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## Oral Presentations

**PS02 - Microwave and Infrared Remote Sensing of Solar System Objects**
Tuesday, August 04, 2015 | 324 | 14:00-15:30

1. **PS02-D2-PM1-324-001** (PS02-A001)

**Detecting Water Eruptions on Europa**

Scott BOLTON[1#+], Paul HARTOGH[2], Andrew INGERSOLL[3], Bill MCKINNON[4]
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Microwave and submillimeter radiometry and spectroscopy is a simple and proven technique to directly measure water abundance, excitation and velocity in any plume. The detection is not dependent on viewing ice particles, or having special occultation geometry, or inferring water from its disassociation. Figure 1ab illustrates a simulated observation of a plume on Europa from a distance of 50,000 and 200,000 km, respectively. The observations can be obtained at a significant distance from Europa allowing for definitive identification, location and evaluation of plume activity in time for navigation engineers to target the plume. The measurements spatially resolve the plume in multiple transitions allowing a complete description of the velocity structure and excitation providing a complete description of the gas leaving the vent. In addition to the capability to observe water vapor directly, such an instrument is also highly sensitive to many other volatile, non-volatile and bio-marker molecules relevant for determining the mechanism and connection between plume and ocean as well as the potential habitability of the ocean.

A description of how millimeter/submillimeter spectroscopy can detect, locate and evaluate the biological significance in plumes on Europa will be presented.

2. **PS02-D2-PM1-324-002** (PS02-A005)

**What is Saturn's H2O External Source?**

Thibault CAVALIÉ[1#+], Vincent HUE[2], Paul HARTOGH[1], Emmanuel LELLOUCH[3], Timothy CASSIDY[4], Michel DOBRIJEVIC[2], Christopher JARCHOW[1]
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The water vapor observed by the Infrared Space Observatory (ISO) in the stratospheres of the giant planets has an external origin. An external supply of water may be provided by: (i) a permanent flux from interplanetary dust particles, (ii) local sources (rings, satellites), (iii) large comet impacts. One of the main objectives of the Herschel key program HssO (Herschel Solar System Observations) consisted in disentangling the various sources of external water in outer planet stratospheres.

Previous observations of Saturn with Herschel led to the detection of a water torus at Enceladus orbit, fed by the geysers of this moon. The fate of water from this torus is eventually to spread in Saturn's system and a fraction of it is predicted to fall in Saturn's stratosphere. In this paper, we present observations of water in Saturn's stratosphere obtained with Herschel/PACS. We test the validity of Enceladus as a source for Saturn's stratospheric water by using a suite of models (3D diffusion of Enceladus water in Saturn's system, 2D oxygen photochemistry of Saturn, 3D radiative transfer).

3. **PS02-D2-PM1-324-003** (PS02-A008)

**Radiation and Dynamics in Jupiter's Stratosphere**

Takeshi KURODA[1#+], Alexander S. MEDVEDEV[2], Jisesh AJITHA SETHUNADH[2], Paul HARTOGH[2]
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Here we present the overview and new inspections about the atmospheric radiation and related atmospheric dynamics in Jupiter's stratosphere. Recently we have developed a new radiation code of radiative heating and cooling for Jupiter's upper troposphere and stratosphere ($10^3$ to $10^{-3}$ hPa) suitable for general circulation models (GCMs). It is based on the correlated k-distribution approach, and accounts for all the major radiative mechanisms in the stratosphere of Jupiter. The code can be applied for also Saturn and extrasolar gas giants. Vertical 1-D calculations using this code demonstrated that temperature of Jupiter's stratosphere is close to radiative-convective equilibrium, and that the radiative relaxation time decreases exponentially with height (from $10^8$ s near the tropopause to $10^5$ s in the upper stratosphere). The latter differs from the study of Conrath et al. (1990), which showed the very long (~$10^8$ s) relaxation time approximately constant throughout the stratosphere. Our calculations with the GCM show that the radiative relaxation time suggested by Conrath et al. (1990) is too long, and cannot sustain convergence of model

solutions. With the newly derived vertical profile of relaxation time, simulations converge and produce realistic temperature and wind in Jupiter's stratosphere.

4. **PS02-D2-PM1-324-004** (PS02-A016)

**Hydrogen Cyanide in the Stratosphere of Titan**

Miriam RENGEL[1,2#+], Hideo SAGAWA[3], Paul HARTOGH[1]

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We have carried out observations of transitions of HCN in the stratosphere of Titan with the Herschel Space Observatory (Rengel et al. 2014), the Atacama Pathfinder Experiment and the IRAM 30m millimeter radio telescope. Using a line-by-line radiative transfer code and the least-squares fitting technique we have analyzed the observations, determined HCN abundances and an inter-comparison analysis. Beyond the intrinsic interest, these ground-based observations proven their usefulness in supporting spacecraft observations of Solar System bodies, in particular, of Titan's atmosphere.

Rengel, M., Sawaga, H., Hartogh, P. et al. 2014, A&A 561, A4

5. **PS02-D2-PM1-324-005** (PS02-A004)

**First Detection of 63 Micron Oxygen Line in the Thermosphere of Mars with GREAT Instrument**

Ladislav REZAC[1#+], Paul HARTOGH[1], Helmut WIESEMEYER[2], Rolf GÜSTEN[1], Christopher JARCHOW[1]

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Atomic oxygen is the key element in several processes governing the energy and mass flow in the upper atmosphere of Mars, and its uncertainty strongly impacts both, the outcomes of global circulation modeling as well as interpretation of remotely sensed satellite data. Despite the recognized need for accurate knowledge of atomic O abundances in the upper atmosphere, only few dedicated measurements are available. In this presentation we describe the new opportunities for planetary spectroscopic observations in the far infrared wavelengths provided by the GREAT instrument on board the Stratospheric Observatory for Infrared Astronomy (SOFIA). SOFIA features a 2.5 dish, and the heterodyne spectrometry available with GREAT provides 44 kHz resolution of 9.5 GHz bandwidth with high S/N ratio, hight enough to resolve Doppler broadened lines and detect Doppler shifts of 0.1 km/s. Here we report on detection of Martian O(3 P) 63 μm line measured on May 14, 2014 from which we estimate Mars thermospheric column density of atomic O, and averaged wind speed in the region 100-150 km. This detection is a promising introduction in to the future possibility of a systematic monitoring of atomic O in the atmosphere of Mars from the ground.

6. **PS02-D2-PM1-324-006** (PS02-A011)

**Chemistry of Atmospheric Compositions in MLT Region Observed by SMILES**

Yasuko KASAI[1#+], Kota KURIBAYASHI[2], Hideo SAGAWA[1], Tomohiro SATO[2], Takayoshi YAMADA[2]

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The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) is an atmospheric observation instrument that is used to observe submillimeter waves emitted from minor atmospheric constituents, with unprecedented sensitivity. SMILES was the first global environment observation instrument in the Japanese Experiment Module onboard the International Space Station (ISS), and succeed to detect minor atmospheric compositions, such ad HCl, HO2, HOCl, and Ozone, in Mesospheric Lower Thermospheric region. We will present Hydrogen and Chlorine chemistry in MLT region. This mission is a joint project of the National Institute of Information and Communications Technology (NICT) and the Japan Aerospace Exploration Agency.

**PS02 - Microwave and Infrared Remote Sensing of Solar System Objects**
Tuesday, August 04, 2015 | 324 | 16:00-18:00

1. **PS02-D2-PM2-324-007** (PS02-A012)

**The Surface Composition and Thermal Properties of the Organic-Rich Surface of Comet 67P/Churyumov-Gerasimenko : VIRTIS/Rosetta Results**

Fabrizio CAPACCIONI[1#+], Gianrico FILACCHIONE[1], Stephane ERARD[2], Gabriele ARNOLD[3], Pierre DROSSART[2], Maria Cristina DE SANCTIS[1], Dominique BOCKELEE-MORVAN[2], Maria Teresa CAPRIA[1], Federico TOSI[1], Cedric LEYRAT[2], Bernard SCHMITT[4], Eric QUIRICO[5], Priscilla CERRONI[1], Vito MENNELLA[6], Andrea RAPONI[1], Mauro CIARNIELLO[1], Ljuba MOROZ[3], Ernesto PALOMBA[1]

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The paper will describe the major results obtained by the instrument VIRTIS (Visible, Infrared and Thermal Imaging Spectrometer), the dual channel spectrometer onboard Rosetta, on the surface composition and thermal properties of the nucleus of comet 67P/Churyumov-Gerasimenko.

VIRTIS is a dual channel spectrometer; VIRTIS-M (M for Mapper) is a hyper spectral imager covering a wide spectral range from 0.25 through 5μm. VIRTIS-M uses a slit and a scan mirror to generate images with spatial resolution of 250 μrad over a FOV of 3.7°. The second channel is VIRTIS-H (H for High-resolution), a point spectrometer with high spectral resolution (λ/Δλ=3000 @3μm) in the range 2-5 μm.

The nucleus observations are performed in a wide range of conditions with spatial resolution varying from the initial 500m down to 2.5m. The surface temperature has been determined since the first distant observations when the nucleus filled one single VIRTIS-M pixel. On the mid of July 2014 from a distance of 15000km the mean surface temperature has been measured as 205+-5K. This pointed to a surface structure largely covered by a porous crust, mainly devoid of water ice. Maximum temperature determined so far are as high as 230K on the subsolar point.

The VIRTIS composition analysis has showed evidence of carbon-bearing compounds on the nucleus of the comet 67P/Churyumov-Gerasimenko. The very low reflectance of the nucleus (normal albedo of 0.060 ± 0.003 at 0.55 μm), the spectral slopes in VIS and IR ranges (5-25 and 1.5-5 % $kÅ^{-1}$) and the broad absorption feature in the 2.9-3.6 μm range present across the entire illuminated surface, are compatible with opaque minerals associated with nonvolatile organic macromolecular materials: a complex mixture of various types of C-H and/or O-H chemical groups, with little contribution of N-H.

Authors acknowledge the support from national funding agencies.

2. **PS02-D2-PM2-324-008** (PS02-A009)

**Observations with the Rosetta/MIRO Instrument at Comet 67P/Churyumov-Gerasimenko**

Samuel GULKIS[#+]
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The MIRO (Microwave Instrument on the Rosetta Orbiter) is a dual frequency (560 GHz and 190 GHz) heterodyne instrument consisting of two broadband channels for continuum measurements, and a high spectral resolution (44 kHz) spectrometer interfaced with the submillimeter radiometer. The spectroscopic receiver is fixed tuned to measure molecular transitions of water, carbon monoxide, ammonia, and methanol. The continuum channels measure the nucleus sub-surface temperatures; the spectrometer channels are sensitive to gas abundance, velocity, and temperature. Broad scientific objectives are to understand heat transport and ice sublimation in comets as interrelated processes reflecting properties acquired at time of formation and subsequent evolution and to understand important processes in the coma. This paper will present an overview of the MIRO instrument, up-to-date spectroscopic and continuum data and analysis.

The authors acknowledge funding support from NASA, CNES and CNRS/INSU, National Central University, and SNSB (Sweden). A part of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. We thank the Rosetta operational support teams from the ESA.

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3. **PS02-D2-PM2-324-009** (PS02-A019)

**Submillimeter Remote Sensing of Planets and Small Bodies in the Solar System: A Review of Recent Missions (i.e. MIRO and Herchel) and Future Prospects**

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In the past decades, technological advances in the field of microwave (particularly the submillimeter range) receivers and spectrometers have allowed their infusion in space-borne instruments (e.g., MLS, MIRO/Rosetta, HIFI/Herschel), as well as the development of large ground-based facilities such as ALMA. Key advantages of microwave, and particularly submillimeter, technologies are: 1/ high sensitivity with high spectral resolution within the frequency range where strong molecular rotational lines can be detected and quantified, and 2/ high sensitivity to thermal emission from opaque media (optically thick atmospheres or surfaces) down to temperatures as low as ~ 10 K. Remote sensing of planetary objects using microwave instruments has consequently become a topic of great interest to the community. A broad range of scientific applications of these measurements has emerged: characterization of thermal emission from surfaces, characterization of planetary atmospheres, quantification and composition (including isotopic ratios) of outgassing on comets and asteroids, etc. This presentation will provide an overview of these applications, as well as recent scientific results from MIRO/Rosetta, HiFi/Herschel, and ground-based observatories.

A part of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. A part of the research was carried out at the Max-Planck-Institut für Sonnensystemforschung with financial support from DLR and MPG.

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4. **PS02-D2-PM2-324-010** (PS02-A018)

**Synthetic Retrievals of the Oxygen 18/16 Isotopic Ratio from Near Nucleus Observation of a Cometary Coma – Case Study for MIRO**

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MIRO is observing for the first time outgassing of molecule of a comet from near nucleus distance. The measured line shapes and intensities are very variable depending on viewing and illumination conditions as well as on the properties of the source region on the nucleus. One of the MIRO science goals is the determination of the O18/O16 isotopic ratio from observations of water molecules. Obtaining of this ratio from the spectra is a non-trivial problem due to the large range of opacity variations.

We study this problem using a self-consistent retrieval algorithm applied for synthetic spectra under realistic conditions as constrained by MIRO observations. We study the sensitivity and the expected range of uncertainties (error analysis) depending on forward modeling and coma model parameters.

The goal is to apply the method to real data in order determine the O18/O16 isotopic ratio for several case studies with favorable conditions. Potential variabilities with heliocentric distance will be investigated.

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5. **PS02-D2-PM2-324-011** (PS02-A002)

**Terahertz Heterodyne Receiver Based on Quantum Cascade Lasers**

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A high-resolution heterodyne spectrometer is of crucial importance for astronomical observation and atmospheric remote sensing in the terahertz (THz) frequency region. Heterodyne receivers based on superconducting mixers as well as room temperature Schottky mixers, with electronically tunable solid- state multiplier-chain local oscillator (LO) sources have been realized up to 2 THz for ground based, balloon-borne, and space telescope instruments, but the development of receivers at higher frequencies will be determined by the availability of suitable solid-state LO sources. In recently years, quantum cascade lasers (QCLs), based on light emission driven from electron transitions between individual subbands within the conduction band, have been proven to a compact coherent signal source in THz spectral region. In this paper, we will review the progresses on the development of heterodyne spectrometer using a QCL as the local oscillator. High-resolution spectroscopy of molecular spectral lines of methanol ($CH_3OH$) gas has been achieved up to 4.7 THz. Moreover, a fully stabilized QCL at 3.5 THz, both in its amplitude and frequency, as the local oscillator operated in a pulse tube cryocooler for a heterodyne receiver has been demonstrated. As a result, terahertz quantum cascade lasers become technologically much more mature and lead to instrumental application in a new NASA mission: Galactic/Xgalactic Ultra long duration balloon Spectroscopic Stratospheric THz Observatory (GUSSTO).

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6. **PS02-D2-PM2-324-012** (PS02-A010)

**Annual and Inter-Annual Variations of the Mesospheric Column Amount of Nitric Oxide (NO) Observed with a Millimeter-Wave Radiometer at Syowa Station in Antarctica**

Tomoo NAGAHAMA[1#+], Miku UEMURA[1], Akira MIZUNO[1], Taku NAKAJIMA[2], Hirofumi OHYAMA[2], Yoshizumi MIYOSHI[2], Yasusuke KOJIMA[2], Yasuko ISONO[1], Masaki TSUTSUMI[3], Takuji NAKAMURA[3]
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Chemical composition in mesosphere and lower thermosphere largely varies caused by changes of solar-terrestrial environment. Recent studies reported enhancement of $NO_x$ caused by the energetic particle precipitation (EPP) into the earth atmosphere in the polar mesospheric region (e.g. Isono et al 2014). To investigate these changes related to the EPPs, as a joint research project of STEL and NIPR, millimeter-wave measurements of the nitric oxide (NO) and ozone spectra with a high-sensitivity superconducting (SIS) mixer receiver and a high frequency-resolution FFT spectrometer have been carried out at Syowa station in Antarctica (69°S, 39°E) since 2012, and we have detected temporal variations of mesospheric column amount of NO which was estimated from the integrated intensity of the 1-day averaged spectrum. The observed NO column amount shows the maximum in winter, but the peak amount in 2014 is about a half of those in 2012 and 2013. To validate the millimeter-wave dataset, we made a comparison of the mesospheric NO column measured with the millimeter-wave radiometer and the AIM/SOFIE sensor, and found that both the data show a same tendency in temporal variation, indicating that the inter-annual variation of the mesospheric NO column measured with the millimeter-wave radiometer is likely. To understand the inter-annual variation of the mesospheric NO column, we compared between a monthly average of the NO column and a monthly integrated electron amount derived from the dataset of the POES/MEPED energetic electron (>30 keV) fluxes. The monthly integrated electron amount in 2014, especially in the winter season, found to be significantly smaller than those in 2012 and 2013, being well correlated with the temporal variations of the mesospheric NO column amount. The result suggests that the energetic electron precipitation may affect to the increase of the polar mesospheric NO amount as well as photo-chemical reactions in the winter season.

7. **PS02-D2-PM2-324-013** (PS02-A014)

**Advanced Millimeter Wave Detection Techniques**

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Recent years have seen continuation of rapid developments in the area of high sensitivity millimeter wave detection techniques. In particular superconducting detectors have made important progress in performance for numerous fields of applications. A review of the current state of the art cryogenic heterodyne and continuum detection will be given. The latest advances go hand in hand with the vast possibilities provided by high speed ADC circuits and modern DSP techniques in the readout and backend sector. Examples of application for solar system observations and atmospheric sounding will be presented.

## Poster Presentations

**PS02-D5-PM2-P-014** (PS02-A006)

**Global Distribution of CO2 Volume Mixing Ratio in the Mesosphere and Lower Thermosphere and Long-Term Changes Observed by SABER**

Ladislav REZAC[1#+], Jia YUE[2], Jian YONGXIAO[2], James M RUSSELL[2], Rolando GARCIA[3], M. Lopez PUERTAS[4], Martin G MLYNCZAK[5]
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Beginning in late January, 2002 and continuing to the present day, SABER instrument on board TIMED has been measuring limb radiance profiles used to retrieve vertical profiles of temperature, volume mixing ratios (VMRs) of O3, CO2, H2O, and volume emission rates of NO, OH(1.6 and 2.1 μm), and $O_2$(singlet delta). The CO2VMR is a new SABER data product that just became available this year. The temperature and CO2 VMRs are simultaneously retrieved in the ~65km to 110 km range (and up to 130 km with additional inputs) using limb radiances measured at 4.3 and 15 micrometers. Results will be presented of CO2 validation studies done using comparisons with coincident ACE-FTS CO2 data and SD-WACCM model simulations. The CO2 VMRs agree with ACE-FTS observations to within reported measurement uncertainties and they are in good agreement with SD-WACCM seasonal and global distributions. The SABER observed $CO_2$ VMR departure from uniform mixing tends to start above ~80 km which is generally higher than what the model indicates. Variations of $CO_2$ VMR with latitude and season are substantial. Seasonal zonal mean cross sections and CO2 time series for selected latitudes and altitudes over the 12.5-year time period, will also be shown. The $CO_2$ VMR increase rate at 100km is in close agreement with in situ results measured at the Mauna Loa Observatory.

**PS02-D5-PM2-P-015** (PS02-A015)

**Vertical Profiles of Molecular Oxygen on Mars Derived from Herschel-HIFI Observations**

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Molecular oxygen in the martian atmosphere at a frequency of 774 GHz was observed with the Heterodyne Instrument for the Far Infrared on Herschel as part of the Key Program “Water and related chemistry in the solar system – Herschel Solar System Observations – HssO” during several occasions. The signal-to-noise-ratios of the observations were between 100 and 300. Vertical profiles deviating from the assumption of a constant with altitude volume mixing ratio were derived using a dedicated high resolution radiative transfer model and retrieval code. Temperature profiles as input for the radiative transfer model were determined by observations of 6 transitions of different CO isotopes between 576 and 922 GHz and compared with MCS temperature profiles. Observations, model and results will be described and interpreted.

**PS02-D5-PM2-P-016** (PS02-A017)

**Solar System Objects as Prime Calibrators for Herschel/HIFI**

Miriam RENGEL[1,2#+], David TEYSSIER[2], Michael MUELLER[3,4], Willem JELLEMA[3], Raphael MORENO[5], Ian AVRUCH[3]
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Solar system objects are unique celestial bodies and needed as calibrators of ground and space-based telescopes because of the high accuracy achieved by models of their thermal and line emission over a wide range of wavelengths. They have served as primary calibrators during decades to characterize properties of instruments (e.g. telescope efficiencies, beam shapes, etc.). In this contribution we focus on Mars and its role with the Heterodyne Instrument for the Far-Infrared (HIFI) onboard Herschel in order to derive various instrument characteristics, with an emphasis on the instrument Point Spread Function (PSF), as well as on the performance of HIFI as a continuum detector.