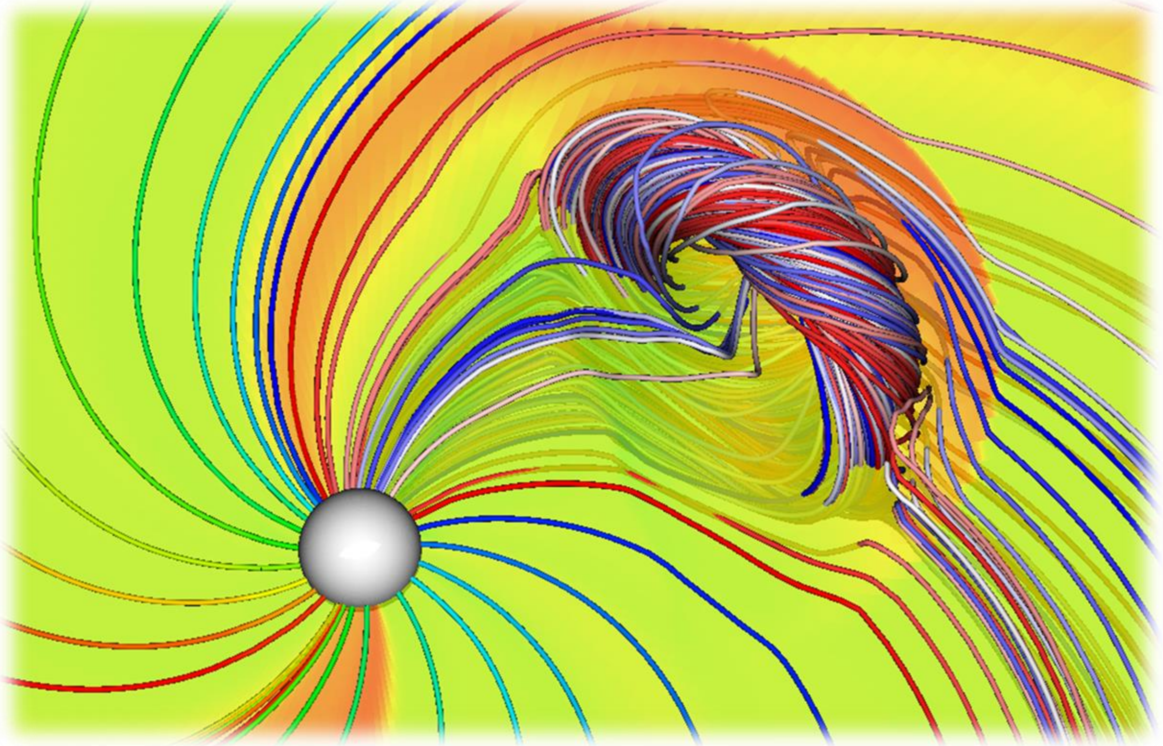
Studying the spheromak rotation for realistic CME modelling with EUHFORIA and its dependency on initial model parameters

EGU General Assembly 2022

euhforia



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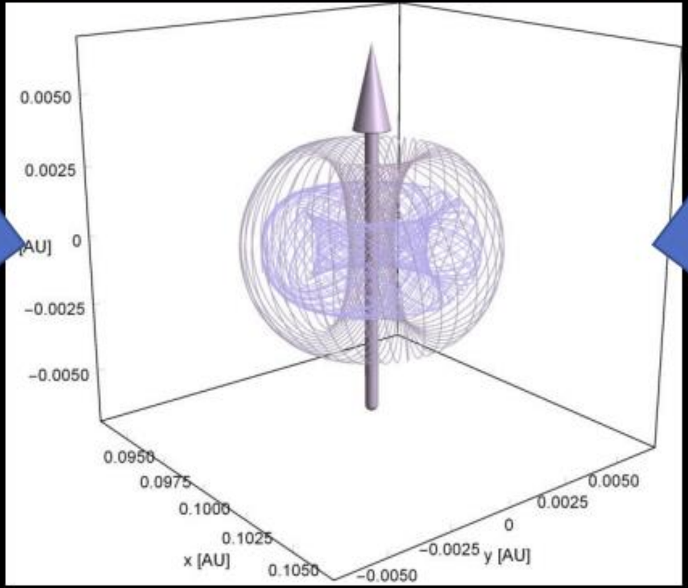
Spheromak rotation due to tilting instability

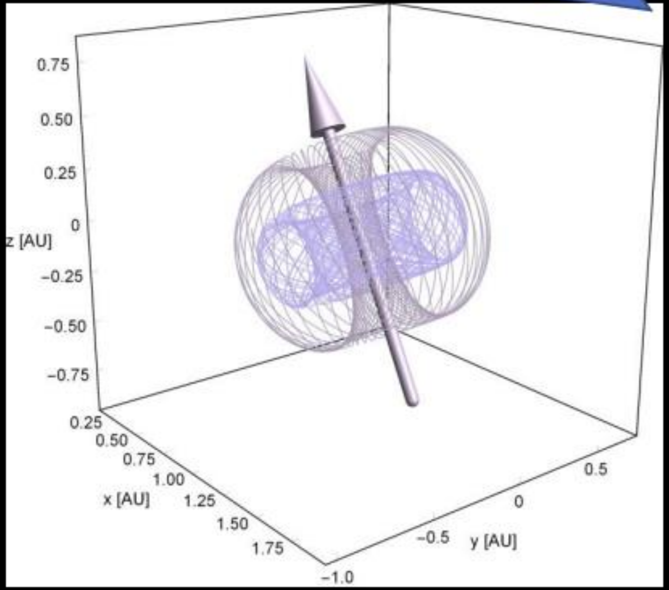
Asvestari et al. 2022
[ST4.1, EGU22-8908]

Initial spheromak orientation

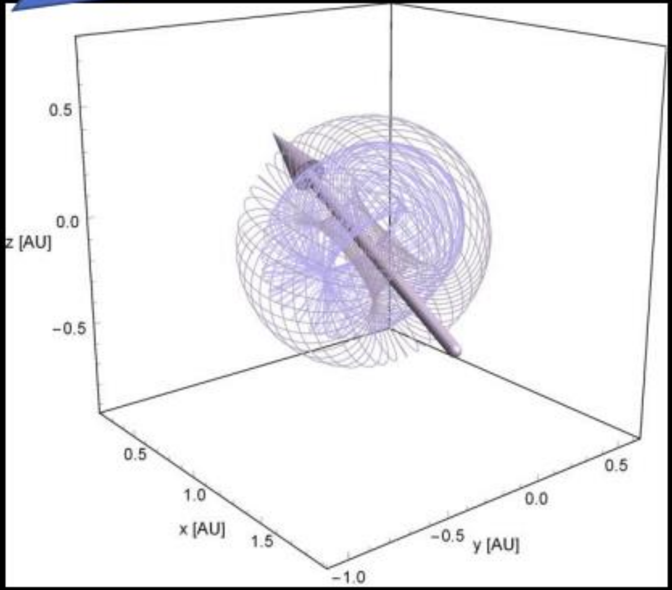


Spheromak inserted in **weak** ambient field

Spheromak inserted in **strong** ambient field

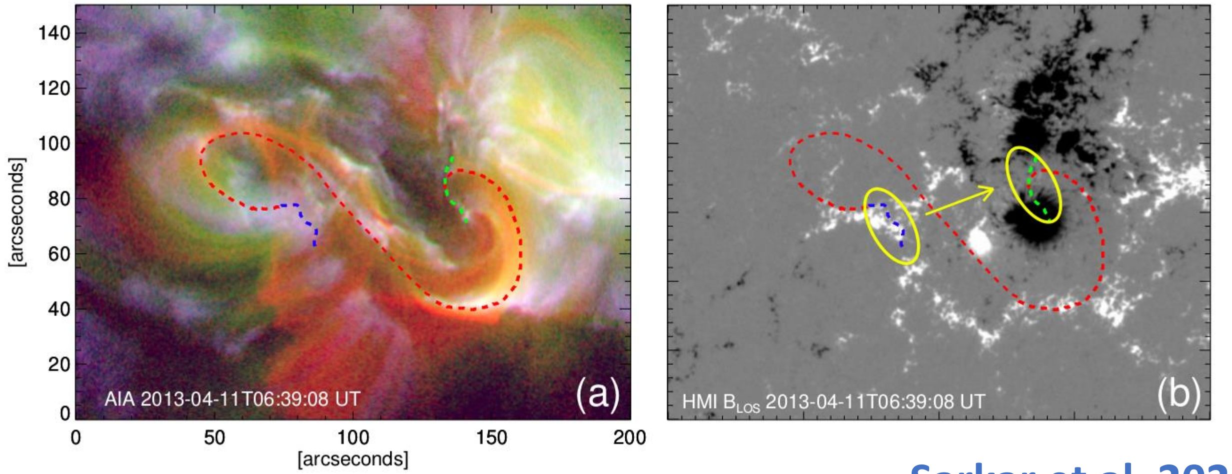


Upon insertion the spheromak starts interacting with the ambient magnetic field and starts rotating (tilting) - its magnetic moment tries to align with the ambient magnetic field in order to lower its magnetic potential energy.



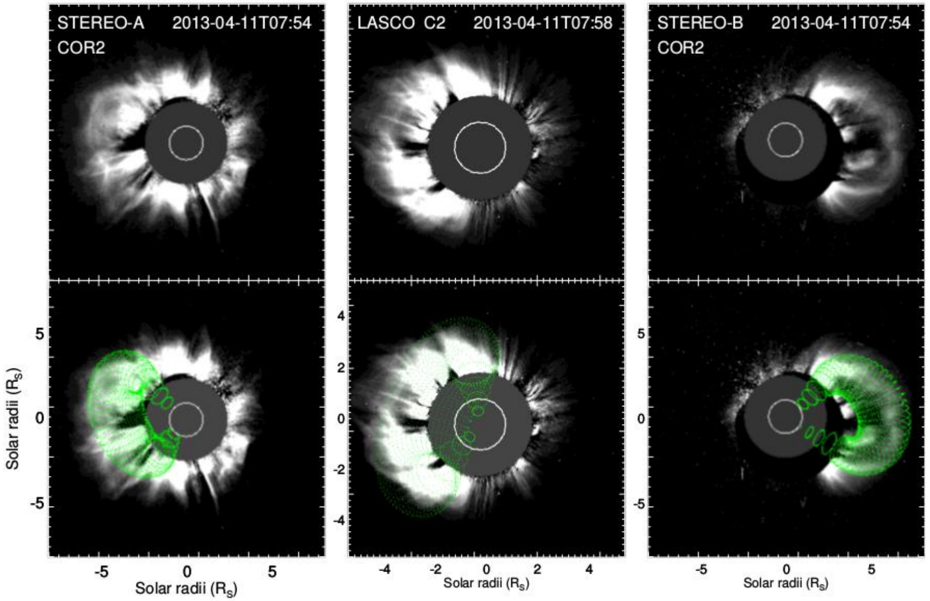
EUHFORIA run with observationally constrained parameters for the CME event on 2013 April 11

Direction of the flux-rope axial field

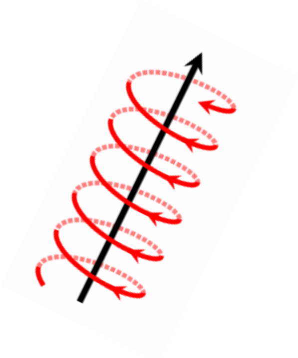


Sarkar et al. 2020

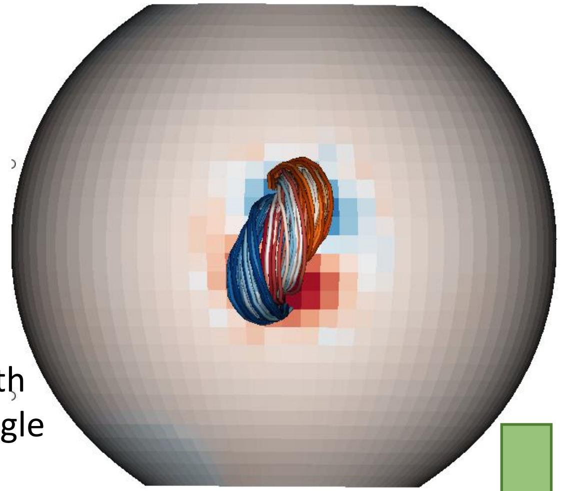
Tilt angle of the flux-rope obtained from GCS Reconstruction



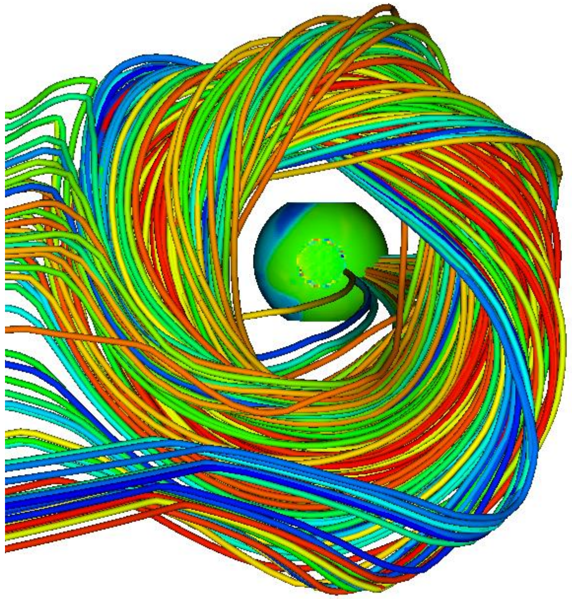
Spheromak tilt during its insertion at 0.1 AU



Northward directed flux-rope with left-handed chirality and a tilt angle of 70° w.r.t ecliptic plane

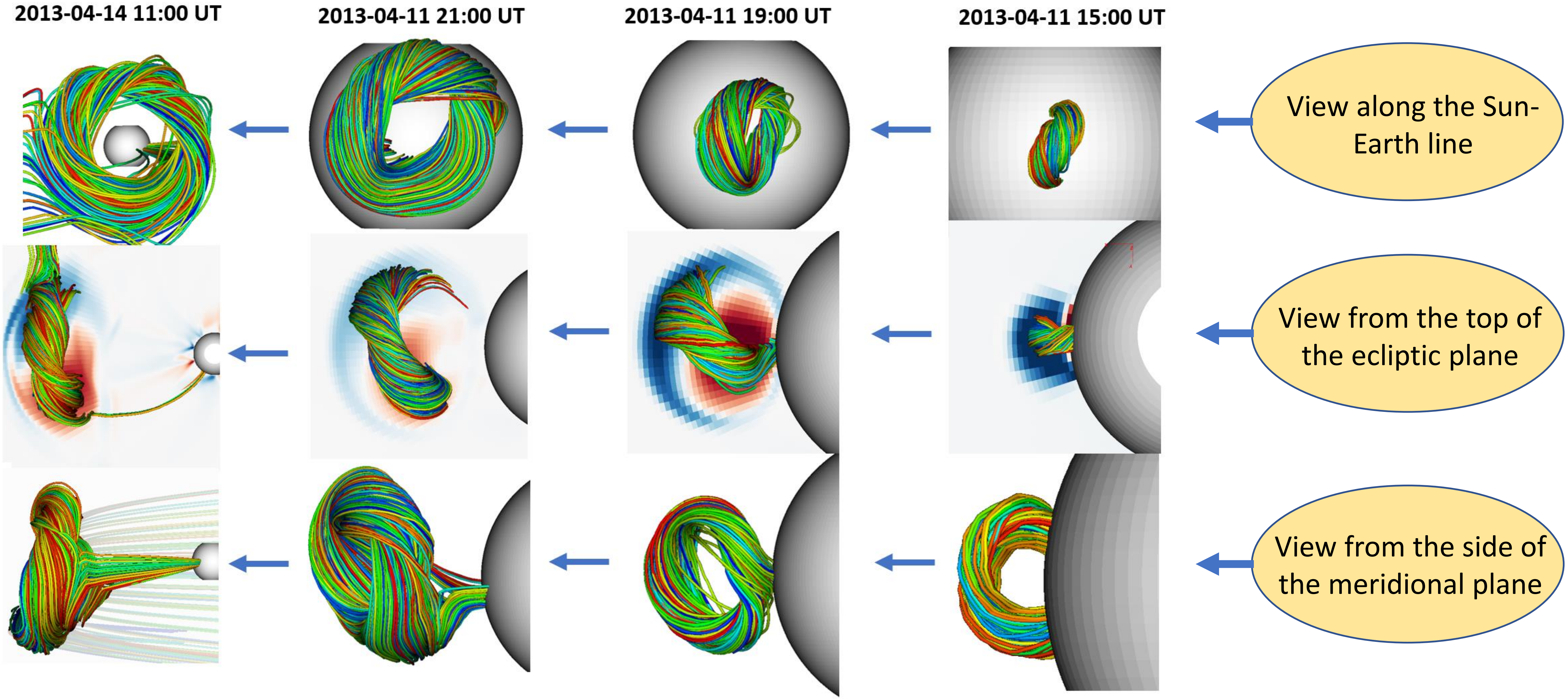


Spheromak tilt at 1 AU



The axis of symmetry of the spheromak undergoes approximately 90° of rotation and nearly aligns along the Sun-Earth line

Rotation of the spheromak magnetic axis as observed from different viewing angle

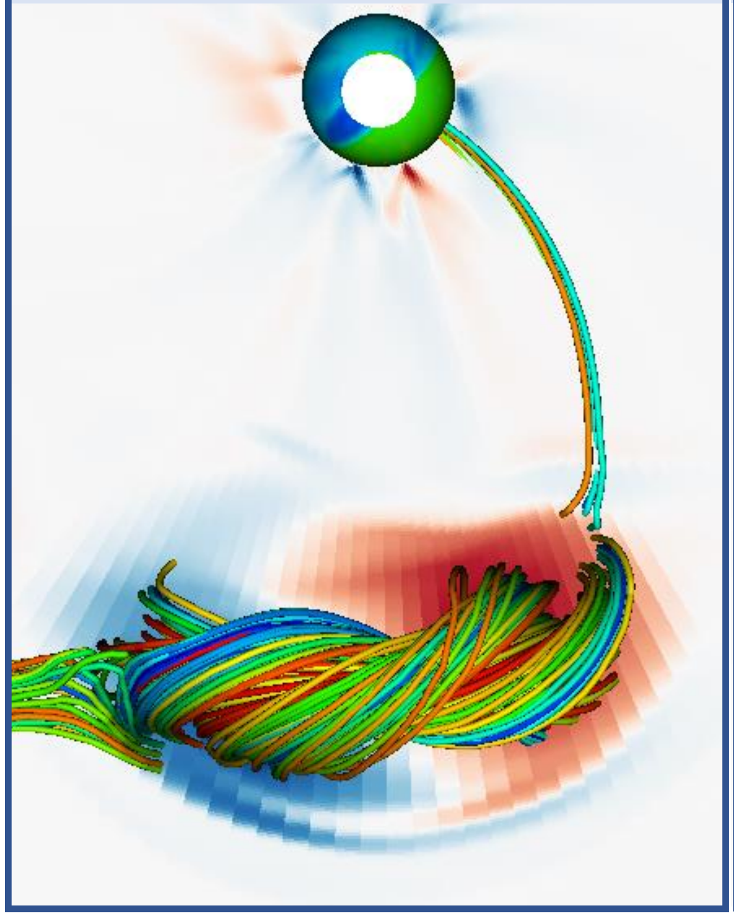


The large rotation of the spheromak is in line with the recent finding of 'Spheromak-tilting-instability' as reported in Asvestari et al. 2022

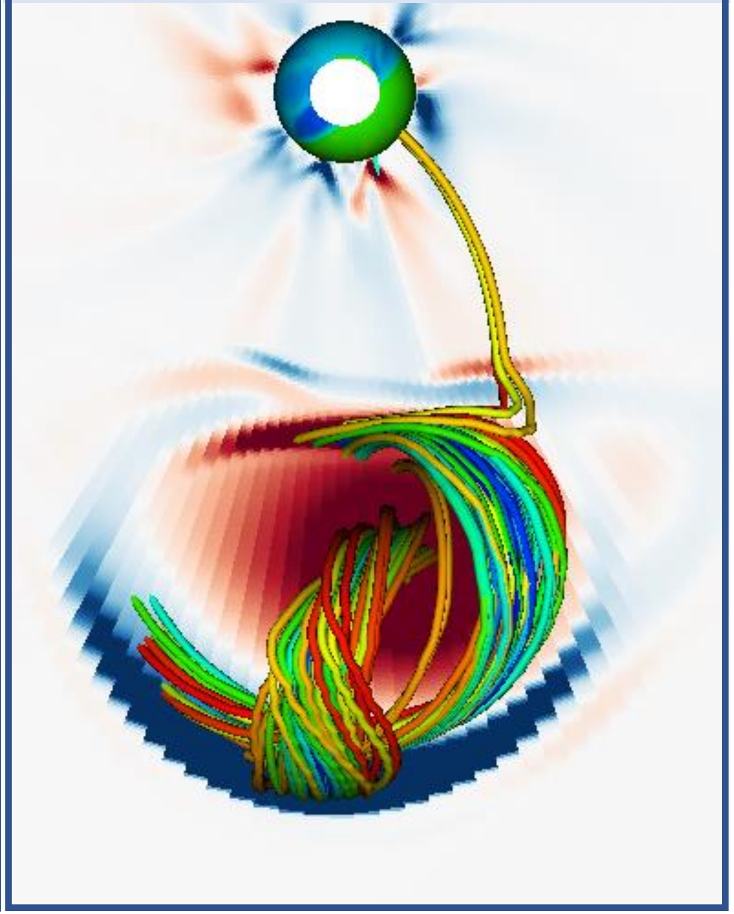
Effect of density on spheromak rotation

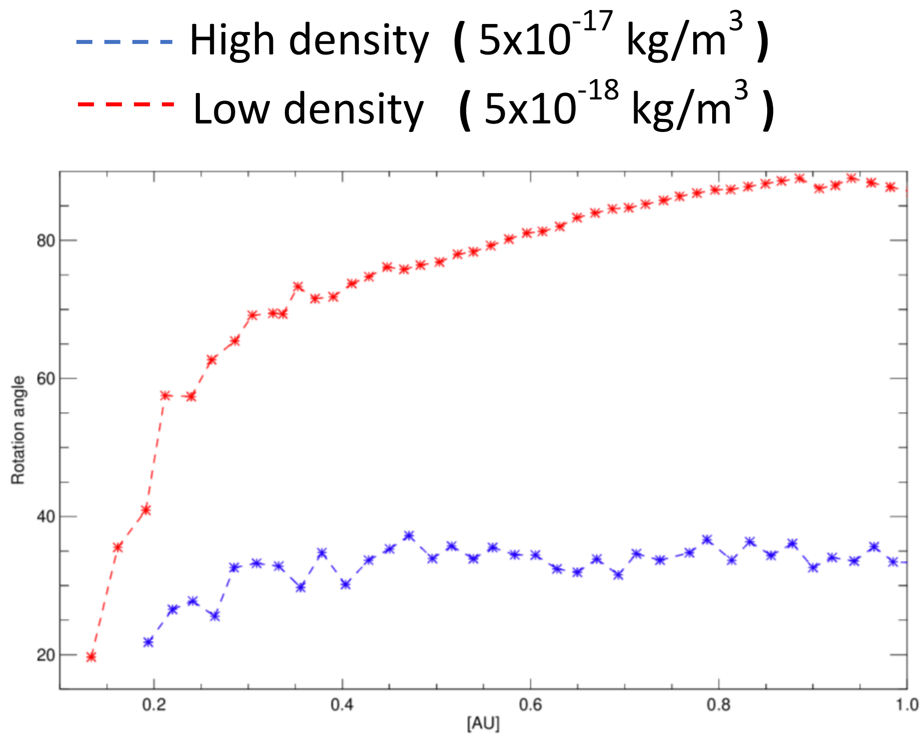
Recent observational study show that the average CME density at 20 solar radii ranges between 10^{-18} to 10^{-17} kg/m^3 (Temmer et al. 2021). Therefore, we conduct a set of EUHFORIA simulations by using different density values within the range 10^{-18} to 10^{-17} kg/m^3

Spheromak with nominal density
(5×10^{-18} kg/m^3)



Spheromak with higher density
(5×10^{-17} kg/m^3)

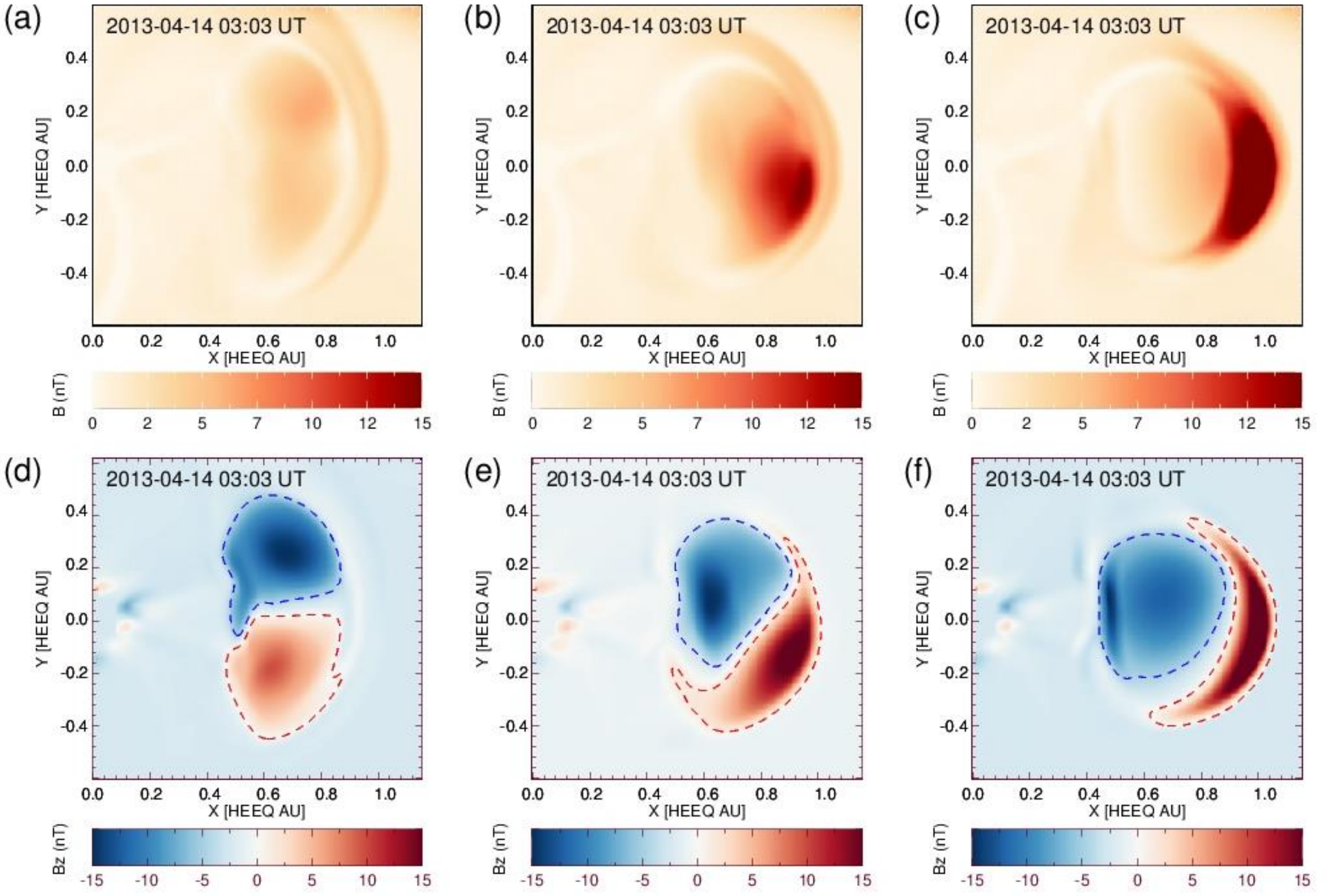




Spheromak rotation is less in case of higher densities.

Evolution of spheromak with different density values

Low Density	Moderate Density	High Density
(0.5×10^{-17} kg/m^3)	(1×10^{-17} kg/m^3)	(5×10^{-17} kg/m^3)



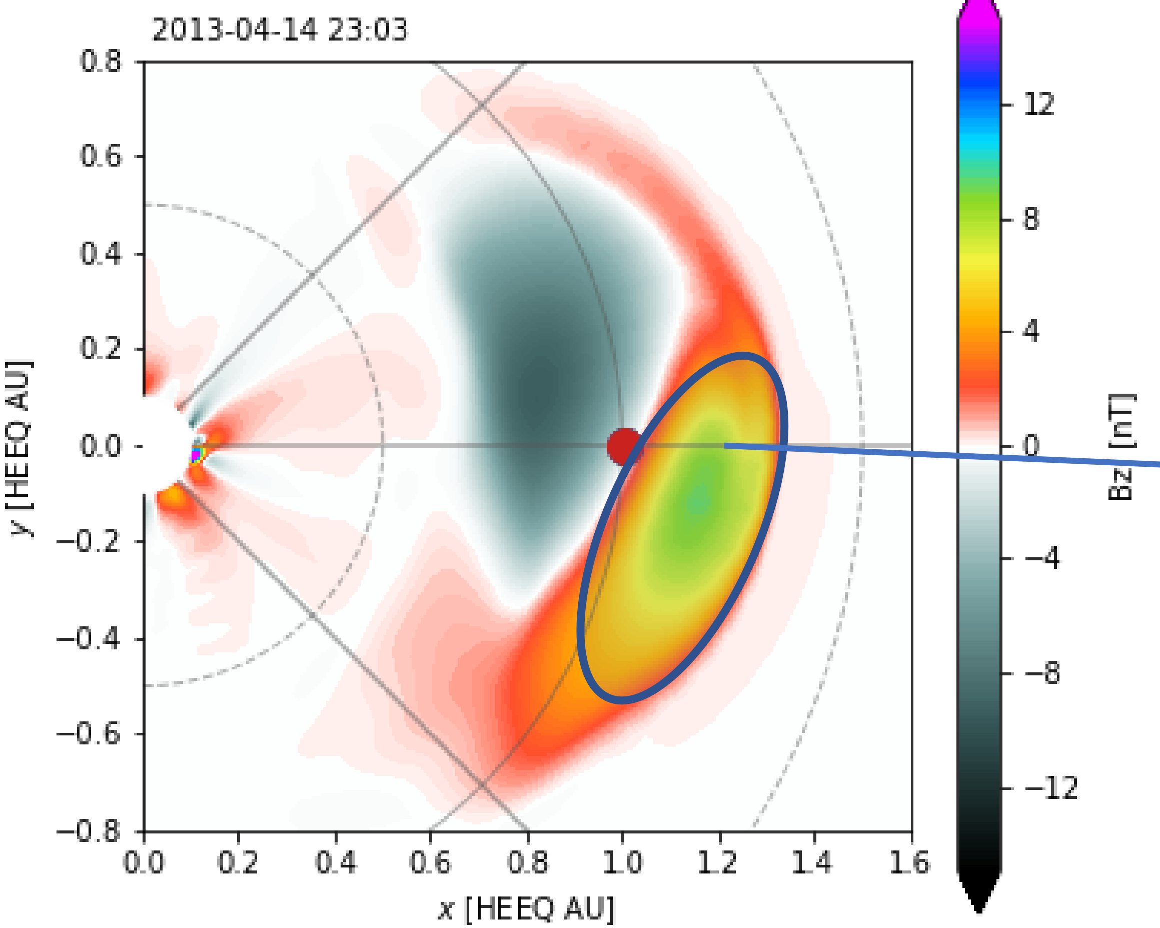
Magnetic field-strength (IBI) plot on the ecliptic plane

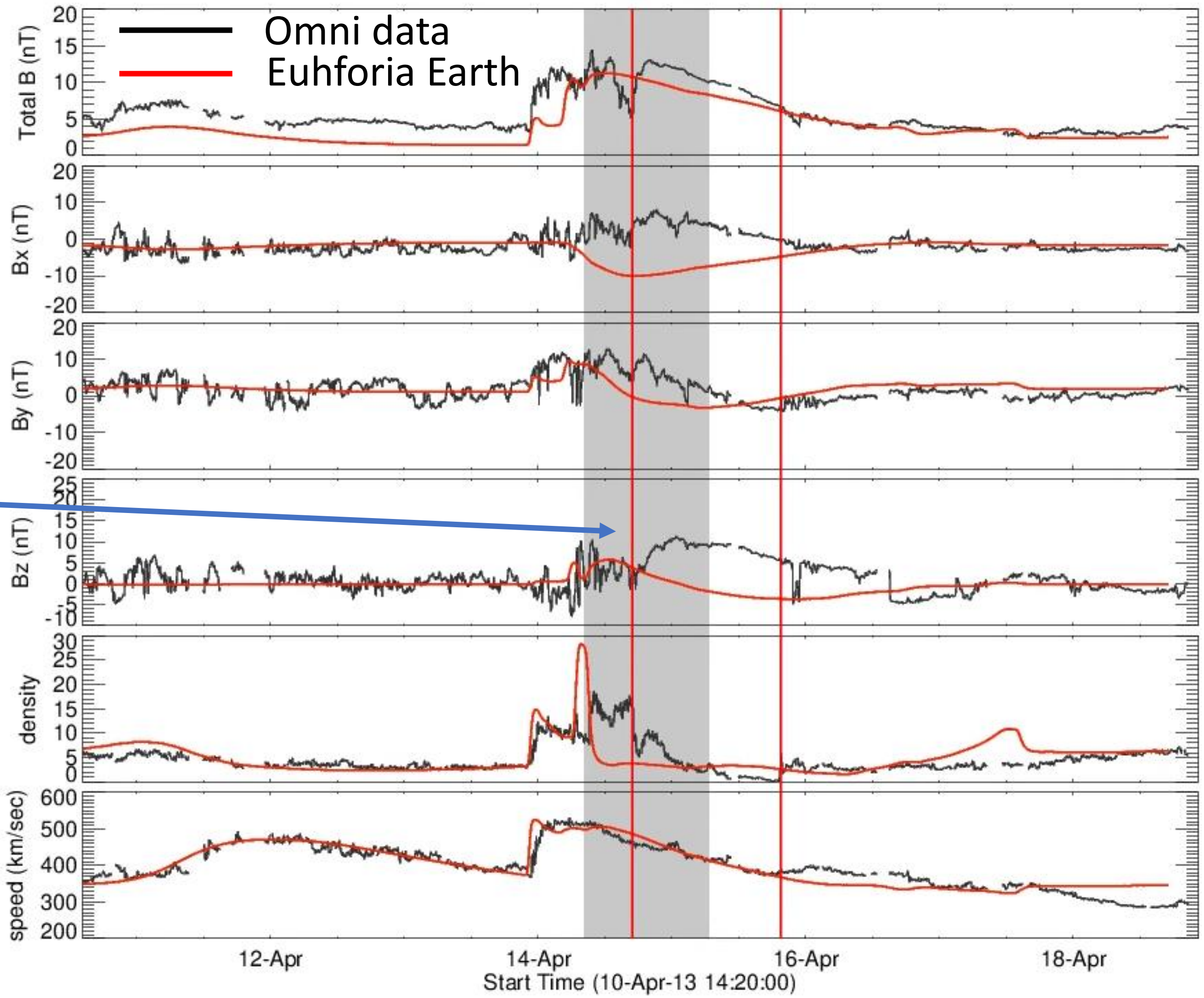
Bz plot on the ecliptic plane

The high-density spheromaks undergo significant compression at the front as compared to the low-density ones

Comparison of model results with in-situ observations

Bz plot on the ecliptic plane

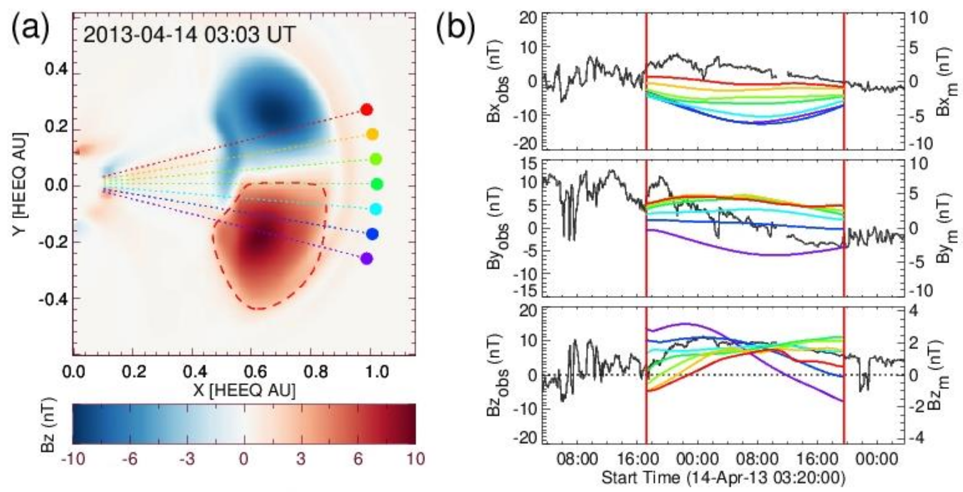




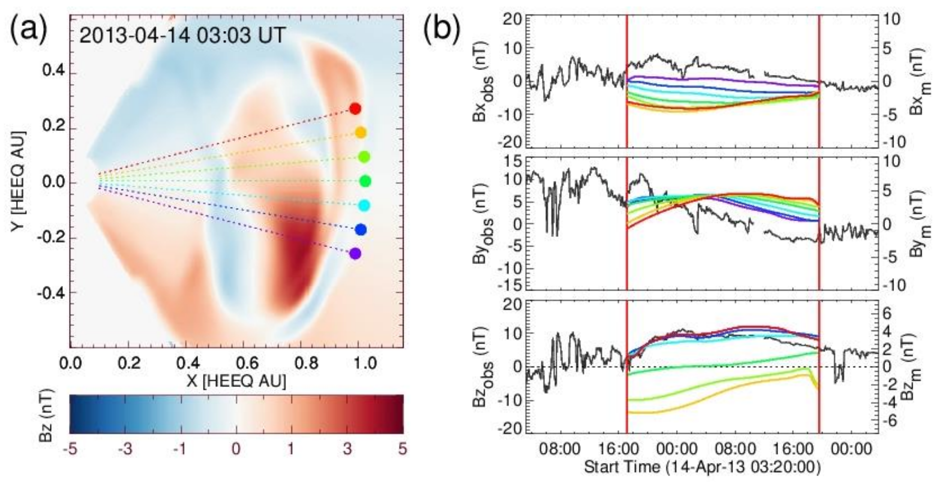
In stead of comparing the magnetic profile of the whole spheromak with that of the observed magnetic cloud at 1 AU, it is important to compare only the part of the spheromak which is constrained from the observation

Assessing the effect of spheromak rotation on Bz prediction

Virtual spacecrafts on the **ecliptic plane**

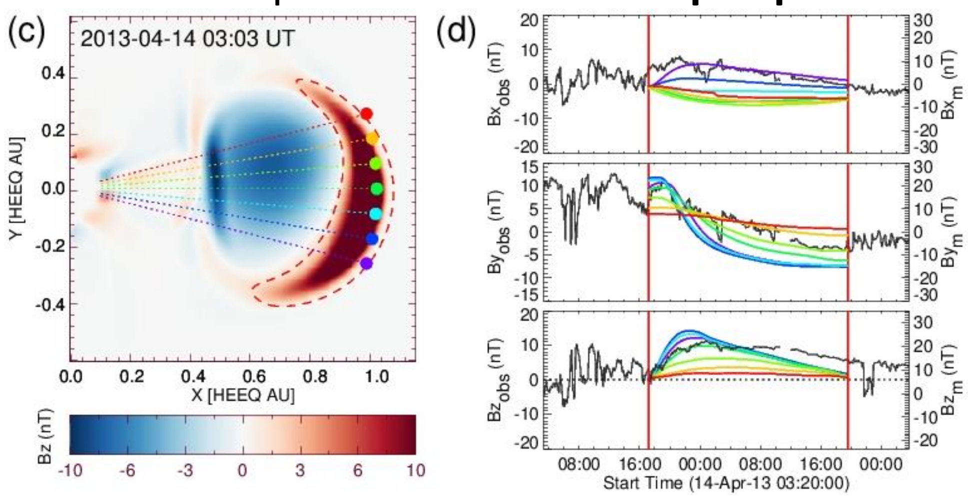


Virtual spacecrafts on the **meridional plane**

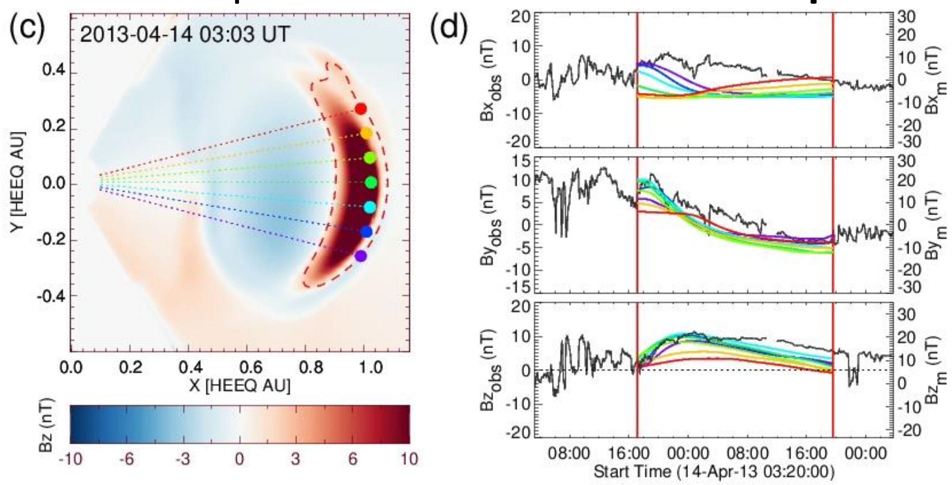


In-situ assessment for the low density spheromak that undergoes large rotation due to tilting instability

Virtual spacecrafts on the **ecliptic plane**



Virtual spacecrafts on the **meridional plane**



In-situ assessment for the high density spheromak that do not undergo any significant rotation

Uncertainty in Bz prediction significantly reduces in absence of large rotation (due to tilting instability) of a spheromak

Summary

- ***We study the spheromak rotation and its dependency on initial model parameters for an Earth impacting CME event on 2013 April 11. The simulation results show that for a nominal density value of the spheromak, its axis of symmetry undergoes approximately 90^0 of rotation and nearly aligns along the Sun-Earth line. This is in line with the finding of 'Spheromak-tilting-instability' as reported in Asvestari et al. 2021.***

- ***Running a set of simulations by using different density values within the observed range, we find that spheromak rotation is lesser in case of higher densities. However, the high-density spheromaks undergo significant compression at the front as compared to the low-density ones.***

- ***In stead of comparing the magnetic profile of the whole spheromak with that of the observed magnetic cloud at 1 AU, we compare only the part of the spheromak which is constrained from the near-Sun observations. Following this approach, we find a good agreement between modelled and observed profile of Bz.***

- ***Uncertainty in Bz prediction significantly reduces in absence of large rotation (due to tilting instability) of a spheromak***

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Sarkar et al. 2022 (In preparation)