High Energy Astronomy From The Moon: Early Activities And Perspectives

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Introduction

The Moon has been recognized from the scientific community (first studies beginning of 1990) **as a suitable platform to explore the Universe**, thanks to its **unicity** for those branches of the science which require a **quiet environment**.

Scientists have also identifyed the Moon as a possible site for the deployment of an Observatory to investigate the Universe with a **complement of Instruments** with which to detect the **electromagnetic and particle radiation**. This type of observatory, which could comprise extremely **large telescopes** can not be put in space due its complexity, dimensions and difficulties in the operations.

Lunar Observatory Science Requirements

The main scientific requirements for the Lunar Observatory Instruments are the following:

- X and Gamma-Rays from **0.1 KeV up to GeV;**
- High energy particles telescopes, neutrinos detectors, Radio Telescopes;
- **Large collecting areas**;
- High Energy Resolution;
- Time and Spatial Resolution;
- **All-Sky visibility**;
- All Lunar day operations;
- Low Lunar dust contamination;
- Thermal stability;
- High Data Rate;

X- and Gamma Ray Telescopes on the Moon

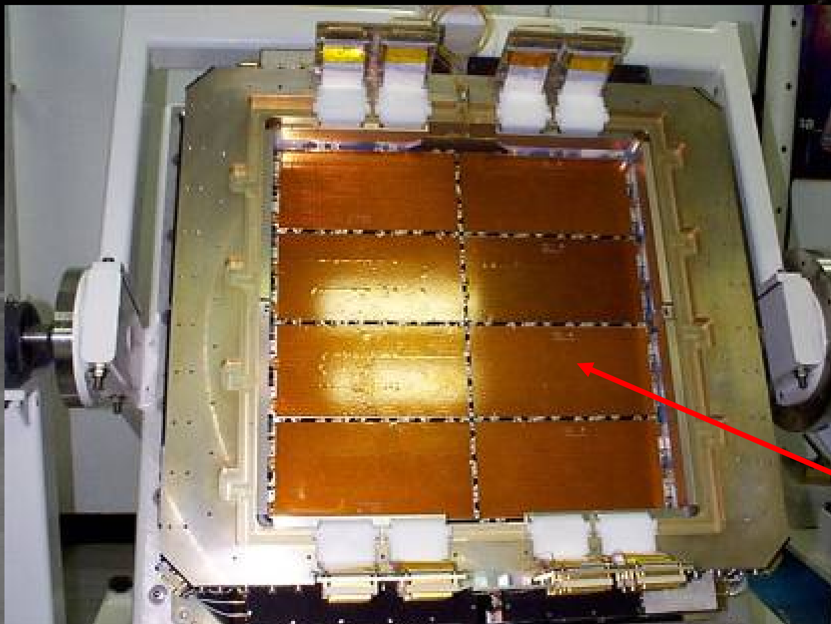
In this presentation we take into consideration some technical issues relevant to X and Gamma Ray telescopes.

- **Large collecting areas (~ 30m²)**, imaging detectors, high energy and time resolution;
- **Tenths of meter focal lenght;**
- For the low energy X-Ray telescopes it is important to evaluate the **scattering of the radiation** due to the lunar environment (i.e. dust).

The above requirements imply in general large masses and **complex structures.**

Serious problems are related to their **accomodation and operation** (including pointing and orientation), in addition to the more general issues of **power generation and thermal stabilisation**.

Examples of X- and Gamma Instrumentation



IBIS Detecor Unit onboard INTEGRAL

Pixels CaeSium Iodide Telescope (8 x 512 pixels)

Critical areas

The design of X- and Gamma Ray telescopes for the Moon requires detailed data relevant to the lunar environment, where the instruments will be located. Some critical areas are:

- Thermal control;
- Power production;
- Day / night operations;
- Dust contamination and X-Ray scattering;
- Background evaluation;
- Farside operations;
- Micrometeorites impact;
- Positioning on the lunar soil;
- Maintenance;

Proposal for “in-situ” experiments on the Moon

Some of these critical areas have been already studied and data are available. For others we envisage the **need to collect the relevant data with “in-situ” measurements** performed with dedicated technological experiments.

Here **we present four small technological experiments** to investigate what we believe are seroius issues for X- and Gamma Ray Astronomy instrumentation.

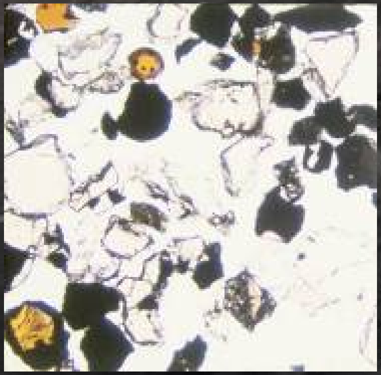
1. Evaluation of the **thermal flux** on an electronic or detector box located on the Moon surface;
2. **X-Ray scattering** due to the lunar dust at various heights from the ground;
3. Measurement of the **micrometeorites flux**;
4. Measurement of the **incoming and albedo radiation** on the Moon surface;

Effects of the Lunar Dust on Experiments

July 20, 1969 Footprint by Apollo 11 astronaut Buzz Aldrin (courtesy NASA: AS11-40-5878)

The surface of the Moon is covered by a **thick (2-30 m) layer of regolith**. The lunar regolith is composed of grains with a **typical size of 40-250 µm**. Results from Apollo 17 LEAM experiment strongly indicate a continuous circulation of the smallest size fraction of lunar fines above the surface.

The contamination from lunar dust is a critical item, both for instruments and electronic units, as electrically-charged moondust can stick to units, darkening their surface and causing overheat.



Thermal flux evaluation (1/2)

Goals of the experiment:

- To measure the **temperature distribution** of a passively shielded box on the Lunar surface;
- To investigate the **thermal effects induced on the box** surface by **abrasion and deposition of Lunar dust** (thermal ageing);
- To investigate the **electrostatic charging** induced by the photoelectric charged lunar dust;
- To screen and identify the main issues related to the **design and manufacturing for thermal shields, radiators and heaters** for detector planes and electronic boxes.

Thermal flux evaluation (2/2)

The guidelines for an experimental configuration are reported hereafter:

- Matallic box of about **10 liters volume** and **1g/cm^3 density** enveloped in several layers of MLI shielding.
- Box positioning at a TBD distance above lunar surface, depending on Lunar Surface Module capabilities.
- No internal power dissipation.
- Thermal sensors will measure the internal temperature as a function of the external one.
- ESD sensor and discharge device.
- Night and day operation.
- Mass budget including read-out electronics lower than 15kg;
- Power budget less than 5W.

Measurement of the X-Ray scattering by dust

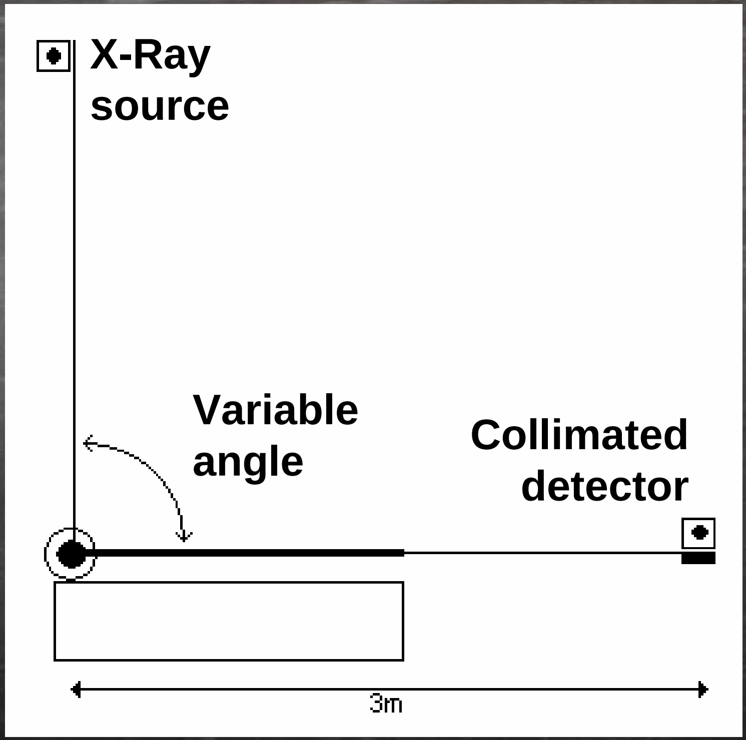
Goal: To measure the **dust contamination** **as a function of the distance from the lunar soil**, by measuring the X-Ray scattering of a collimated X-Ray beam;

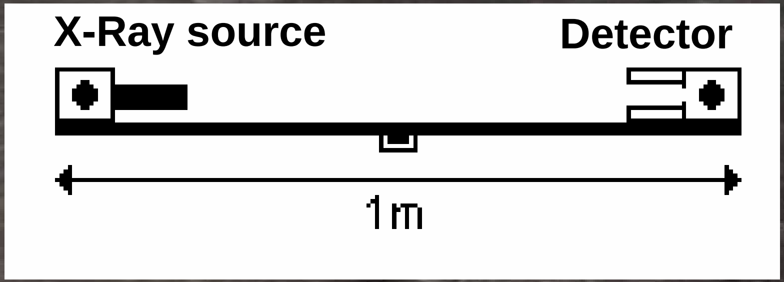
Configuration:

- X-Ray source and detector along one axis;
- Typical distance between detector and source is 1m in order to have enough dust between the X-Ray source and the detector;
- Collimated X-Ray beam in the energy range 0.1keV – 15keV;
- The detector shall have enough sensitivity to measure the X-Ray flux variation as function of the amount of dust between the detector itself and the X-Ray source. The flux variation as function of the distance from the ground will be measured. The collimated source will be identified within those in the range of X scattering.

Measurement of the X-Ray scattering by dust

The detection system will be placed on a support which will guarantee the possibility to work at different height.





Measurement of Micrometeorites Impact (1/2)

Millions of micrometeorites strike the Moon every day. Micrometeorites are a millimeter or less in size. The known statitics of events is indicate that the amount of events indicate:

- ❑ 300 events / year / m^2 2π sr on 10 μm craters.
- ❑ 30000 events / year / m^2 2π sr on 0.1 μm craters.

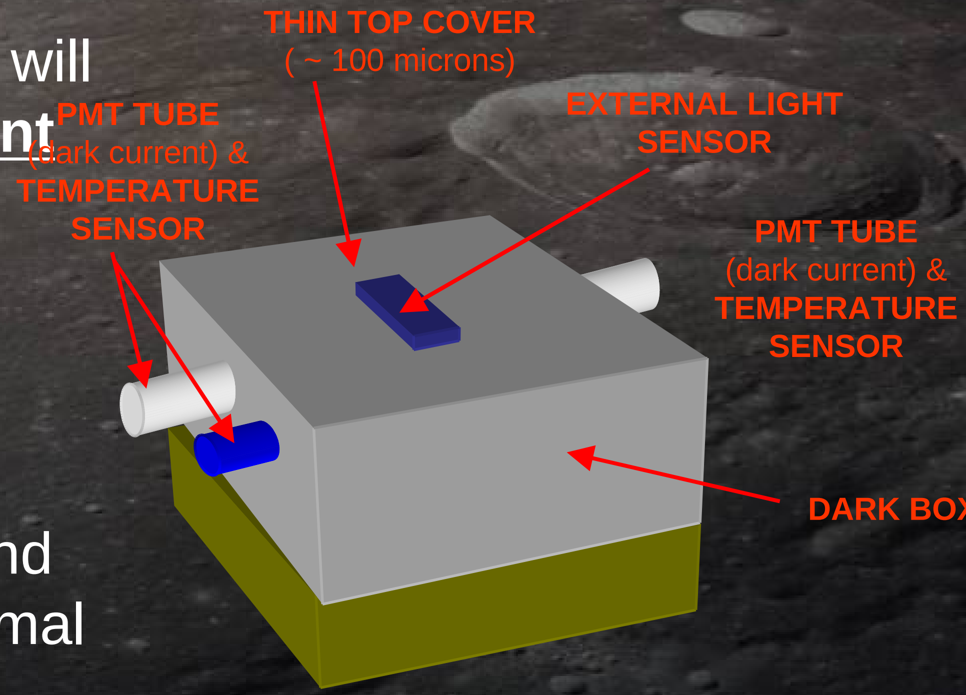
Goal:

<u>To evaluate the micrometeorites flux</u> at the lunar soil, in order to properly shield the telescopes and the instrumentation.

Measurement of Micrometeorites Impact (2/2)

Configuration:

- A **metal box** with wide collecting area (**about 1m^2**), **10 kg mass** and very thin **upper side (~ 0.1-1mm),** placed on the lunar soil.
- High reflectivity internal walls, **light-proof**.
- PMTs and a thermal sensor will **measure the photon current** and the box temperature, respectively.
- Temperature information is used to compute the photodiode dark current.
- Thermal shielding of P.M. and P.D. is needed to allow thermal stability.



Lunar Albedo Radiation Measurement (1/3)

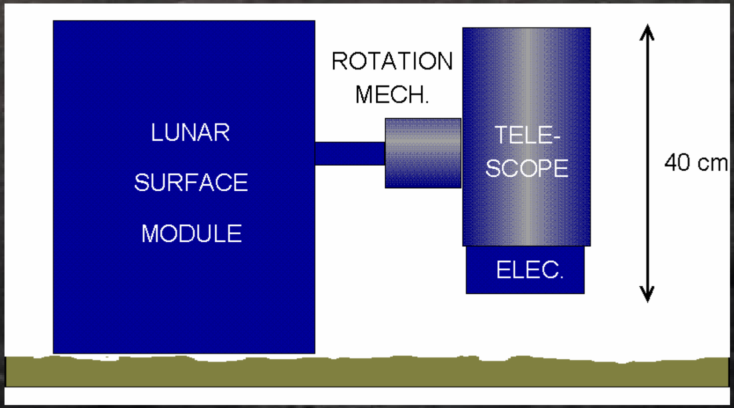
On the lunar surface the incoming Cosmic Raditaion Flux is about half that experienced in HEO or in the Lagrangian points. But to this flux we have to add the one coming from the ground due to the impact of the cosmic rays.

Goal:

- To measure the radiation flux at different angles w.r.t. the Moon surface;
- All day measurements;

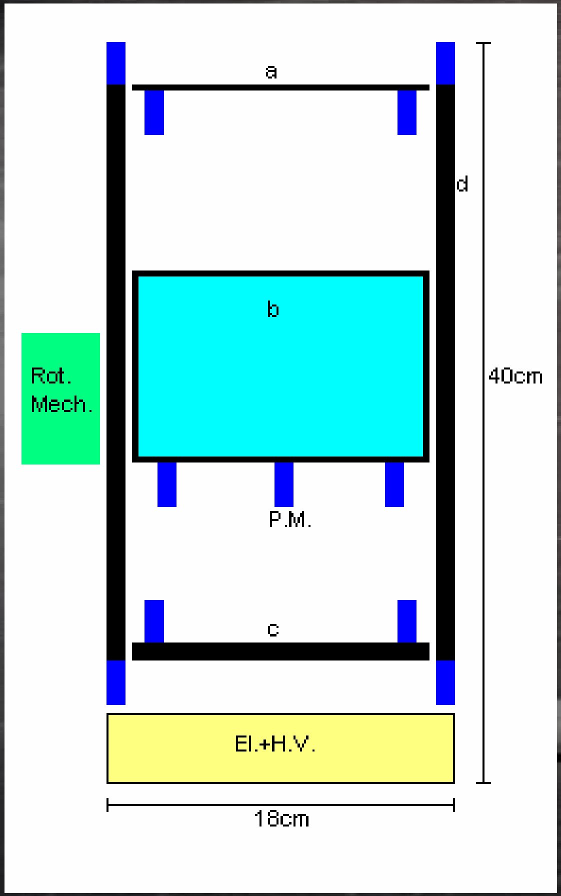
Configuration:

- Small telescope, sensitive to electromagnetic and particle radiation;
- Full 360° rotation along Z-axis;



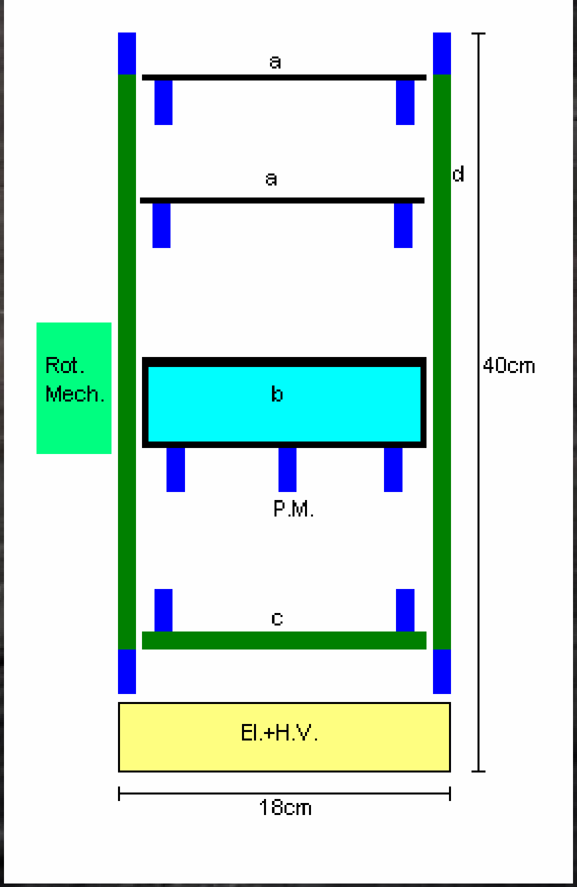
Lunar Albedo Radiation Measurement (2/3)

Configuration A:



- Measurement of the X- and Gamma-Ray flux through detector planes a, b, c and d (coincidence and anti-coincidence).
- Detection energy range depending on final dimension and type of the scintillators.

Configuration B:



Lunar Albedo Radiation Measurement (3/3)

Evaluation of typical budgets for configuration A, based on:

- 18cm aperture x 40cm height
- Two layers of plastic scintillators
- One layer of CsI scintillators

Mass budget	25-50kg
Power budget	10-15W
Rotation speed	360°/hour
Temperature range	-15°C to +40°C
Data rate	5-10 kbit/sec
Exposure time	5 Lunar days

Conclusions

The Moon has been recognized as a preferred site for the installation of large X- and Gamma Ray Telescopes.

Their design and manufacturing involves the resolution of several technological issues, part of which requires a better understanding of the characteristics of the Lunar site.

For this purpose we have identified four critical areas, the study of which could be initiated immediately with small-seized experiments. They involve the following measurements:

- ❑ Thermal flux on a passively shielded electronics and thermal stability;
- ❑ Scattering of soft X-Rays induced by Lunar dust;
- ❑ Flux of micrometeorites;
- ❑ Albedo at the Lunar surface;