地球内部磁気圏統合データ同化システム開発の現状

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Motivation

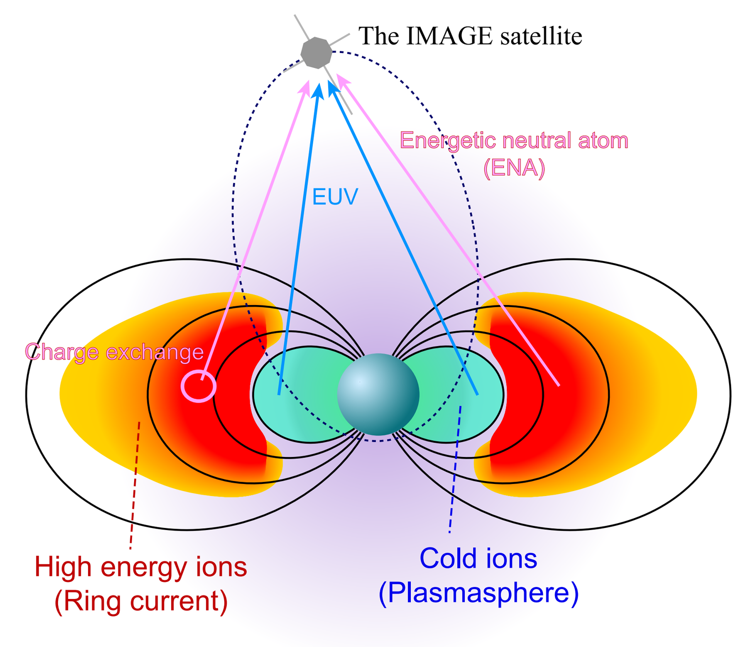
In our past studies...

- The temporal evolution of the ring current was reproduced by data assimilation of the IMAGE/HENA data into a ring current model (Nakano et al., 2008).
- The temporal evolution of the plasmasphere was reproduced by data assimilation of the IMAGE/EUV data into a plasmasphere model (Nakano et al., 2014).

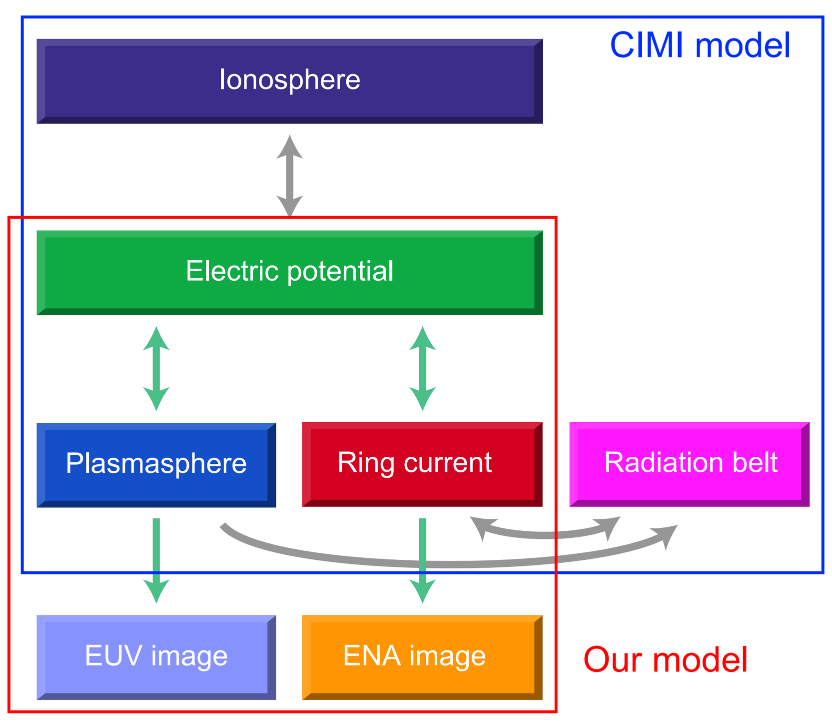
Our two data assimilation methods were based on similar frameworks. Thus, these two methods can be combined.

The plasmasphere is located deep inside of the magnetosphere, and the ring current is typically distributed just outside the plasmasphere.

In terms of estimating the electric field distribution, the ENA emission from the ring current would provide complementary information to the EUV emission from the plasmasphere.



Model and method



We use an inner magnetosphere model in which the plasmasphere and the ring current are driven by a common magnetic and electric fields.

This model is based on the Comprehensive Inner Magnetosphere Ionosphere (CIMI) model (Fok et al., 2014), but the magnetosphere-ionosphere coupling and the plasma-wave effects on the radiation belt are turned off.

At presenet, the IMAGE/HENA data at two channels (20-27keV and 39-50keV) and the IMAGE/EUV data are considered for our data asimilation.

The evolution of the ring current is computed using a four dimensional model based on the Boltzmann equation (Fok et al., 1997):

$$\frac{\partial \bar{f}}{\partial t}+\langle\dot{\lambda}_i\rangle\frac{\partial \bar{f}}{\partial \lambda_i}+\langle\dot{\phi}_i\rangle\frac{\partial \bar{f}}{\partial \phi_i}=-v\sigma\langle n\rangle\bar{f}-\left(\frac{\bar{f}}{0.5\tau_b}\right)_{\text{losscone}},$$

where $\langle\dot{\lambda}_i\rangle$ and $\langle\dot{\phi}_i\rangle$ indicate the bounce-averaged velocity which depends on the background magnetic and electric fields.

The evolution of the plasmaspheric plasma density $\bar{N}$ can be described by the following equations (Ober et al., 1997):

$$\frac{\partial \bar{N}}{\partial t}-\frac{\nabla\Phi\times\boldsymbol{B}}{B^2}\cdot\frac{\partial \bar{N}}{\partial \boldsymbol{x}}=0.$$

Φ : Electric potential,
$\boldsymbol{B}$: Magnetic field.

The electric potential distribution is treated as an unknown factor to be estimated. Here we represent the electric potential distribution by the sum of the Volland-Stern type potential and the series of cylindrical functions as

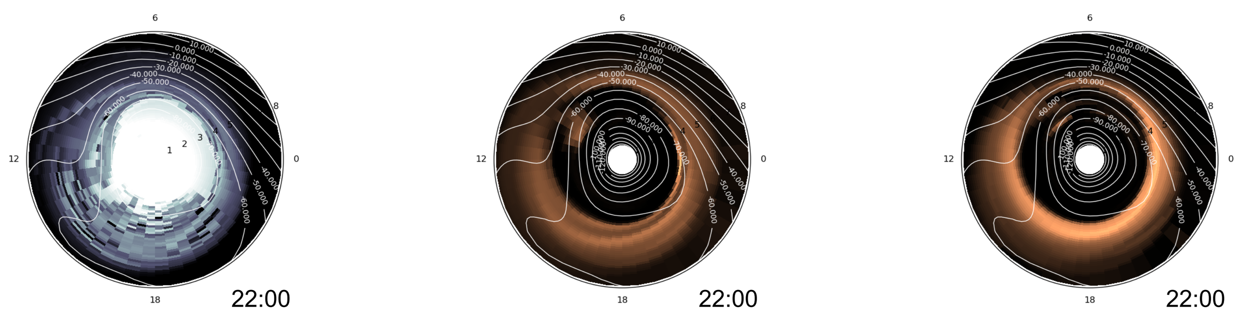
$$\Phi=\Phi_0\left[\left(\frac{r}{R}\right)^2\sin\phi+\sum_{n,j}a_{n,j}\mathcal{J}_n\left(\xi_{nj}\frac{r}{R}\right)\cos n\phi+\sum_{n,j}b_{nj}\mathcal{J}_n\left(\xi_{nj}\frac{r}{R}\right)\sin n\phi\right]$$

where R is the equatorial radius of the outer boundary of the simulation domain, $\mathcal{J}_n$ is the n-th order Bessel function, and ξ_{nj} is the positive roots of $\mathcal{J}_n(\xi_{nj})=0$.

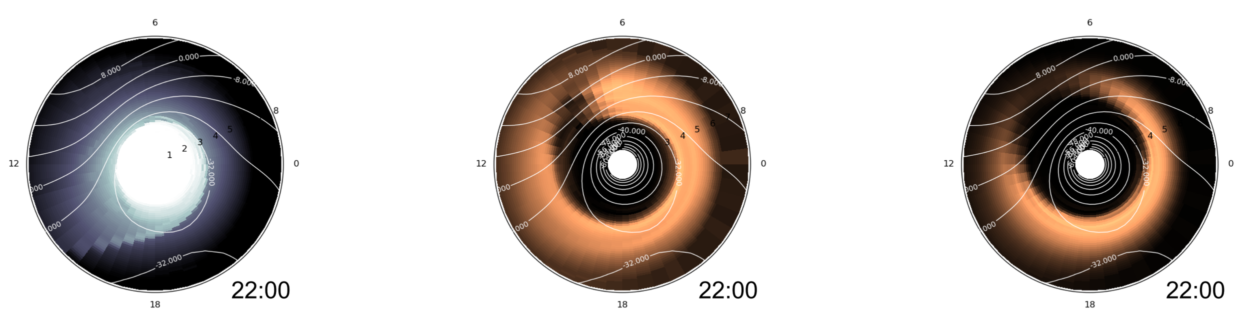
The parameters Φ and the coefficients a_{nj} and b_{nj} are to be estimated using the data assimilation.

The ensemble transform Kalman filter (Bishop et al., 2001) was used in order to achieve the estimation of the plasmasphere, ring current, and electric field. (Assimilation cycle: 30 minutes; ensemble size: 64; covariance inflation factor: 1.05 for every 30 min.)

Only with the HENA data

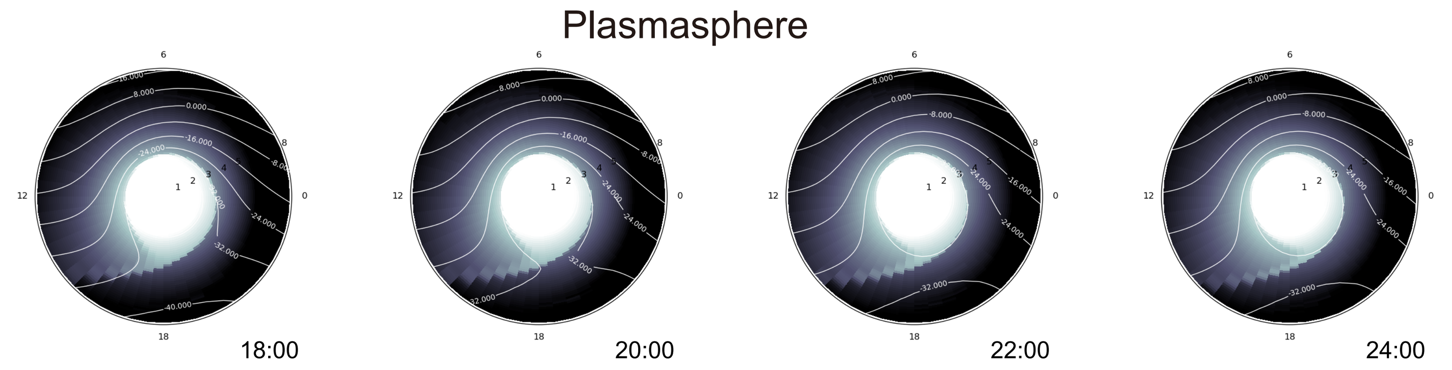


Only with the EUV data

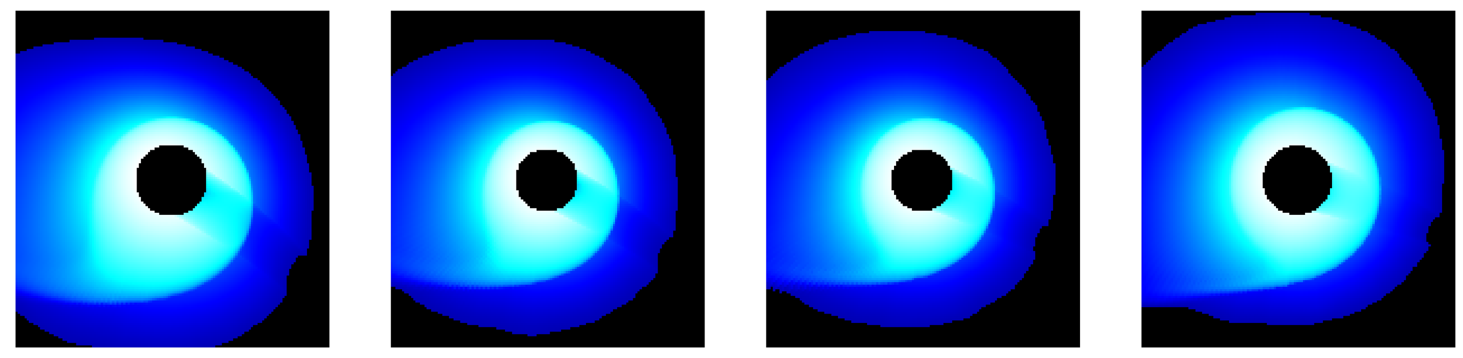


Test run for generating artificial data

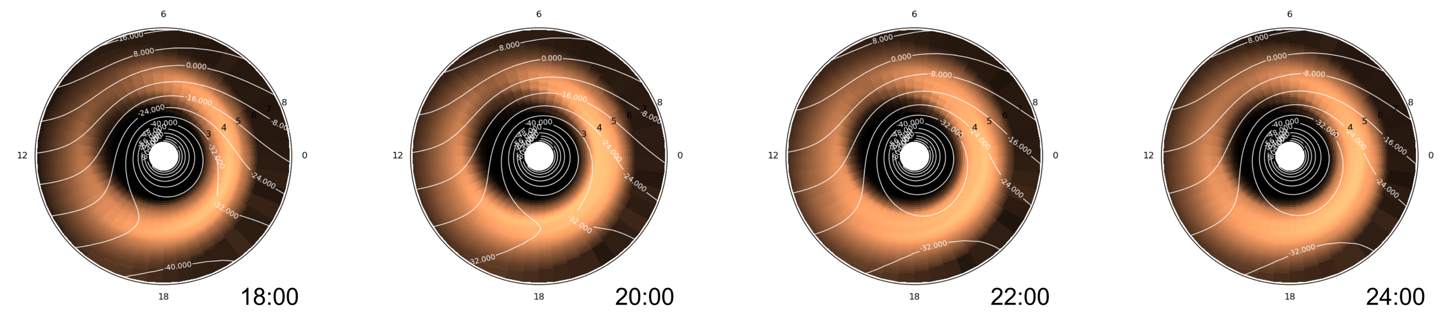
Plasmasphere



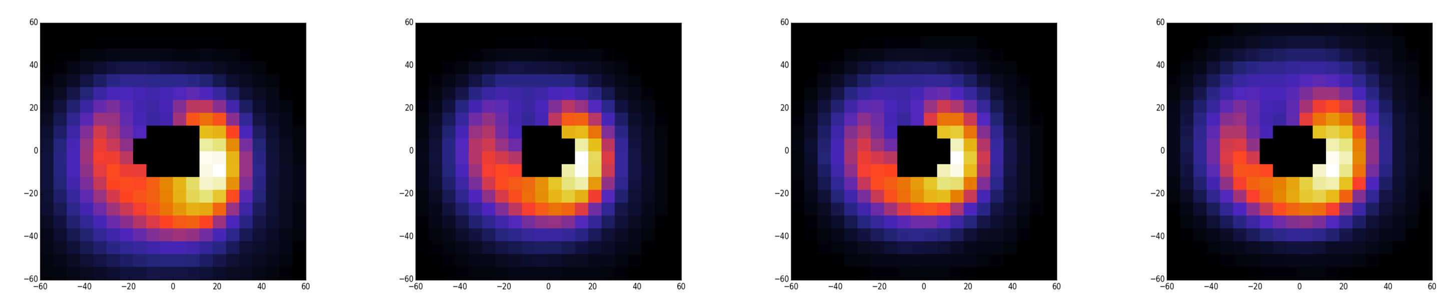
Artifical EUV data



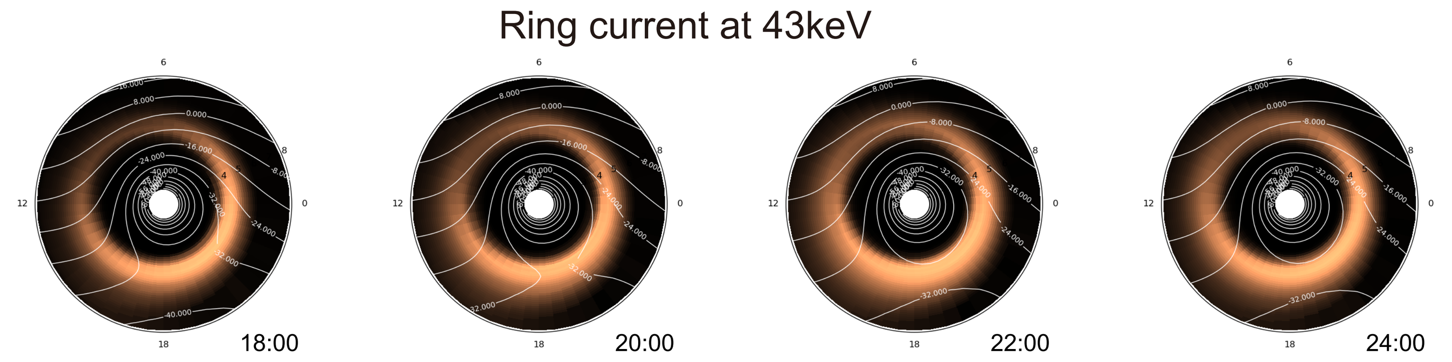
Ring current at 21keV



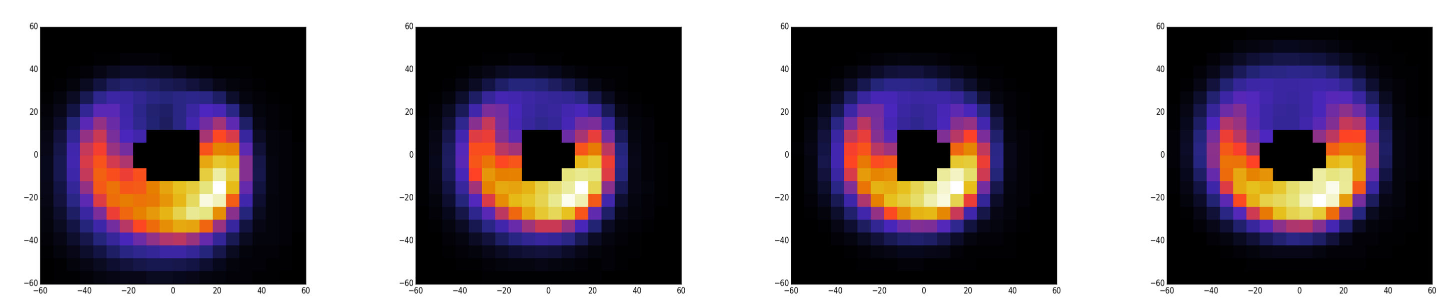
Artifical ENA data at 21keV



Ring current at 43keV

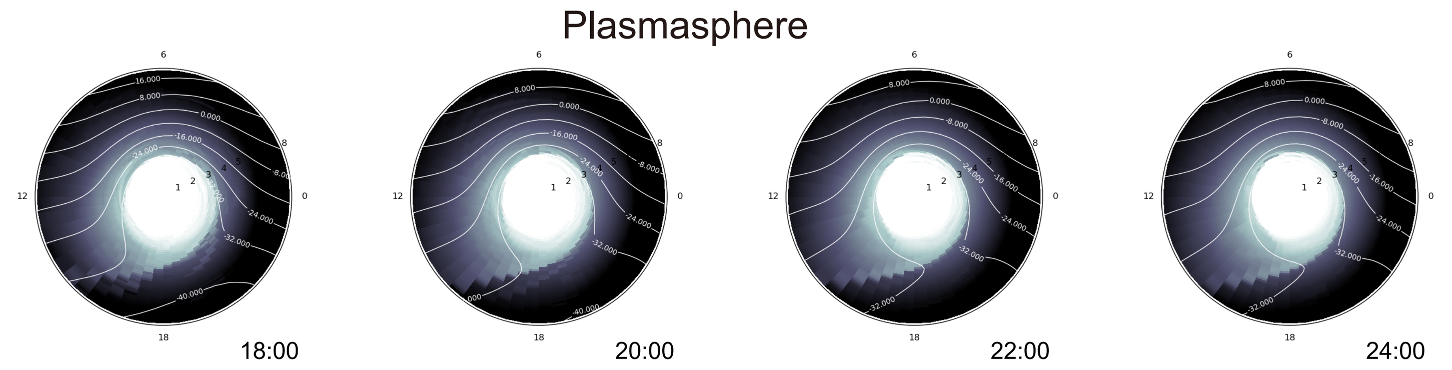


Artifical ENA data at 43keV

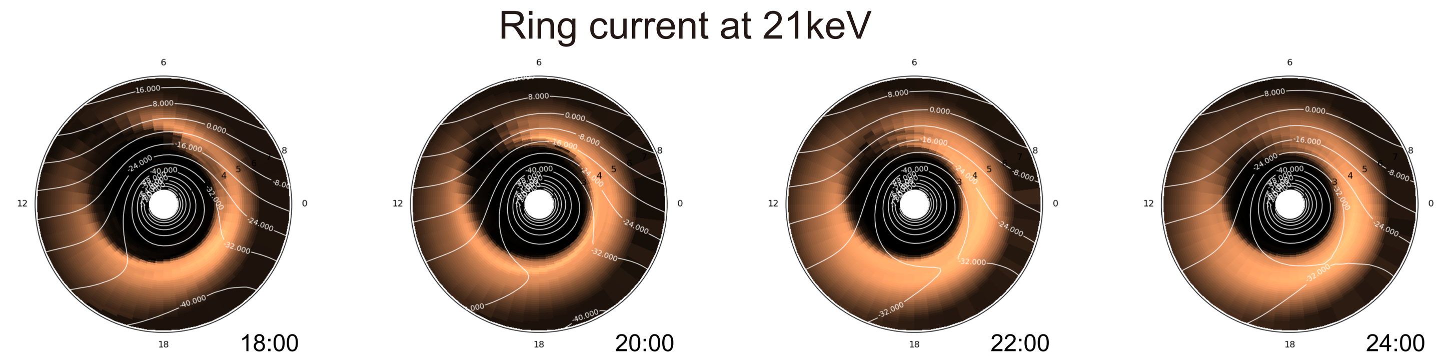


Result of the experiment with the artificial data

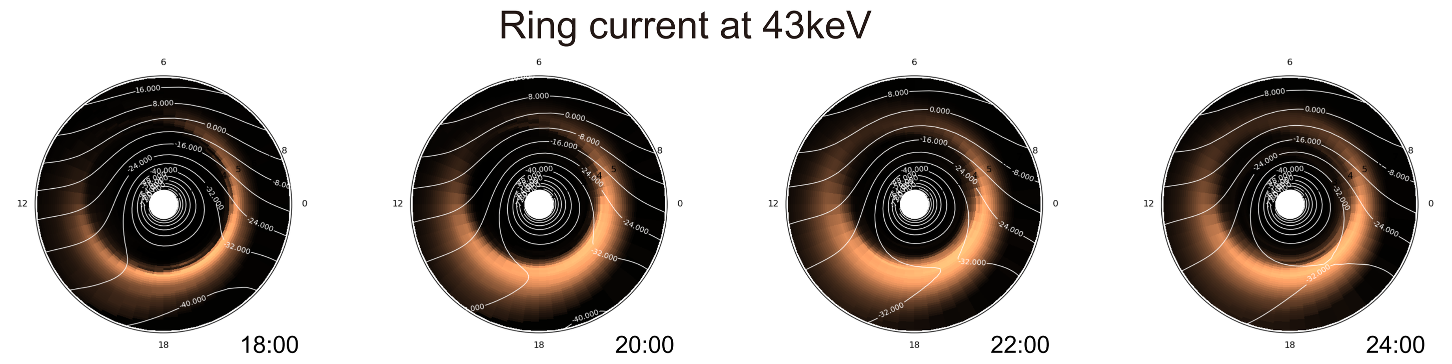
Plasmasphere



Ring current at 21keV



Ring current at 43keV



Future tasks:

At present, the spatial pattern of the electric potential is assumed to be constant over time. But, this should be resolved.

It is also necessary to implement the estimation of the initial state of the plasmasphere.

References

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