[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

2019年5月28日(火) 9:00 ~ 10:30 | A03 東京ベイ幕張ホール

[P-PS01] Outer Solar System Exploration Today, and Tomorrow

コンビーナ:木村 淳(大阪大学)、笠羽 康正(東北大学 惑星プラズマ・大気研究センター)、Kunio M. Sayanagi(Hampton University)、座長:Kunio Sayanagi(Hampton University)、黒田 剛史

The giant planets provide many keys to understanding planetary processes. They play an important role in shaping our solar system, and the physical and chemical processes they harbor also provide a unique opportunity to study the phenomena relevant for studying Earth and other planets, including exoplanetary systems. In this session, we discuss a wide range of topics encompassing the giant planets and their moons, including their origins, interiors, atmospheres, compositions, surface features, and electromagnetic fields. To advocate for current and future outer planets exploration (Cassini, Juno, New Horizons, JUICE, and beyond), we also call for discussions on future missions to explore giant planet systems, including how to develop better international cooperation. Discussion in this latter category will include progress in developing a solar sail mission concept for observing the Jupiter system and its trojan asteroids.

9:00 ~ 9:15

[PPS01-06] Radiative transfer simulation including a non-LTE model for terahertz observations of Ganymede's atmosphere

*山田 崇貴[1]、Rezac Ladislav[2]、Larsson Richard[2]、Hartogh Paul[2]、吉田 尚弘[3]、笠井 康子[1,3] (1.情報通信研究機構、2.マックスプランク太陽系研究所、3.東京工業大学)

9:15 ~ 9:30

[PPS01-07] Vertical Mass Flux by the 2010-2011 Great Storm of Saturn

*Sayanagi Kunio M.[1]、Gunnarson Jacob L.[1]、Blalock John J.[1]、Achterberg Richard K.[2]、Flasar F. Michael[2]、Ingersoll Andrew P.[3]、Ewald Shawn P.[3]、Dyudina Ulyana A.[3] (1.Hampton University、2.NASA Goddard Space Flight Center、3.California Institute of Technology)

9:30 ~ 9:48

[PPS01-08] Microwave observations of the giant planets - Cassini/Radar and Juno/MWR

★Invited Papers

*Cheng Li[1]、Virgil Adumitroaie[2]、John Arballo[2]、Sushil K Atreya[3]、Scott J Bolton[4]、Andrew Ingersoll[1]、Michael Janssen[2]、Steven Levin[2]、Jonathan Lunine[5]、Glenn Orton[2]、Paul Steffes[6]、Hunter Waite[4] (1.California Institute of Technology、2.Jet Propulsion Laboratory、3.University of Michigan Ann Arbor、4.Southwest Research Institute、5.Cornell University、6.Georgia Institute of Technology)

9:48 ~ 10:06

[PPS01-09] **Tracing Formation and Evolution of Outer Solar System Bodies through Stable Isotopes and Noble Gas Abundances**

★Invited Papers

*Kathleen Mandt[1] (1.Johns Hopkins University Applied Physics Laboratory)

10:06 ~ 10:24

[PPS01-10] Icy Giant Planet Exploration

★Invited Papers

*Sushil K Atreya[1]、Mark D. Hofstadter[2]、Amy Simon[3]、Kim R. Reh[2]、Olivier Mousis[4]、Krista Soderlund[5] (1.University of Michigan Ann Arbor、2.Jet Propulsion Laboratory、3.Goddard Space Flight Center、4.Laboratoire d'Astrophysique de Marseille、5.University of Texas at Austin)

10:24 ~ 10:30

Discussion

Radiative transfer simulation including a non-LTE model for terahertz observations of Ganymede's atmosphere

*山田 崇貴[1]、Rezac Ladislav[2]、Larsson Richard[2]、Hartogh Paul[2]、吉田 尚弘[3]、笠井 康子[1,3]
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We are developing a teraherz radiative transfer code, named Atmospheric Teraherz Radiation Simulator (ATRASU), for simulations of sub-millimeter observations of planetary atmospheres.
Because of the tenuous Ganymede atmosphere we need to include non-local thermodynamic equilibrium (non-LTE) conditions of H_2O rotational levels to simulate observations by the Submillimeter Wave Instrument (SWI) on the JUpiter ICy moon Explorer (JUICE). The frequency windows of the JUICE/SWI are 530 to 625 GHz and 1080 to 1275 GHz with 100 kHz spectral resolution.
We developed a deterministic non-LTE solution based on the multilevel Gauss–Seidel method. The simulated energy level populations of H_2O for SWI observations start to deviate from LTE at 100 to 200 km altitude around sub-solar latitudes of 10 degrees. At sub-solar latitudes around 60 degrees the populations are in non-LTE over the entire range, starting from the surface. The difference of the simulated spectra between LTE and non-LTE conditions, and their sensitivity to various parameters, such as collisional rates for H_2O, will be presented.

キーワード：THz、放射伝達計算
Keywords: THz, Radiative trasfer

Vertical Mass Flux by the 2010-2011 Great Storm of Saturn

*Sayanagi Kunio M.[1]、Gunnarson Jacob L.[1]、Blalock John J.[1]、Achterberg Richard K.[2]、Flasar F. Michael[2]、Ingersoll Andrew P.[3]、Ewald Shawn P.[3]、Dyudina Ulyana A.[3]
*Kunio M. Sayanagi[1], Jacob L. Gunnarson[1], John J. Blalock[1], Richard K. Achterberg[2], F. Michael Flasar[2], Andrew P. Ingersoll.[3], Shawn P. Ewald[3], Ulyana A. Dyudina[3]

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We present a re-analysis of Cassini Composite Infrared Spectrometer (CIRS) data captured during the 2010-2011 Great Storm of Saturn to calculate the vertical mass flux caused by the storm. The intense cumulus outburst started on December 5, 2010 at 33ºN planetocentric latitude, and the clouds that emanated from the storm engulfed the entire latitude band over the subsequent months. The CIRS observation captured the storm’s impact on the tropospheric thermal structure (Achterberg et al. 2014). The change in the thermal structure detected by Achterberg et al. (2014) is caused by the vertical uplifting of mass by the cumulus convection in the storm. We re-analyze the CIRS data processed by Achterberg et al. (2014) to determine the vertical mass flux. Images captured by the Imaging Science Subsystem (ISS) camera showed that active convective phase of the storm lasted until August 2011 (Sayanagi et al. 2013). Our preliminary analysis of CIRS data shows that, by August 2011, between 15ºN and 45ºN latitudes, the storm lifted about 1.65×10^{19} kg of mass to levels above the 700-mbar pressure altitude from levels below.

Analyzing images captured by ISS using the CB2 (750 nm) filter and Cassini Visible and Infrared Mapping Spectrometer (VIMS)’s 5-micron channel reveals that, after August 2011, cumulus activities ceased in the storm’s latitudes, and a vast cloudless area grew until it encircled the entire band between 30ºN and 40ºN latitude by January 2012. The cloudless region further grew to the south and reached 20ºN by December 2012. Interestingly, analysis of the CIRS data indicates that the vertical mass flux continued as the clouds cleared after the storm. Our preliminary analysis shows that, between August 2011 and August 2012, 1.9×10^{18} kg more mass was lifted to altitudes above the ~700-mbar level. We hypothesize that the vertical mass flux during the cloud clearing was caused when the tropospheric air parcels became buoyant when they were relieved from the mass loading of the storm clouds.

We note that measuring vertical mass flux caused by a cumulus storm is extremely difficult for storms on Earth because the mass uplifted by the storms is rapidly dispersed and diluted by the storm’s environment. In comparison, Saturn’s Great Storm of 2010-2011 completely filled the latitude zone between 20°N and 40°N; thus, the storm was essentially contained in a closed box, and allowed us to measure the storm’s vertical mass flux.

References:

Achterberg, R. K., Gierasch, P. J., Conrath, B. J., Fletcher, L. N., Hesman, B. E., Bjoraker, G. L., Flasar, F. M., 2014. Changes to Saturn's Zonal-mean Tropospheric Thermal Structure after the 2010-2011 Northern Hemisphere Storm. Astrophysical Journal 786, 92.

Sayanagi, K. M., Dyudina, U. A., Ewald, S. P., Fischer, G., Ingersoll, A. P., Kurth, W. S., Muro, G. D., Porco, C. C., West, R. A., 2013. Dynamics of Saturn's great storm of 2010-2011 from Cassini ISS and RPWS. Icarus 223, 460-478.

キーワード：土星、惑星大気、カッシーニ・ミッション
Keywords: Saturn, Planetary Atmospheres, Cassini Mission

Microwave observations of the giant planets - Cassini/Radar and Juno/MWR

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The thermal emission of a giant planet’s atmosphere in the microwave region reveals the thermal structure and composition of the atmosphere below the clouds. During the last decade, the Cassini/Radar instrument mapped Saturn’s global thermal radiation at 2.2 cm wavelength. Particularly, in the year 2010, the planet-encircling giant storm on Saturn appeared 16 K brighter than average, revealing desiccation of ammonia gas due to convection and atmospheric dynamics. More recently at Jupiter, the Juno spacecraft has completed a dozen orbits around the planet, making detailed observations of Jupiter’s troposphere from north to south and down to pressures of about 200 bars. The results are both astonishing and stimulating. Jupiter’s equatorial zone appears cold in all six channels of Juno/MWR, which range from 1.2 –50 cm, whereas the other latitudes are significantly warmer than what was predicted by an adiabatic model. The internal structure of the GRS has also been mapped during orbit 7th close approach. Yet, the interpretation is partly confounded by the inhomogeneous distribution of ammonia gas. We will give an overview of the previous findings, current challenges, and future opportunities of microwave sounding of the giant planets.

Keywords: Jupiter, Saturn, Cassini, Juno, microwave, composition

Tracing Formation and Evolution of Outer Solar System Bodies through Stable Isotopes and Noble Gas Abundances

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Comparative planetology using isotope geochemistry has played a critical role in understanding processes at work in and the history of outer Solar System bodies [see 1, and references therein]. The $^{12}C/^{13}C$ measured in methane on Titan has enabled us to determine the maximum length of time that methane has been present in the atmosphere [2,3], showing that methane has not been present in Titan’s atmosphere throughout the history of the solar system and is limited to no more than 1 billion years (Gyr) [3]. We have also determined how much methane has been converted to organics over that were then deposited on the surface [3] and find agreement with estimates of surface inventories [4]. Observations of $^{14}N/^{15}N$ in HCN and N_2 in the atmosphere of Titan provides direct evidence of how photochemistry influences stable isotopes [5,6]. We have used these observations to determine that Titan’s nitrogen originated as NH_3 in the protosolar nebula [7]. All of this work relies on spacecraft-based observations made at Titan. Ground-based observations combined with spacecraft observations are also of high value. The lower limit observed for $^{14}N/^{15}N$ in HCN in Pluto’s atmosphere by ALMA [8] combined with New Horizons observations of the atmospheric composition [9] provides a valuable tool for determining the origin of nitrogen for Pluto if the influences of condensation and aerosol trapping on isotopes can be constrained [10] for which work is ongoing. All of this work is relevant to a future Ice Giants mission to Neptune, where the same methods could be applied to Triton and combined with ALMA observations. Furthermore, a mission to Io that makes in situ observations of the isotopic composition of the atmosphere could provide important information about volatile loss and interior processes at Io, assuming production and loss processes can be well constrained. Finally, noble gas abundances have been an important tool for understanding the origin and evolution of volatiles in the terrestrial planet atmospheres [see review in 1]. The recent measurement of cometary noble gas abundances [11] provides important information on the composition of the icy bodies that contributed to the formation of the gas giants, providing constraints for future in situ measurements that should be made with an atmospheric probe [12].

[1] Mandt K. E. et al. (2015a) *SSRv, 197,* 297–342. [2] Mandt K. E. et al., (2009) *PSS, 57,* 1917–1930. [3] Mandt K. E. et al., (2012) *ApJ, 749,* 160. [4] Lorenz, R. D. et al. (2008). *GRL*, *35*(2), L02206. [5] Liang et al. (2007) *ApJL, 664*, L115-L118. [6] Mandt et al. (2012b) *JGR, 117*, E10006. [7] Mandt K. E. et al., (2014) *ApJL, 788,* L24. [8] Lellouch et al. (2017) *Icarus, 286*, 289-307. [9] Young et al. (2017). [10] Mandt et al. (2017) *MNRAS*, *472*, 118-128. [11] Rubin et al. (2017) *Sci Adv*, *4*(7), eaar6297. [12] Mandt et al., in preparation.

Keywords: Titan, Pluto, Triton, Ice Giants, Stable Isotopes, Noble Gases

Icy Giant Planet Exploration

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Giant planets hold the secrets of solar system formation, and there is much interest in their exploration. They also serve as analogs for the giant planets in extrasolar systems. While Saturn-Jupiter sized exoplanets number about 500, mini-Neptune and Neptune sized objects (2-5 times Earth) comprise nearly half of approximately 4000 confirmed exoplanets to date. Since the early 1970’s, spacecraft have explored the gas giants, Jupiter and Saturn, extensively using flybys, orbiters and an entry probe (at Jupiter). Voyager 2 is the only spacecraft ever to visit the two icy giants, with a flyby of Uranus in 1986 and Neptune in 1989. Though the Voyager instruments were optimized for observations of Jupiter and Saturn, tantalizing data were collected at Uranus and Neptune as well. Those data have raised such fundamental questions as: did Uranus and Neptune form in the same manner as the gas giants, did they form at their present orbital locations or not, what role did migration play in their formation and evolution, why (and how) does Neptune generate internal heat, whereas Uranus does not, what is responsible for their intrinsic magnetic fields in the absence of a metallic hydrogen phase, why are the rings of Uranus different from Neptune’s rings and what’s maintaining them, why does Neptune’s moon Triton possess an atmosphere of nitrogen and methane, etc. To address these questions and others requires a comprehensive exploration of the icy giant planet systems by an orbiter-probe spacecraft at Uranus or Neptune or both [1], like the Galileo orbiter-probe mission at Jupiter. International partnership is most desirable for maximizing the science return of such a mission. [1] M. Hofstadter, A. Simon, K. Reh, J. Elliott, and the NASA Ice Giants Science Definition Team, Ice Giants Pre-Decadal Survey Report (2017) NASA-JPL-ID-100520, https://www.lpi.usra.edu/icegiants/mission_study/Full-Report.pdf

Keywords: Giant Planets, Origin and Evolution, Uranus and Neptune Missions, Extrasolar Planets, International Partnerships