Satellite remote sensing of aerosols in the Earth atmosphere

IAA Study Group 1.9. Activity in Mar 2015 - Sep 2015

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Outline

1. Needs for atmosphere aerosol investigation

2. Microphysics of aerosols – polarimetric study

3. Aerosol-UA polarimetry ScanPol & MSIP: current state of the project and instrumentation

4. Conclusions

1. Needs of atmosphere aerosol study

Atmospheric aerosols have strong influences on:
climate, clouds, precipitation, atmospheric chemistry, atmospheric visibility, and human health

Crimea, dust storm, September 2012

Kyiv, smog , June, August 2015

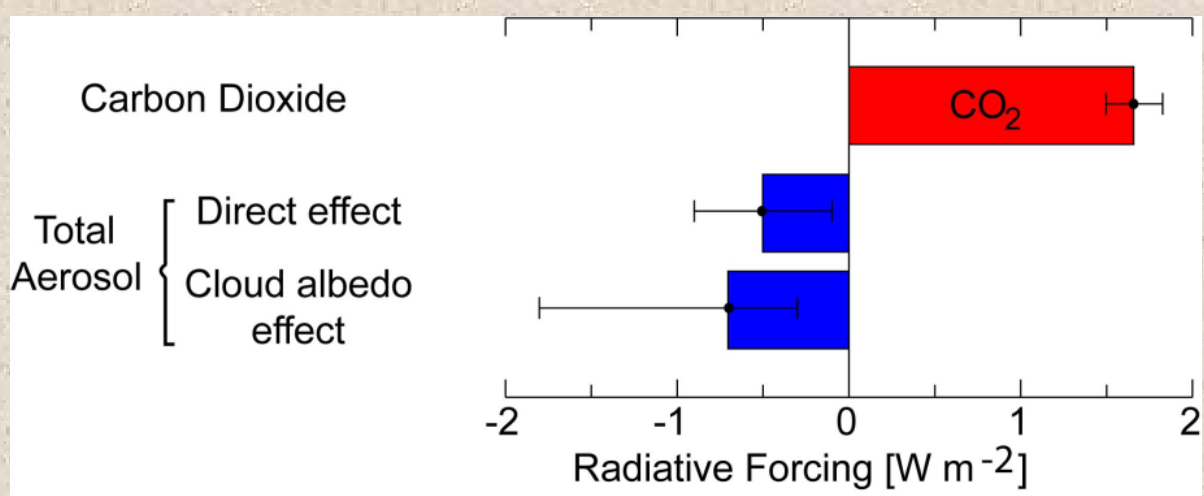
Germany, June 2015

Lot of aerosol still is released to atmosphere

2. Microphysics of aerosol for climate models

Atmospheric aerosols direct climate impact by absorbing (black carbon aerosols) and reflecting (sulfates aerosols) sunlight producing heating or cooling the atmosphere

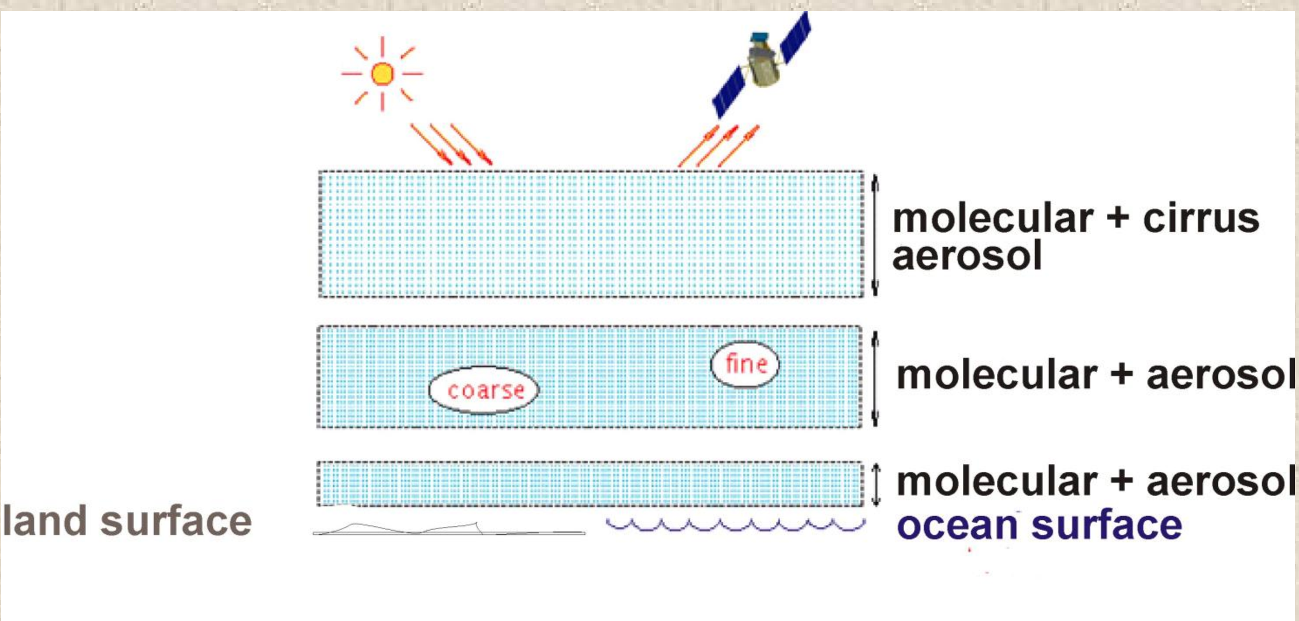
Aerosols also cause indirect cooling effect by modulating cloud properties: increased numbers of aerosols lead to larger numbers of smaller cloud droplets



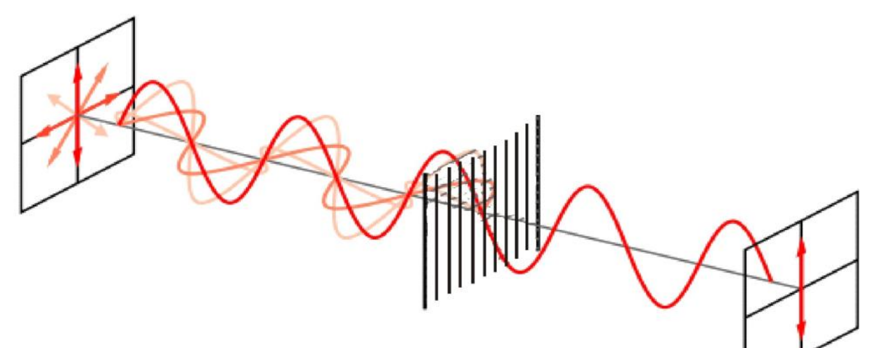
Climate effects of aerosols remain poorly quantified due to lack data for microphysics (refractive index, type, size etc.)

(IPCC 2007)

Complexity of aerosol retrievals from space



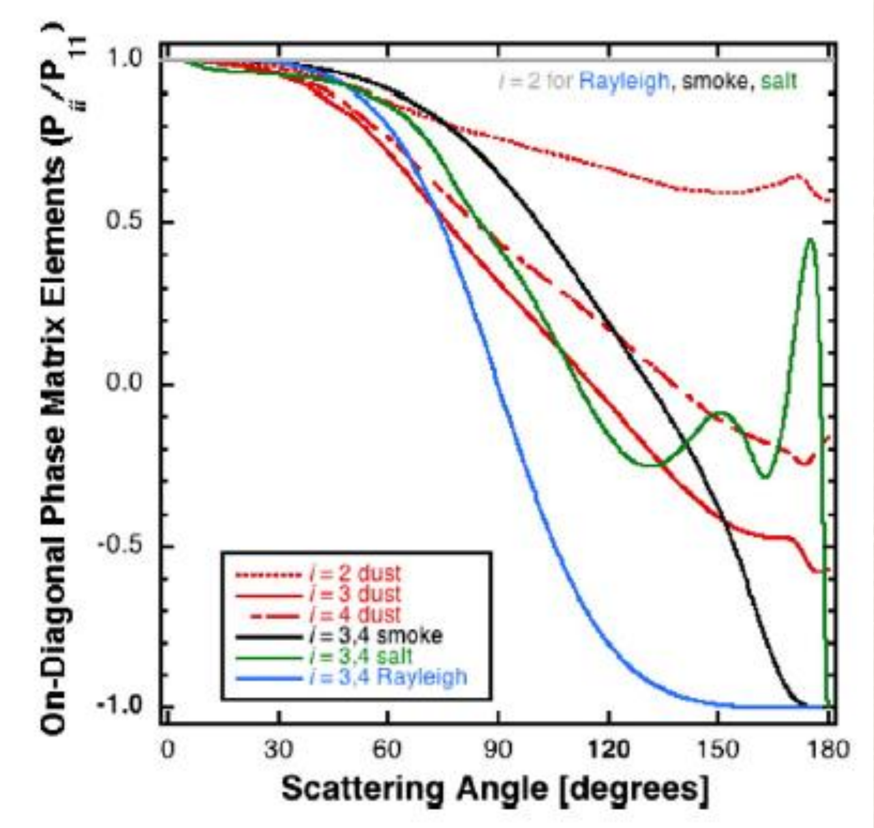
The intensity of the scattered light is not sensitive to the microphysics of particles.

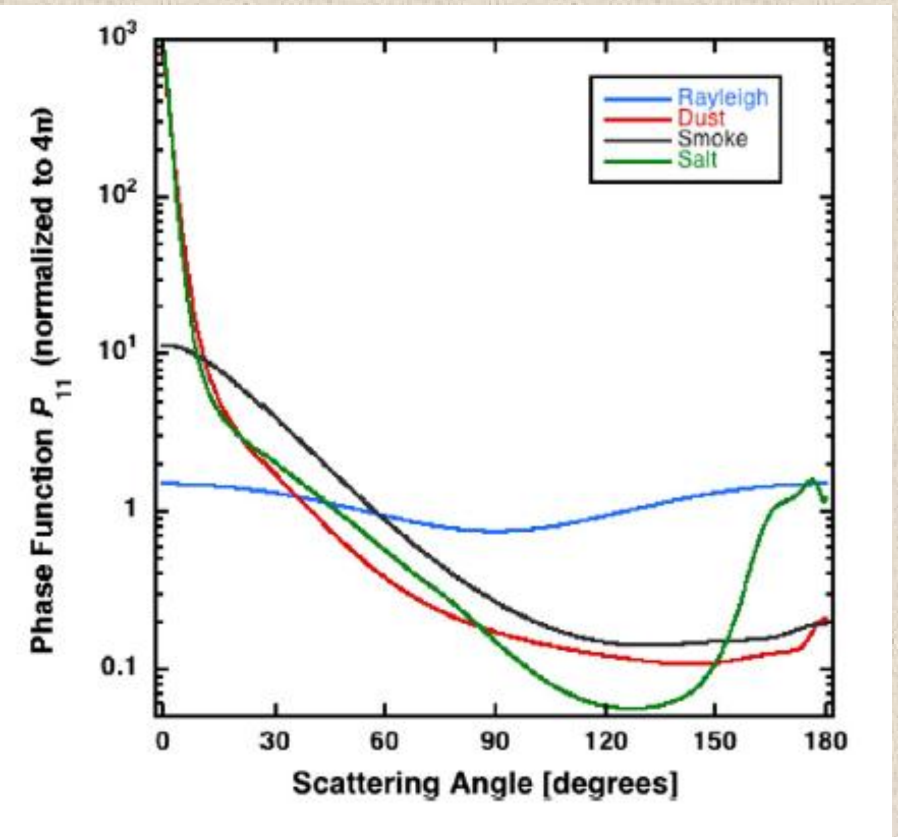

(Mishchenko et al. 2010)

Polarization of light

Measurements of polarization contain information on the physical and chemical properties of particles (refraction index).

Microphysics dependency in polarimetric data





Need Polarization and many Scattering angles !

(Kokhanovsky et al., Earth-Science Reviews, 2015)

3. Aerosol-UA polarimetry by ScanPol & MSIP: current state of the project and instrumentation

Instruments:

ScanPol: Scanning Polarimeter

MSIP: MultiSpectral Imager/Polarimeter

Goal: remote sensing of tropospheric aerosols in the terrestrial atmosphere

Satellite:

ScanPol + MSIP

AERONET:

Validation

Data processing:

Mission products

Basic strategy: receive maximum information in the reflected sunlight

Aerosol-UA: ScanPol (*I, Q, U*) + MSIP (image, *I, Q, U*)

- Polarization is a relative measurement that can be made accurately.
- Polarimetric ScanPol measurements can stably calibrated on the orbit.
- Polarization change with scattering angle and wavelength gives size, refractive index and shape of aerosol.
- Synergy of scanner and imager will produce new quality of data different from similar aerosol missions.

Technical characteristics of the orbital platform

Orbit

Type: sun-synchronous

Inclination: ~98°

Altitude: ~670 km

Platform needs

Pointing accuracy: ~0.1°

Total mass of scientific payload: ~40 kg

Power for payload: ~40 W

Design life: >3 years

ScanPol:

Scan: period 1.5 sec, expos. 1ms, along ground track, +50/-60°

Spatial resolution: ~6 km at nadir

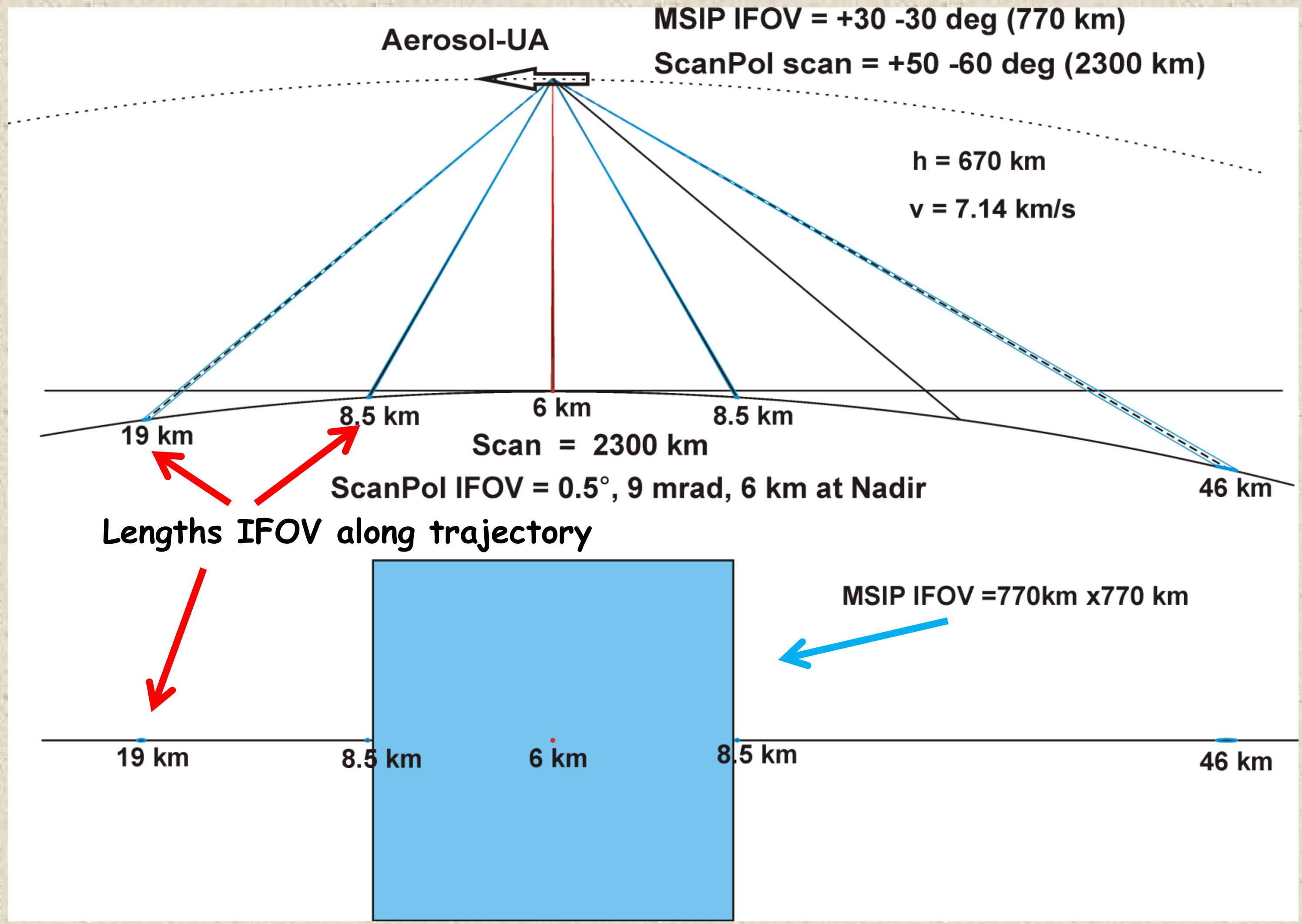
MSIP:

Image:+30/-30°, 770x770 km

Spatial resolution: ~4 km at nadir

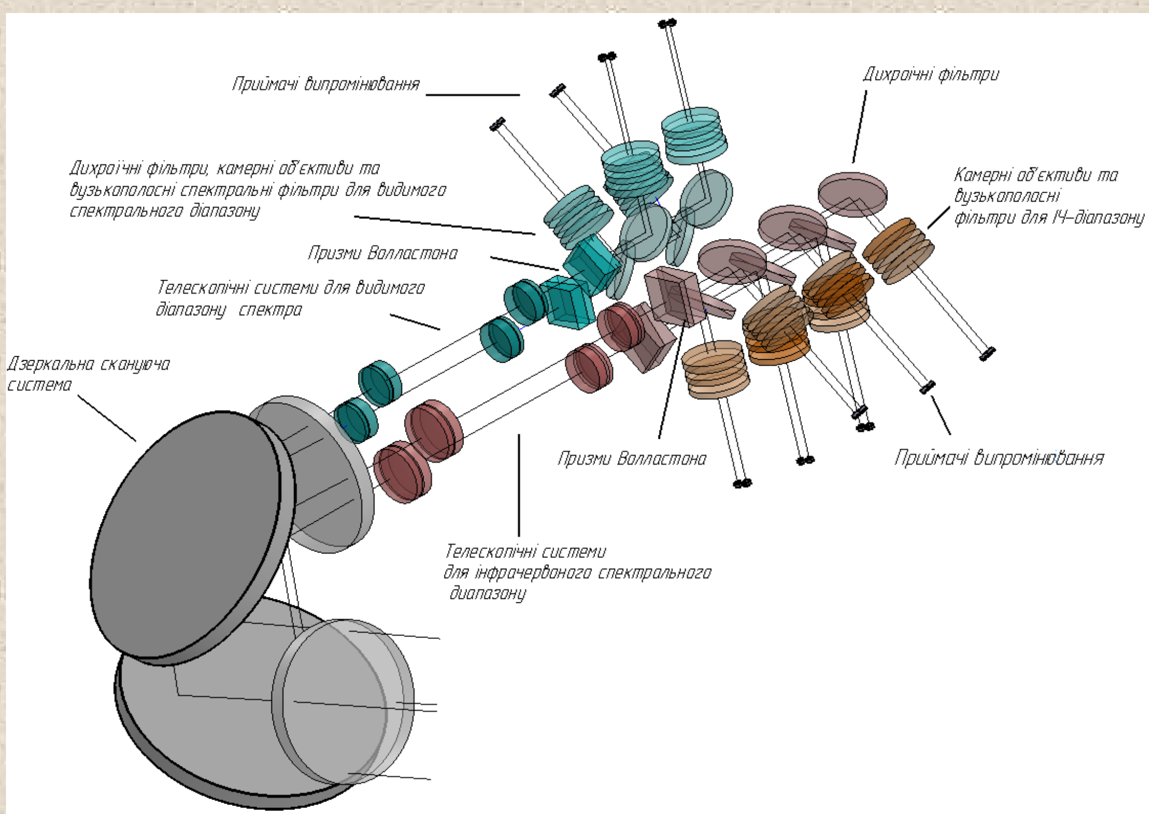
Is MC-2-8 platform suit to these parameters?

Aerosol-UA mission scanning geometry: ScanPol, MSIP



Polarimeter ScanPol: optical alignment

Spectral band: 370-1610 nm,
six spectral channels:



370 nm – tropospheric aerosol and top of clouds

410 nm – aerosol over ocean and surface

555 нм – aerosol over ocean and surface, ocean color

865 nm – aerosol over ocean and surface

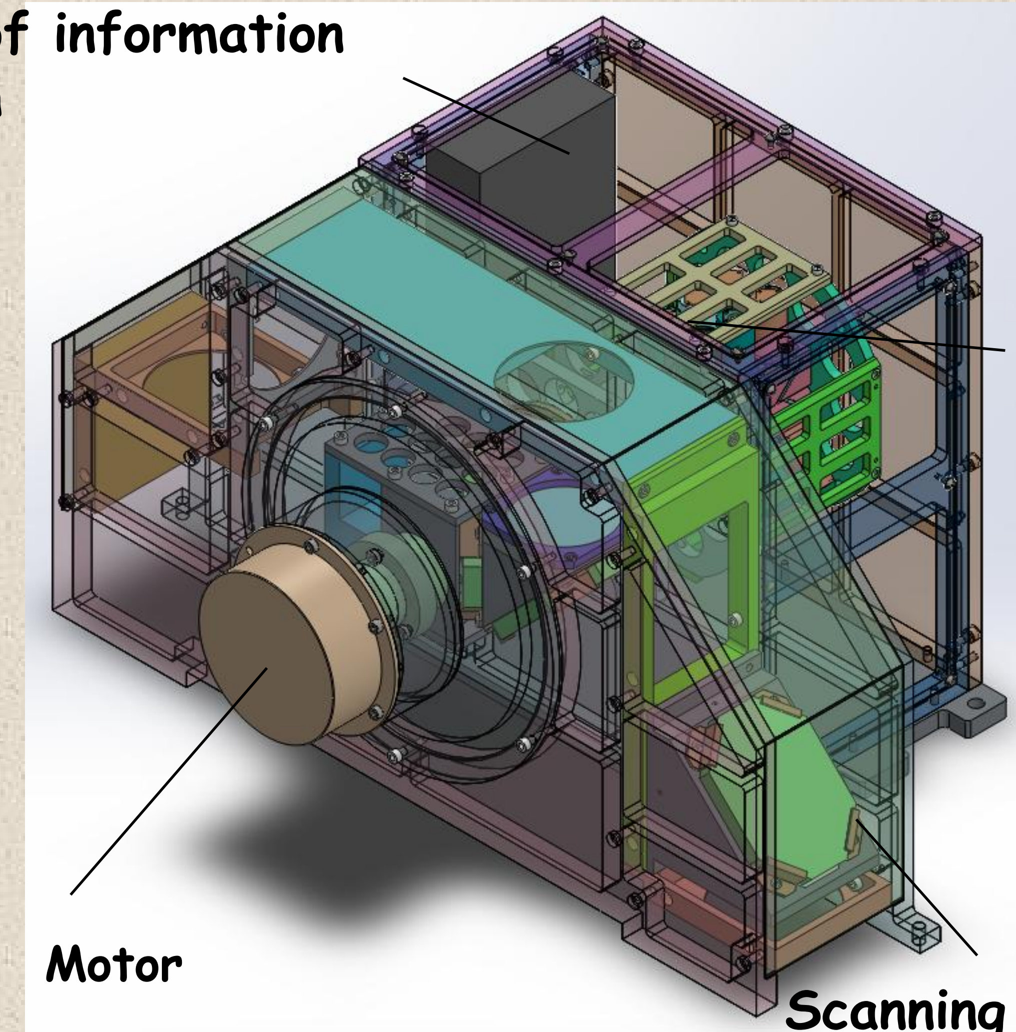
1378 nm – separate cirrus clouds, stratosphere aerosol, separation of troposphere and stratosphere aerosol in case of volcanic eruption

1610 nm – separation surface signal from aerosol over Earth' surface

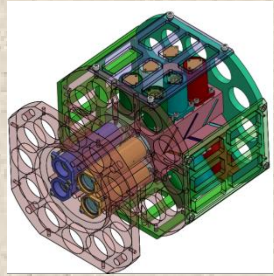
Observable Stokes parameters: I, Q, U (0,90,45,135°)
Photometric accuracy: 4%
Polarimetric accuracy: 0.15%
On-board calibration: all three Stokes parameters

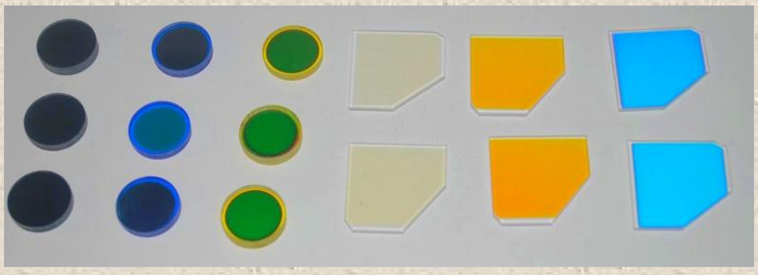
Filter ½ width 20 - 60 nm

Optical/mechanical ScanPol Unit with scanning mirrors for aircraft test measurements



Details of ScanPol Unit (July 2015)

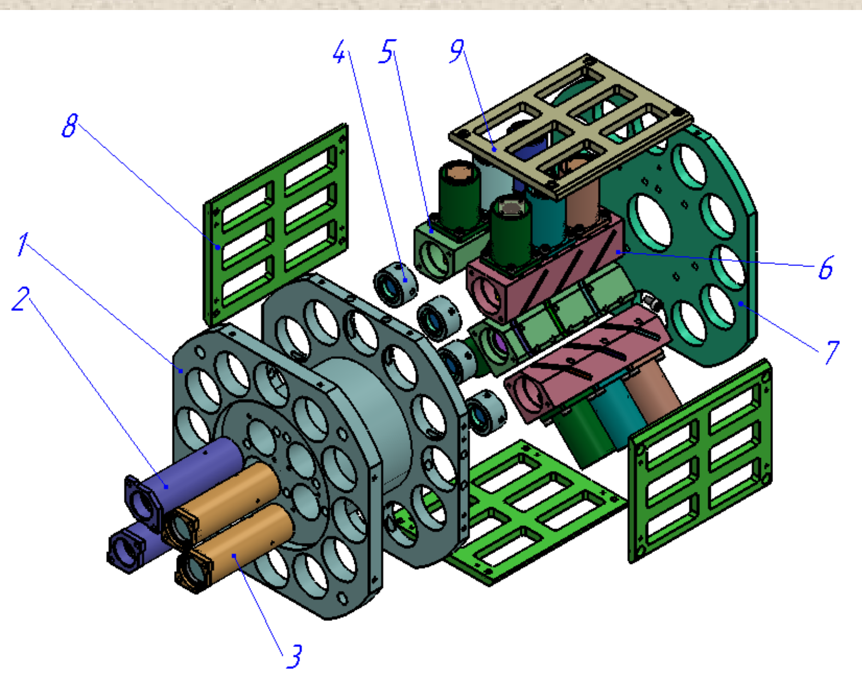




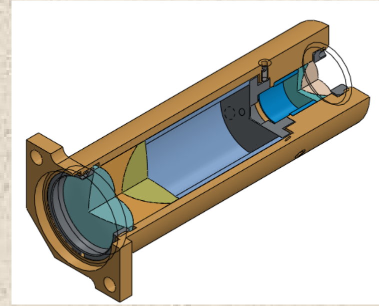
Optical elements for spectral selection

Mechanical elements

ScanPol spectropolarimeter: details of optical-mechanics unit



1 — base, *2* — input lens and collimator VIS, *3* — input lens and collimator IR, *4* — Wollaston prisms, *5* — spectral selection and camera lens VIS unit, *6* — spectral selection and camera lens IR unit



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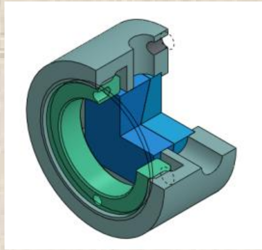

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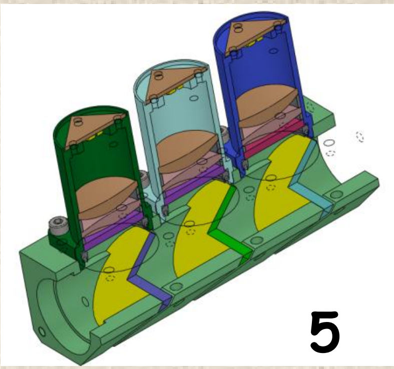

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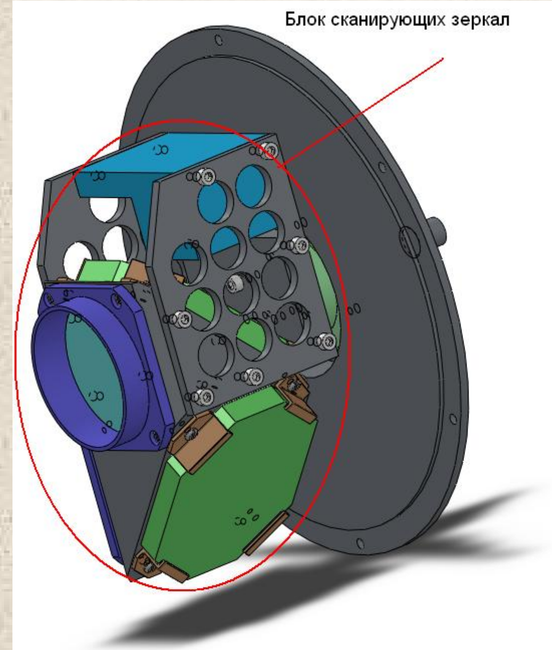
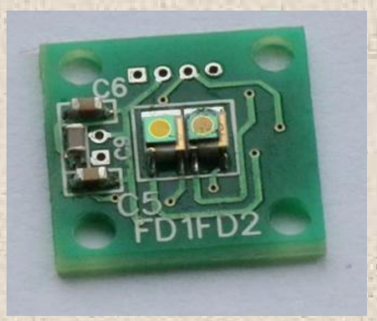
ScanPol Unit with scanning mirrors



Mirror unit

ScanPol: motor for scanning mirrors and photodiodes units

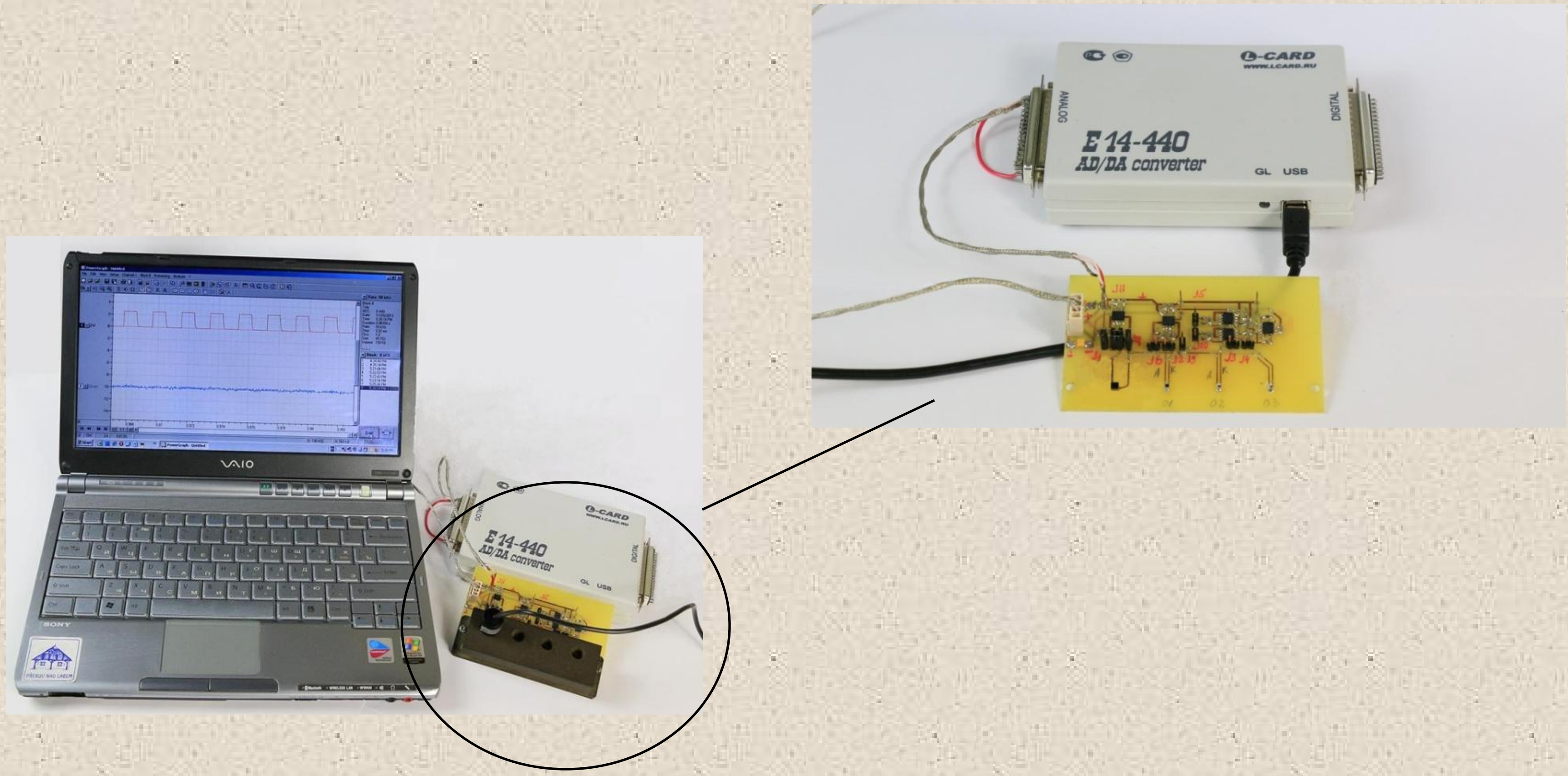



Si - S10356-01 (Hamamatsu)

InAsGa - G8941-01 (Hamamatsu)

Motor for mirrors (Institute of Electrodynamics)

ScanPol: information collection unit

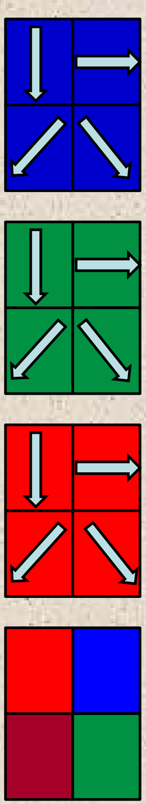


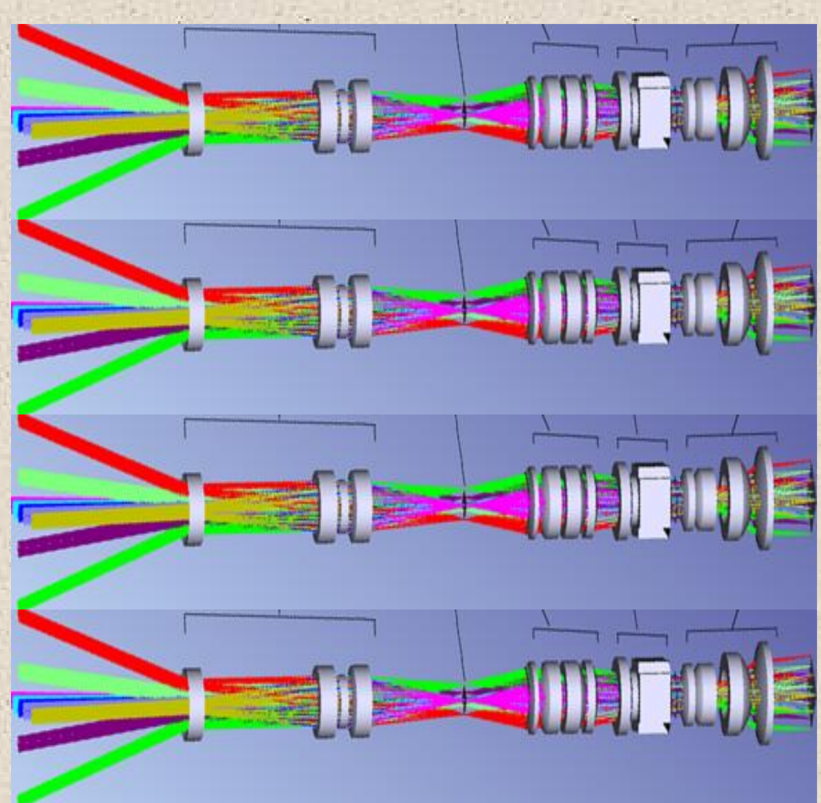
Information is collected from 24 channels by 32-channels AD/DA collector 14-440.

MultiSpectral Imager/Polalimeter (MSIP)

- MSIP main purposes: aerosol/cloud parameters and aerosol - cloud separation
- Three spectral polarimetric channels: 410, 555, 865 nm 0°, 45°, 90°, 135° polarization each
- One intensity channel: 410, 555, 865, 936 nm
- FOV: 60°x60°, 770x770 km, resolution 4 km
- Images rate 1.5 s^{-1} ÷ 6.0 s^{-1} (dependent on data rate transmission), exposure <0.1 s
- Calibration using ScanPol scans, <1% accuracy

Preliminary optical design of MSIP: four channels (1) 410P, (2) 555P, (3) 865P, (4) 410+555+865+936I



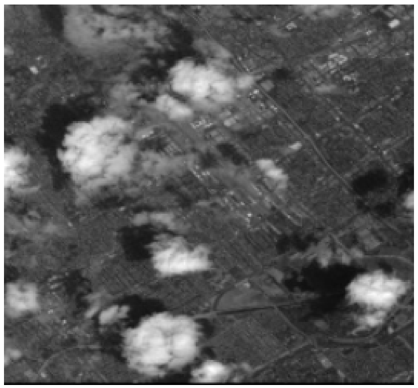


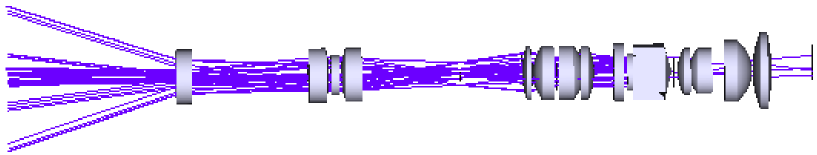
Aperture Ø 22 mm
Length 300 mm
FOV 60x60°

Unit of the polarization analysis: birefringent prisms or polarizer films

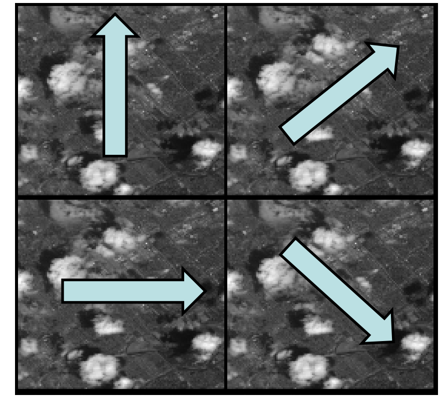
How MSIP imager/polarimeter works?

scene



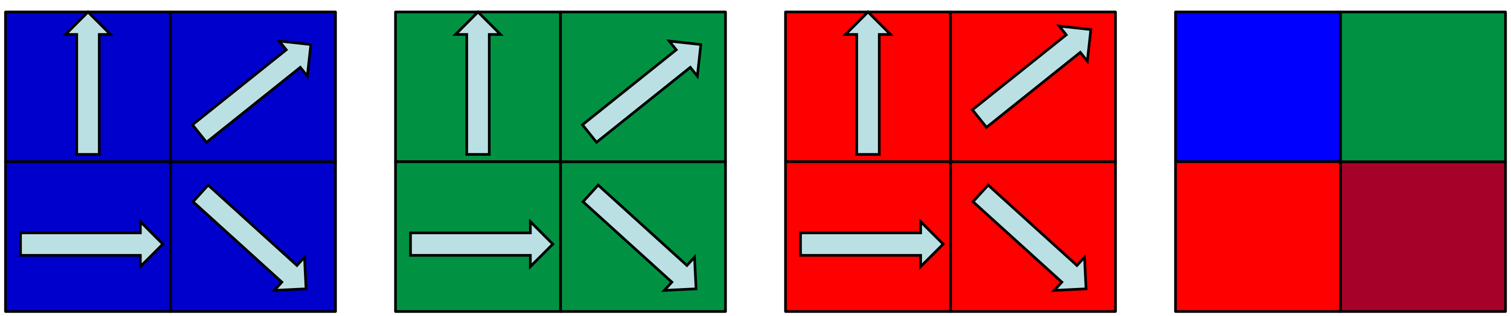


4 images on the CCD detector
with polarization components
0° 45° 90° 135°



Detector
2K x 2K, size 20 x 20 mm

Polarization 0°, 45°, 90°, 135° **Intensity**

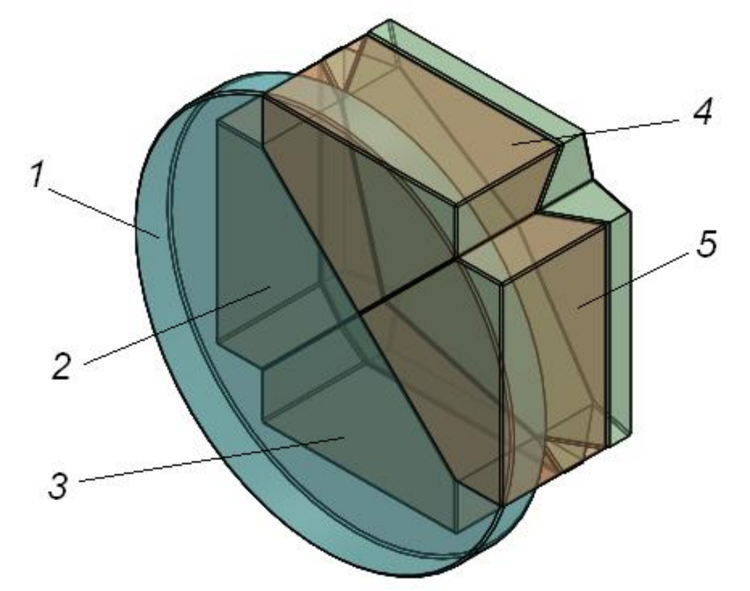


410 nm **555 nm** **865 nm** **410+555+865+936 nm**

Overall 16 channels

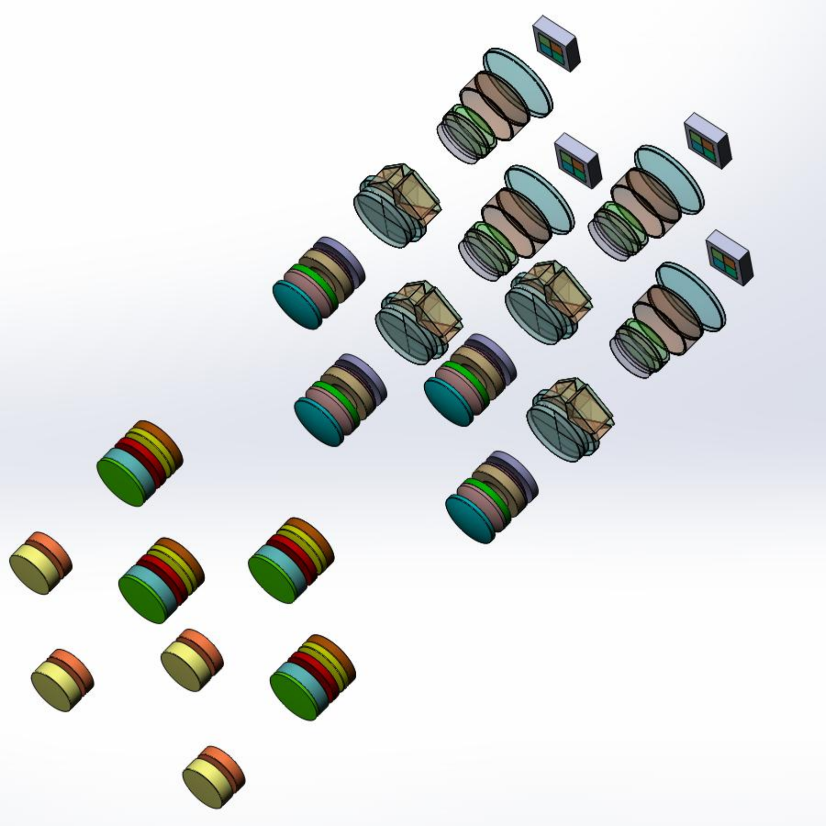
Image dividing system

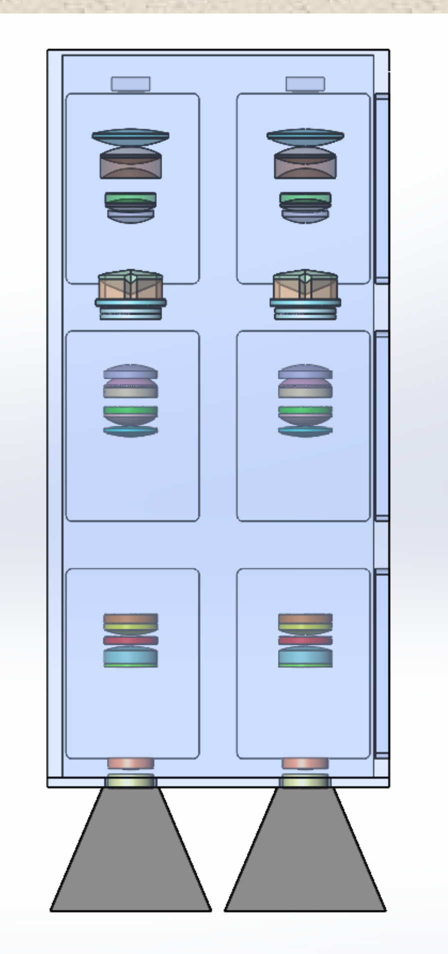
To divide the input image for four the prism achromatic in 420-900 nm system is used. Система состоит из двух склеенных клиньев из стёкол различного типа для каждого канала



1-plate, 2-5 achromatic wedges for each of four channels.

Optical layout and general sketch of MSIP





Dimensions:

Lengths 120 mm, width 120 mm, height 300 mm.

Weight 5-6 kg.

4. Conclusions

1. Aerosol-UA concept instruments provides synergy of precision scanner-polarimeter and imager-polarimeter

Timeline Aerosol-UA

1. Finalizing of ScanPol model – end of 2015
2. Technical Documents for MSIP – end of 2015
3. ScanPol laboratory testing - end of 2015
4. Data processing algorithm – spring of 2016
5. On flight ScanPol testing – mid 2016