Spectropolarimetry for EJSM

_The SPEX Instrument_

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Outline

Spectropolarimetry

SPEX Instrument

SPEX Simulator

Radiation hardness

Summary
Spectropolarimetry

- Polarization state of light: direction of oscillation of E-M-field
- Degree of polarization of scattered and reflected light is very sensitive to size, shape & composition of the scatterers
- Strong wavelength and scattering (phase) angle dependence
Science case for spectropolarimetry on EJSM

**EJSM science objectives:**

Characterizing the composition and structure of

- Jupiter's atmosphere: aerosol & cloud particles
- Jupiter's rings: ring particles
- Surface Jovian moons: roughness, regolith particles

Spectropolarimetry can reveal the microphysical properties and spatial/temporal distribution of scattering particles

SPEX is complementary to model payload and essential for meeting overall science objectives
Remote sensing instrument for measuring and characterizing aerosols, clouds, dust, hazes, surfaces and rings

Innovative instrument concept:

• Simultaneous measurement of polarization state and flux
• Wavelength range 400 - 800 nm
• No moving parts – fixed viewing angles
• Compact and low mass

Multi-wavelength
Multi-polarization
Multi-viewing angle
Imaging
spectropolarimeter
SPEX: Mechanical and Optical design

Dimensions: 15x12x6 cm³

Courtesy of Mecon

Aspherical lenses
Grating

Detector

Spherical mirror
Flat folding mirror

Polarization pre-optics

Slit

Courtesy of ASTRON
SPEX: Polarization measurement principle

1. *Temporal modulation*: rotating waveplate or liquid crystal.
   → Risk of failure; large power consumption; timing issues.

2. *Spatial modulation*: split up beam according to four (three) linear polarization directions.
   → Not precise enough; too large.


Key technology:

Birefringent crystals Patented (Keller, Snik, SIU)
**SPEX: Polarization measurement principle**

![Diagram showing polarization measurement principles](image)

- **Polarization encoded in flux spectrum:** spectral modulation
- **Amplitude** \( \sim \) degree of linear pol. (DoLP)
- **Phase** \( \sim \) angle of linear pol. (AoLP)
**SPEX: Polarization optics**

- Athermal multiple order retarder (Sapphire + MgF$_2$)
- Achromatic quarter wave retarder (Fresnel rhomb)
- Polarizing beam splitter (Wollaston prism)
- Lens
- Slit

Distance: ~5m
Demodulation → DoLP & AoLP

Full Stokes radiative transfer modeling

Retrieval of atmosphere composition

SPEX Measurement & Analysis
SPEX End-To-End Simulator

Simulator enables:

- Support science studies, e.g.
  - Definition of science/instrument requirements
  - Retrieval of particle properties from simulated DoLP and AoLP
- Support design tradeoff studies
- Instrument performance analysis for wide range of mission scenarios
- Evaluation and tracing of possible system degradation
- Testing demodulation algorithms (for obtaining DoLP and AoLP)
SPEX End-To-End Simulator: Model blocks

- Atmosphere model
- Full Stokes RTM
  - RTM output database
- Simulation Input file
  - Orbit generation
  - Input spectrum generation
- Polarization Optics
- Imaging Optics
- Detector & Electronics
  - Demodulation (DoLP & AoLP)
- Instrument data library
  - Retrieval
Input spectra for each ground pixel (identical)

SPEX Detector Signal
SPEX End-To-End Simulator

Demodulation

- Polarization resolution $\sim 20$ nm
- Instrument imperfections induce errors
- Algorithm development

Total flux obtained from complementary modulated spectrum (with opposite phase)
SPEX Radiation hardness / TDA

SPEX Critical components:

- Polarization optics
  - entrance aperture, full exposure

- Fresnel rhomb
  - BK7G18
  - $\text{Al}_2\text{O}_3$ (sapphire) and MgF$_2$
  - $\alpha$-BBO, YVO$_4$, TiO$_2$

- Retarder plates
- Wollaston prism

- Study plan item
  - Radiation tolerance study of crystals

Common critical components:

- Lenses
  - Suprasil, F2G12

- Detector and Electronics
Current SPEX development status

- **SPEX prototype**: procurement of parts has started
- **SPEX calibrator unit**: lab model successfully finished
- **SPEX simulator**: operational
  - science requirements
  - detailed performance analysis
  - synergy studies
- **TDA**: national funding will be requested
Involved parties SPEX instrument

Instrument:
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SRON
TNO / ASTRON
Dutch Space
MECON
Cosine

Science:
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