

第15回宇宙科学シンポジウム,
7 Jan 2015, ISAS/JAXA相模原

微小重力環境下における微粒子プラズマクーロン結晶の構造 Structure of Coulomb Crystals in Dusty Plasmas under Microgravity

(WG 次期実験装置PK-4を利用した微小重力実験計画検討)

高橋和生¹, 足立聡², 東辻浩夫³
Kazuo Takahashi¹, Satoshi Adachi², Hiroo Totsuji³

¹京都工芸繊維大学電子システム工学部門
Department of Electronics, Kyoto Institute of Technology

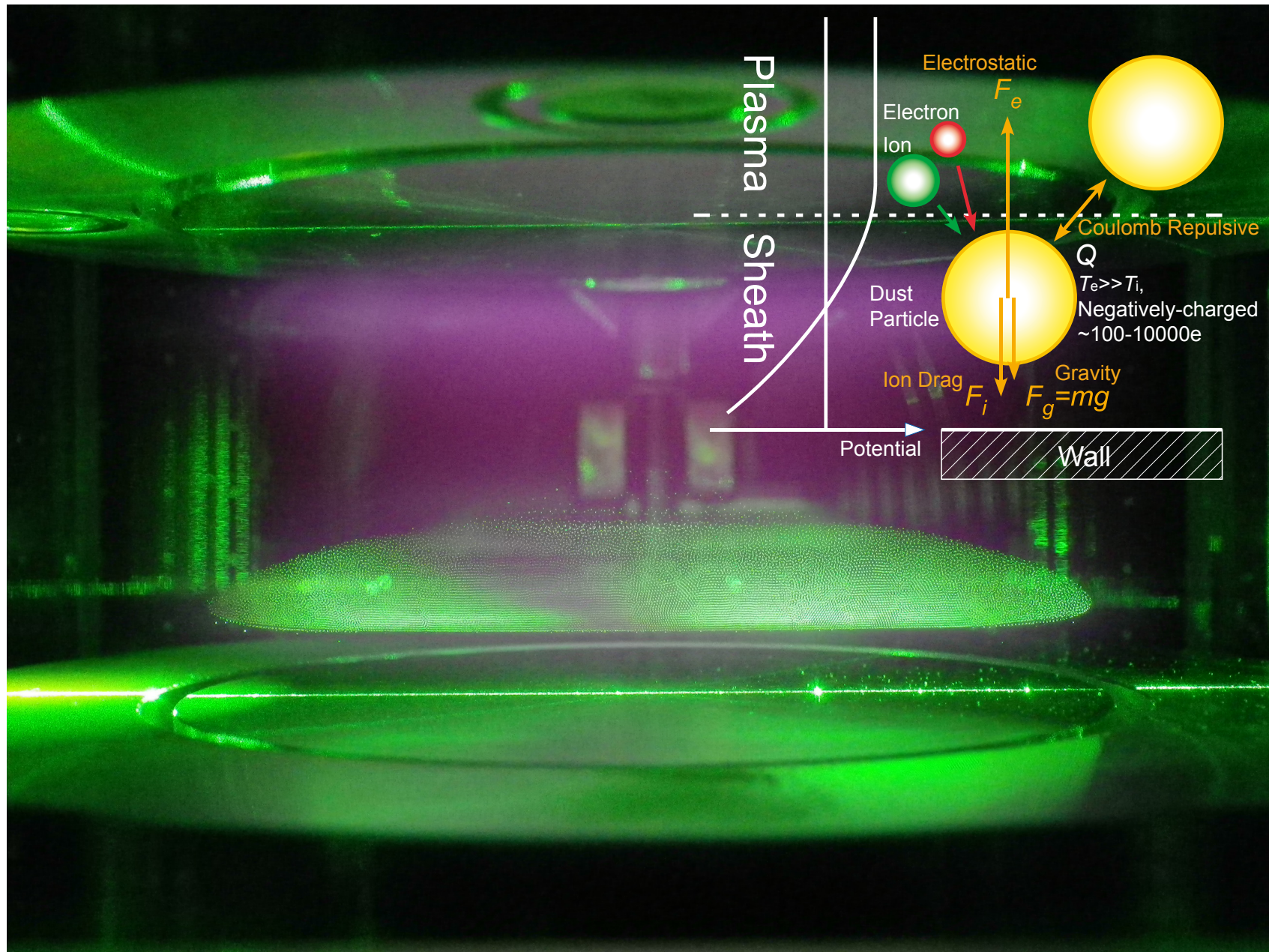
²ISAS/JAXA
Institute of Space and Astronautical Science,
Japan Aerospace Exploration Agency

³岡山大学
Professor Emeritus, Okayama University



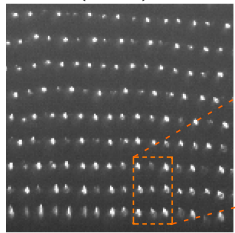
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Dusty (Fine Particle, Complex) Plasmas



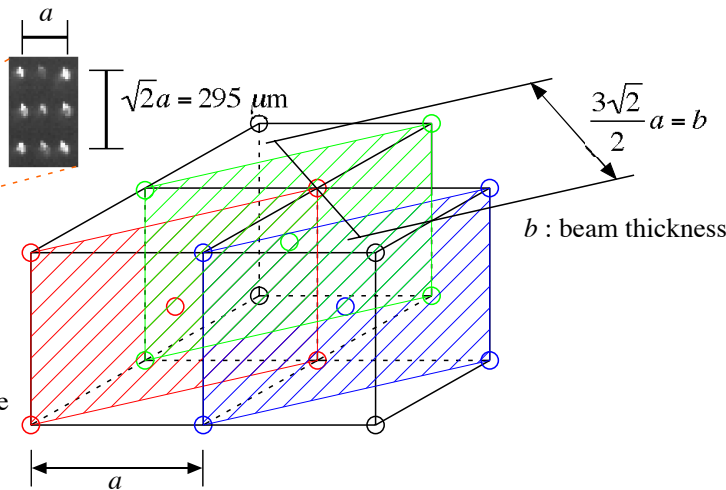
Coulomb Crystal

bcc (110) face



Particle: 3.38 μm ,
Power (sp): 1600 mW,
Pressure: 300 mTorr,
Gas: Ar,
Flow: 0.5 sccm,
in PK-3 plus KIT module

$b = 443 \mu\text{m}$



Estimation of laser beam thickness with body-centered cubic structure

(28 Apr. 2009, Kazuo Takahashi)

Formed by strongly-coupled charged dust particles

- Exploring physics of Coulomb crystal
- For model of general crystals
- Study of matter under microgravity

Crystallization, Melting,
Phase transition,
Interaction between atoms,
Critical phenomenon,
Phase separation (s., l., g.)

||

Exploring a new physics
Progress in material sciences

Experiments under Microgravity

Joint Russian/German Project on the ISS
PK-3, a successor in 2006-2013
PK-4, just launched, 2014-

Japanese Activities supported by JAXA
Parabolic Flights of Air Craft

Japan Experiment Module (KIBO) on the ISS

PK-4 successfully launched on 29/10/2014

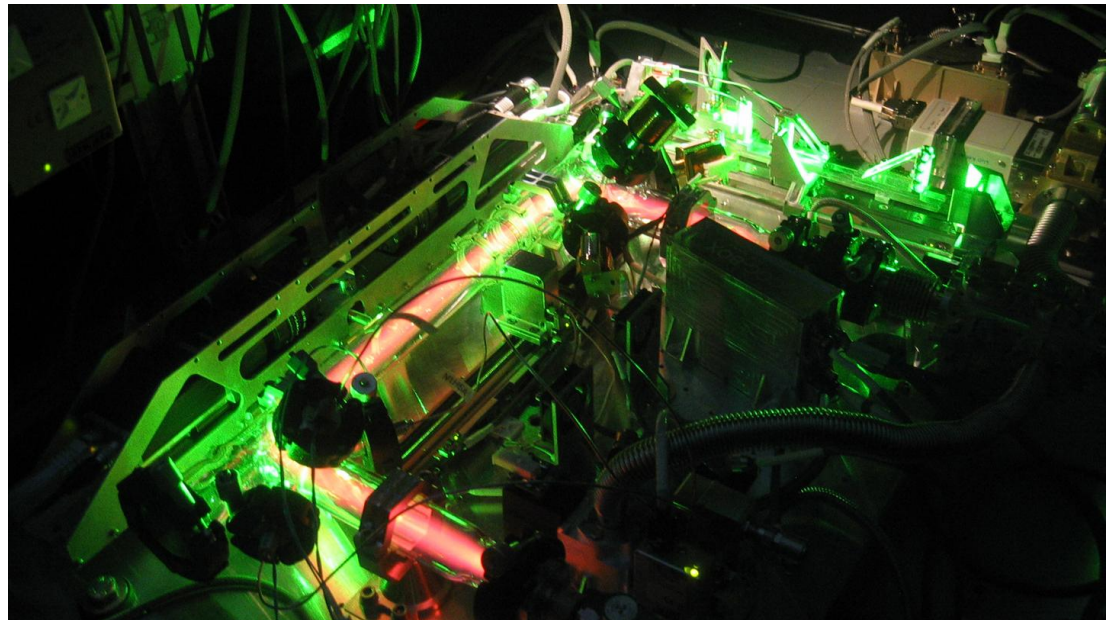
On the site of DLR (Deutsches Zentrum Luft- und Raumfahrt)

http://www.dlr.de/dlr/desktopdefault.aspx/tabid-10261/371_read-11936/#!/gallery/16986

Plasmaforschung: Labor auf dem Weg zur ISS

Mittwoch, 29. Oktober 2014

Es gewittert, es blitzt und plötzlich entsteht es - Plasma. Ein ionisiertes Gas, das auf der Erde sonst selten auftritt. Nur der Blick zum Plasmaball Sonne verrät seine natürliche Umgebung, den Weltraum. Es kann auch künstlich hergestellt werden und wird besonders im technischen Bereich genutzt, etwa in Plasmafernsehern oder Leuchtstoffröhren.



Künftig sind auch Anwendungen in der Medizin, im Umweltschutz und vielen anderen Bereichen denkbar. Zur Erforschung von Eigenschaften und Verhalten von einem sehr speziellen, dem komplexen Plasma, haben bisher mehr als 30 Kosmonauten und Astronauten Plasmakristall-Experimente im Weltall durchgeführt. Die Forschungsgruppe Komplexe Plasmen des Deutschen Zentrums für Luft- und Raumfahrt (DLR) plant eine neue Experimentreihe: Am 29. Oktober 2014 startete in Baikonur eine Progress-Rakete mit dem Plasmakristall-Labor "PK-4" zur Internationalen Raumstation ISS.

PK-4 *successfully launched on 29/10/2014*

On the site of OHB System AG (Kayser-Threde GmbH)

<https://www.ohb-system.de/press-releases-details/iss-pk-4-research-laboratory-successfully-launched.html>

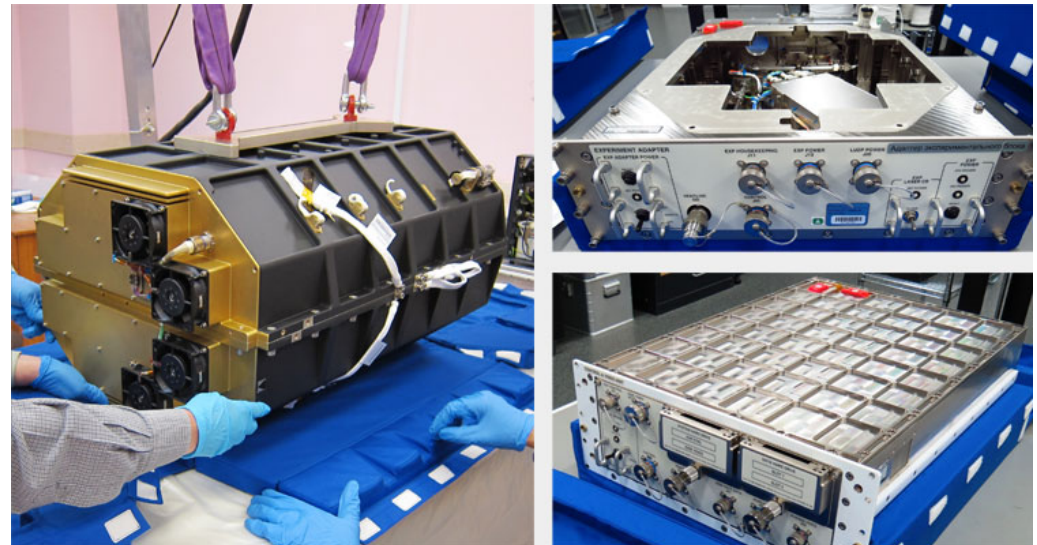
29.10.2014

ISS “PK-4” research laboratory successfully launched

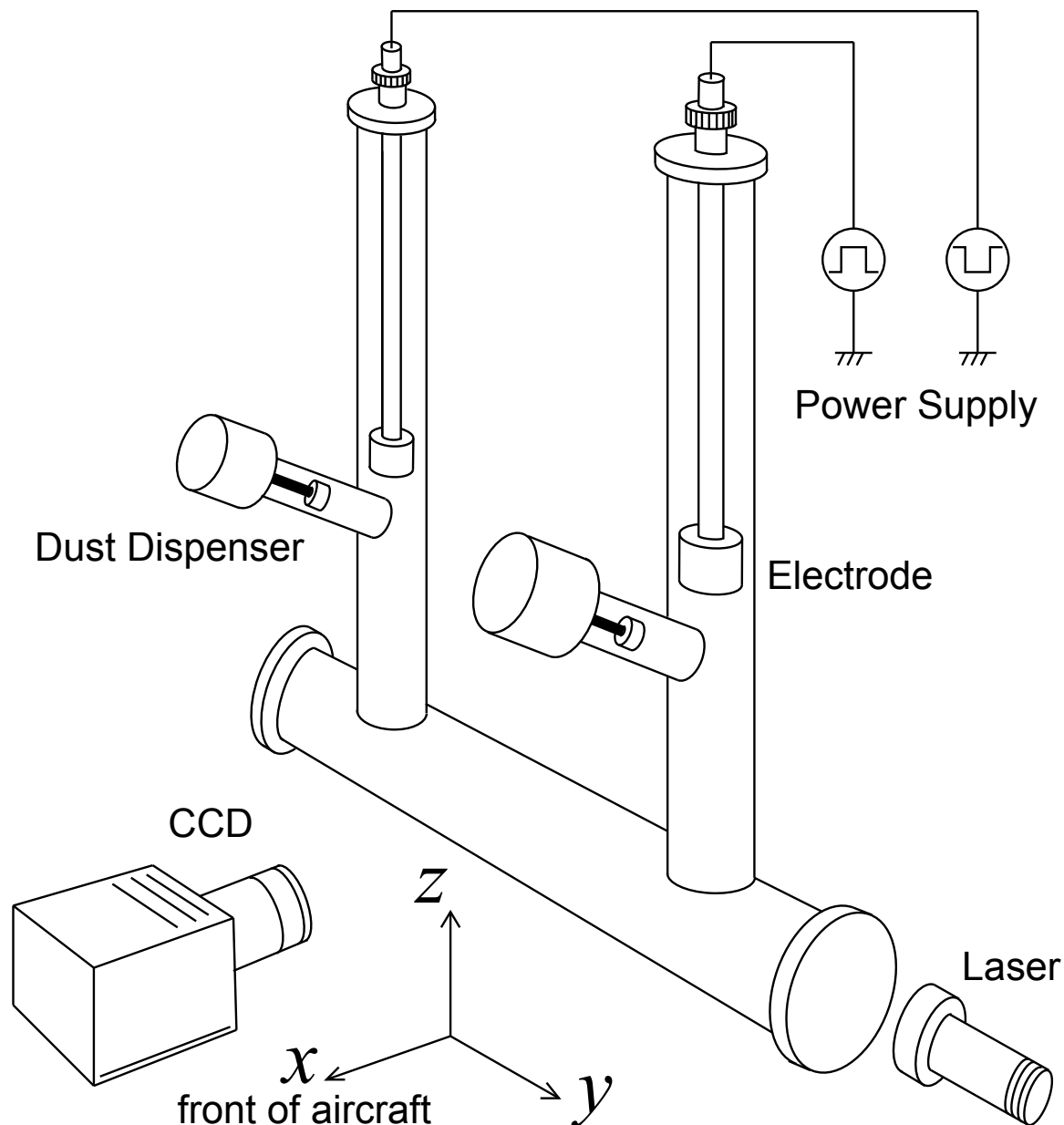
Key role played by OHB System AG in the plasma crystal laboratory for the Columbus module

Baikonur / Munich. At 8:09 hours CET on October 29, 2014, the European-Russian plasma crystal laboratory “PK-4” lifted off from the Baikonur Cosmodrome on board a Progress launcher headed for the International Space Station ISS. As planned, docking the freighter at the ISS took place in the early afternoon.

As with the previous two laboratories, OHB System AG (previously Kayser-Threde GmbH) was the prime contractor and, in this capacity, responsible for all system tasks. “PK-4” is a permanent installation within the European Columbus research module designed to conduct experiments on complex plasmas.



Experimental (PK-4J)



Plasmas symmetrically driven by the electrodes, applied the voltage of LF (rectangular pulse)

Discharges

LF (1 kHz):

$V_{pp} = 650\text{-}1000\text{ V}$,
(current $\sim\text{mA}$)

Gas: Ar

Flow Rate: $\leq 5\text{ sccm}$

Pressure: 27 - 40 Pa

Observation

Particle: 2.55 μm ,

Melamine-formaldehyde

Laser & CCD

on translation mechanical stage

-> 3D data recording

200 fps + 4.5 mm/s

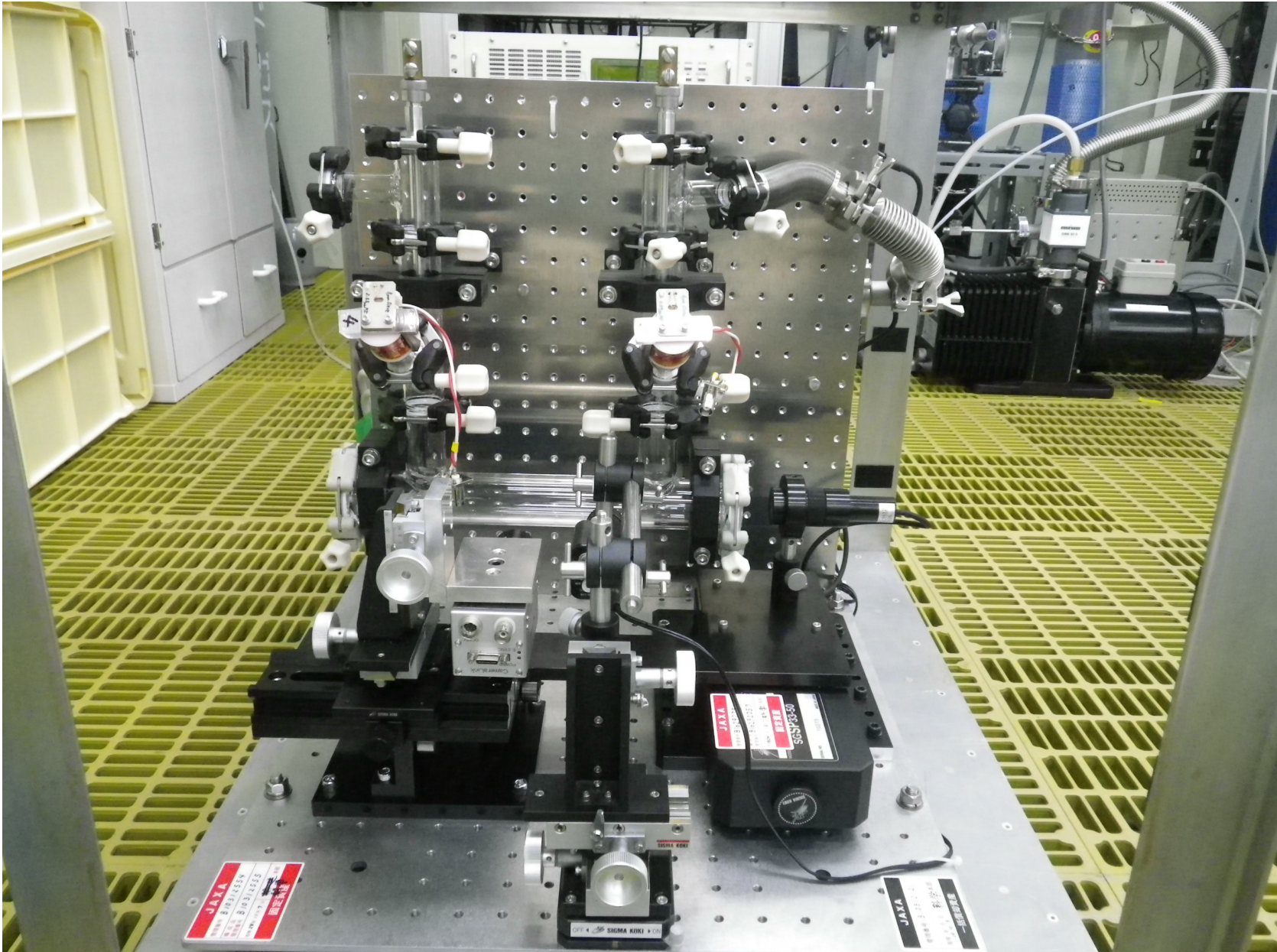


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PK-4J in 2013

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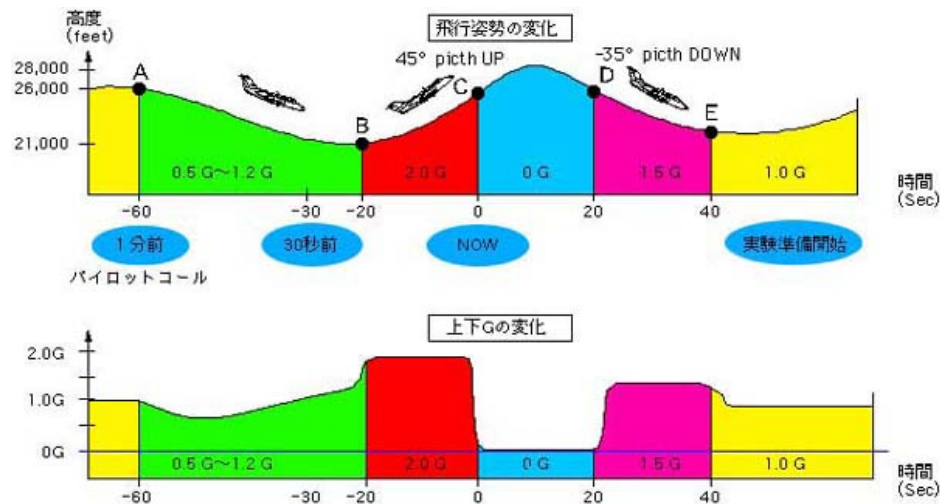


Parabolic Flights in 2013

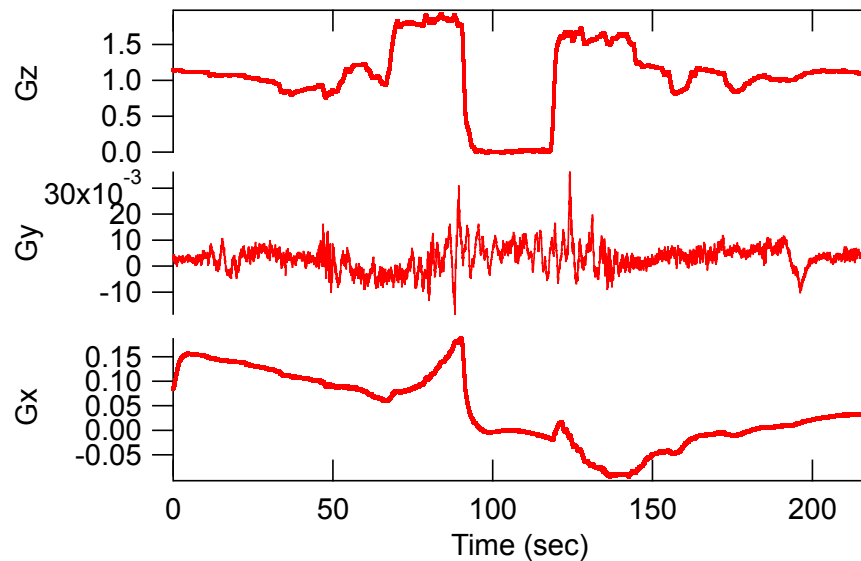
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From 11 to 22 Mar., 4 flights on 15th, 19th, 20th, 21st with G-II.



130315 PF09



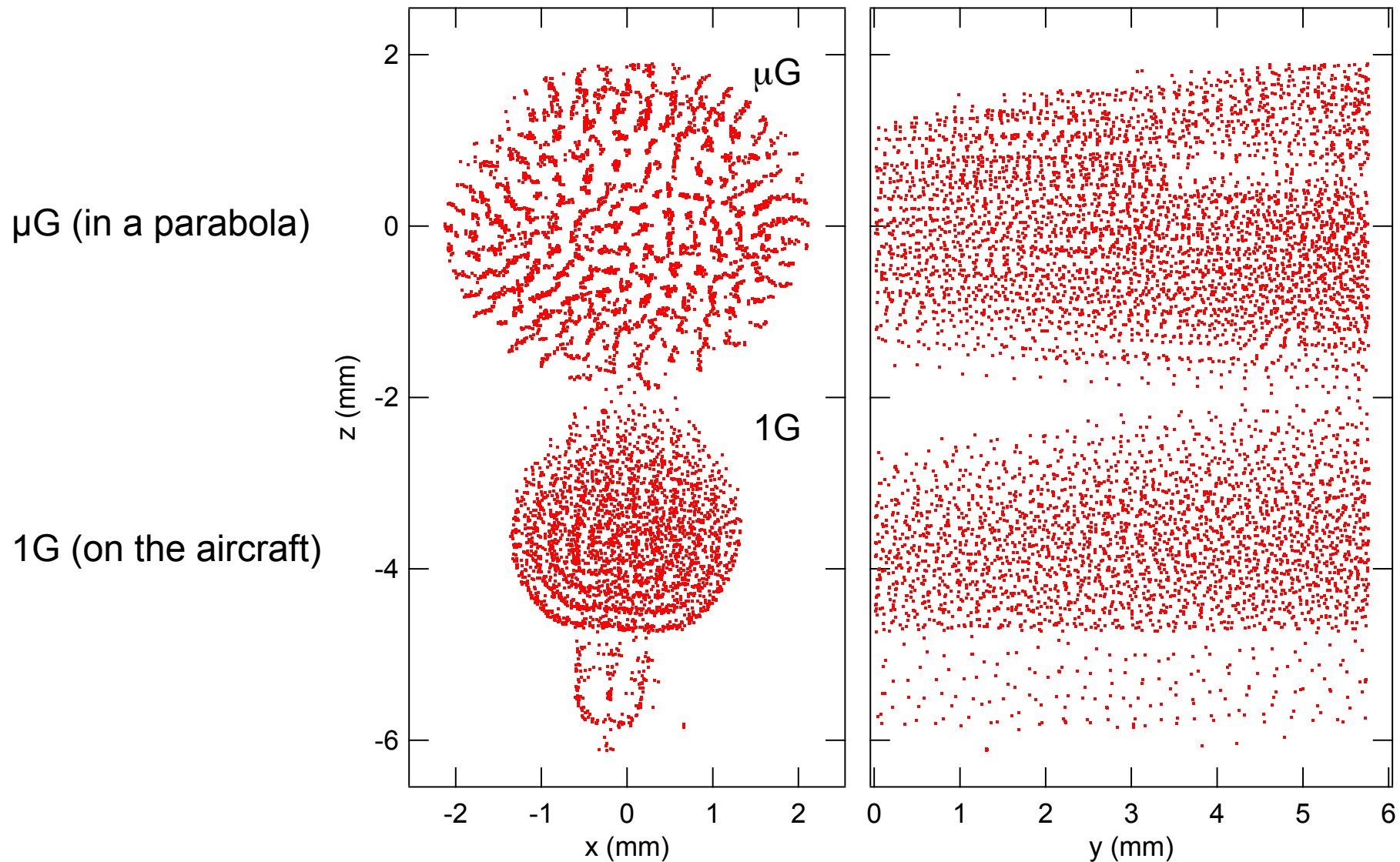
Cylindrical Structures

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analyzed with scanning laser and high speed camera at 200 Hz.

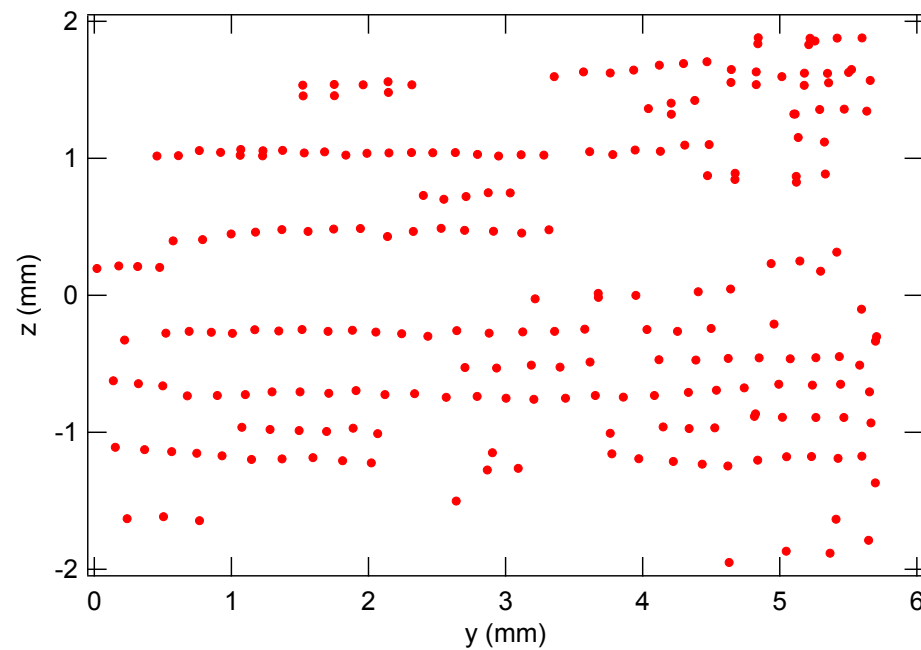
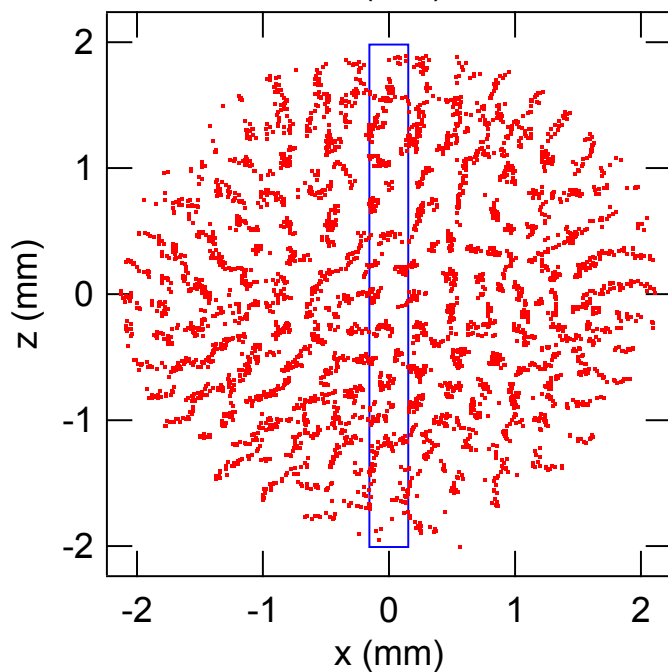
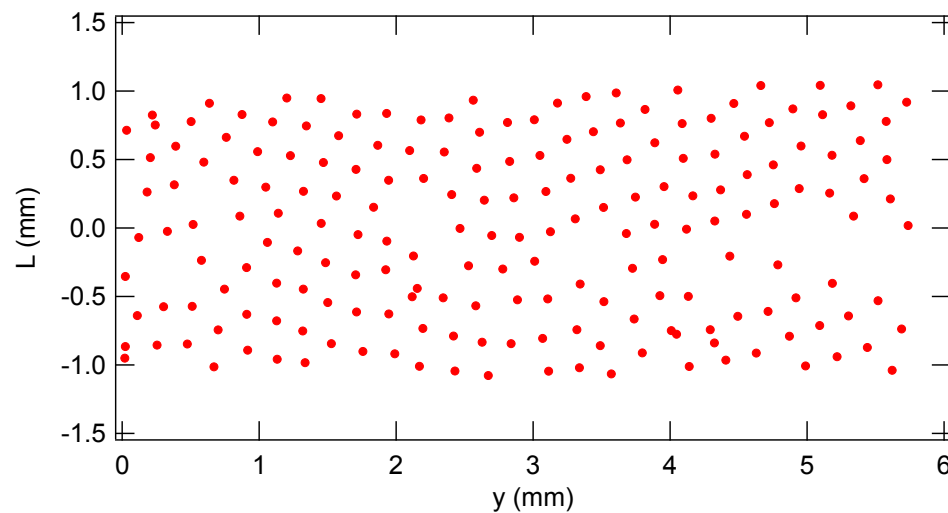
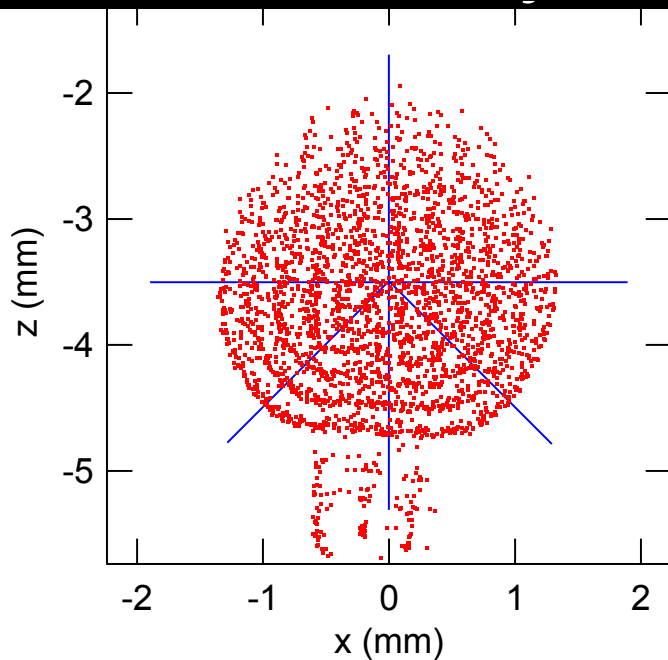
700 V, 250 mTorr, $2.6 \mu\text{m}$



Structural Analyses (Gravity & uG)

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Summary

Cylindrical Distribution of Dust Particles in Low-Frequency Discharge

Under Gravity

Multi-Shell Structure

2D Closed-Packed (Triangular Lattice)
in a shell

Under Microgravity

Bundle of Threads

(Interaction of Wake?)

K. Takahashi *et al.*, PRE 58, 7805, 1998.

A. Ivlev *et al.*, PRL 100, 095003, 2008.

Switching of Wake

Center of Cylindrical Grass Tube

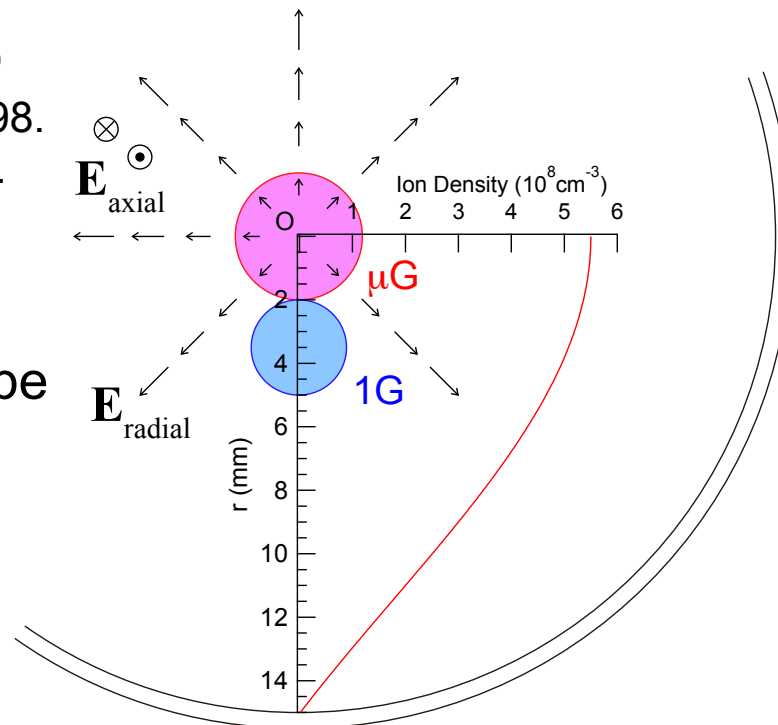
$E_{\text{axial}} \gg 0$, $E_{\text{radial}} \sim 0$

Wake, available

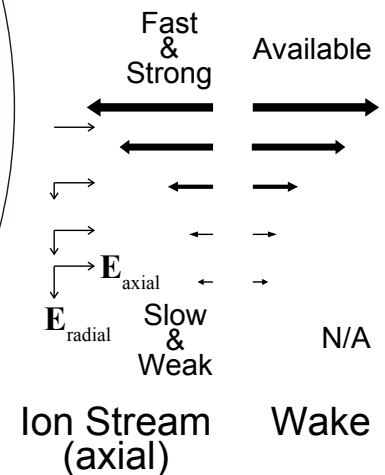
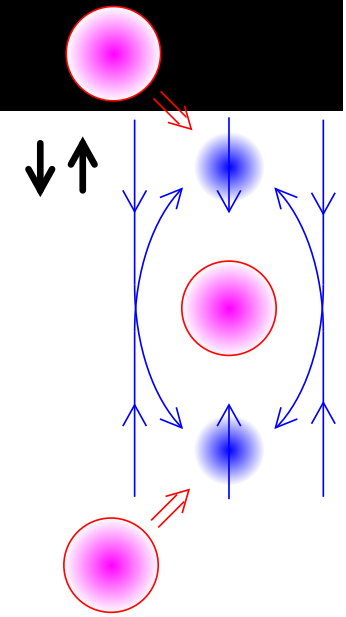
Off-Center

$E_{\text{axial}} \gg 0$, $E_{\text{radial}} \gg 0$

Wake, not available



(Cross-sectional View)



(Side View)