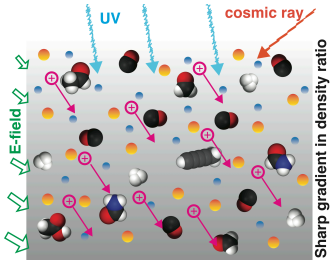
# Plasma-neutral gas interactions in various space environments beyond simplified approximations:

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# Why ion-neutral interaction?

Observations of partially ionized plasma in space suggest that the present knowledge on **plasma-neutral gas interactions** is far from complete, particularly for **low energy**.

⇒ **ion-neutral cross-section in space cannot be quantitatively measured in laboratory !**

(1) Low-energy particles are easily affected by the environment, particulary by (a) tenuous gas with gradient (b) very low temperature (c) micro-gravity.

(2) Many sources of external energies into the system that are high compared the neutral/ion energy (e.g., E, UV, radiation, electron, cosmic ray) and convoluted.



# Why ion-neutral interaction?

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We then have the following questions:

- Physical aspect (Theme A): What is the actual neutral behaviors in a tenuous plasma (upper thermosphere and exosphere, comet, interstellar medium), particular for low-energy? ⇒ this talk
- Chemical aspect (Theme B): How organic matters are formed in low-density and low-temperature environments (titan ionosphere, comet, interstellar medium), where neutral-neutral interactions is less efficient than neutral-ion interactions ?
  ⇒ not today



# **Theme** (A): physical aspect

**How and by how much do plasma-neutral gas interactions influence the re-distribution of externally provided energy to the composing species?**

(A1) Impact of ion-neutral energy exchange on long-term evolution of planet, comet, ring, etc.

(A2) Structures and variability of the upper thermosphere and exosphere

(A3) Energy cascade in partially ionized plasma with large gradients or layered structures

(A4) Role of ion-neutral momentum transfer in the super-rotation and cold ion flows



# What to measure?

Basic parameters that must be measured (**mandatory**):

**(1) ion energy/velocity distribution (including density)**

**(2) neutral energy/velocity distribution (including density)**

(3) composition if posasible

Possible parameters that influence the interaction (**optional measurements**) :

**(1) Temperature**

**(2) Density and ionization ratio (including their gradient)**

**(3) Gravity**

**(4) External free energy** (electron, cosmic ray, E-field, B-field, EM wave)

note. these extreme conditions are difficult to achieve by laboratory experiments



# Where to go?

Here, we assume **M-class / F-class payload**.

- M-class dedicated mission (Earth/Venus)
- F-class payload onL-missions (> 2 AU)

| Mission destination | (1) T | (2) n | (3) g | A1 | A2 | A3 | A4 | mother mission*2 |
|---|---|---|---|---|---|---|---|---|
| Interstellar/Oort cloud | very low | very low | very low | x | - | x | (x) | LL or L |
| Ice Giant atmosphere | very low | medium | high | x | x | x | x | LL |
| plumes (Enceladus, Io, Europe) | low | medium | medium | x | x | x | (x) | L or LL |
| Titan around exobase | low | medium | high | x | x | x | (x) | L or LL |
| **comet rendezvous** | **wide*1** | **wide*1** | **low** | **x** | **x** | **x** | **x** | **L** |
| deep inside gas giant | medium | high | very high | (x) | - | (x) | - | L |
| artificial comet | medium | high | medium | x | - | x | (x) | M, F |
| **Earth around exobase** | **high** | **medium** | **high** | **x** | **x** | **x** | **x** | **M, F** |
| **Venus around exobase** | **high** | **medium** | **high** | **x** | **x** | **x** | **x** | **M, F** |
| planetary L2 comp. | (mixed) | low | very low | x | (x) | | (x) | < M |

*1 It ranges from very low to high along the orbit.
*2 LL: Need to collaborate with other agency (for cost or RTG).