Lunar Meteoroid Impacts And How To Observe Them Astronomers Observing S

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RORY PATEL

Ground-based Observational Techniques for Meteoroid Lunar Impact Generated Electromagnetic Pulses and Lunar Sub-surface Structure Detection

Cambridge University Press

A quantitative measure of the accuracy of the rate coefficients and the excess energies is a desirable goal of this analysis. There are two major sources of uncertainties: The atomic and molecular data and the solar irradiance. The cross sections and branching ratios used in this analysis come from many different sources; many of them without any error indications. For this reason, we must confine ourselves to a qualitative indication of the reliability of the results. Specifically we give a quality scale in Table II for the data of each mother molecule; A indicating the highest quality of atomic and molecular data and F the lowest quality. The letter B typically means that the threshold is uncertain. For most molecules the cross section at threshold is very small and the rate coefficient for these molecules is therefore not influenced by this uncertainty. For atomic species the cross section is usually large near threshold, but for these species the threshold is known quite accurately. The letter B, therefore, indicates that the rate

coefficient is most likely quite accurate, but the excess energy is less accurately known. The letter C usually means that the branching ratios are not well known. This means that the total rate coefficient is very good, but the rate coefficients and the excess energies for the individual branches are less accurate.

Bibliography of Lunar and Planetary Research Geological Society of America

The only work to date to collect data gathered during the American and Soviet missions in an accessible and complete reference of current scientific and technical information about the Moon.

Lunar and Planetary Science XXVII Springer

Bringing together some of the most recognized and influential researchers and scientists in various space-related disciplines, Lunar Settlements addresses the many issues that surround the permanent human return to the Moon. Numerous international contributors offer their insights into how certain technological, physiological, and psychological challenges must be met to make permanent lunar settlements possible. The book first looks to the past, covering the Apollo and Saturn legacies. In addition, former astronaut and U.S. Senator Harrison H. Schmitt discusses how to maintain deep space exploration and settlement. The book then discusses economic aspects, such as funding for lunar commerce, managing human

resources, and commercial transportation logistics. After examining how cultural elements will fit into habitat design, the text explores the physiological, psychological, and ethical impact of living on a lunar settlement. It also describes the planning/technical requirements of lunar habitation, the design of both manned and modular lunar bases, and the protection of lunar habitats against meteoroids. Focusing on lunar soil mechanics, the book concludes with discussions on lunar concrete, terraforming, and using greenhouses for agricultural purposes. Drawing from the lunar experiences of the six Apollo landing missions to the many American and Soviet robotic missions to current space activities and research, this volume summarizes the problems, prospects, and practicality of enduring lunar settlements. It reflects the key disciplines, including engineering, physics, architecture, psychology, biology, and anthropology, that will play significant roles in establishing these settlements.

Exploring Planet Earth and the Moon CUP Archive

Meteoroid experiments by five Lunar Orbiters have provided a direct measurement in the near-lunar environment of the rate of meteoroid penetration of 0.025-mm-thick beryllium-copper. Each experiment used 20 pressurized-cell detectors having a total effective exposed area of 0.186 m2. The spacecraft carrying the cells were in

both equatorial and polar orbits; altituded ranged between 30 and 6200 km. Data collected continuously for 17 months indicate that the rate of penetration in the lunar environment is approximately half the rate in the near-earth environment as measured by detectors of the same type aboard Explorers XVI and XXIII.

The Lunar Surface Layer

Lunar Meteoroid Impacts and How to Observe Them A gathering of essays from various scientific journals by the noted British astronomer, Richard A. Proctor (1837-88). Proctor was the author of more than 40 books on the subject and is credited with popularizing astronomy in the 19th century. He was the first to suggest that lunar craters were the result of meteor impacts and not volcanic activity and won recogition for his 1867 map of the surface of Mars showing continents, seas, bays and straits. This book contains essays on subjects including: Sir John Herschel; the planet Mars; Saturn's rings; meteors and shooting stars; the zodiacal light; the solar corona; the sun's journey through space; distribution of the nebulae; a new theory of the Milky Way; the diurnal rotation of Mars; the proper motion of the Sun; the transit of Venus in 1874 and many other subjects. The illustrations include a handsome frontis lithograph of Saturn and its rings and there is also a folding plan of the orbits of Earth and Mars and 5 folding charts showing various stages of

the transit of Venus in 1874. There are 3 full-page polar and equatorial maps on black paper showing distribution of Nebulae.
Springer Science & Business Media
This volume contains five articles describing the mission and its instruments. The first paper, by the project scientist Richard C. Elphic and his colleagues, describes the mission objectives, the launch vehicle, spacecraft and the mission itself. This is followed by a description of LADEE's Neutral Mass Spectrometer by Paul Mahaffy and company. This paper describes the investigation that directly targets the lunar exosphere, which can also be explored optically in the ultraviolet. In the following article Anthony Colaprete describes LADEE's Ultraviolet and Visible Spectrometer that operated from 230 nm to 810 nm scanning the atmosphere just above the surface. Not only is there atmosphere but there is also dust that putatively can be levitated above the surface, possibly by electric fields on the Moon's surface. Mihaly Horanyi leads this investigation, called the Lunar Dust Experiment, aimed at understanding the purported observations of levitated dust. This experiment was also very successful, but in this case their discovery was not the electrostatic levitation of dust, but that the dust was raised by meteoroid impacts. This is not what had been expected but clearly is the explanation

that best fits the data. Originally published in Space Science Reviews, Volume 185, Issue 1-4, 2014.

Sustainable Lunar Habitat Protection Against Damage by Meteoroid Impacts Geological Society of America

Abstract : Location, orbit and energy of a meteoroid impacting the moon during the Lunar Eclipse of January 21, 2019 During the total lunar eclipse of January 21, 2019 at least two meteoroids impacted the moon producing visible flash lights on the near side. One of the impacts occurred on the darkest side of the visible lunar face and was witnessed by many astrophotographers. In this paper we present estimations of the location, impact parameters (velocity and incoming direction), orbit and energy of the meteoroid, as obtained from images and videos collected by amateur astronomers in Colombia, the Dominican Republic, Morocco, USA, Canary Islands, Cape Verde, Czech Republic, Austria, and Germany. Astrometric measurements on the images put the impact location at selenographic lat = -29.43 and lon = -67.89 while photometric measurements predict the flash brightness of Gf = 6.7. The novel Gravitational Ray Tracing (GRT) technique is used to estimate the orbital properties and radiant of the impactor. We find that that the meteoroid impacted the moon with a speed of 13.8 km/s (70% C.L.) and in a relatively shallow angle, (6 of visible

light in a short time (0.3 seconds). The total impact energy was ~0.5 tons of TNT which correspond to a body with a mass ~20 kg and a diameter of ~30 cm. If our assumptions are correct, the crater left by the impact will have ~10 meters across and it could be detectable by prospecting lunar probes. These results arose from a timely collaboration between professional and amateur astronomers which highlight the importance of citizen science in contemporary astronomy. Testing the Weak Equivalence Principle with Cosmological Gamma Ray Bursts Gamma Ray Bursts (GRBs) with rapid variations at cosmological distances are used to place new limits on violations of the gravitational weak equivalence principle (WEP). These limits track intrinsic timing deviations between GRB photons of different energies as they cross the universe, in particular in the KeV to GeV energy range. Previous limits in this energy range have involved only the gravitational potential of local sources and utilized temporal variability on the order of 0.1 seconds. Here WEP violation limits are derived from sources with greater distance, faster variability, and larger intervening mass. Specifically, GRB sources with redshifts as high as 6.5 are considered, with variability as fast 0.2 milliseconds, and passing the gravitational potentials of inferred clusters of galaxies distributed randomly around the line of sight.

WEP violation limits are derived from data from GRB 910711, GRB 920229, GRB 021206, GRB 051221, GRB 090429, and GRB 090510. The strongest constraint in the very early universe comes from GRB 090429 which limits gamma (500 keV) - gamma(250 keV) -13. The strongest overall constraint comes from GRB 090510 which yields a WEP violation limit of gamma(30 GeV) - gamma (1 GeV) -16. This strongest constraint is not only a new record for WEP violation limit for gamma-ray photons and in the early universe, but the strongest upper bound for Delta gamma that has ever been recorded between any two energy bands.

Lunar Settlements

Cambridge University Press

This definitive guide provides advanced students and researchers with a detailed yet accessible overview of all of the central topics of meteor science. Leading figures from the field summarise their active research on themes ranging from the physical composition of meteoroids to the most recent optical and radar observations and ongoing theoretical developments. Crucial practical issues are also considered, such as the risk posed by meteoroids - to spacecraft, and on the ground - and future avenues of research are explored. Taking advantage of the latest dynamical models, insights are offered into meteor flight phenomena and the evolution of meteoroid streams and complexes, as well as

describing the in-depth laboratory analysis of recovered material. The rapid rate of progress in twenty-first-century research makes this volume essential reading for anyone who wishes to understand how recent developments broaden our understanding of meteors, meteoroids and their origins.

Supplement No. 2-1966
Springer

Lunar Meteoroid Impacts and How to Observe ThemSpringer Science & Business Media

Bibliography of Lunar and Planetary Research Supplement No. 3-1967
Cambridge University Press

We are so used to Earth and its wonders that sometimes it is hard to remember that it is just one of the millions of planets scattered throughout the universe. In this heavily illustrated volume, students will learn all about our home planet and its moon. Packed with facts about the planet's properties, students will learn how Earth and the moon work together, what we have learned about the moon from years of space exploration, and the moon's influence on weather and ocean tides. One day they might even live in a colony on the moon!

The Lunar Atmosphere and Dust Environment Explorer Mission (LADEE)
Springer Science & Business Media

The degree to which the thin Martian atmosphere filters out meteoroids approaching the Martian surface was calculated by using a model of the meteoroid environment, a

model of the Martian atmosphere, and equations of meteor physics. The secondary particle environment on the surface of Mars caused by the material ejected from meteoroid craters was modeled. The model consists of the mass distribution and the speed distribution of the secondary particles. Calculations were made of the penetration flux for aluminum structures on the Martian surface. The penetration hazard on the Martian surface was compared with the penetration hazard in space near Mars and on the lunar surface.

An Interdisciplinary Approach Springer Science & Business Media Discusses the nature and origin of the Moon, Mars, and meteorites, and gives, an account of the six moon landings from 1969-1972.

1753-1767 The Rosen Publishing Group, Inc Meteor Showers and their Parent Comets is a unique handbook for astronomers interested in observing meteor storms and outbursts. Spectacular displays of 'shooting stars' are created when the Earth's orbit crosses a meteoroid stream, as each meteoroid causes a bright light when it enters our atmosphere at high speed. Jenniskens, an active meteor storm chaser, explains how meteoroid streams originate from the decay of meteoroids, comets and asteroids, and how they cause meteor showers on Earth. He includes the findings of recent space missions to comets and asteroids, the risk of meteor impacts on

Earth, and how meteor showers may have seeded the Earth with ingredients that made life possible. All known meteor showers are identified, accompanied by fascinating details on the most important showers and their parent comets. The book predicts when exceptional meteor showers will occur over the next fifty years, making it a valuable resource for both amateur and professional astronomers.

Meteoroid Impacts on Mars and the Secondary Particle Environment

Frontiers Media SA

Proceedings of the Fourth International Conference on Large Meteorite Impacts and Planetary Evolution held at the Vredefort Dome, South Africa, in Aug. 2008.

Comet/Asteroid Impacts and Human Society

Springer Science & Business Media

The lunar surface is pockmarked with large and small craters mostly formed due to meteoroid impacts on the Moon. Most of the craters formed are not erased with time due to lack of "weathering" processes such as no atmosphere and little erosion. The main focus of this research is to develop ground-based observational techniques to search for ongoing hypervelocity meteoroid impacts on the lunar surface. Additionally, to design radar observational techniques to detect and map sub-surface structures that have been buried by the lunar regolith.It is hypothesized that the developing, optically-

dense hot ejecta cloud associated with the hypervelocity meteoroid impacts produce an associated complex plasma component that rapidly evolves resulting in a highly-transient Electromagnetic pulse (EMP) in the VHF/UHF spectral region. An observational EMP search was conducted in May 2014 for about 5 hours using an overlapping-band (425-445 MHz) at the Arecibo (AO; Puerto Rico) and Haystack-(HO, Massachusetts, USA) observatories simultaneously to track the common visible lunar surface from two different locations on the Earth. Observations from two locations is helpful in eliminating the false impacts. Interleaved radar observations were used to calibrate the timing and synchronize both the AO and HO systems. As the AO/HO UHF EMP search was interference dominated, an alternative search mechanism using the Arecibo L-band ALFA Array that consists of seven beams arranged in the hexagonal manner was conducted in February 2016. During these observations, at any given time few of the receive-beams were on-Moon and few off-Moon thus allowing discrimination against local interference that might resemble the expected EMP signals. While still encountering local out-of-band radar interference, this observational paradigm did yield a few likely lunar impact EMPs.Additionally, to detect the sub-surface lunar structures, high power large aperture -

Jicamarca Radio Observatory (JRO) 50 MHz radar located near Lima, Peru was used to map the lunar surface and subsurface features. This was accomplished by developing or refining various calibration and imaging procedures. This radar provides the ability to map the lunar sub-surface because the 6-meter wavelength radar signal penetrates the low-loss regolith and scatters from larger sub-surface structures allowing study of these structures. This analysis further depends on the (de)polarization of the return signals. Interpretation of lunar radar signal polarization is greatly complicated by the double traverse of the ionosphere at or near wavevector near to perpendicular to the geomagnetic field geometry as described. Preliminary radar observations were conducted in October 2015 by transmitting a circular polarized coded pulse during the lunar transit over JRO. The detected lunar echoes of the duration of 13 minutes were then processed to generate the lunar Range-Doppler maps and identify the (sub)surface features. Preliminary science results from the observations are given.Each of the three observational set-up's along with the signal processing paradigms such as Inverse Synthetic Aperture Radar (ISAR) mapping to form the lunar maps and the time-frequency technique to process the collected observational data are explained. Implications of

the observed transient EMP events, processed lunar surface maps, characterization of the observed satellite radar echoes and the difficult radio-frequency interference environment (terrestrial-origin, Moon-bounce signals) surrounding these observations are discussed.

CRC Press

Explore Earth's closest neighbor, the Moon, in this fascinating and timely book and discover what we should expect from this seemingly familiar but strange, new frontier. What startling discoveries are being uncovered on the Moon? What will these tell us about our place in the Universe? How can exploring the Moon benefit development on Earth? Discover the role of the Moon in Earth's past and present; read about the lunar environment and how it could be made more habitable for humans; consider whether continued exploration of the Moon is justified; and view rare Apollo-era photos and film stills. This is a complete story of the human lunar experience, presenting many interesting but little-known and significant events in lunar science for the first time. It will appeal to anyone wanting to know more about the stunning discoveries being uncovered on the Moon.

A Study of the Origin of Its Features Elsevier

This book includes a selection of 30 reviewed and enhanced manuscripts published during the 15th SpaceOps Conference held in May 2018 in Marseille, France.

The selection was driven by their quality and relevance to the space operations community. The papers represent a cross-section of three main subject areas: Mission Management – management tasks for designing, preparing and operating a particular mission Spacecraft Operations – preparation and implementation of all activities to operate a space vehicle (crewed and uncrewed) under all conditions Ground Operations – preparation, qualification, and operations of a mission dedicated ground segment and appropriate infrastructure including antennas, control centers, and communication means and interfaces This book promotes the SpaceOps Committee's mission to foster the technical interchange on all aspects of space mission operations and ground data systems while promoting and maintaining an international community of space operations experts.

The Lunar Orbiter Meteoroid Experiments Springer Science & Business Media

In this volume, the geologic and planetary science communities explore impact events and how they affected the evolution of Earth and other planetary bodies. these papers are the outcome of a conference held every five years.

Meteorite Craters and Impact Structures of the Earth Springer

This excellent overview will appeal to all researchers who have an interest in Leonid

showers. It contains over forty research papers that present some of the first observational results of the November 1999 Leonid meteor storm, the first storm observed by modern observing techniques.

Large Meteorite Impacts and Planetary Evolution V

Geological Society of America

Astromineralogy deals with the science of gathering mineralogical information from the astronomical spectroscopy of asteroids, comets and dust in the circumstellar environments in general. It is only recently, however, that this field has received a tremendous boost with the reliable identification of minerals by the Infrared Space Observatory. This book is the first comprehensive and coherent account of this exciting field. Beyond addressing the specialist in the field, the book is intended as a high-level but readable introduction to astromineralogy for both the nonspecialist researcher and the advanced student.