

On the study of small bodies and
Zodiacal light in the near-Earth and
interplanetary space by the
polarimetry methods

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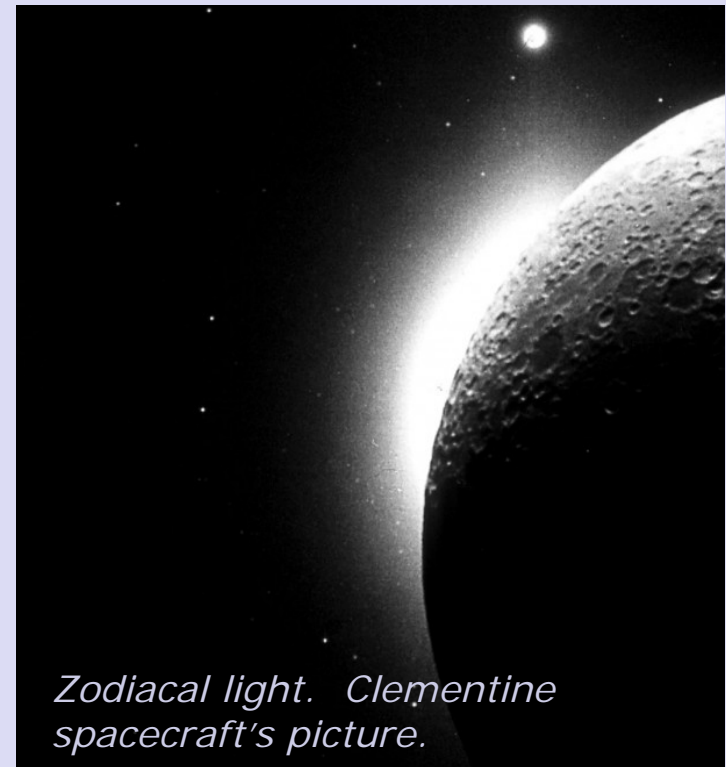
Georgi Chamov

Purpose

We aim to investigate the properties of an interplanetary space by applying the methods of polarimetry. Examination of the light source polarization is the most important test to define the radiation generation mechanism in the space matter. We present the conception of our new project that will investigate the polarimetry of the zodiacal light on a Sun-synchronous low Earth orbit.

Objects of research

- Small bodies: comets, asteroids;
- Diffuse matter;
- Dust particles;
- Zodiacal light.



Zodiacal light. Clementine spacecraft's picture.

Objects: Zodiacal light

- arises from two independent physical processes:
 - thermal emission from solar radiation, absorbed by interplanetary dust and reemitted at infrared wavelengths;
 - scattering of solar continuum radiation by interplanetary dust;
- caused by sunlight scattered or absorbed by particles in the interplanetary medium;

Image of zodiacal light taken at ESO's La Silla Observatory in Chile

Objects: Zodiacal light.

Importance of investigation:

- a source of information about the integrated properties of the whole ensemble of interplanetary dust;
- physical properties of the dust particles in the interplanetary space;
- optical properties and spatial distribution of the scattering particles;

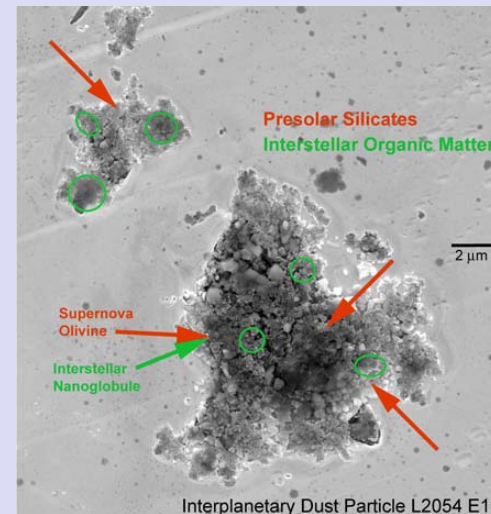


Figure. Dust particle example. Credit: Henner Busemann, Univ. of Manchester

Objects: Zodiacal light. Instruments

From Earth

Earth-based camera (1955)

Infrared observations – IRAS and COBE; mid-infrared camera – ISOCAM (Reach et al. 2003) (Cesarsky et al. 1996);

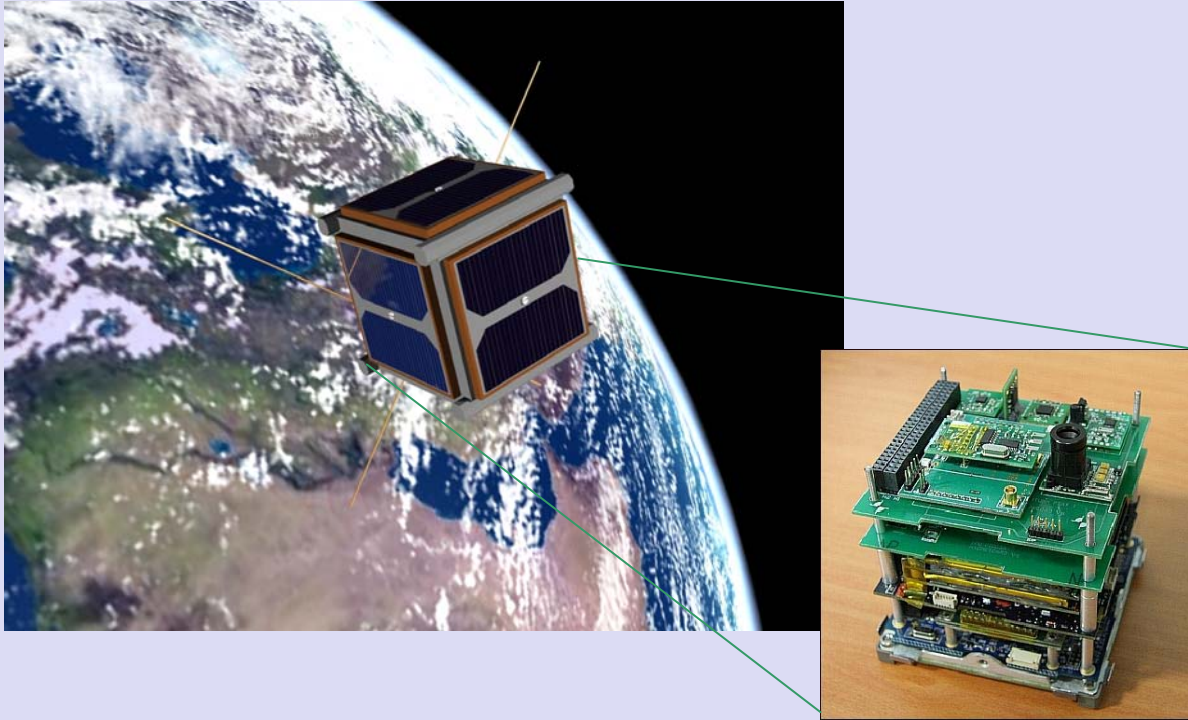
From Space

Satellites - CLIMENTINE (1994);

Nanosatellites

- Pollution from diffuse light sources;
- The sunlight dims faint zodiacal light;
- Low quality photometry;
- Less known inner part of the Zodiacal light;

Objects: Zodiacal light. Instruments. Nanosatellites.



Contemporary trends:

- advances in electronic miniaturization; the possibility of independence in space;

Advantages of nanosatellites:

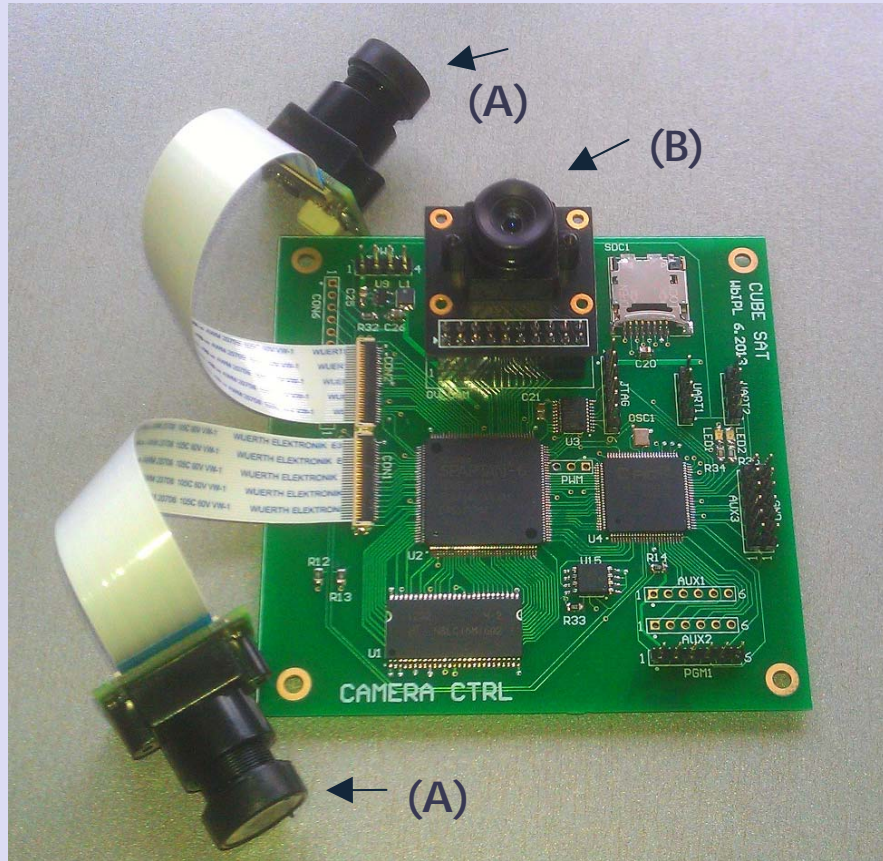
- low-cost; fast delivery; easy for the educational purpose;

**Objects: Zodiacal light. Instruments and Methods.
NanoSat Project**

The aim of our project is polarimetric measurements of Zodiacal light by using nanosatellite (such as CubeSat). It includes the following steps:

- ❑ Design and construction of the nanosatellite;
- ❑ Experimental measurements of the Stokes parameters by nanosatellite's cameras;
- ❑ Construction of a mobile-modular ground station;
- ❑ Software development for cubesat-to-ground communication;
- ❑ Day in the life, vibration and thermal-vacuum testing;
- ❑ Choice of a launcher, launch location and date;
- ❑ Polarimetry of the zodiacal light on sunsynchronous low-earth orbit.

Design and construction of the nanosatellite. Observation/measurement module.



- to measure Stokes parameters for every zone in the field of view
- to take colour panorama pictures of the space
- 3 nanosatellite's cameras
 - Black and white camera type (A)
 - Panorama color camera (B)

Nanosatellite project. Design and construction of a nanosatellite.

Construction of a mobile-modular ground station

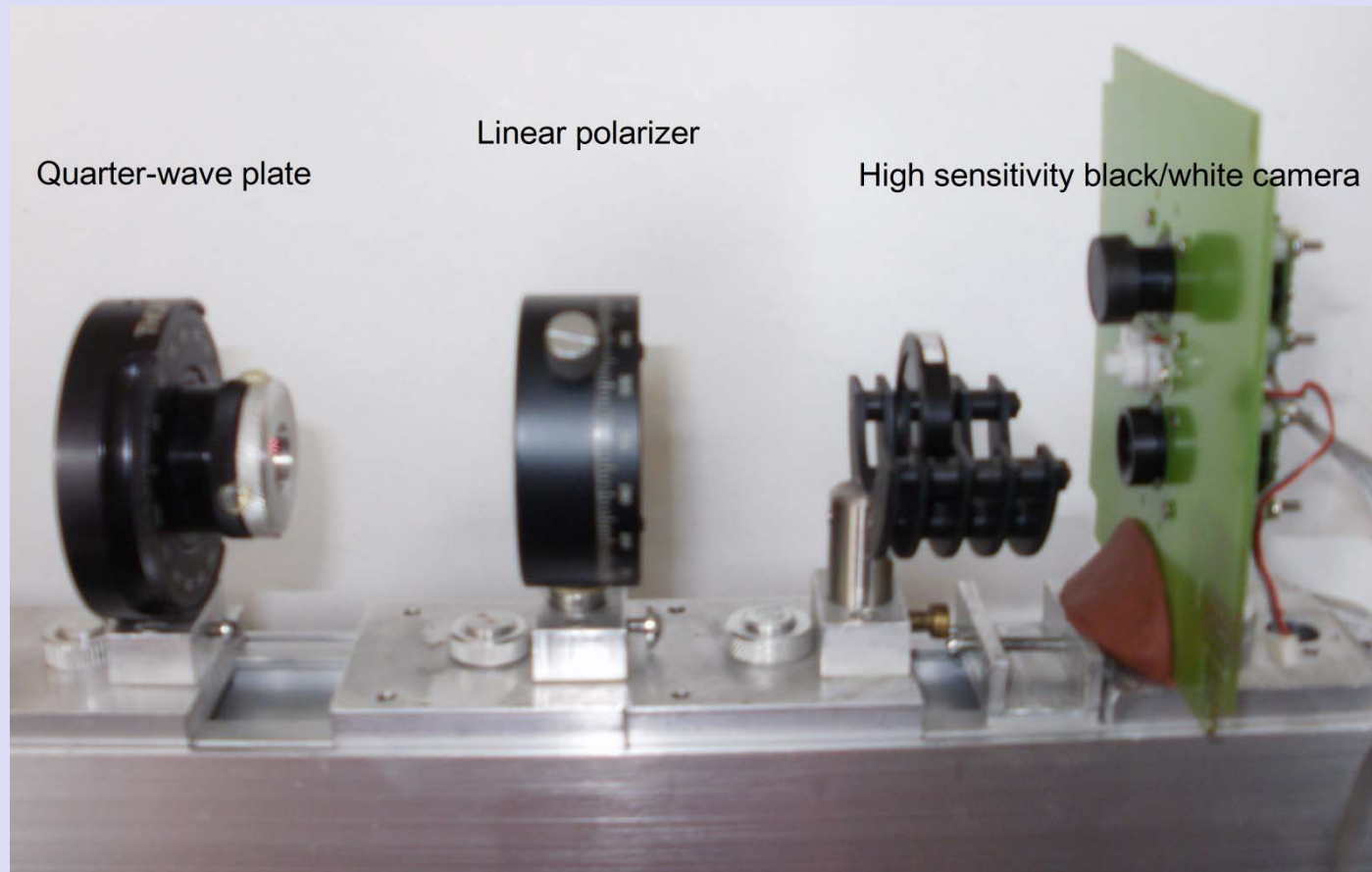
- ❑ constructed for direct communication;
- ❑ operates in the VHF range-uplink UHF range - 9,6 Kbit/sec downlin; 2,4 GHz range (high speed -192 Kbit/sec downlink);
- ❑ a cross Yagi antenna for VHF and UHF ranges;
- ❑ satellite transmit power of 27.0 dBm, satellite antenna gain of 3 dB, and ground station antenna gain of 16 dBi;
- ❑ the calculated signal power at the ground station is -109 dBm and the calculated signal power at the transceiver is -89 dBm at UHF range with S/N ratio 20 dB.

Nanosatellite project. Design and construction of a nanosatellite.

Software development for CubeSat-to-ground communication

- ❑ C programming language and PIC assembly language;
- ❑ compatible with the 32 bit RISC processor (PIC32) ;
- ❑ allow for the ground station to upload or reload software modules to the PIC during flight;
- ❑ capable of disabling all subsystems except Command and Data Handling (CDH) and Power (EPS);
- ❑ nominally read from each sensor every 30 seconds and record the data to memory.

Nanosatellite project. Experimental measurements of the Stokes parameters by nanosatellite's cameras.



Measurements of the Stokes parameters in experimental conditions

Polarimetry of the zodiacal light on a Sun-synchronous low Earth orbit. Methods.

Analysis by calculating the Stokes parameters:

$$\mathbf{S} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I_x + I_y \\ I_x - I_y \\ I_+ - I_- \\ I_R - I_L \end{pmatrix}$$



Measurement the intensity of the light in the NIR spectral area

- 920nm

Points of the study:

- Rate and angle of polarization;
- To define the type of polarization;
- Modeling the received data.

Current status:

Initial version of the observational camera and the Ground station - ready;
Software is in progress;

Expected results:

Creation and deployment the nanosatellite to LEO;
Establishment the communication between nanosatellite and the ground station;
To obtain and transfer the pictures and data;
To define the Zodiacal light polarization from the receiving pictures;

Future: To create a model to measure the concentration, size, surface properties, reflecting capability; The model and the results could be use to study the small bodies in near Earth space, diffuse matter, interplanetary space and the Milky Way.

THANK YOU! 😊



The Zodiacal Light as seen from Paranal. (Credit: ESO/Y. Beletsky)

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