Multipoint in situ observations near L1 and their relevance to improved space weather prediction

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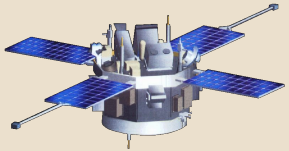
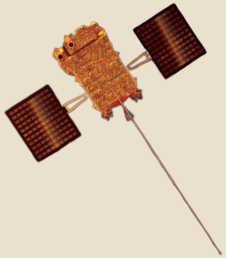
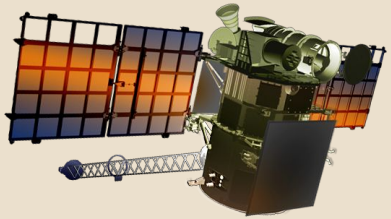
Golden era for L1 Solar wind monitors : In situ field and particles



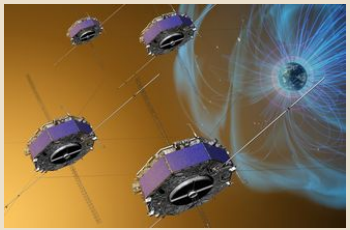
ACE



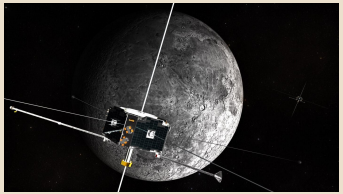
Aditya-L1



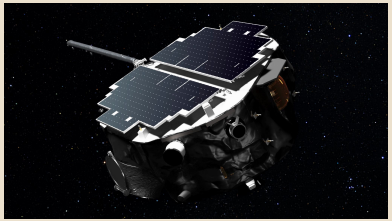
DSCOVR



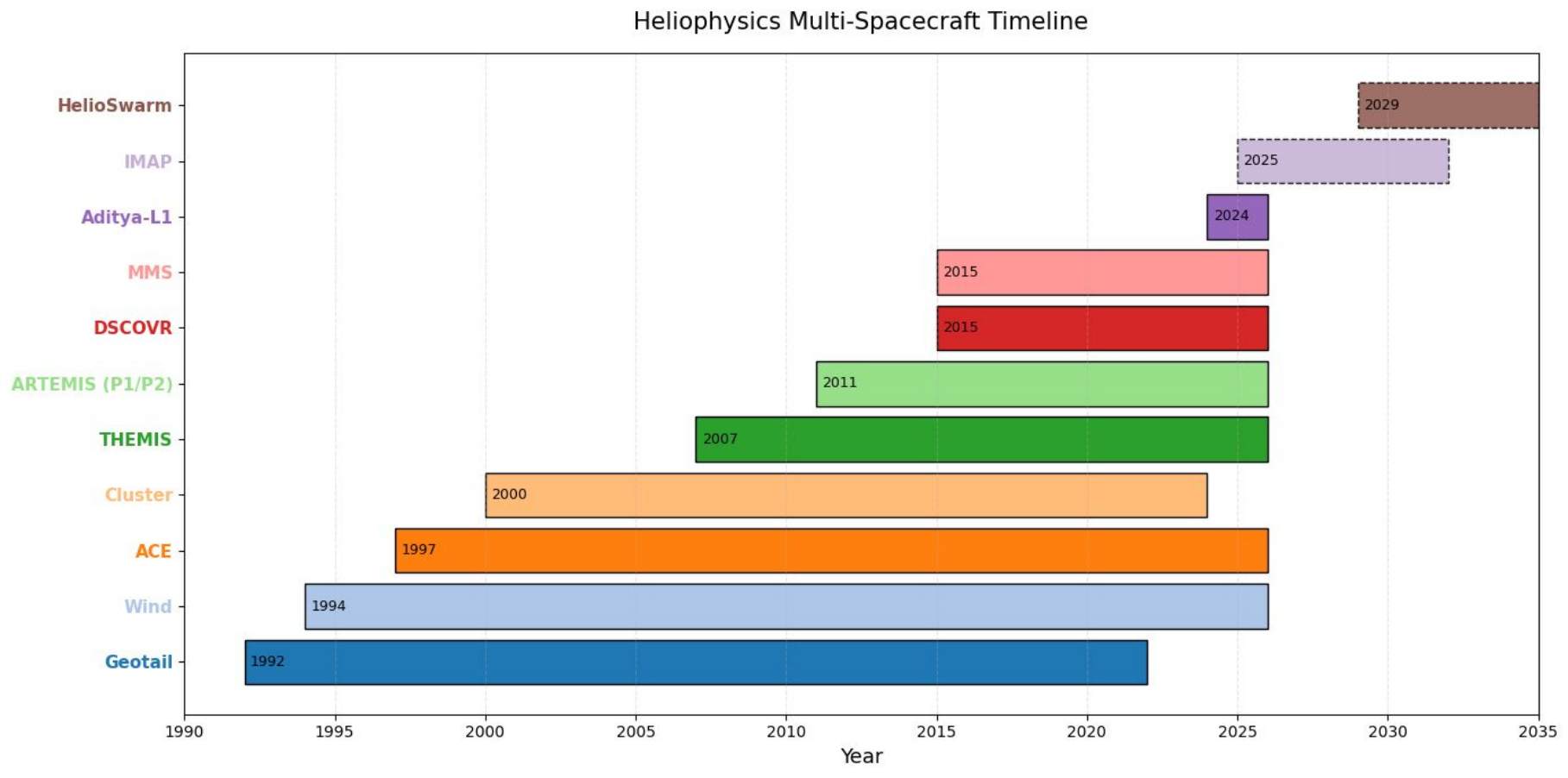
MMS

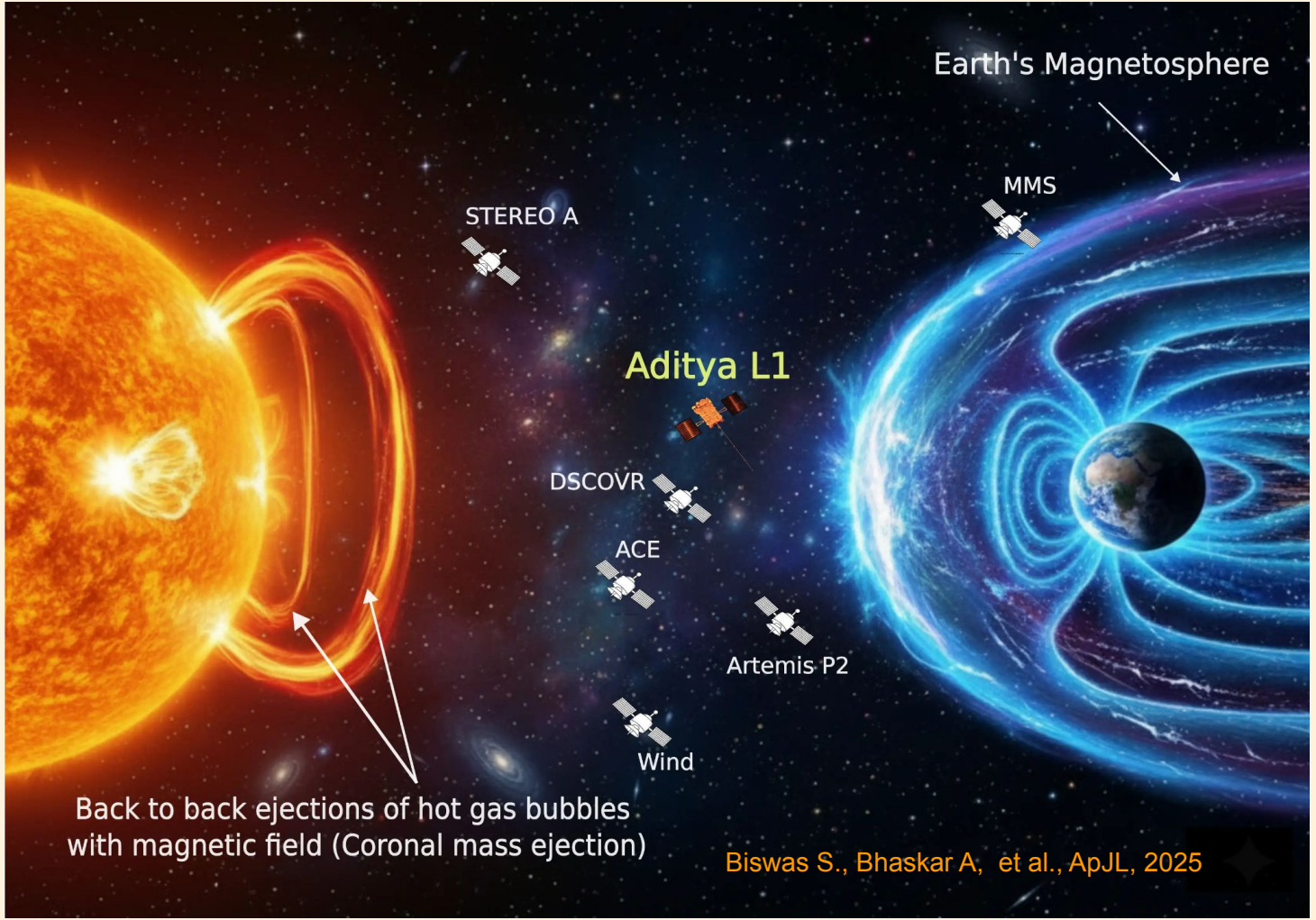


Artemes,
P1, P2



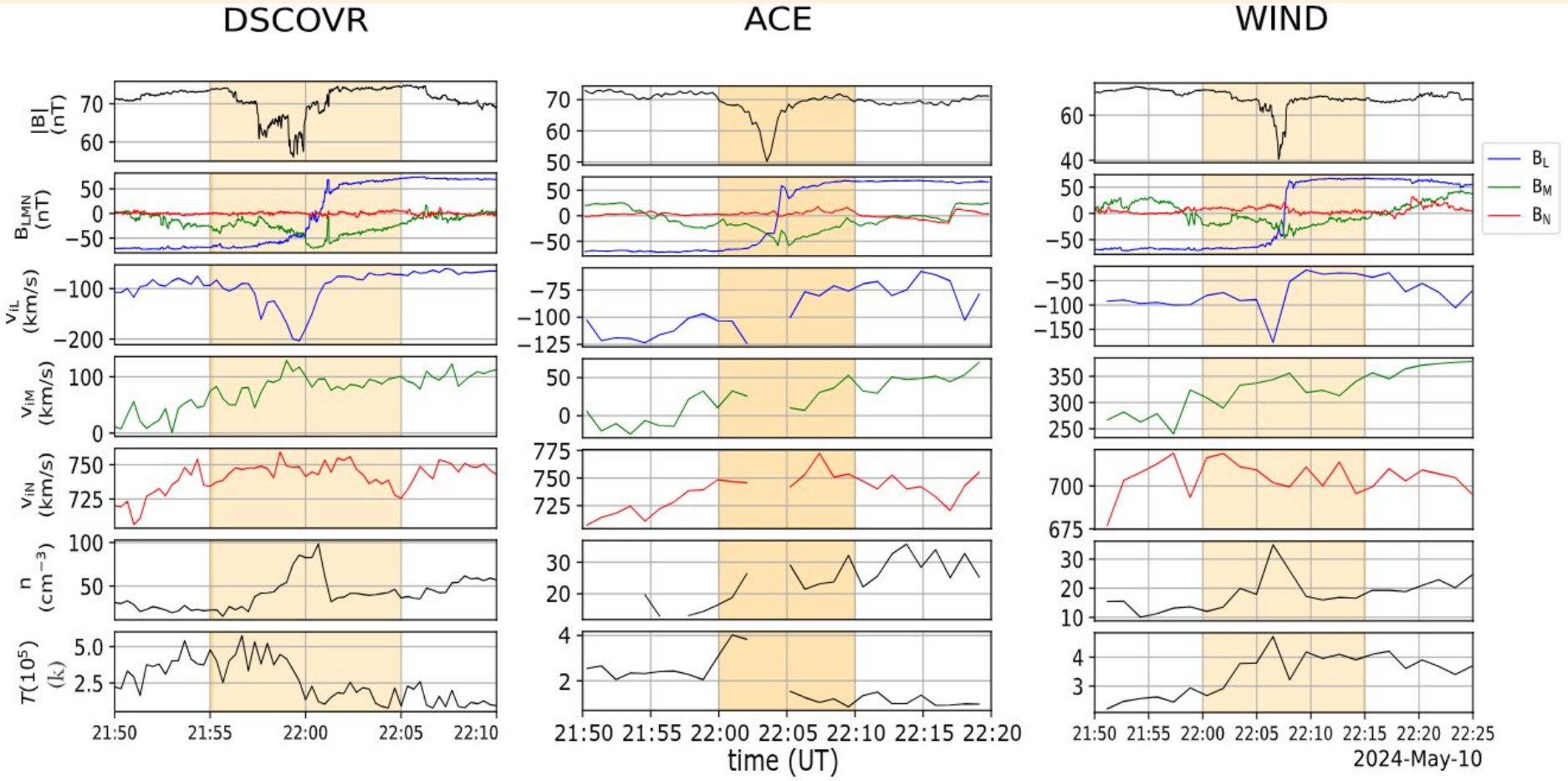
IMAP


Heliophysics Multi-Spacecraft Timeline
HelioSwarm
IMAP
Aditya-L1
MMS
DSCOVR
ARTEMIS (P1/P2)
THEMIS
Cluster
ACE
Wind
Geotail
2029
2025
2024
2015
2015
2011
2007
2000
1997
1994
1992
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Year

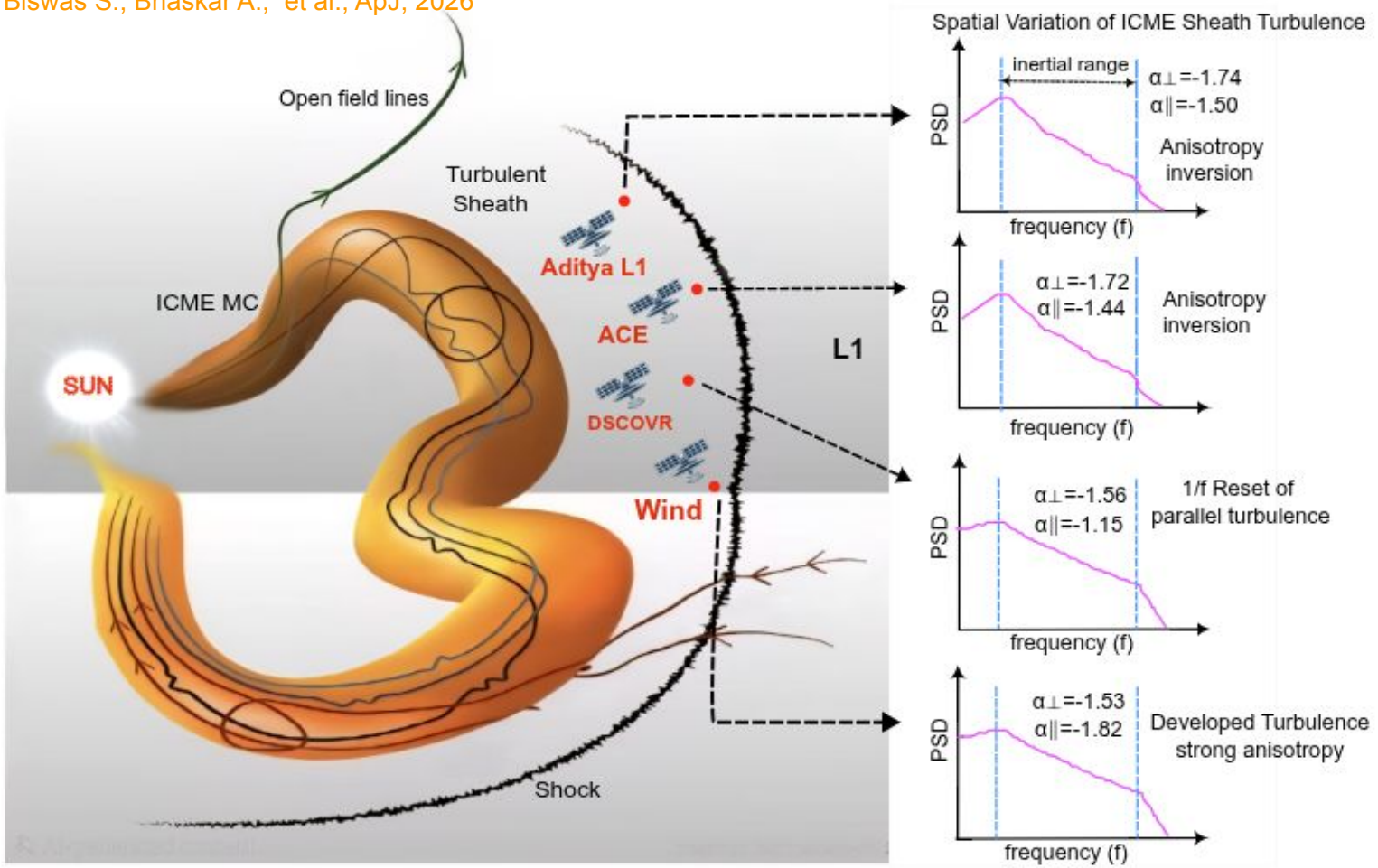

Earth's Magnetosphere
MMS
STEREO A
Aditya L1
DSCOVR
ACE
Artemis P2
Wind
Back to back ejections of hot gas bubbles
with magnetic field (Coronal mass ejection)
Biswas S., Bhaskar A, et al., ApJL, 2025

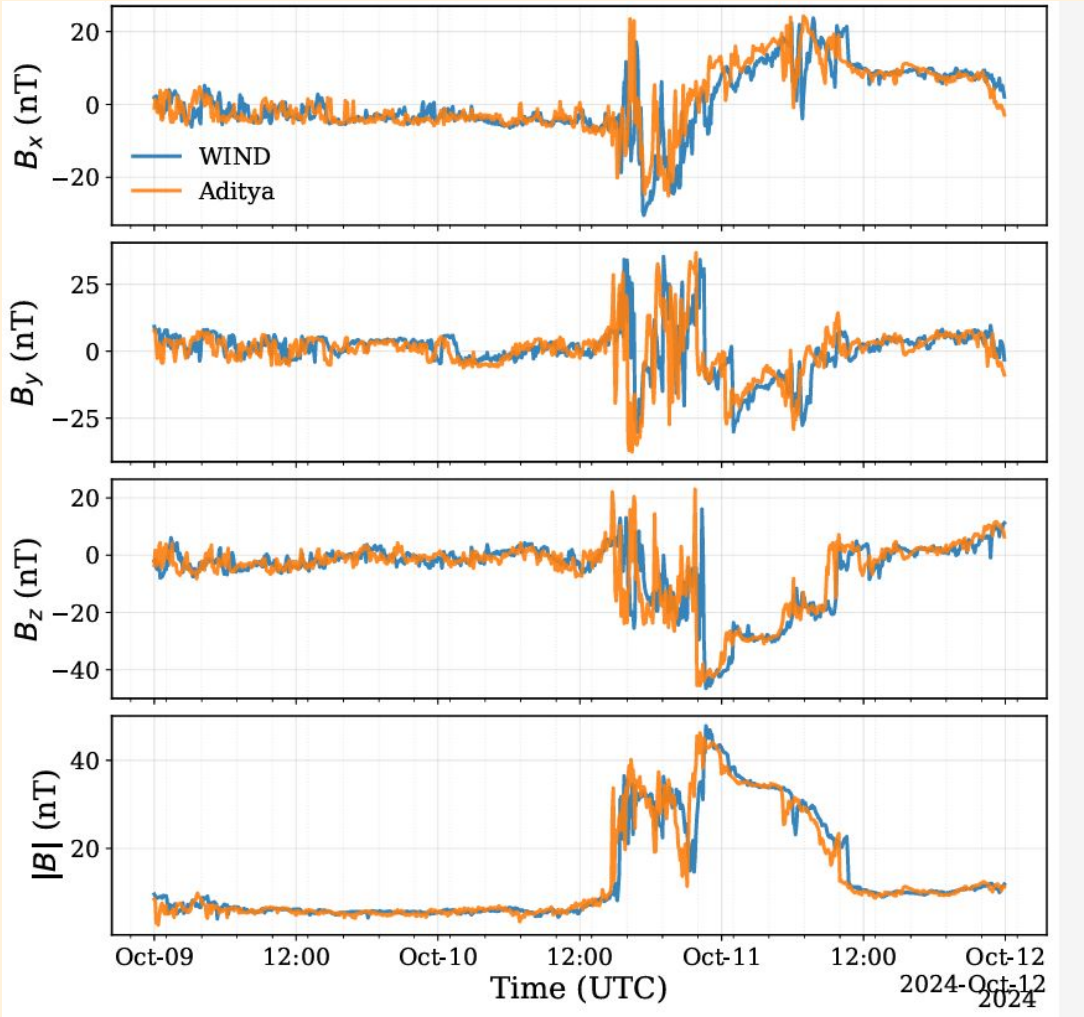
Multipoint investigation of magnetic reconnection within ICME

Biswas S., Bhaskar A, et al.,
ApJL, 2025



Biswas S., Bhaskar A., et al., ApJ, 2026




B_x (nT)
20
0
−20
WIND
Aditya
B_y (nT)
25
0
−25
B_z (nT)
20
0
−20
−40
|B| (nT)
40
20
Oct-09
12:00
Oct-10
12:00
Oct-11
12:00
Oct-12
Time (UTC)
2024-Oct-12
2024

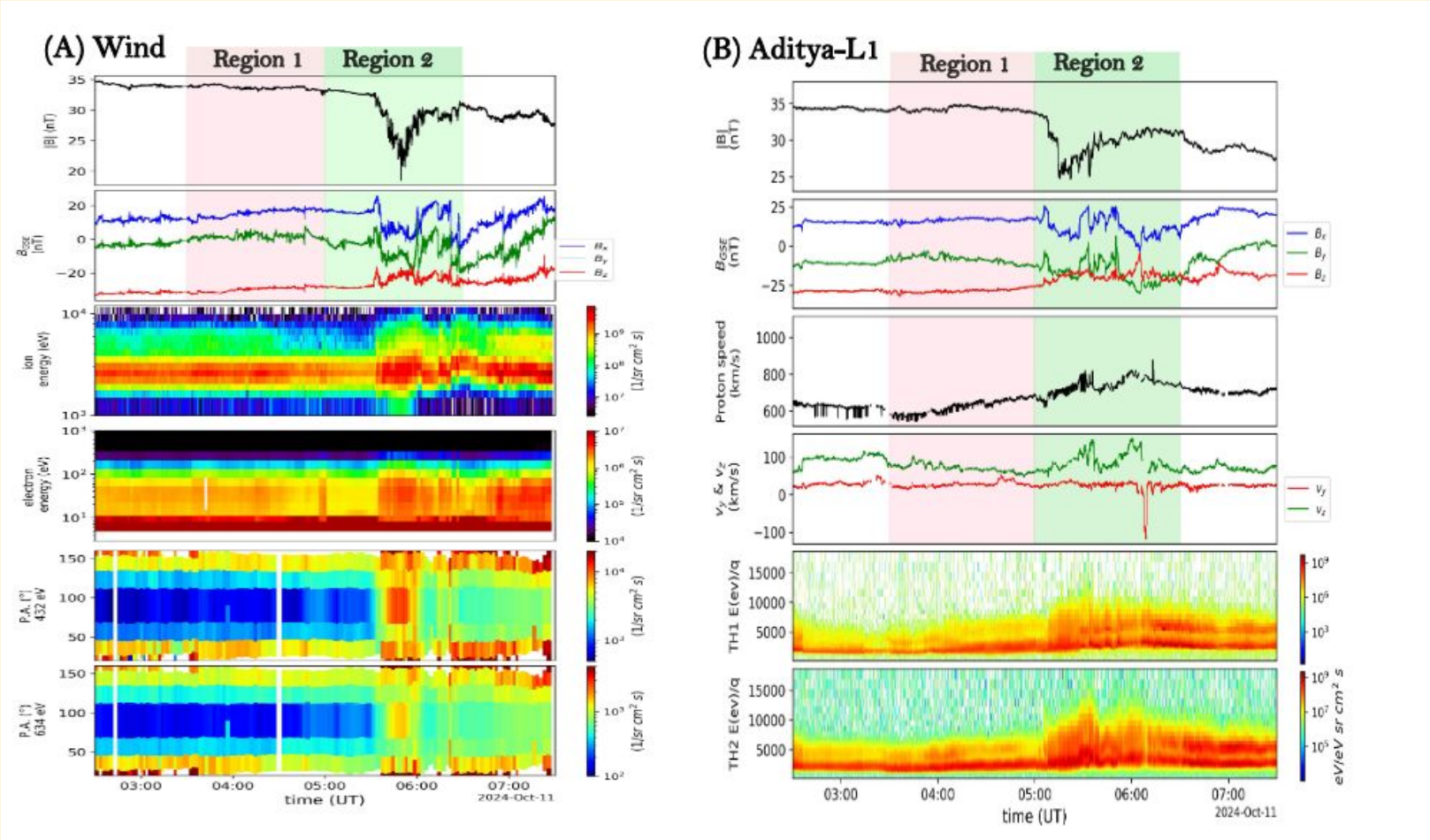
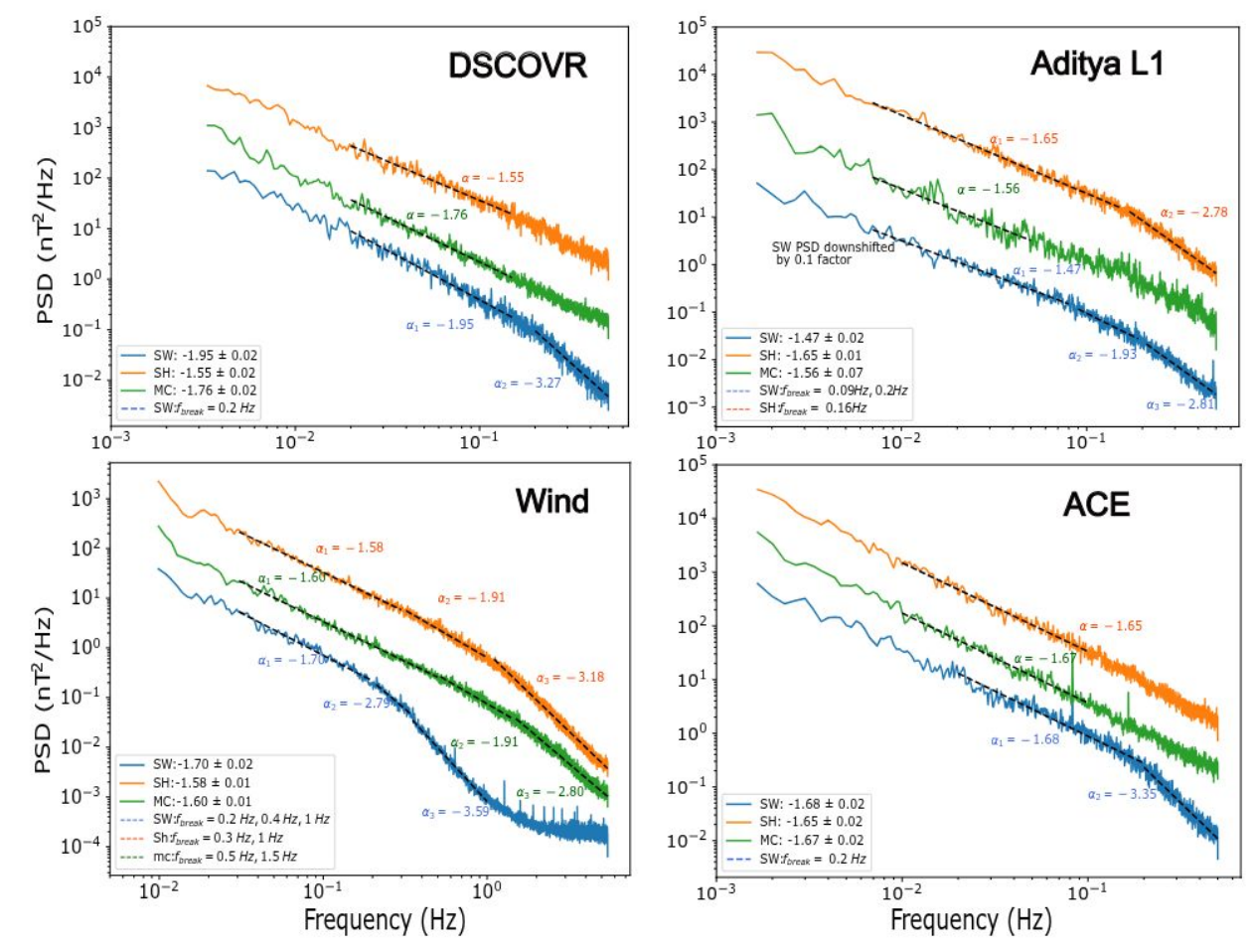


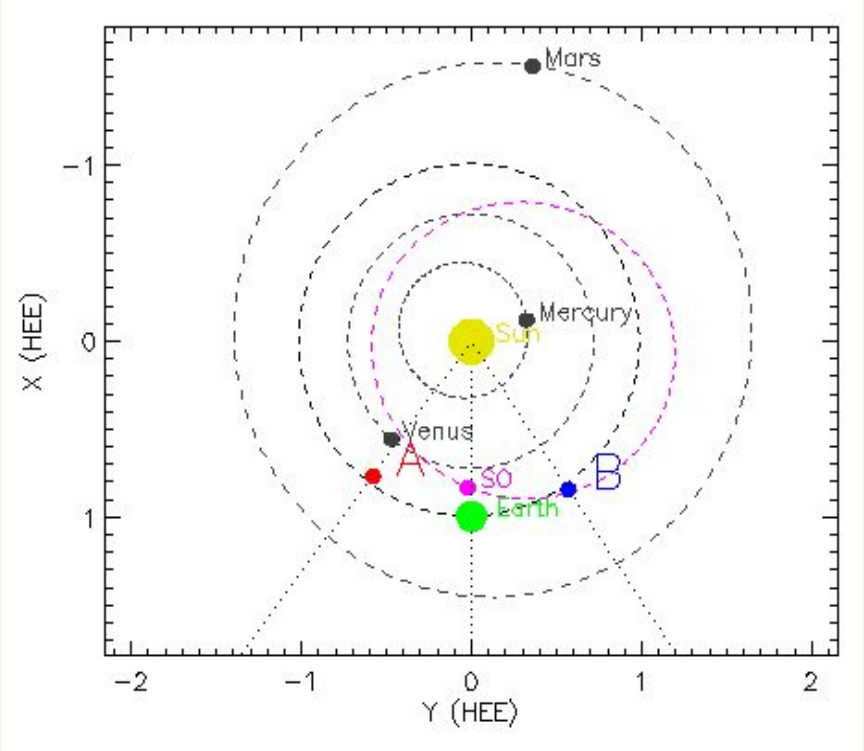
Figure shows magnetic field and plasma data from the two widely separated spacecrafts, Wind and Aditya-L1, in panels A and B, respectively.

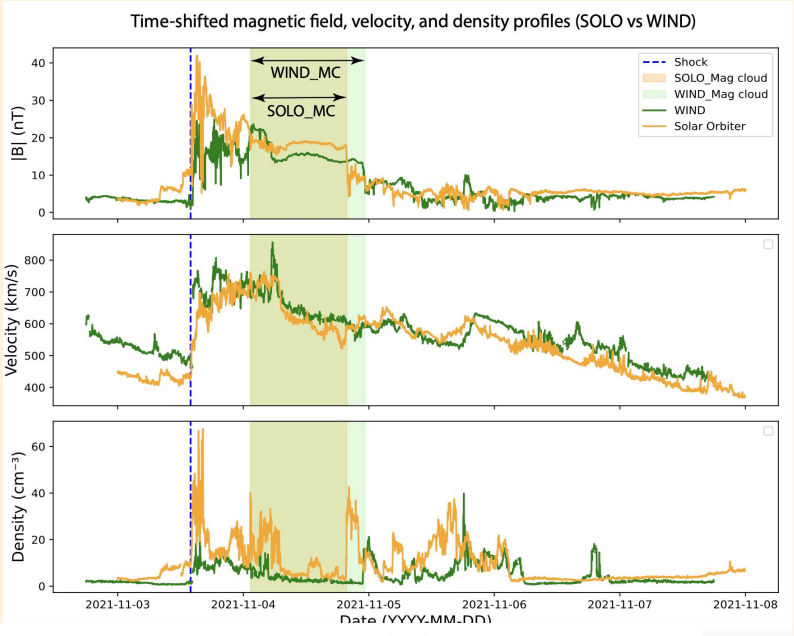
Multipoint investigation Spatially Varying ICME Turbulence of Different Ages

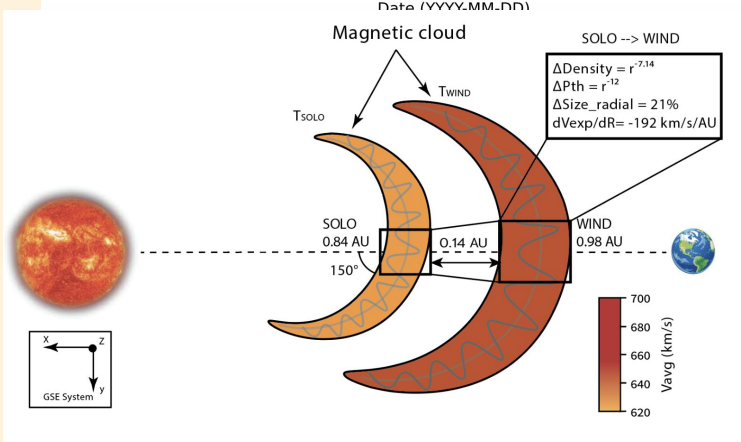


Biswas S. , Bhaskar A, et al., ApJ, 2026, In press

Multipoint obs. of Radial Evolution of ICME in 0.14 AU separation







Soni S., Bhaskar A, et al., MNRAS, 2026

Limitations of Single-Point observations

- Operational forecasting relies almost entirely on single-point L1 measurements from spacecraft like DSCOVR or ACE
- A single vantage point cannot capture the full 3D structure of complex solar wind transients like ICMEs

The Core Problem

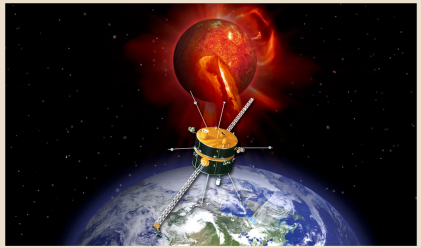
Solar wind structures are inherently heterogeneous in space and time. A single spacecraft measurement captures only one thread of an intricate tapestry.

– Missing fine-scale features, orientations information, and transient sub-structures that directly drive geomagnetic activity.

–Thus single-point measurements produce an incomplete upstream picture, introducing systematic uncertainties into every downstream forecast model.

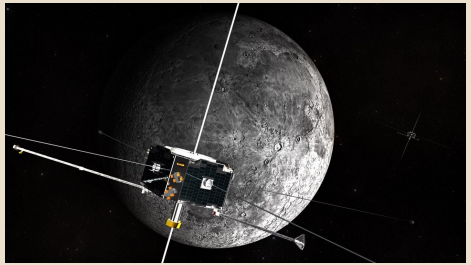
The L1 Constellation: A New Era of Observation

Unprecedented cluster of spacecraft now samples the solar wind near the Sun-Earth L1 point – nearly simultaneously and from multiple vantage points.



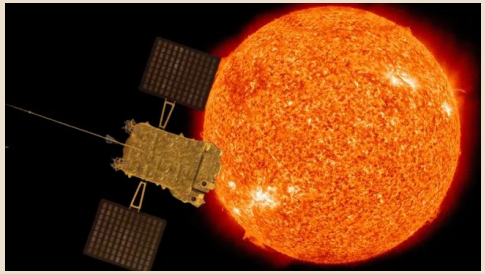
NASA Legacy Fleet

Wind, **ACE**, and **DSCOVR** provide decades of continuous in situ plasma and field data at L1, forming the observational backbone.



Extended Coverage

ARTEMIS-P2, **STEREO-A**, and **MMS, IMAP** expand spatial coverage upstream and in the magnetospheric



ISRO's Aditya-L1

India's newest mission adds a critical new node to the constellation, enhancing global multipoint capability at L1

The Road Ahead: Towards Predictive Space Weather

Coordinated Observations

Sustained, multi-agency coordination of L1 assets is the immediate priority — maximizing science return from the current unique constellation

Multipoint as Foundation

Multipoint measurements are not merely for research — they are required for improved weather prediction at Earth

Open Data and Collaboration

International data sharing and open-access frameworks are essential to fully exploit the scientific potential of this unprecedented observational era

L1 consellation

The path forward lies in utilizing existing satellite swarm near L1 and asses its impact on forecasting geoeffeciveness of soalr wind transeients.

The current era — with Aditya-L1, Wind, ACE, DSCOVR, ARTEMIS, STEREO-A, IMAP, and MMS operating simultaneously — provides a golden opportunity that must be fully exploited now.

Already L1 constellation data product generation in action!

Thank You