Contribution of numerical simulations to planetary exploration missions
（今後の惑星ミッションとシミュレーション研究の関わりについて）

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Background (本セッションのきっかけ)

- SGEPSS subcommittee on computer simulations
(SGEPSSシミューレーション分科会)
  - Collaboration between space plasma simulation researchers and various satellite observations
- Satellite observation missions in domestic and foreign countries (国内外のミッション)
  - RFI from JAXA (研究領域の目標・戦略・工程表の宇宙研によるまとめ)
  - BepiColombo (水星探査ミッション)
- Research trend in association with planetary missions
(惑星ミッション関連のシミュレーション研究動向)
  - Papers presented in AGU, EGU, ISSS

The issue is how the simulation researchers can be involved in the coming planetary missions.
(我々シミュレーション研究者は,今後の惑星ミッションにどう関わっていくか。

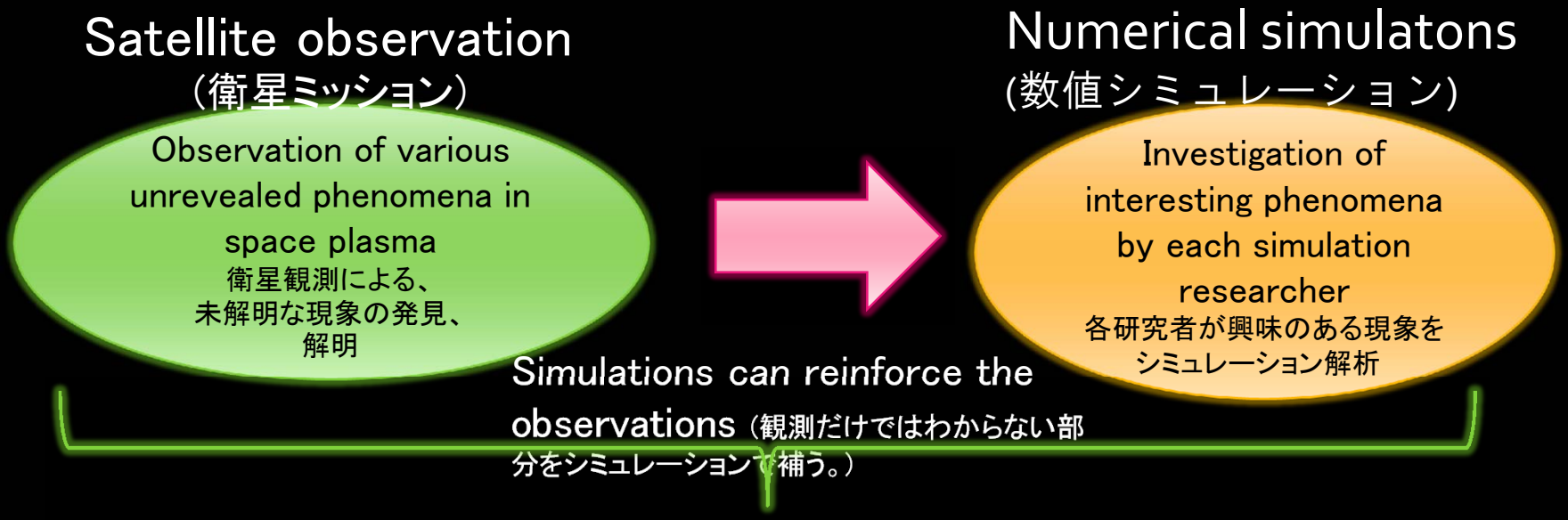
Satellite observation and simulation (1)
衛星観測とシミュレーション（1）

	Satellite observation(衛星観測)	**Simulations**
Method to obtain data (データ取得の仕組み)	Science instruments (各衛星機器)	Simulation programs (各種プログラムコード)
Hardware (データ取得の基盤)	Satellite (special made)	Supercomputer （General use, various types）
Data (データの特徴)	In-situ observation (real data, non-reproducible)	Multi-point data (reproducible)
Research unit	Group of researchers (衛星を核にした各グループ)	Individual researcher (研究者単位)

→ Simulation researcher can work individually by himself because he can produce the data with his simulation

(シミュレーションは、ある意味、一匹狼的な立場で、自分の力量で研究ができる。(必要なデータは地上で自分で出せる。)

Satellite observation and simulation (2)
衛星観測とシミュレーション(2)



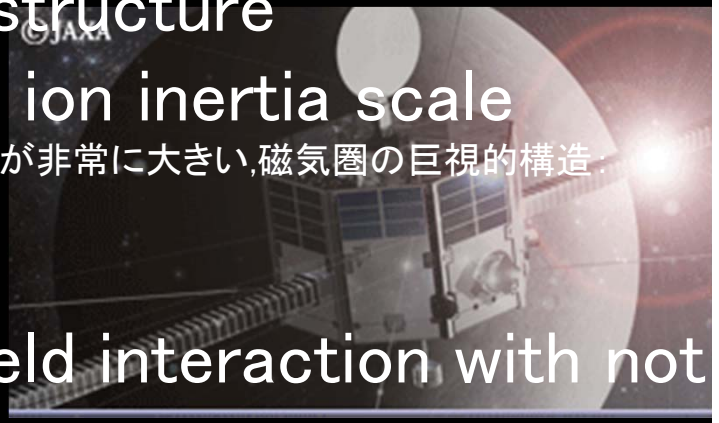
Complementary relation between observations and simulations (観測とシミュレーションの相補性、シナジー)

(In the current situation, however, the observation comes first and simulations follows later. (でも、どちらかというと、観測現象ありきで補助的に数値シミュレーション)

→ Simulation people are not directly involved in satellite missions in terms of development of SI and observation.
(シミュレーション側は、衛星ミッション(SI開発や観測)そのものには直接的には関わっていない).

BepiColombo（例えばBepiColombo）

- 1/20 of Earth's magnetosphere
- Large ratio of Mercury itself in the magnetosphere
- MHD scale of the magnetosphere structure
- Each region of magnetosphere has ion inertia scale



- 磁気圏サイズは地球の 1/20 程度, 惑星本体が磁気圏中に占める割合が非常に大きい,磁気圏の巨視的構造：MHD, 各構造：ジャイロ半径と同程度のスケール長程度

- Formation of exosphere
- Solar wind–weak dipole magnetic field interaction with not ionosphere
- Aurora, radiation belt, substorm ?

外気圏の形成の機構は何か？ 電離圏がない状況で、太陽風-磁場相互作用は？ オーロラ、放射線帯、サブストーム等は存在するか？

In 2005, we had a space plasma seminar on the Mercury physics in Kyoto. However, since then, we have not continued the scientific discussion on the Mercury environment.
It may be necessary to reboot the discussion and start simulation analysis before the satellites reach Mercury in 2024.

Paper in association with planetary simulations presented in ISSS-12 (2015/July)

The number of papers of planets/satellites including moon seems to increase.

Mercury

- Global Hybrid Simulations of the Hermean Magnetosphere (G. M. Chanteur)
- Global Kinetic Simulations of Plasma Transport, Acceleration, and Loss in Mercury's Magnetosphere (D. Schriver, P. Travnicek)

Jupiter

- Simulation Studies of Plasma Transport in Outer Planet Magnetospheres （ R. J. Walker, K. Fukazawa)
- Hybrid Simulation of Callisto's Interaction with Jovian Magnetosphere
- A Hybrid Simulation Study of Moon-Magnetosphere Interactions at Callisto and Titan （L. Liuzzo, M. Feyerabend, S. Simon)
- The Role of Io in the Dynamics of Jupiter's Magnetosphere: A Sandpile Modelling Approach (J. J. Reed, C. M. Jackman, M. P. Freeman)
- Plasma Interaction at Io: Multi-species Hybrid Simulations (O. Šebek, P. M. Trávníček, R. J. Walker, P. Hellinger)

Lunar

- PIC Simulations of the Solar Wind Interaction with Lunar Magnetic Anomalies: Ion and Electron Dynamics (J. Deca et al.)
- New Fully Kinetic Model for the Study of Electric Potential, Plasma and Dust Above Lunar Landscapes (S. Dyadechkin, E. Kallio, P. Wurz)
- Full-Particle Simulations on Plasma Environment Around Lunar Vertical Hole （ Miyake and Nishino)

- So far simulation researchers have obtained the results individually（STPシミュレーションは研究者単位で成果を出してきた。）
- Meanwhile planetary missions are on-going such as BepiColombo（BepiColomboを始め、惑星ミッションが実施される。）
- To gain the maximum achievement in the planetary missions, numerical simulations are inevitable.（ミッションの最大成果を出すには数値シミュレーションは重要。）

Now, the issue is how we, STP simulation researchers will be able to be involved to the planetary missions.（さて、我々、日本のSTPのシミュレーション研究者はどう対応していくか。）

We have some time before the satellites start the observation. Simulations are expected for the prediction of plasma phenomena and feedback to the observation mode. (観測が始まるまでにはまだ時間があり、シミュレーションによる現象予測、解明、観測モードへのフィードバックが期待されている。)

Two standpoints for simulation researchers:
(シミュレーションから見た2つの立場)

1. a member of a simulation group formed in each mission and perform mission-oriented simulations
   (各ミッション内のSIチームに加えて、シミュレーションチームをガッチリ作りその中のメンバーになる(がっちり連携))
2. an independent researcher who can freely choose a research target in the scientific objectives of the missions (ミッションの理学的目的の中で興味のあるものを選んでシミュレーション。(緩やかな連携))

Summary

Practical standpoint for simulation researchers seems to be #2 in the previous slide.

Prior to the observation, it is ideal that each possible plasma phenomenon raised in the scientific objectives or previous works can be analyzed and revealed by numerical simulations, which can be also counted as the achievement from the mission side.

（観測開始前にシミュレーションで全部調べ尽くすのが理想。ミッション側の成果としてもカウント。）