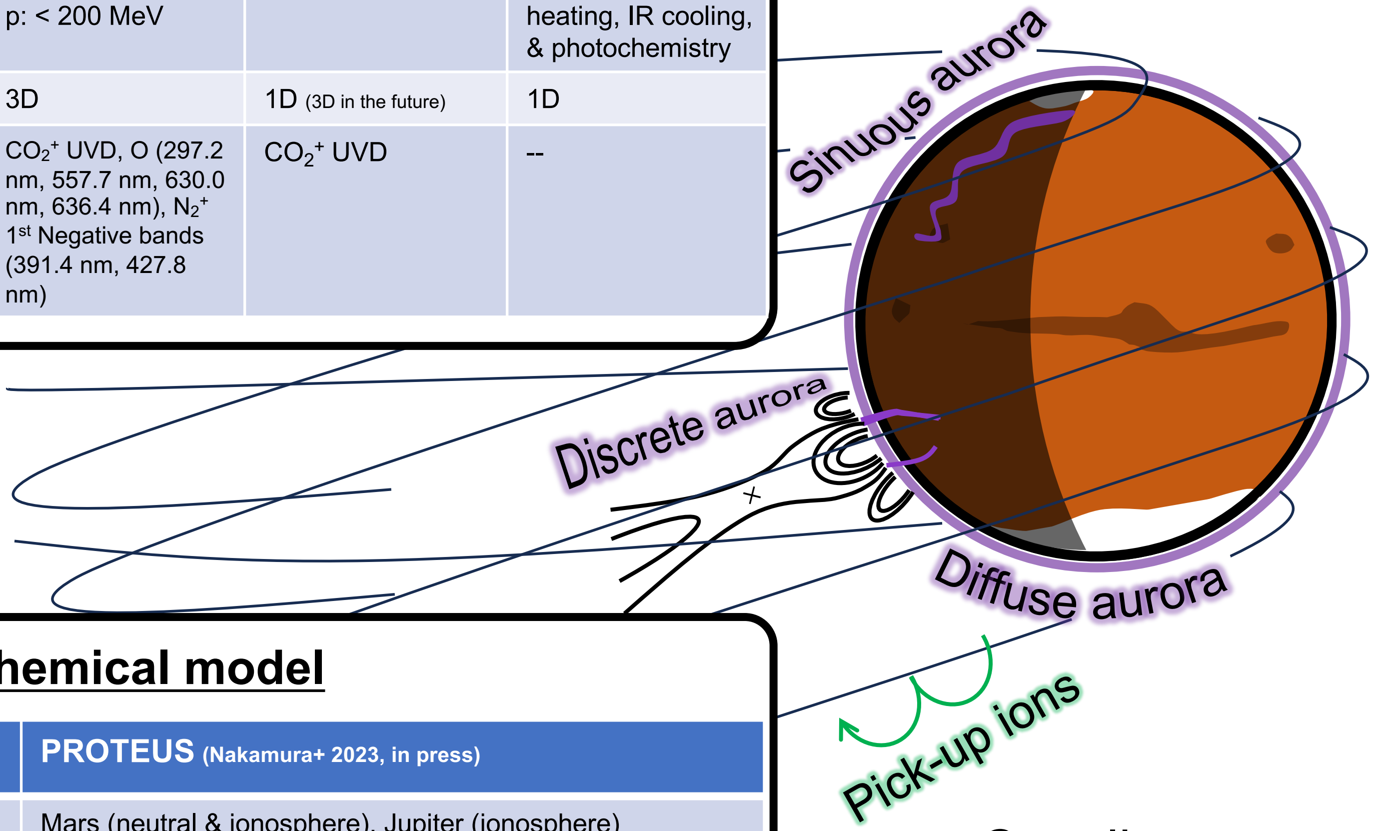
Focus topic (A): Numerical modeling group

Monte Carlo models

	PTRIP (Nakamura+ 2022)	Okiyama's (Okiyama+ in prep)	DSMC (Terada+ 2016)
Particle	Electron & Proton e: < 100 keV p: < 200 MeV	Electron e: < 1 MeV	Full particles w/ collisions, solar heating, IR cooling, & photochemistry
Dimension	3D	1D (3D in the future)	1D
Emission lines	CO_2^+ UVD, O (297.2 nm, 557.7 nm, 630.0 nm, 636.4 nm), N_2^+ 1st Negative bands (391.4 nm, 427.8 nm)	CO_2^+ UVD	--

Coupling



MHD models

	BATS-R-US (e.g., Ma+ 2002)	REPPU-Planets (Terada+ 2009)	MAESTRO (Sakata+ in prep)	GAMERA (Zhang+ 2019)
Model	MS, MF & MFPe	MS	MS, MF & MFPe	MF & MFPe
Ion species	4 species (recently 5)	14 species	5 species	4 species
Grid	Spherical	Unstructured Triangle	Cubed sphere	Spherical
Radial res.	5 – 600 km (non-uniform)	4 – 1000 km (non-uniform)	3 – 3100 km (non-uniform)	> 10 km (non-uniform)
Spatial res.	3 deg.	3 – 4 deg.	2.7 – 3.6 deg.	2.8 – 5.6 deg.
Crustal fields	Yes	No. It will be implemented	It started to be implemented.	No. It will be implemented

Photochemical model

	PROTEUS (Nakamura+ 2023, in press)
Planets	Mars (neutral & ionosphere), Jupiter (ionosphere)
Reactions	Potentially, more than 6,000 reactions are available. Photochemical reactions & vertical diffusion are solved.

Coupling

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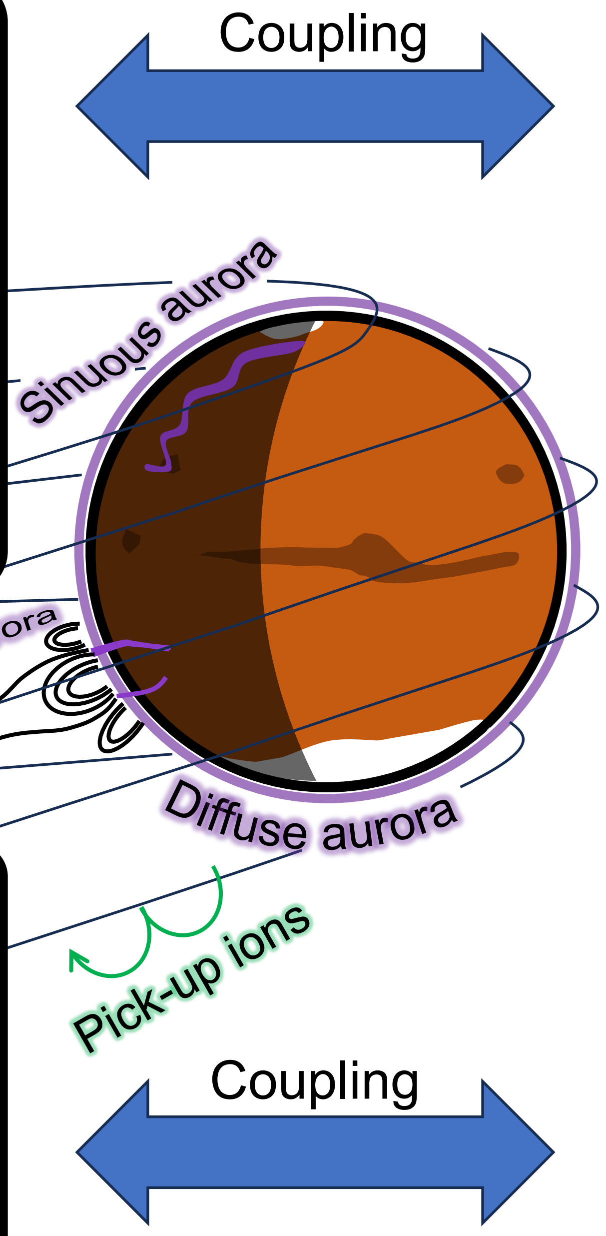
Emission lines

- CO_2^+ FDB (~430 nm), CO 4th Positive bands, CO Cameron bands, O 130.4 nm, and 135.6 nm emissions. (M-MATISSE, MAVEN, EMM)
- Radiative transfer should be solved for optically thick lines such as O 130.4 nm emissions. (EMM)

Coupling with MHD models

- Carefully determining the boundary condition.
- Interpolation method of magnetic fields.



MHD models

Aurora-related simulation

1. Reconnection

- Current models are around 3° horizontal resolution. Finer grid should be used for reconnection.
- GAMERA: Suitable for particle tracing (div-B free).
- Hall-MHD + PIC simulation or a PIC in a small area seems good for discrete aurora.
- Div-B method is important in the magnetic field configuration.
- How to simulate potential drops?

2. Nightside ionization

- Electron impact ionization is important, and it depends on not only N_n and T_e but also B field direction and strength.
- Electron pitch angle and magnetic mirror ratio might be important factors.

Atmospheric escape modeling

1. Important species to be added

- C^+, N^+, NO^+, hydrocarbon group, water group, and isotope ratio (D/H, $^{18}O/^{16}O$, $^{13}C/^{12}C$).

Photochemical model

Coupling with MHD models

- Developing a unified subroutine, which can be easily implemented into MHD models.
- Reaction analysis scheme should be developed to identify which reactions are important.