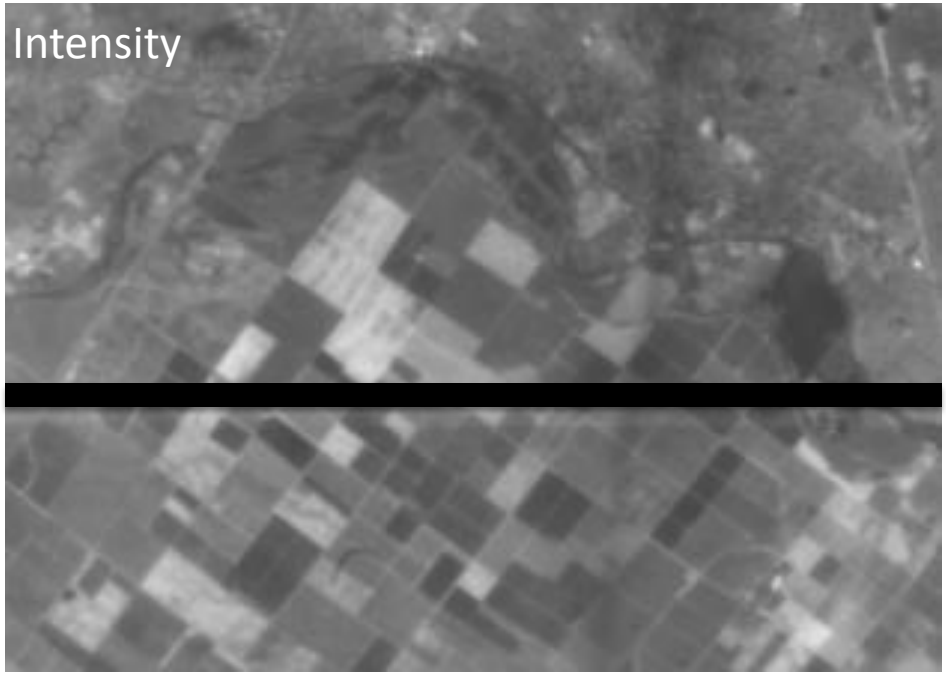


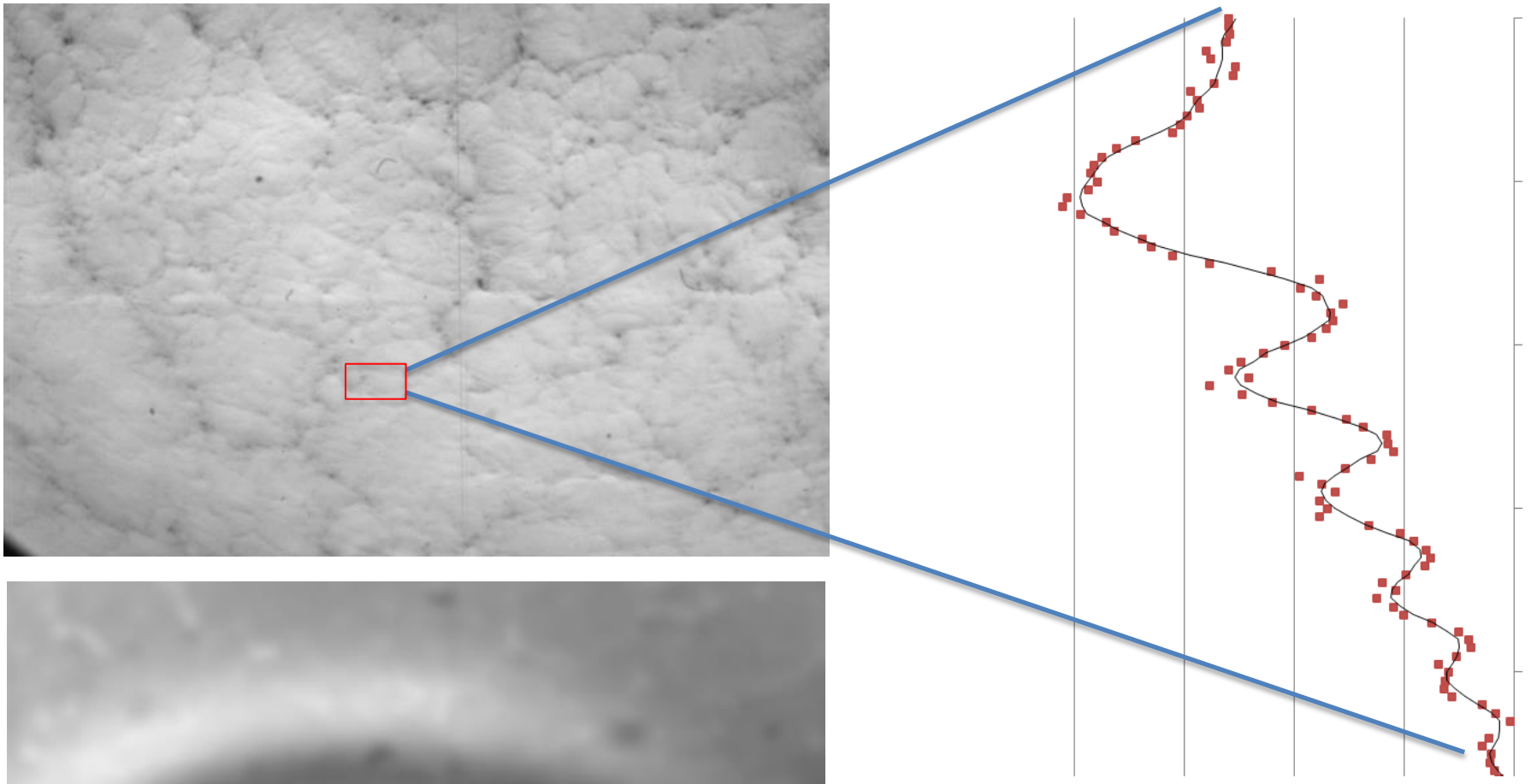
Single View Pushbroom



Examples of PACS Data from PODEX







Hyperangular Capability Provides Cloudbow from small area (~2x2km from space)

Thanks Warren for the inspiration,

for the theories,

for the codes,

and much more.

Happy Birthday!!!