Characterizing Auroral Radio Emission Produced by Large-scale Stellar Magnetospheres

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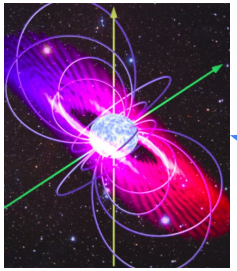
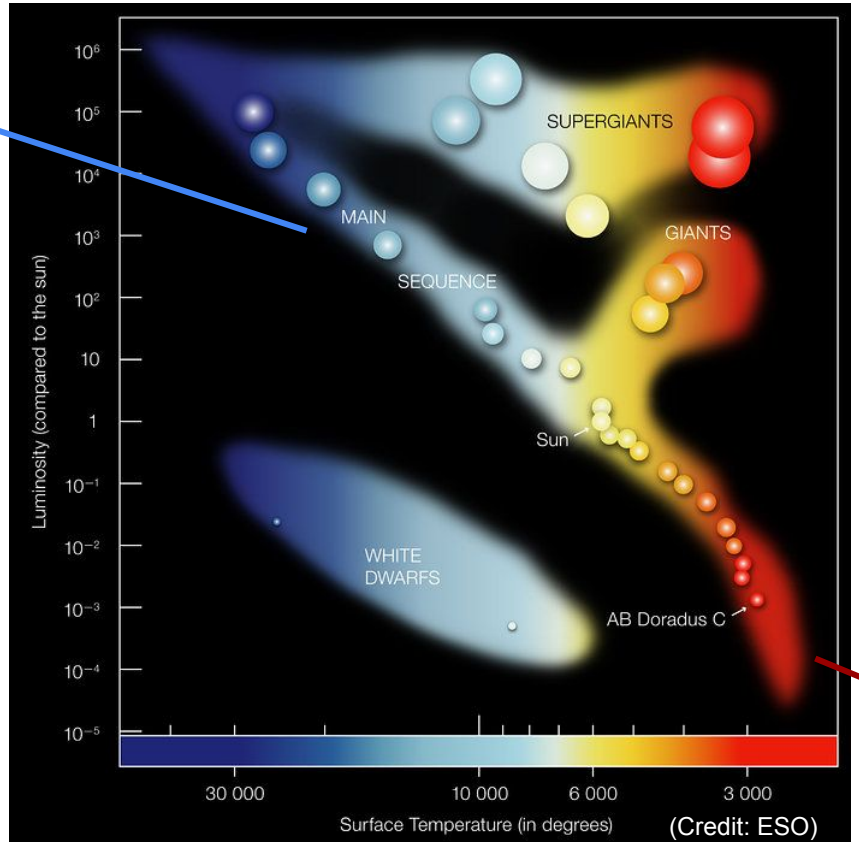
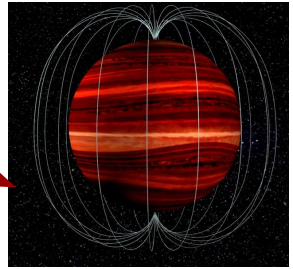
Large-scale Magnetospheres are seen at the two-ends of the spectral-classification scheme



(Credit: R. Townsend)

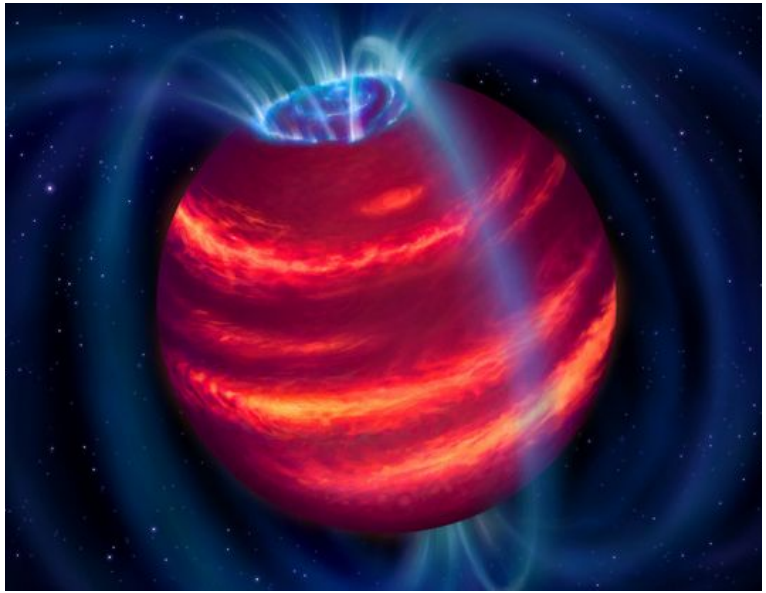




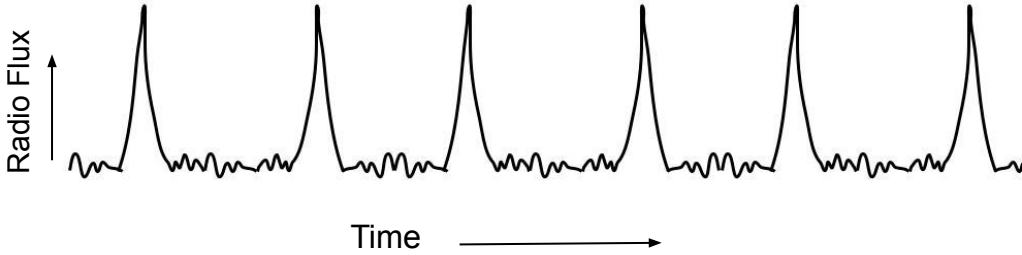
(Credit: Bill Saxton, NRAO/AUI/NSF)

They exhibit certain common properties such as…

Production of radio aurorae in their magnetospheres, observed as periodic radio pulses

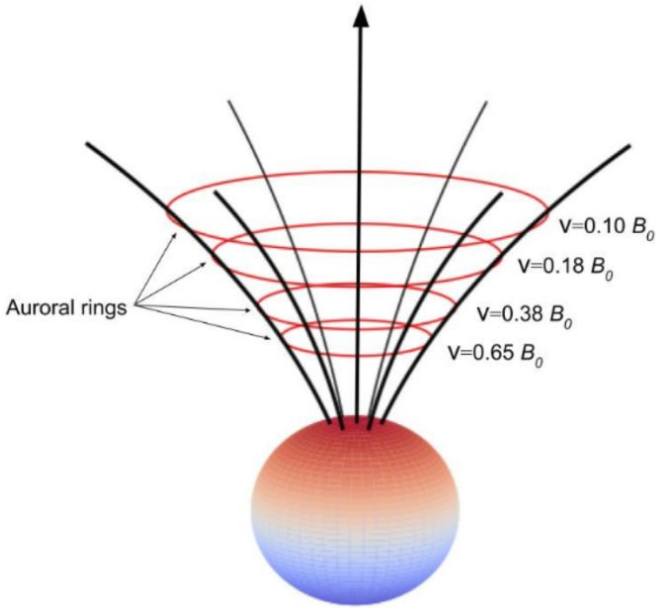


(Credit: ASTRON/Danielle Futselaar)



Radio Aurorae are produced by electron cyclotron maser emission (ECME)

- Intrinsically a narrow-band emission, emission frequency is proportional to the magnetic field strength at the emission site -> used for estimating magnetic field strength



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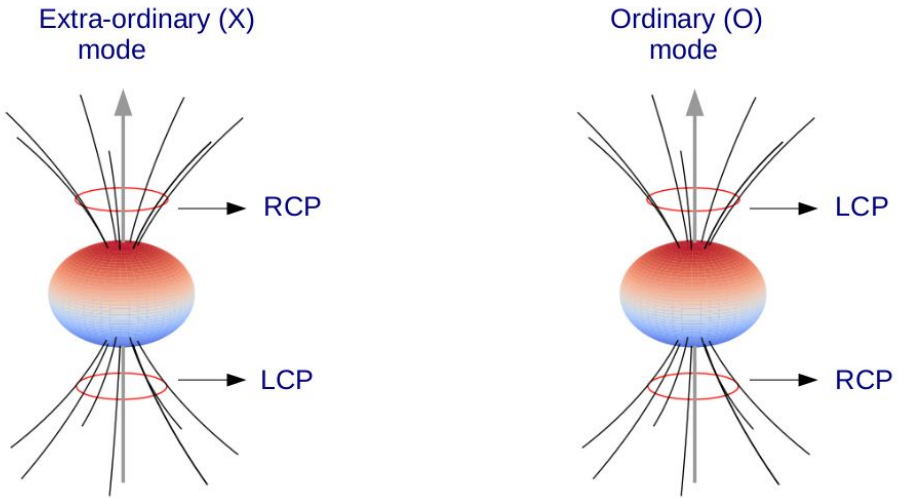
- Highly circularly polarized -> often used to identify ECME, also to indirectly estimate plasma density at the emission site



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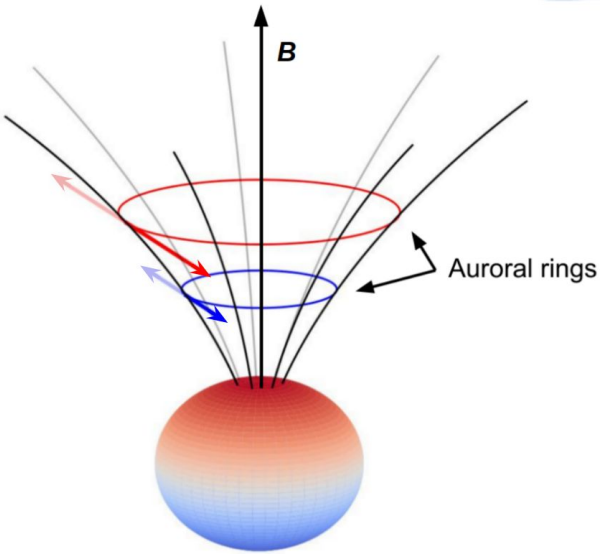
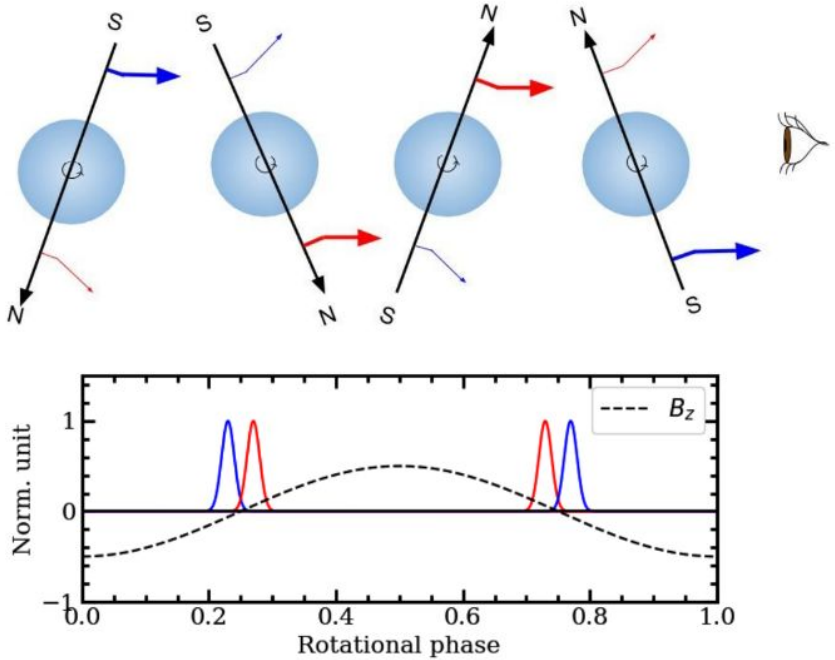
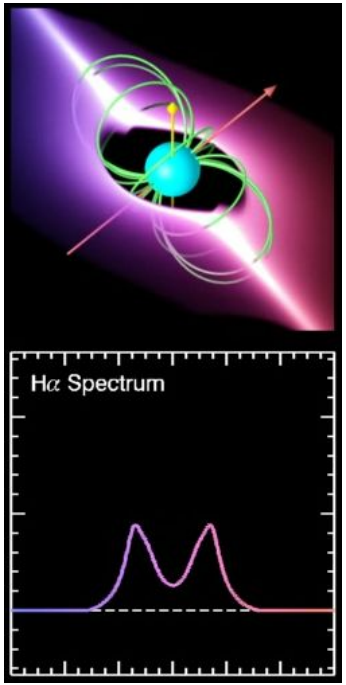
- Highly directed -> can help constrain the emission site/magnetic loops, not really used for magnetospheric studies.





But high directivity of ECME makes it unique among all other magnetospheric emission!



Credit: R. Townsend

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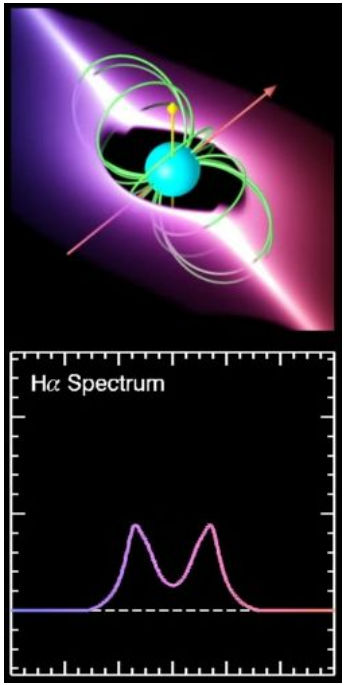

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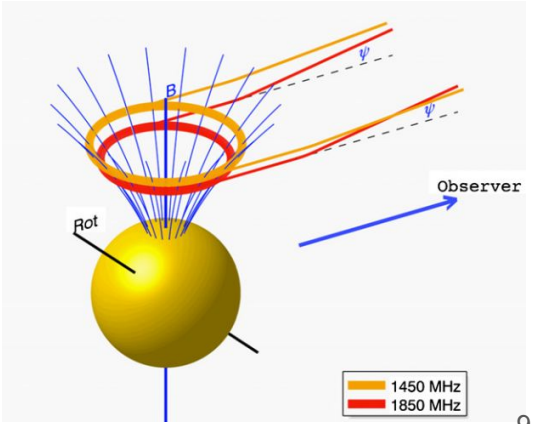
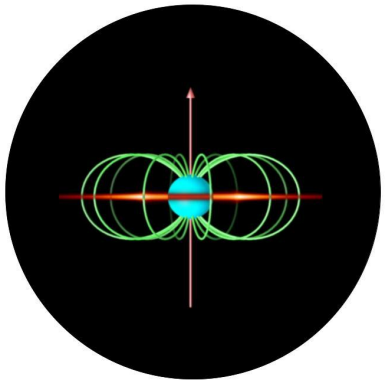
- ECME, on the other hand, has much smaller ‘effective’ size of emission sites-> makes them sensitive to small-scale changes/structures.



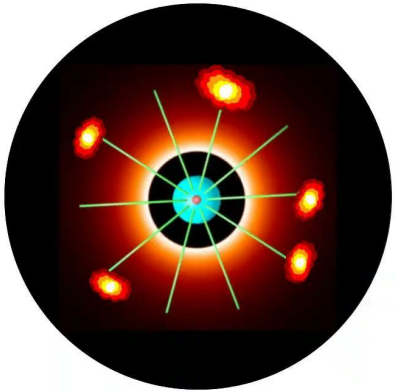
(Trigilio et al. 2011)

We care about having information at both large and small spatial scales because

- We may miss important physics if we don't have access to small-scale changes.



Equator-on view



Pole-on view

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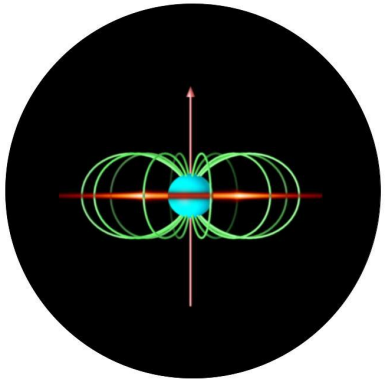

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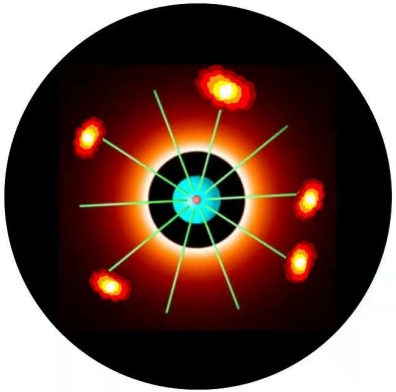

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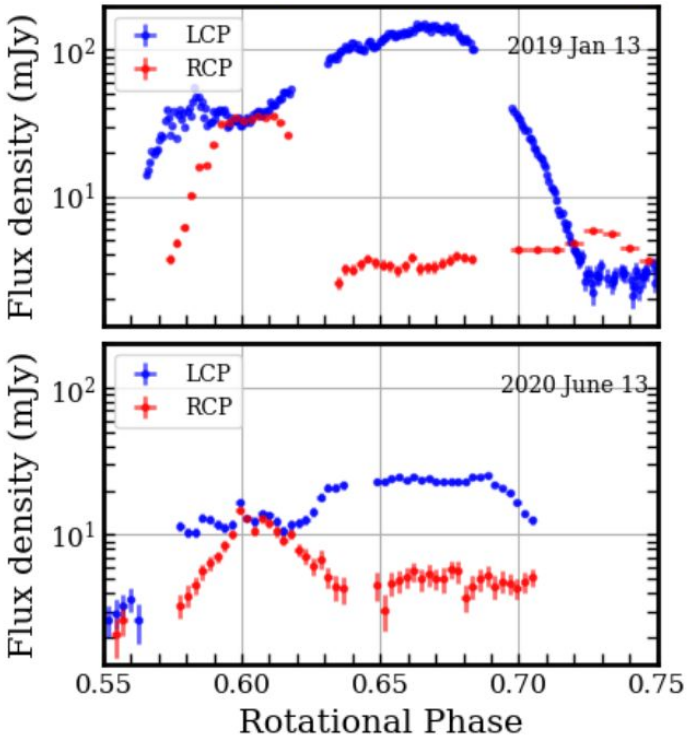
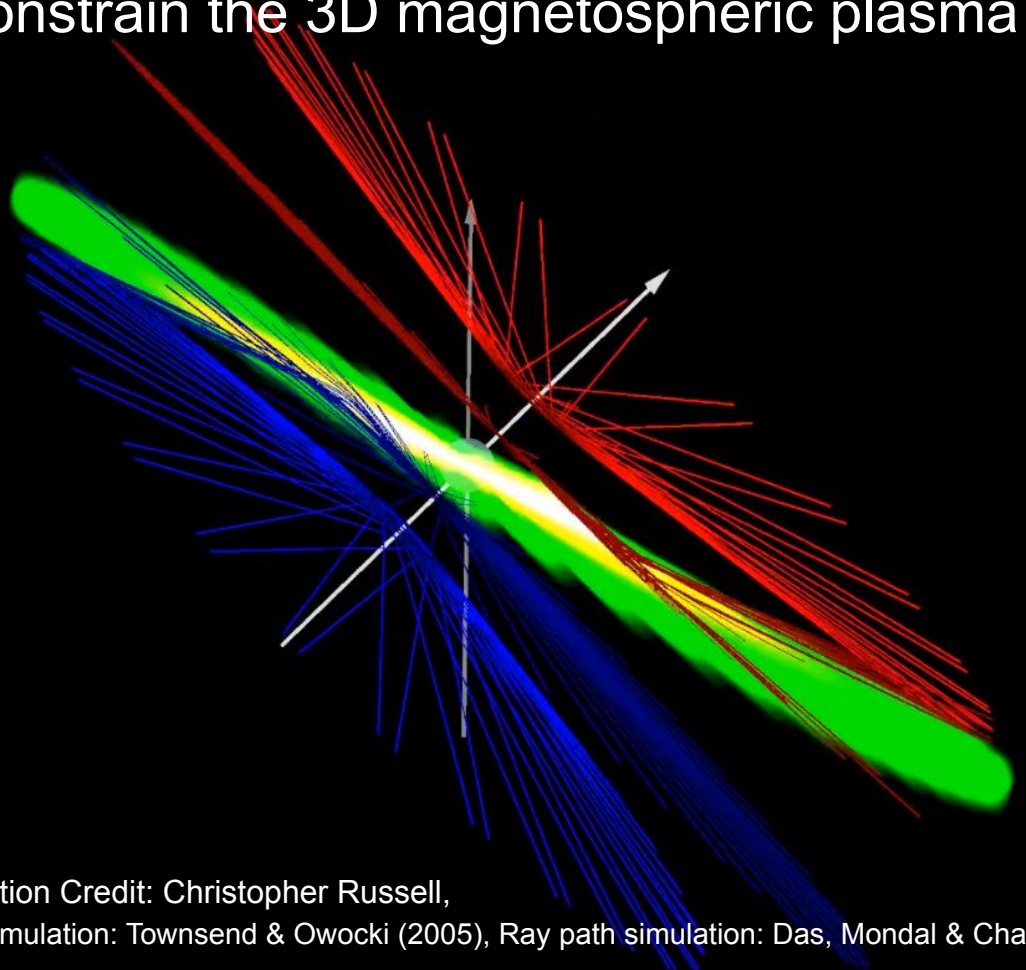


(Das & Chandra 2021)

High directivity, combined with the narrow-band property can even help us to constrain the 3D magnetospheric plasma distribution



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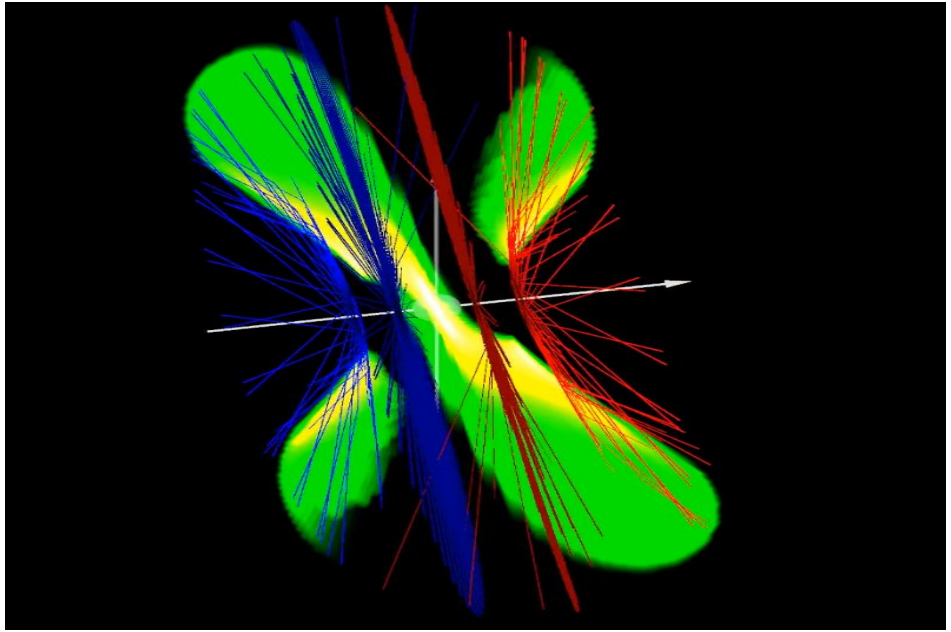
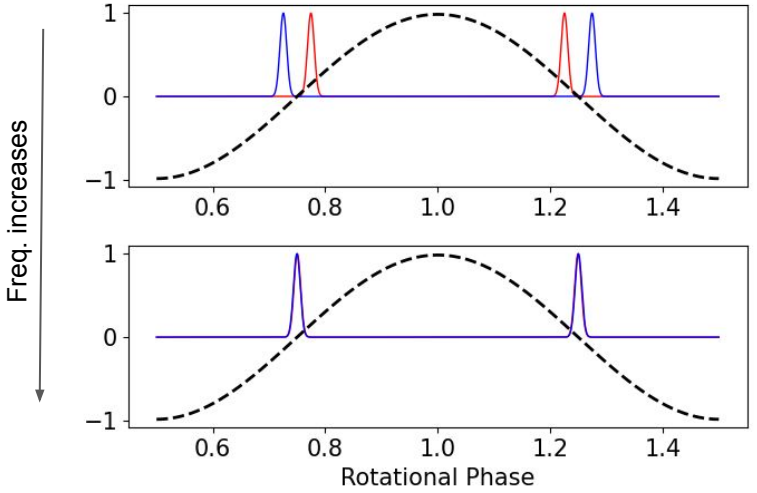


No encounter with the ‘disc’



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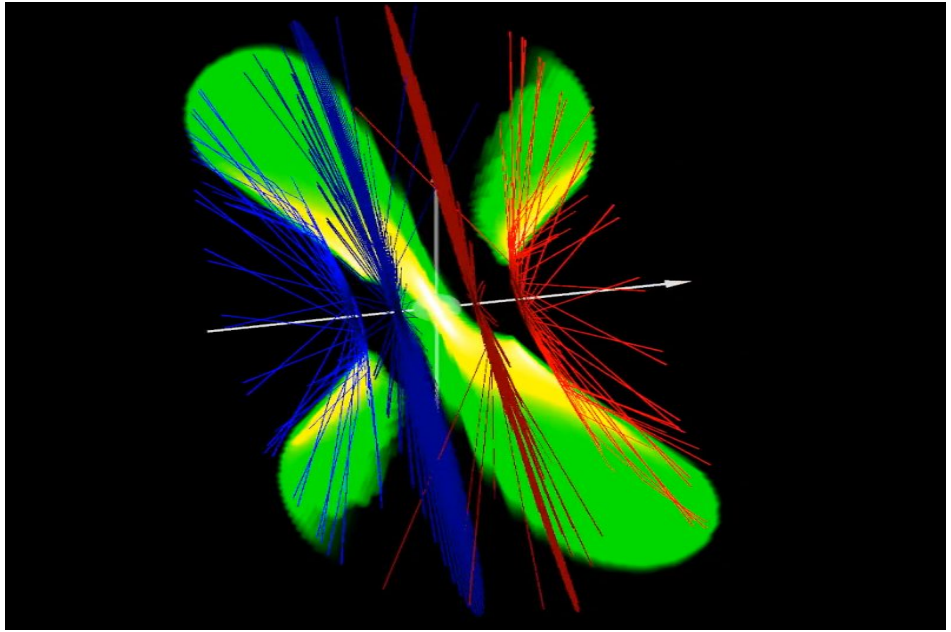

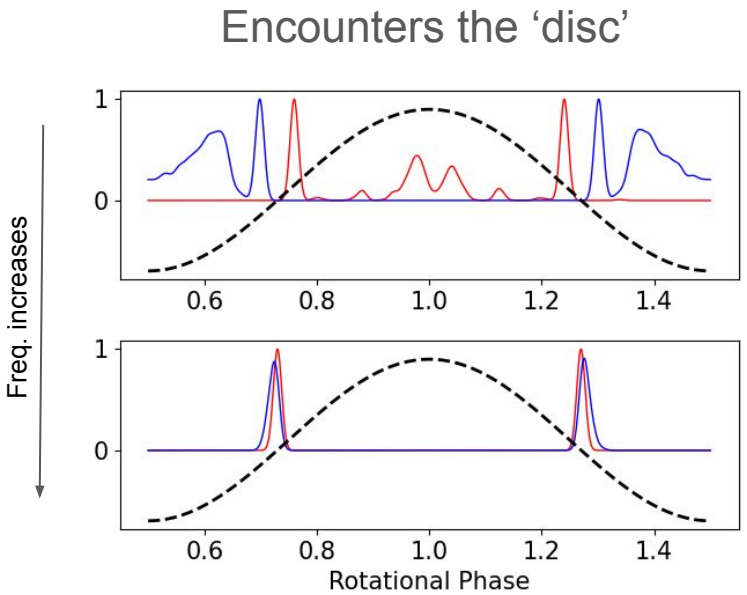

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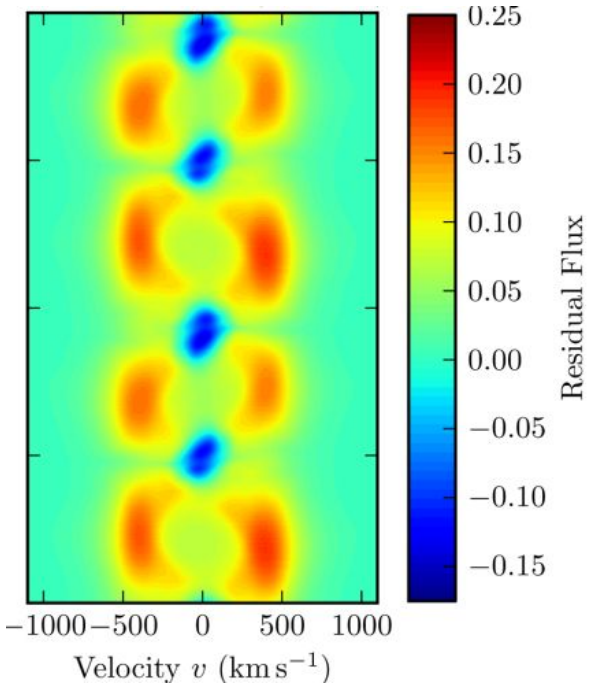
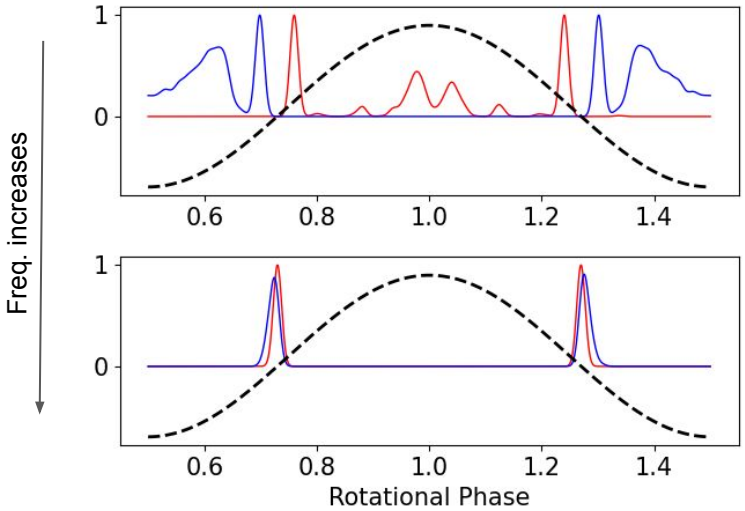
The small-scale information provided by ECME is complementary to those provided by emission sensitive to large-scale magnetospheric structures



Simulated Hα dynamic spectrum
(Oksala et al. 2015)



Simulated ECME light curves
(Das, Mondal & Chandra 2020)

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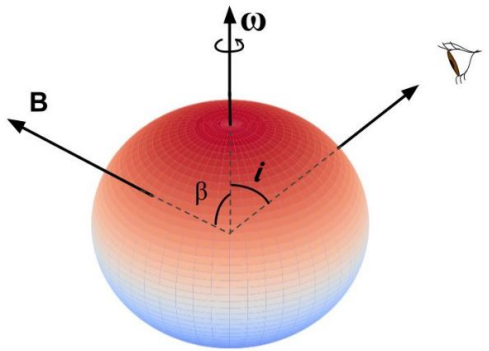
- Also, we need to have adequate knowledge about the magneto-rotational properties of the star.



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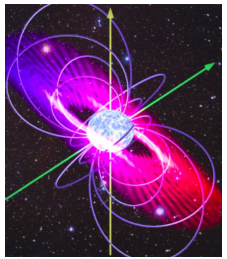

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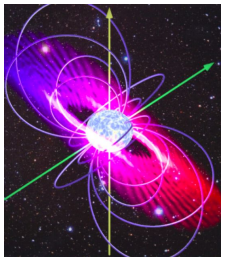
  - Hot magnetic stars producing ECME have been named as Main-sequence Radio Pulse emitters (MRPs, Das & Chandra 2021)



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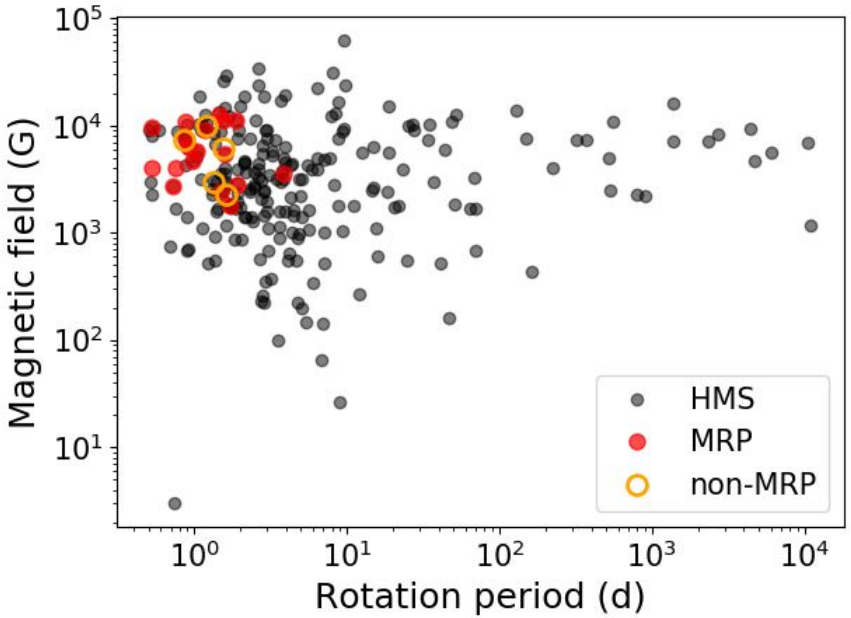
How does the current sample span the parameter space?



(Credit for HMS catalog: Shultz et al. in prep.)

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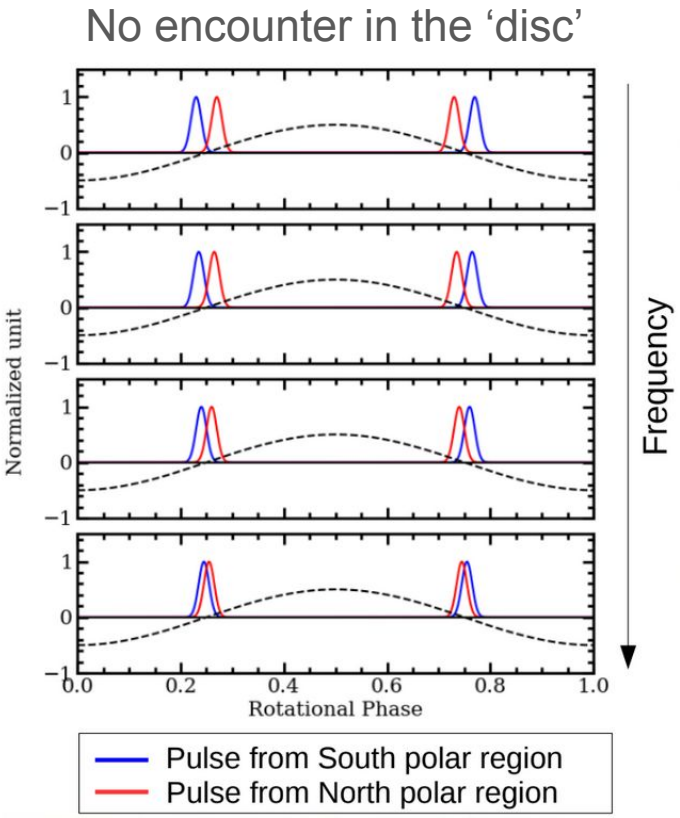
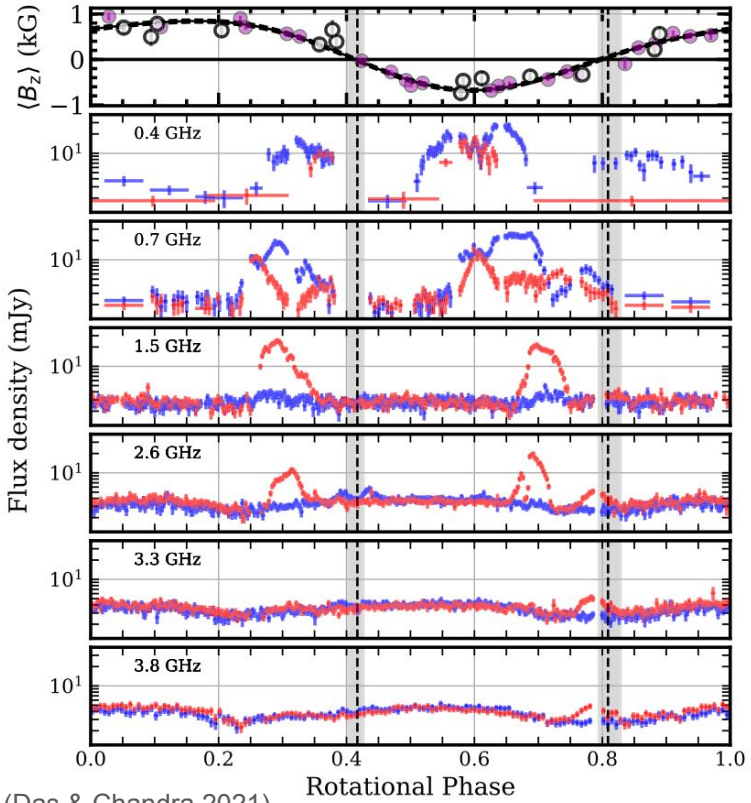
Wideband observations show signs of propagation effects





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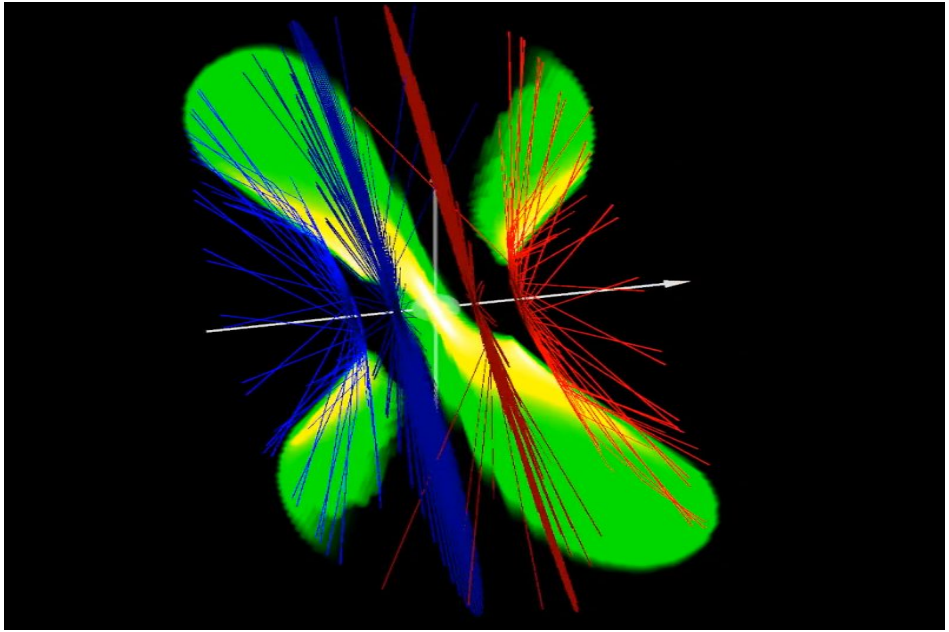

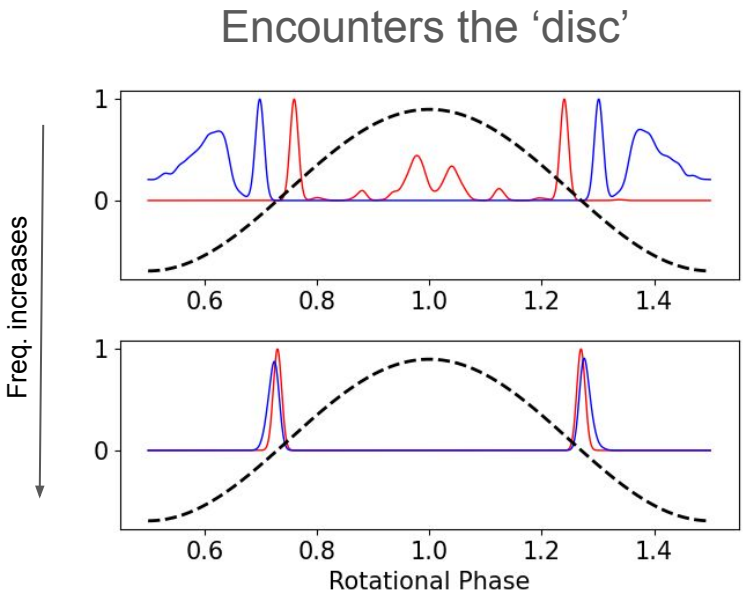

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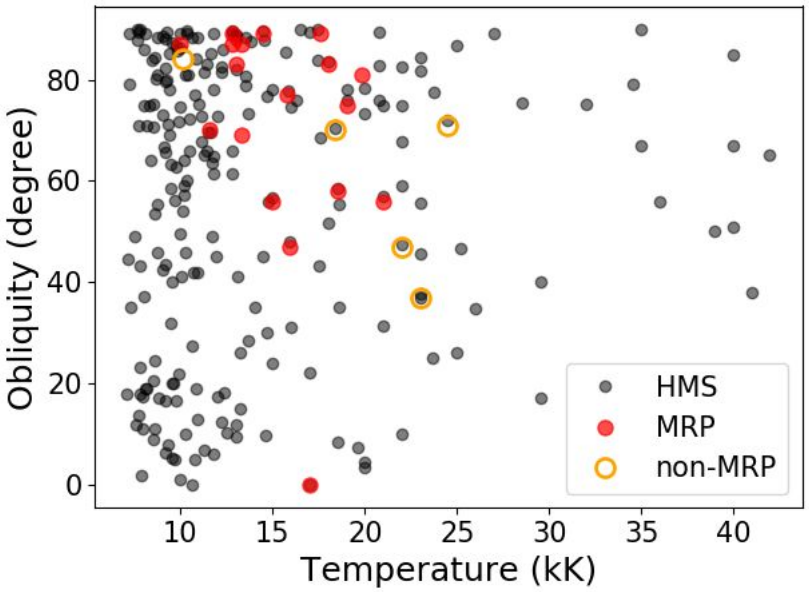
- Full rotational phase coverages, with large instantaneous bandwidth
  - Targeted observations with telescopes with large FoV (e.g. ASKAP)

Summary

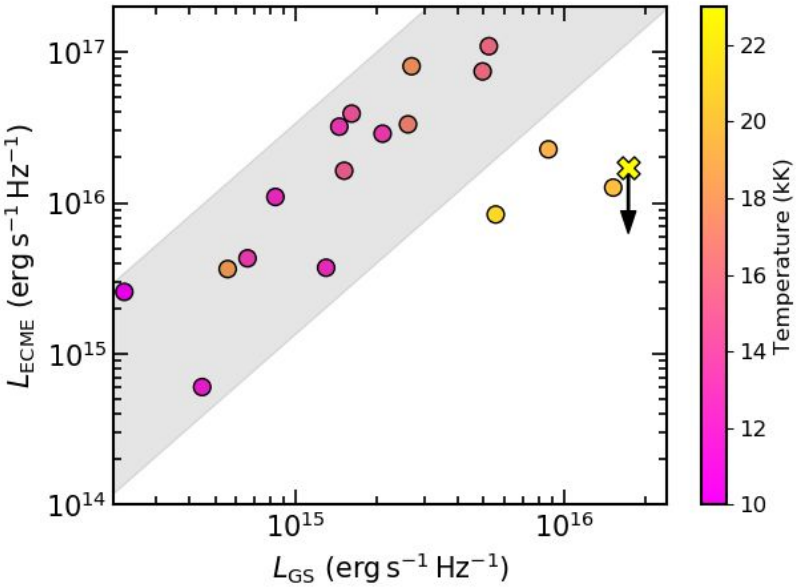
- Auroral radio emission (ECME), observed from hot magnetic stars, ultracool dwarfs, brown dwarfs etc. has the potential to become a versatile stellar magnetospheric probe.
- For that, we must first characterize the phenomenon.
- Hot magnetic stars, with their extremely stable and well-characterized magnetic fields, offer an ideal test-bed.
- The current sample is not large enough to obtain a quantitative understanding.
- Surveys by new-generation radio telescopes and future facilities will be instrumental in overcoming this limitation.

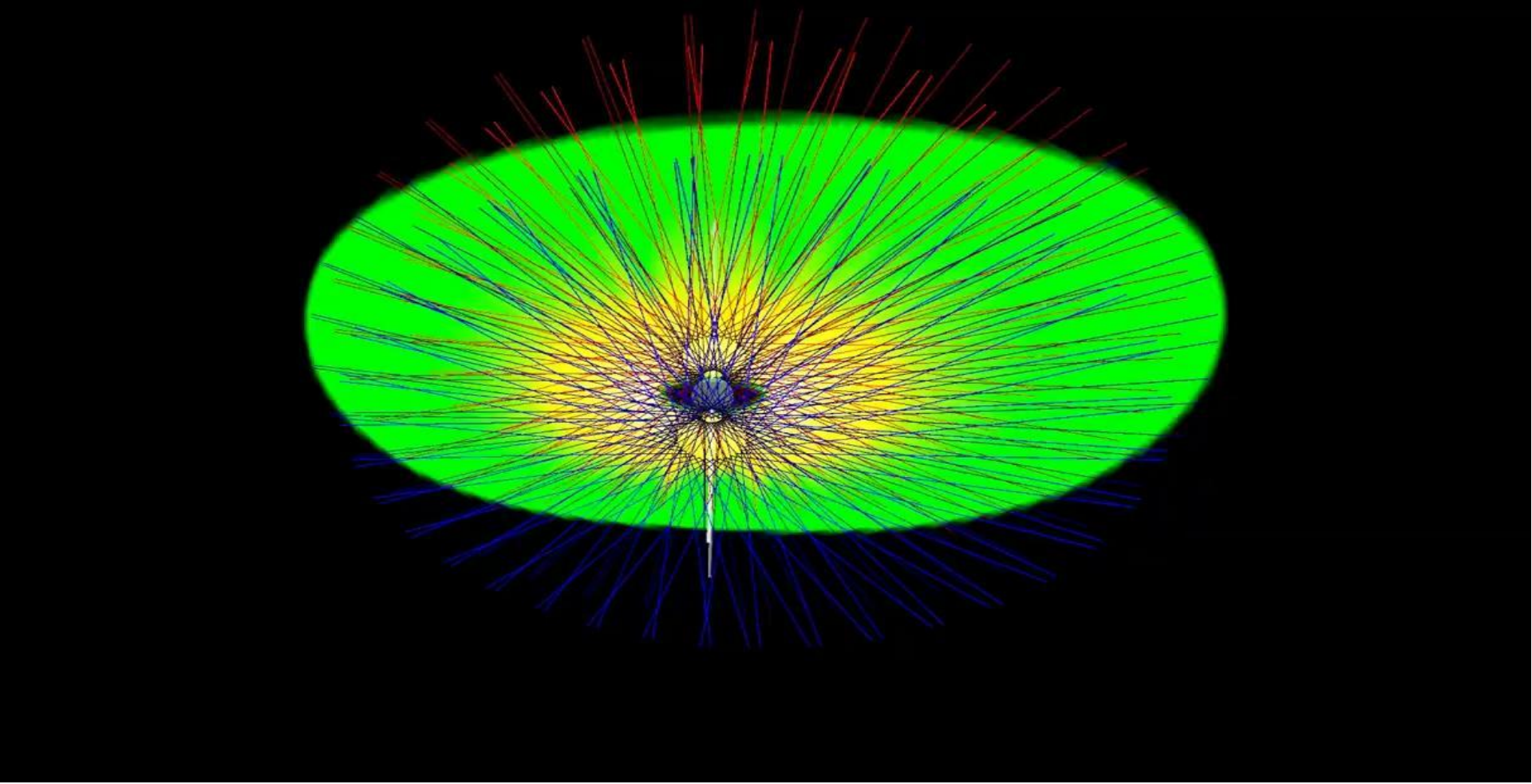
END

EXTRA SLIDES



(Das et al. 2022c)





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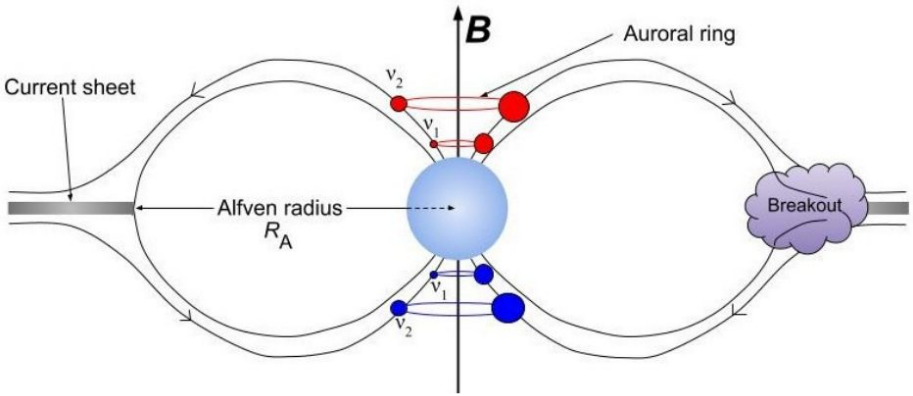

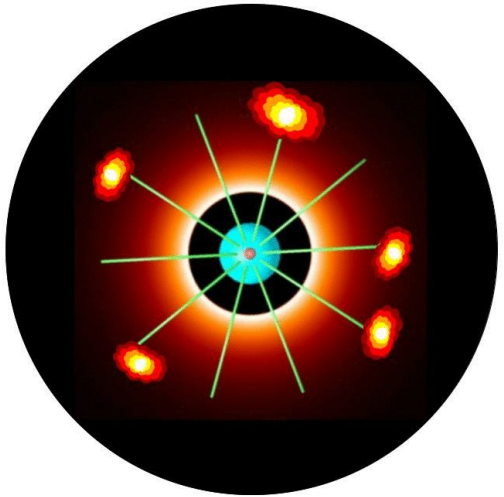

Pole-on view

Credit for background stellar magnetosphere: R. Townsend

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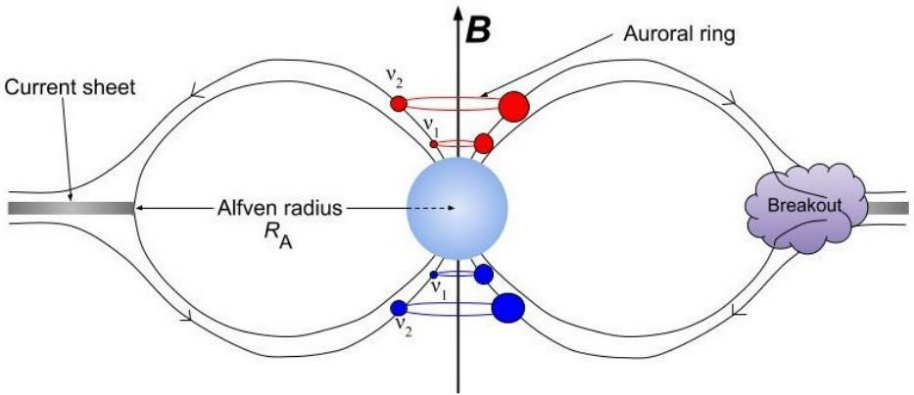
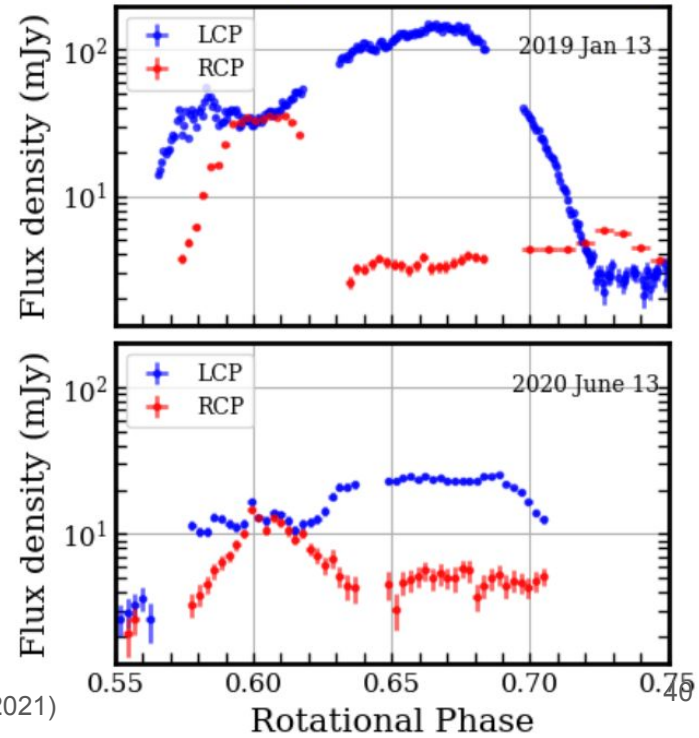
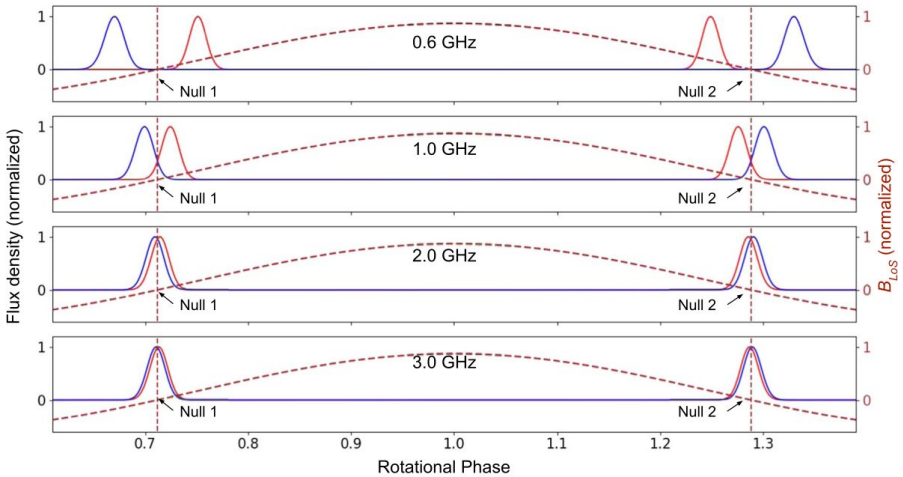
- Such signatures have indeed been observed!





(Das & Chandra 2021)

Without refraction in the ‘disc’



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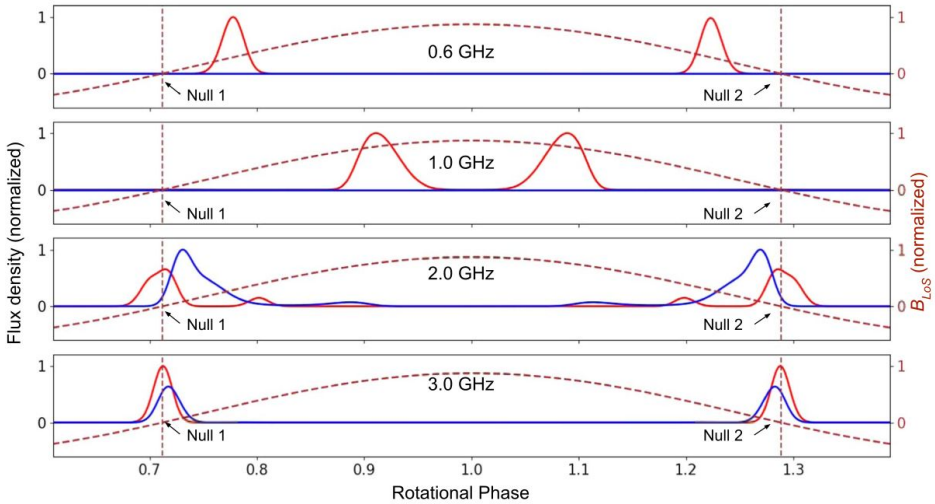

(Das, Mondal & Chandra 2020)