3D Simulations of Earth's Magnetosphere-Ionosphere Coupling

BJLPIC EM code

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Head Topics

Code overview: Past, Present and Future

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Examples of Old and New Runs

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Code overview: Past, Present and Future

Examples of Old and New Runs

Future plans

Code overview: Past, Present and Future

TRISTAN Three Dimensional Stanford University

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Originally written by (Buneman,1992,1993,1995)

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Wodincka, 2006, 2009

Spitkovsky, 2002,2004,2006,2008

Old version: Some Examples

1. Mass Ratio case : Old version
2. PIC and CCMC Comparison case: Old version
3. Cusps Study Case : Old version
4. Magnetosphere ionosphere coupling case : New version , IAP-UPMC-CNRS, France.

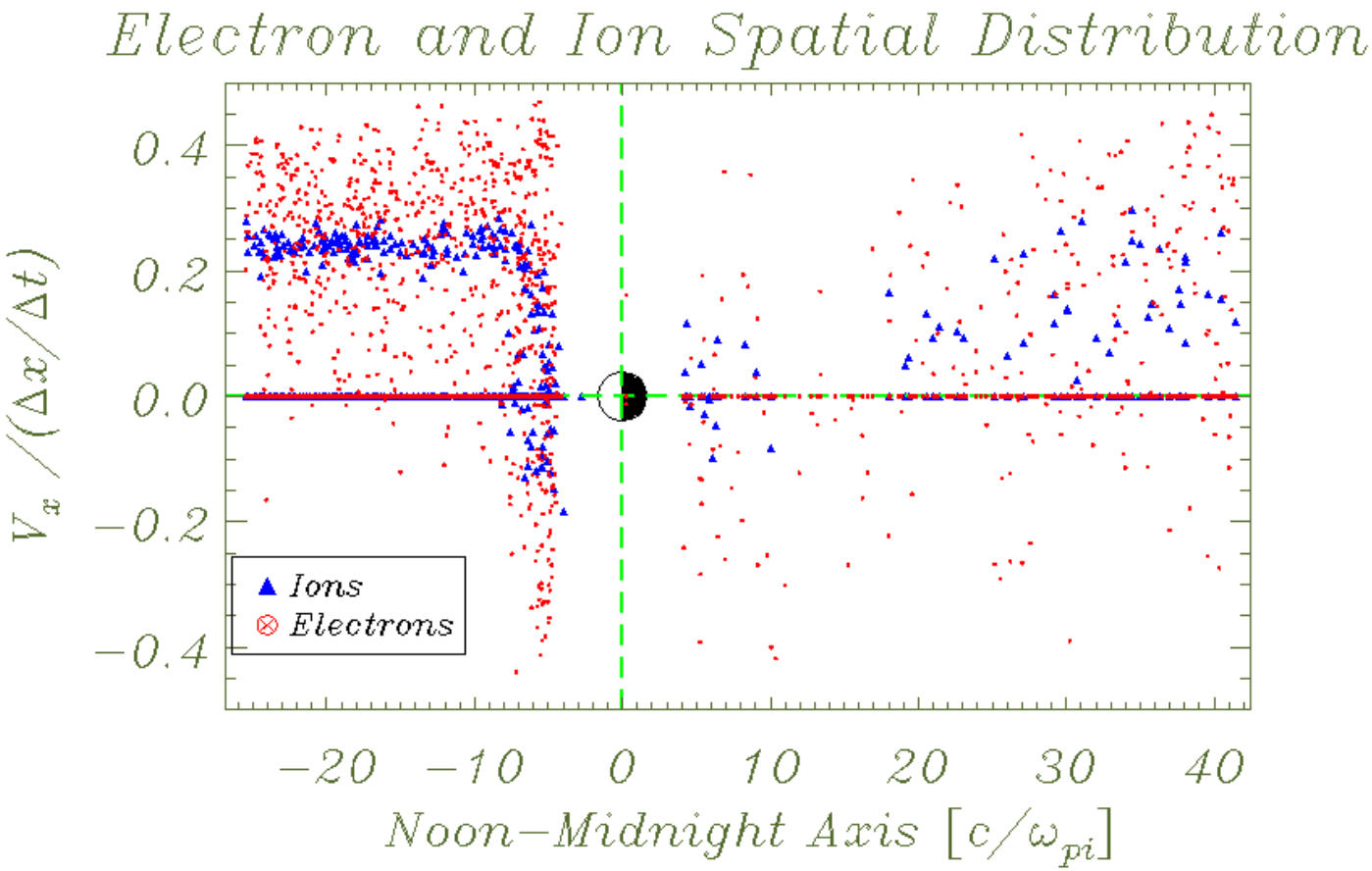
Mass Ratio Study

	mi/me=16	mi/me=32	mi/me=64
$\frac{Q}{m}$	1	1	1
N_e	5	5	5
N_i	5	5	5
T_e	8×10^{-5}	8×10^{-5}	8×10^{-5}
T_i	8×10^{-5}	8×10^{-5}	8×10^{-5}
V_{the}	0.1	0.1	0.1
V_{thi}	0.025	0.0176777	0.0125
ω_{ce}	0.15	0.15	0.15
ω_{ci}	0.009375	0.0046875	0.00234375
ω_{pe}	0.2	0.2	0.2
ω_{pI}	0.05	0.0353553	0.025

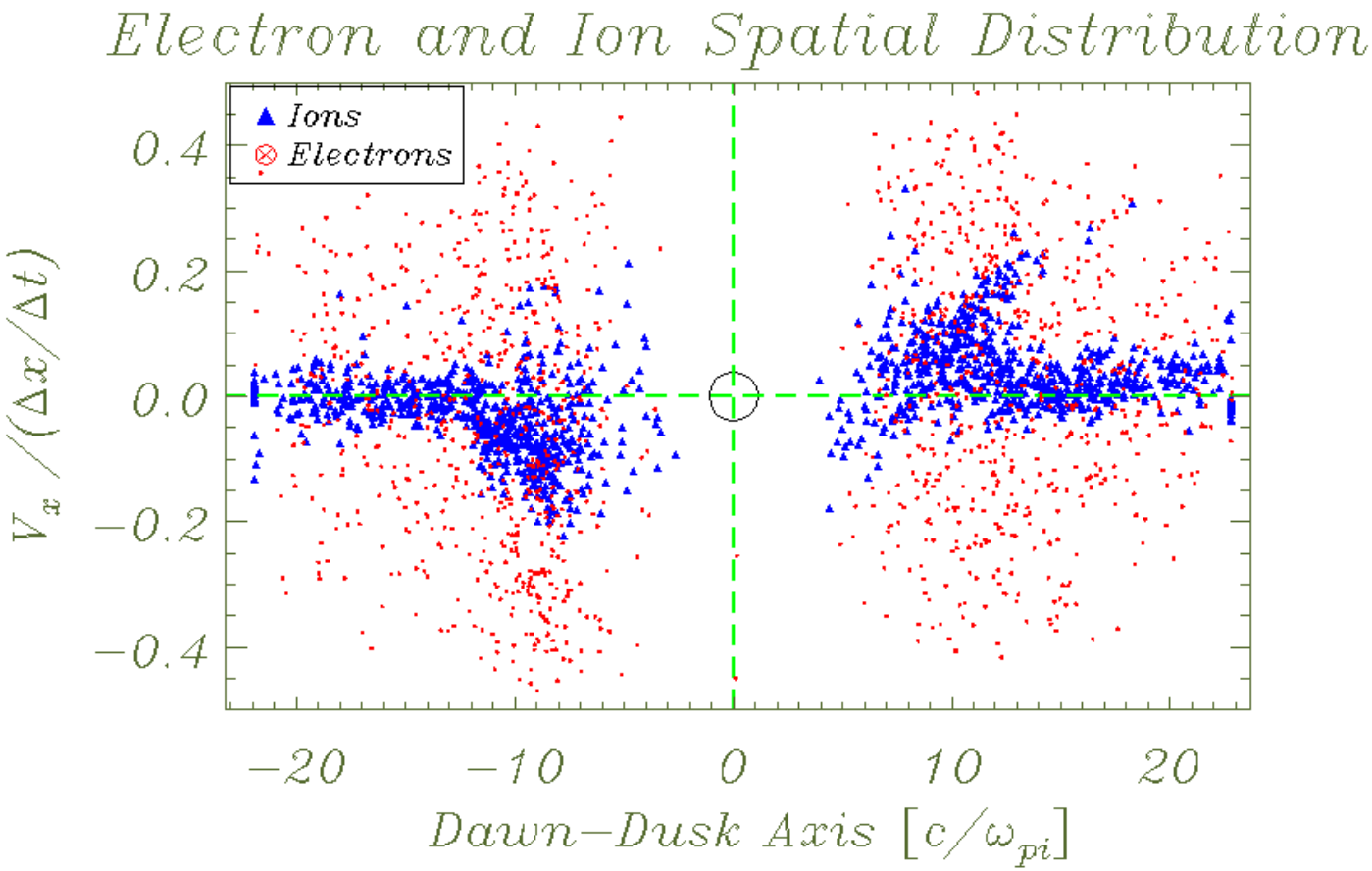
Mass Ratio Continued . . .

	mi/me=16	mi/me=32	mi/me=64
B_z	0.15	0.15	0.15
λ_e	1.66667	1.66667	1.66667
λ_i	26.6667	53.3333	106.667
β_e	0.142222	0.142222	0.142222
β_i	0.142222	0.142222	0.142222
λ_{De}	0.5	0.5	0.5
λ_{Di}	0.5	0.5	0.5
C_s	0.0485071	0.0348155	0.0248069
V_A	0.0909509	0.0652791	0.046513
M_s	5.15388	7.1807	10.0778
M_A	2.74874	3.82971	5.37484
M_{MS}	2.42536	3.37915	4.7425
$de = c/\omega_{pe}$	2.5	2.5	2.5
$di = c/\omega_{pi}$	10	14.1421	20

Ion Electron Spatial Distribution in Noon-Midnight plane



Ion Electron Spatial Distribution in Dawn-Dusk plane



Mass Ratio Study

3D Simulations of Earth's Magnetosphere Ionosphere Coupling

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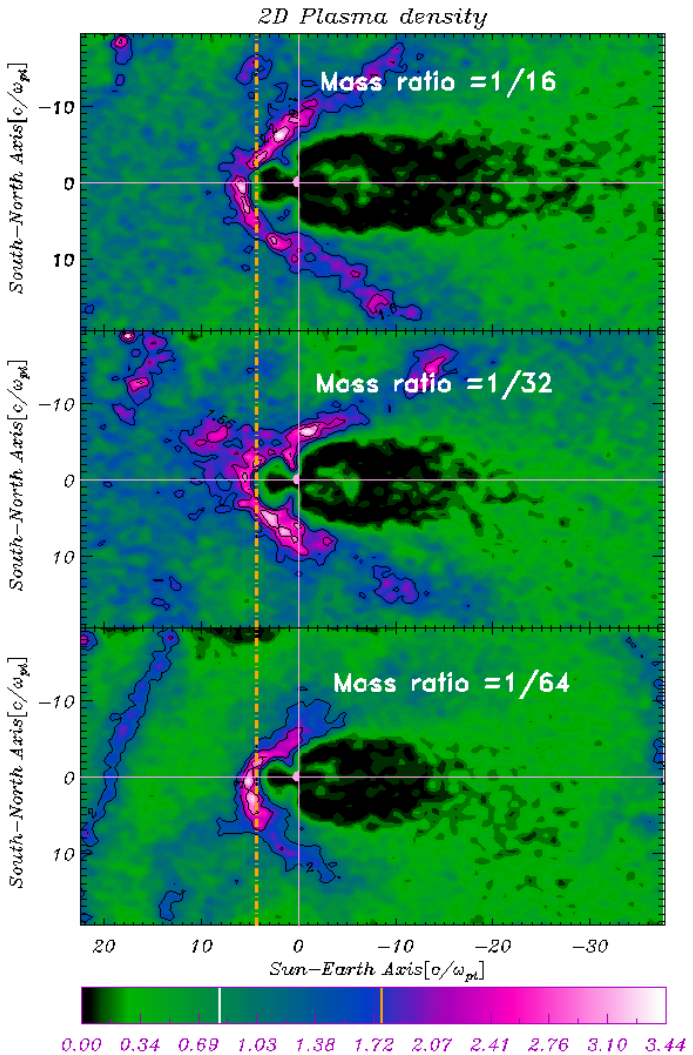

Reconnection under northern IMF in norther and souther cusps

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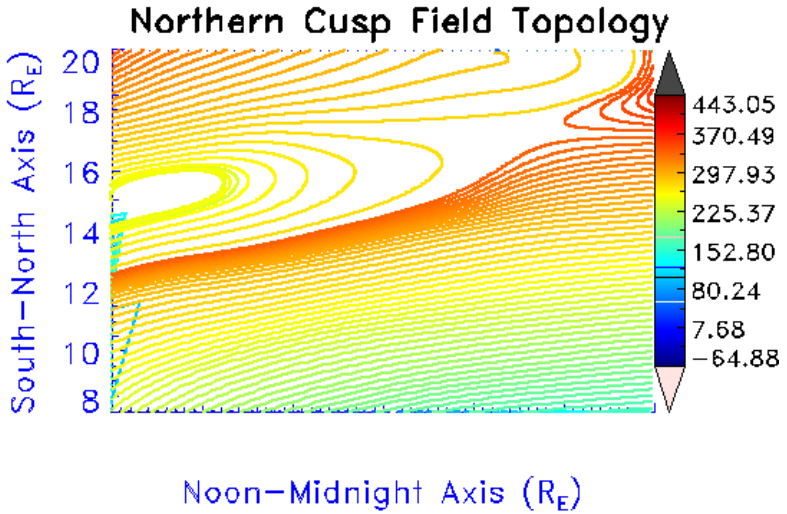
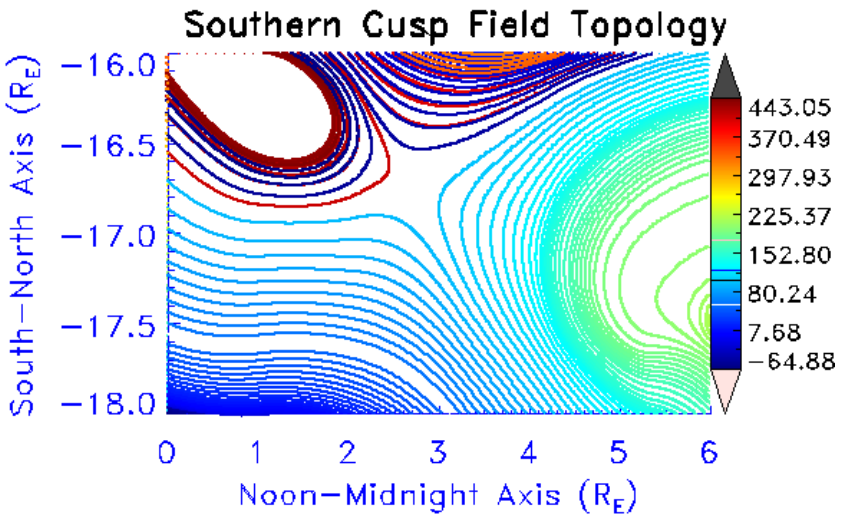




Erasmus Mundus

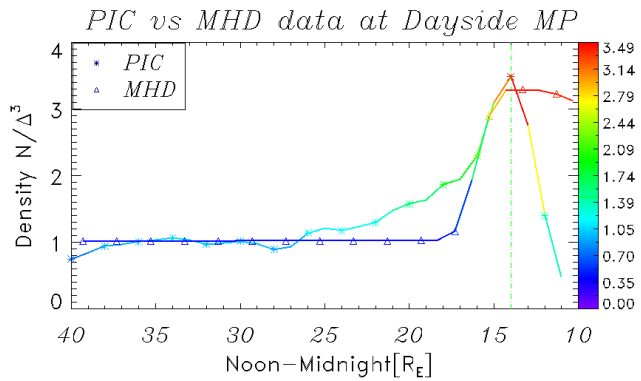
PIC and MHD code comparison
Input Data

Parameters	PIC code	GUMICS-v4
CPU time	50 Min	5 Hours
Machine	Single processor PC	CCMC-Super Computer
Ionosphere	No	Yes
Grid Cell	Fixed	Adaptive
Grid size	$1R_E^3$	$(0.1 - 8R_E)^3$
Small Box Size	$155 \times 105 \times 105 R_E$	$250 \times 130 \times 130 R_E$
$\rho(x, y, z)$	$0.8 \frac{N}{\Delta^3}$	$5.0 cm^{-3}$
$B_z(x)$	0.2	$6.5(nT)$
$V_x(x)$	0.25	500 $(km.sec^{-1})$
$V_A(y)$	0.028	$63(km.sec^{-1})$

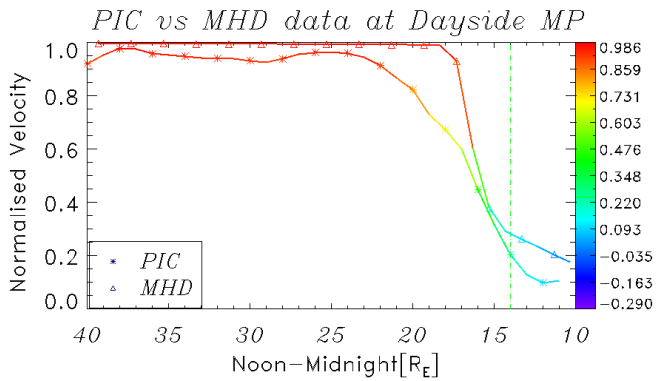
Unitless values

Parameters	PIC code	GUMICS-v4
$\frac{V_A}{V_{SW}}$	0.11	0.12
M_A	8.9	7.8
M_{MS}	5.5	5.2
β	1.6	2.7

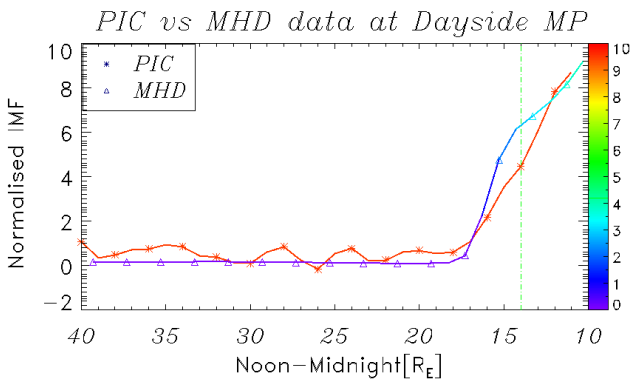
PIC and MHD comparison



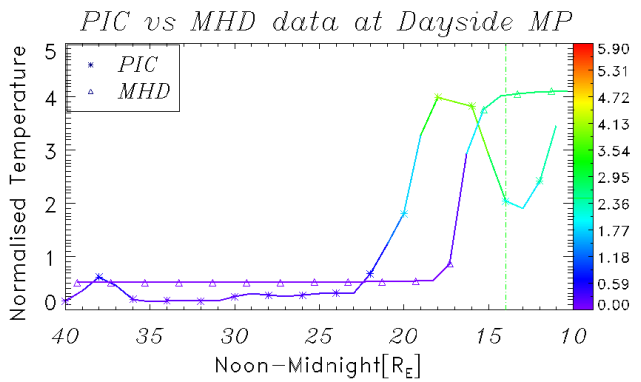
A



B

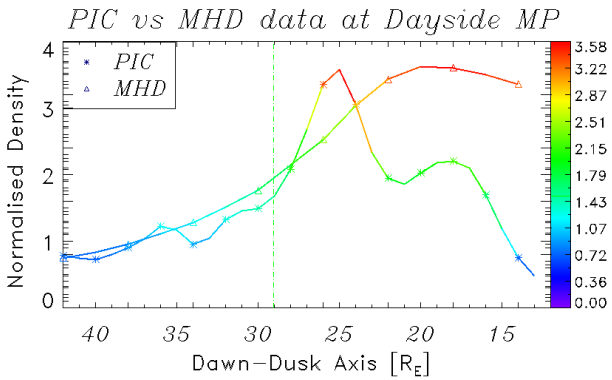


C

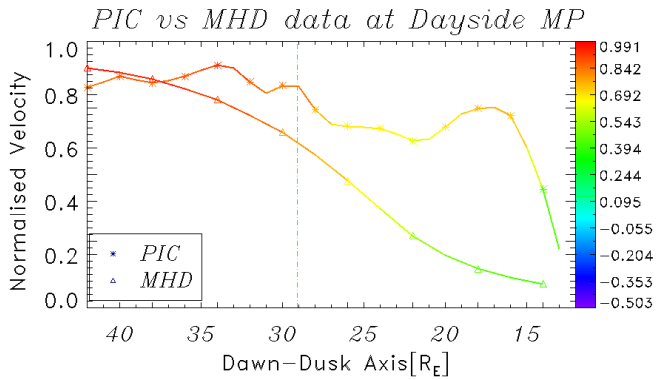


D

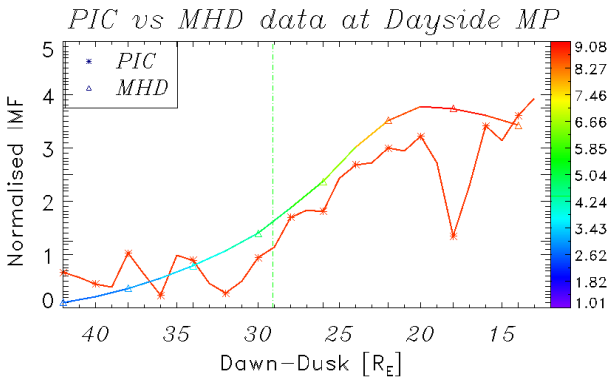
PIC and MHD comparison continued . . .



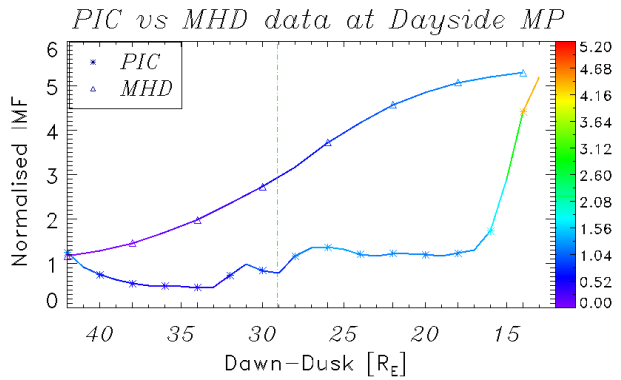
A



B



C

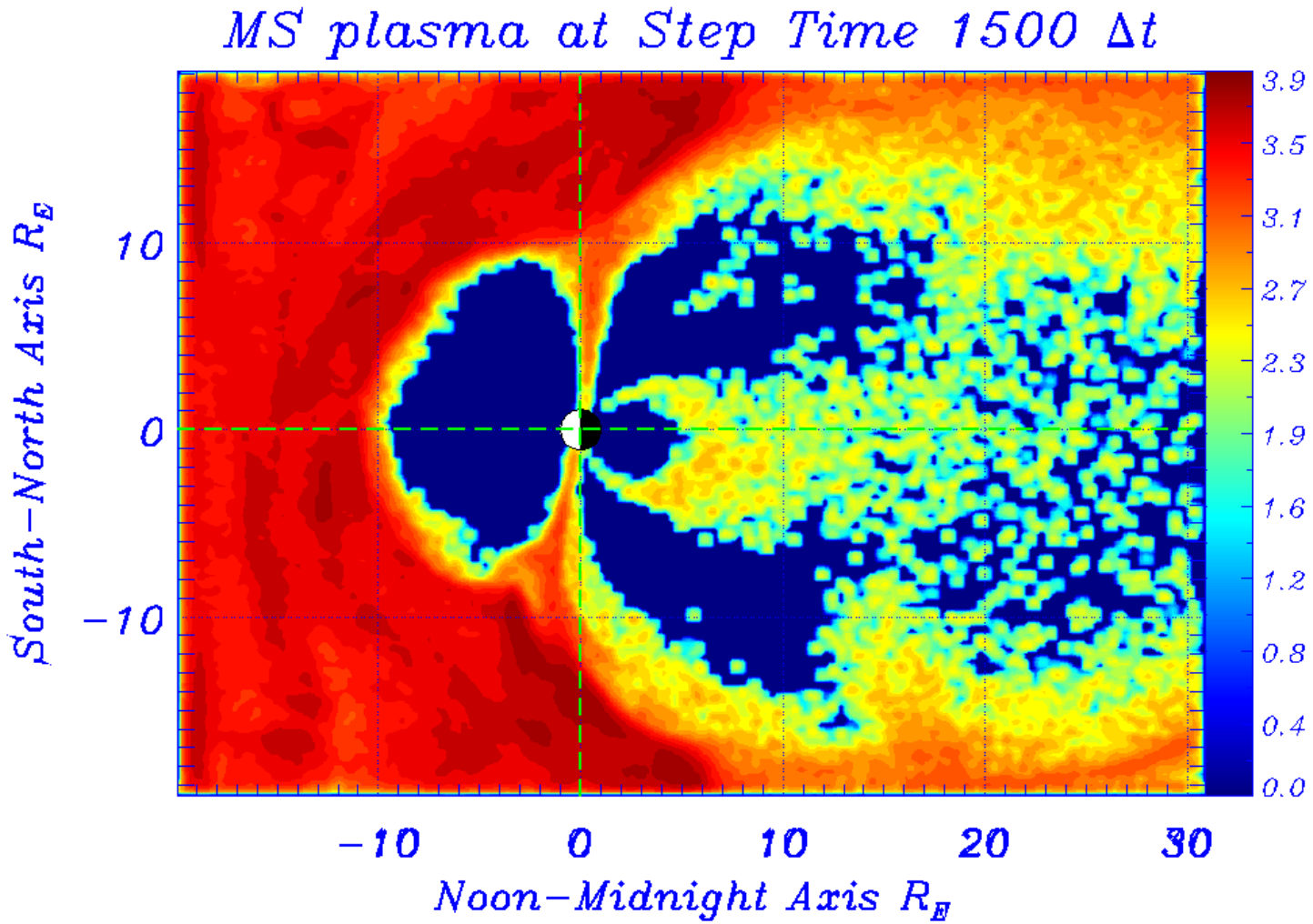


D

Current Version of the code what is new?

1. Grid size $\approx 0.2R_E$ and can be worked out with $\approx 0.1R_E$
2. No. of Particles 5×10^7 for MS and 3×10^7 for planet particles.
3. Mass ratio $\frac{m_i}{m_e}$=64 and be up to 400
4. Planet tilt=10°
5. Ionosphere from (`http://irimodel.org/`) International Reference Ionosphere is included. ions with bulk velocity equal to zero . Only thermal velocities are considered.
6. Multi-species are simulated for $O^+$and H^+, and as many as needed can be included!

New run outputs: Density distribution of magnetospheric plasma in Noon-Midnight plane



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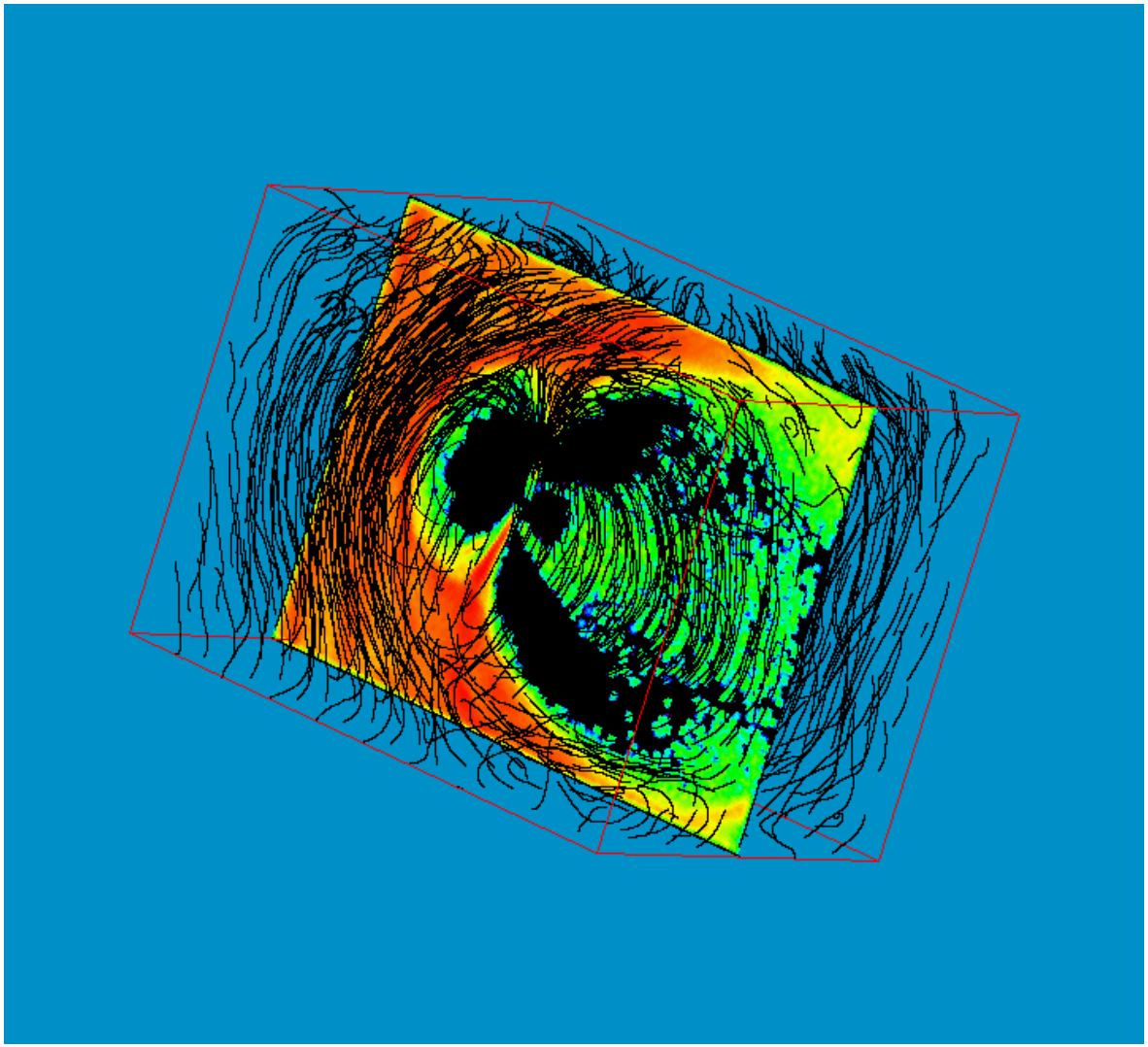
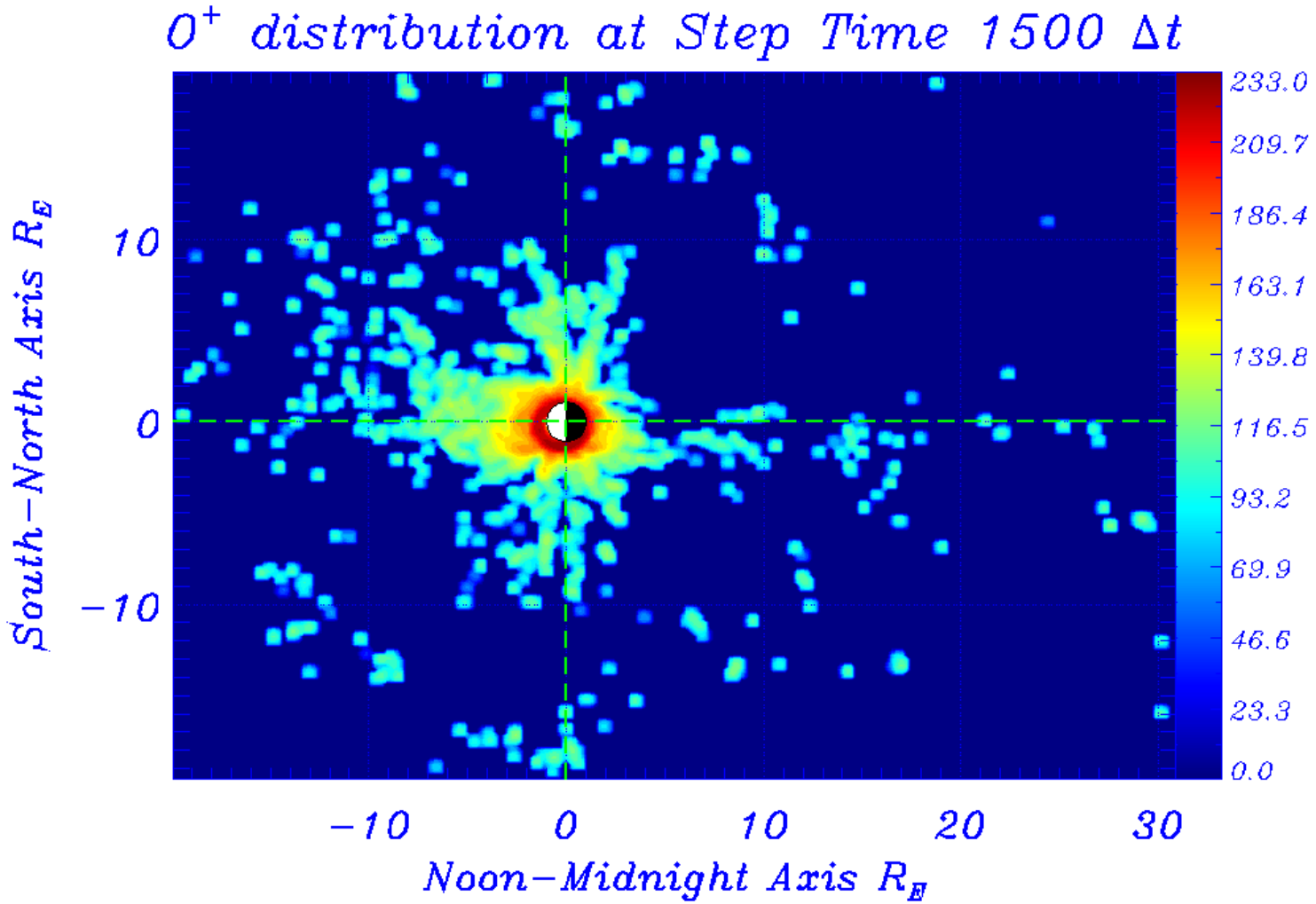
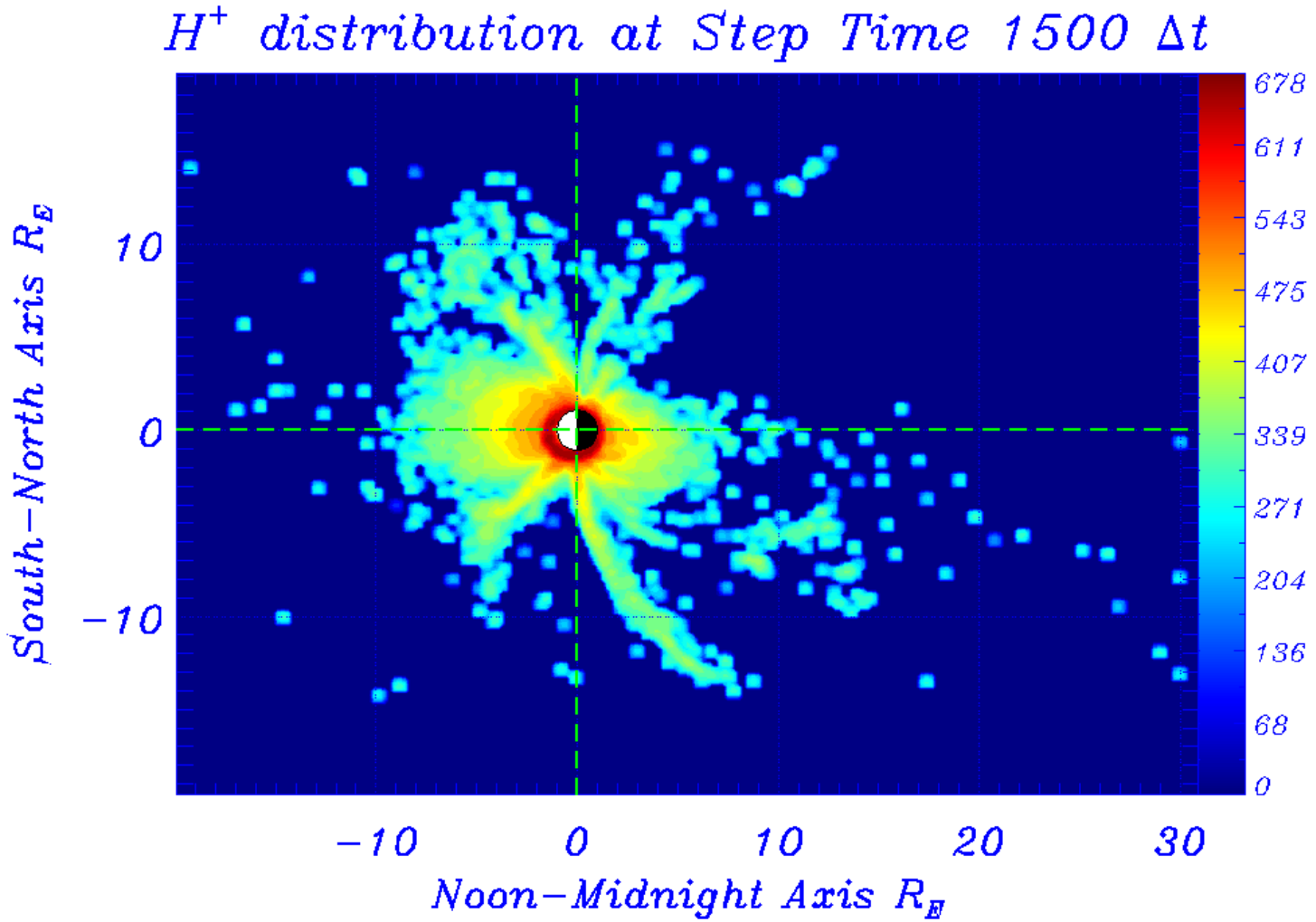


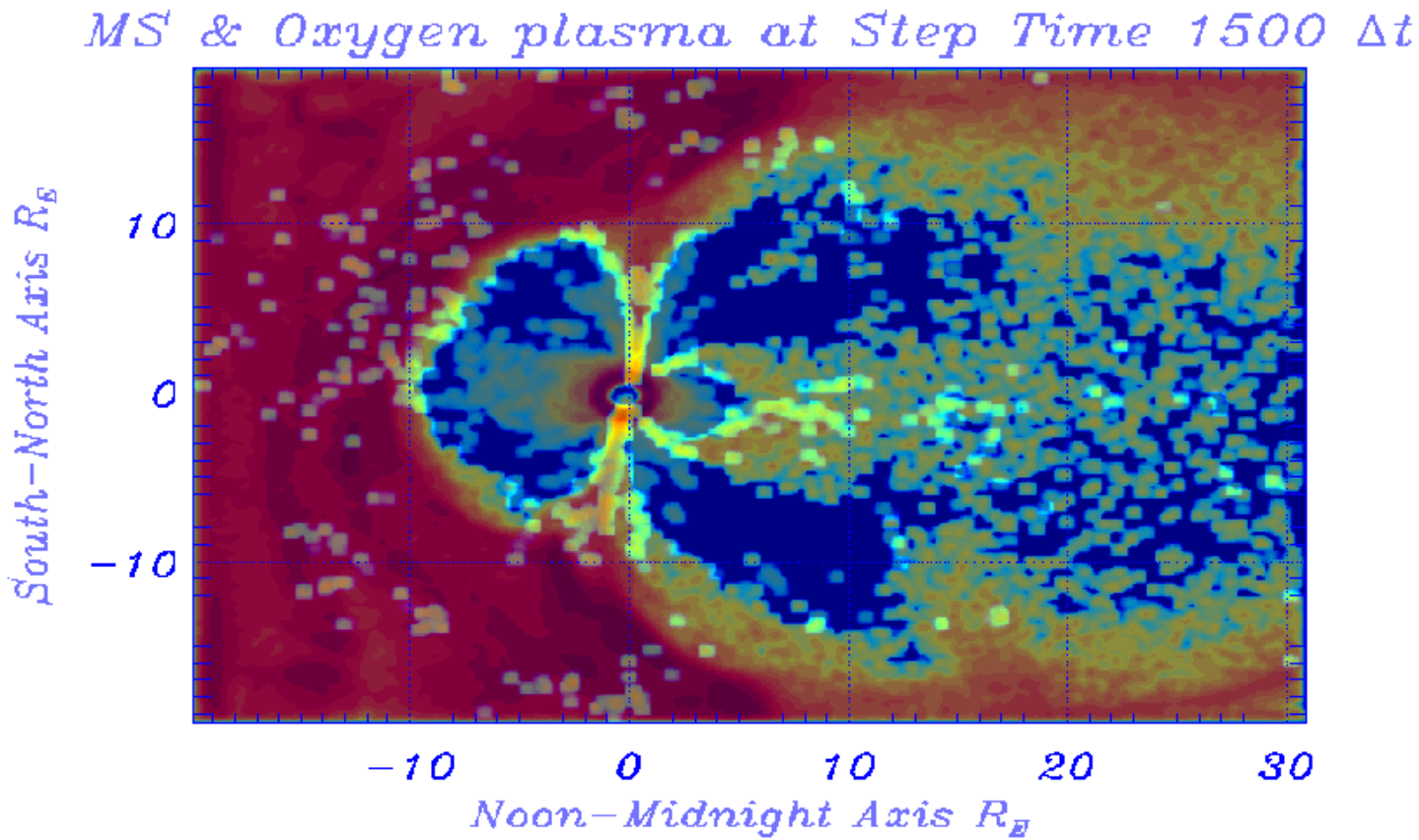
New run outputs: Density distribution of O^+ in Noon-Midnight plane



New run outputs: Density distribution of H^+ in Noon-Midnight plane



2D Plasma distribution for MS and O^+ plasma :Merged



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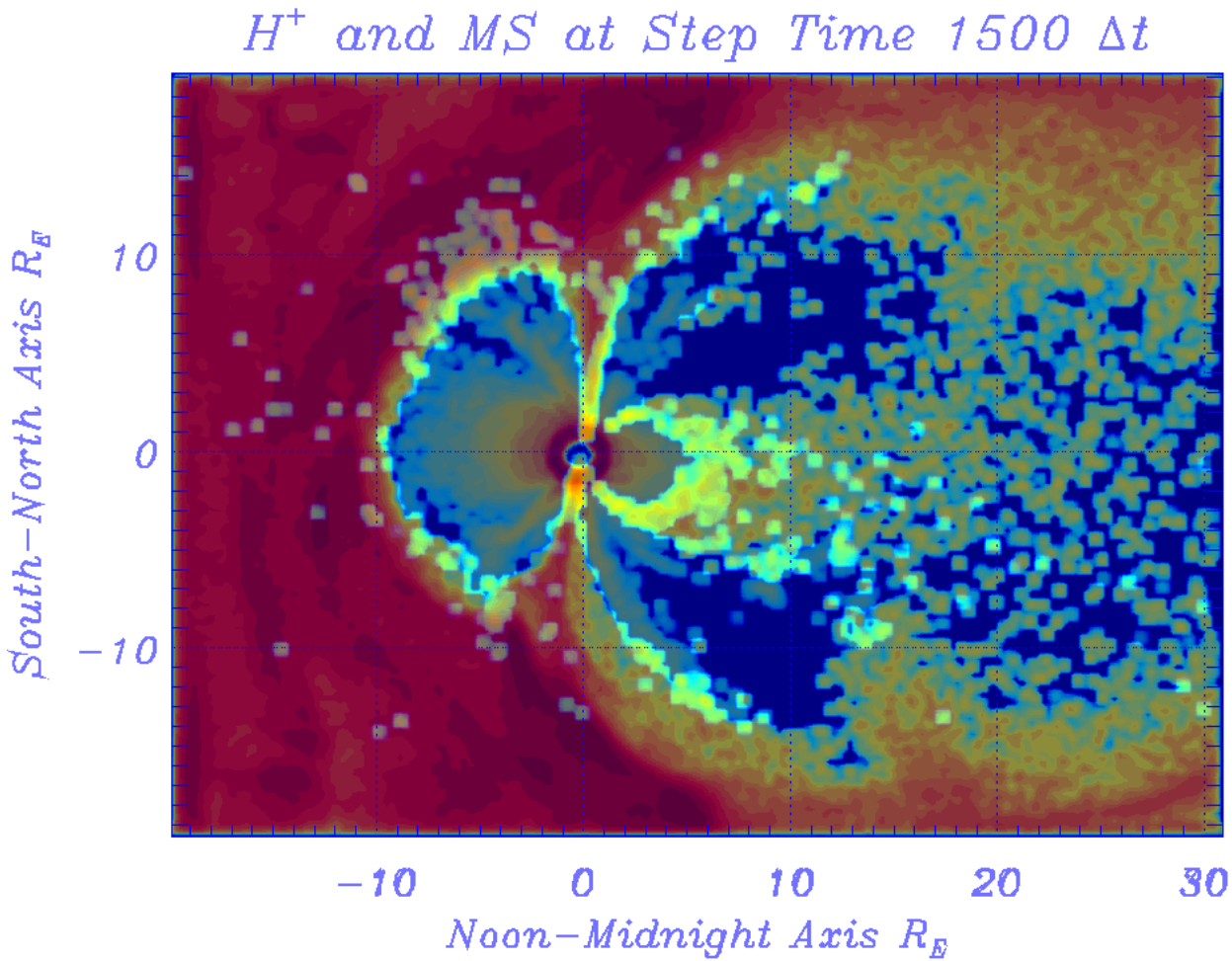
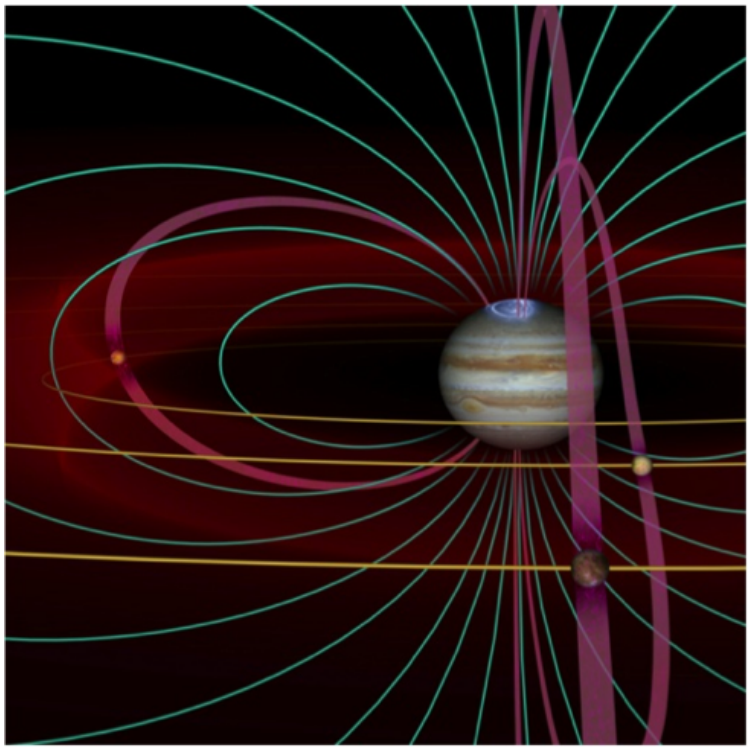


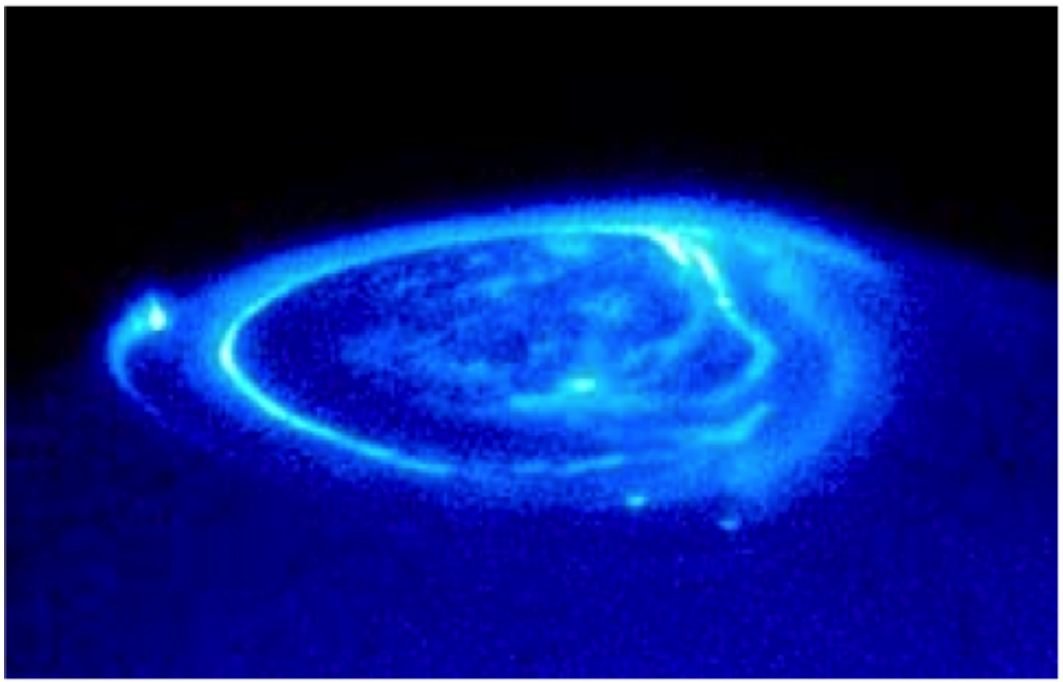
Other BJLPIC code potential simulations

This figures is showing the Galilean satellites of Jupiter (**Io, Europe, Ganymede**) on their orbits (yellow) and flux tubes (pink) connecting the satellites positions to spots in the Jovian auroral regions (north and south by magnetic symmetry)



Observations that can be simulated by BJLPIC

Exactly as observed by Hubble Space Telescope (*Clarke, Ballester, Ben-Jaffel et al., Nature, 2002*).



Explanation we let the planet orbits until it passes in front of the line observer-star: at that time any gas or plasma around the planet will absorb the stellar light that we can detect with a telescope like HST (in that paper it's about the far UV and ions CII line 1334.7 Angstrom

Satellite-Planet EM interaction
Like I_O Torus in Jupiter System

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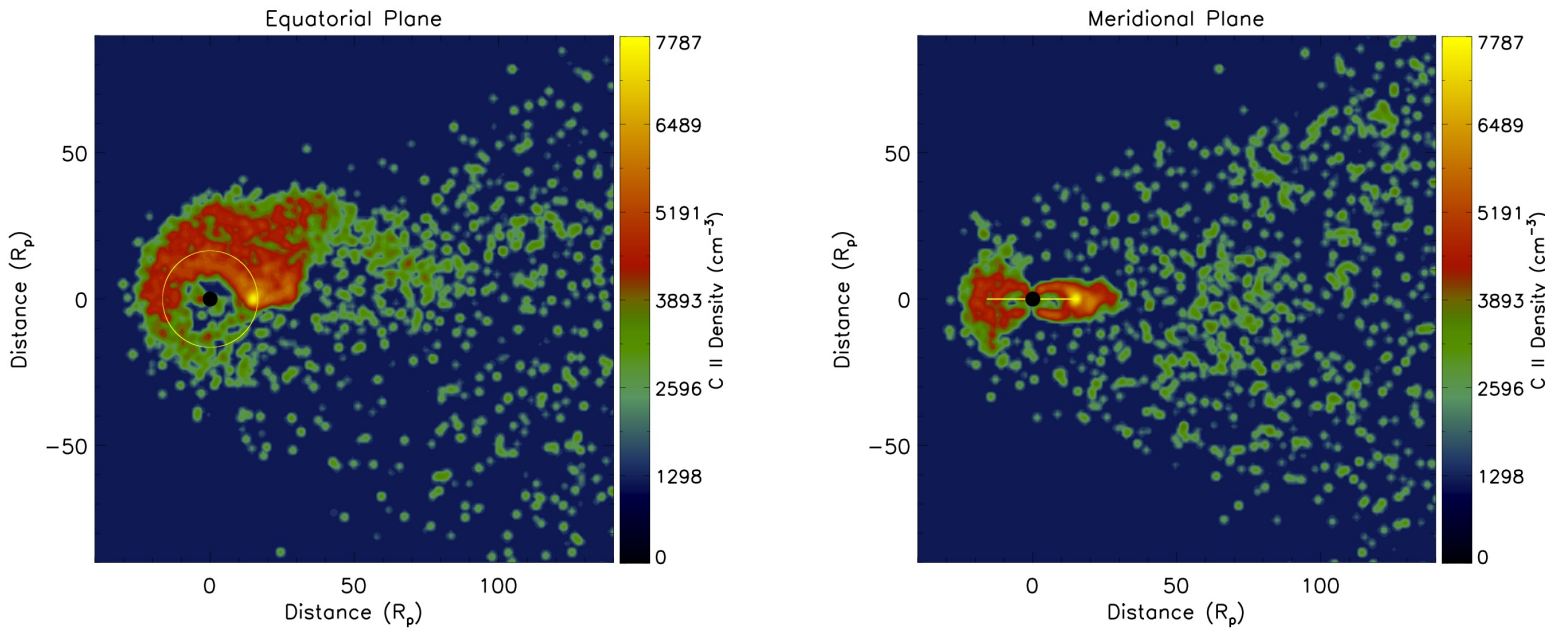

(Ben-Jaffel and Ballster, 2014)

Future Code Ideas and Enhancement

1. Include more particle with reduced cell size below $\sim 0.1 R_E$
2. Seasonal variation i.e. summer and winter ...
3. Include ionospheric density, temperature as a function of local time (LT) and to study their impact on the structure of Magnetosphere in macrotructure scale.
4. Apply MPI to code to study small scale kinetics i.e. reconnection and application to MMS data.

Work plans in Uppsala

1. My work plan at Uppsala was meant to compare data to our BJLPIC code. In order to efficiently compare the data, training on how to deal with data is important.
2. Discuss with colleagues to make this very short visit productive and maximizes the mutual cooperation in the field
3. Set future cooperation plans.
4. Discuss "investment in People" future students from Palestine engagement is research at Uppsala University.
5. other issues of mutual interests are welcome.

شُكراً جَزِيلاً عَلَى حُسْنِ إِستِمَاعِكمْ

Tack så väldigt för uppmärksamheten

Thank you for your attention