Coherent and Incoherent Emission from the Ordered Magnetospheres of Low-Mass Stars, UCDs, and Massive Stars

Francesco Cavallaro on behalf of all the co-authors

Why should you care about stellar astrophysics?

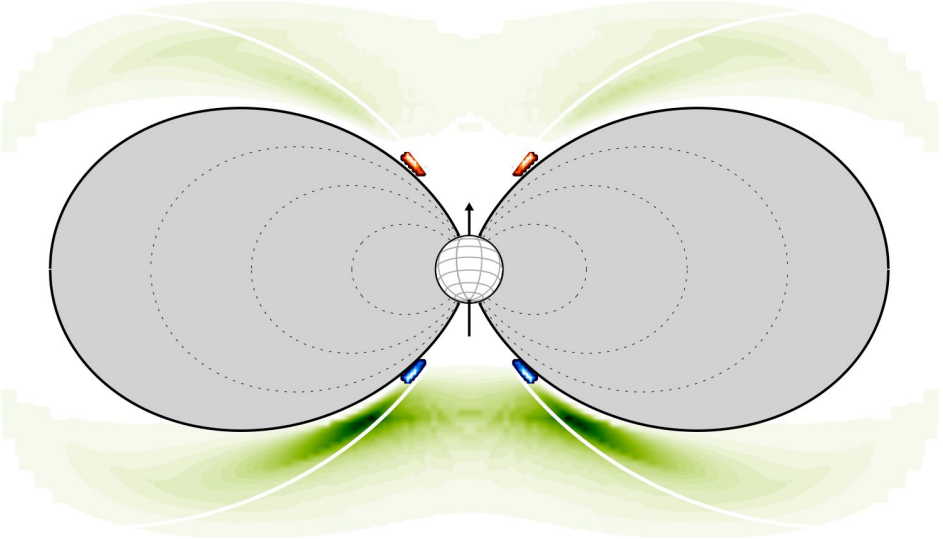
- They are ubiquitous foreground radio emitters at SKA sensitivities.
- They produce both coherent and incoherent emission, sometimes highly polarized, sometimes bursty so they could mimic FRBs, pulsar single pulses, or low-frequency transients.
- They are laboratories for:
    - Particle acceleration in ordered magnetospheres
    - Auroral emission physics (also relevant for exoplanets and planets)
    - Non-thermal processes in plasmas

Across the HR diagram, some objects maintain large-scale stable magnetic fields:

- Massive B/A stars with kG dipoles
- Ultracool dwarfs (UCDs; later than M7) with fully convective interiors but still strong, ordered fields
- Planets (e.g. Jupiter)

Despite huge differences in mass and temperature, they share:

- Rigidly rotating magnetospheres
- Non-thermal energetic electrons
- Coherent ECM pulses
- Gyrosynchrotron belts (radiation belts)
- Rotational modulation



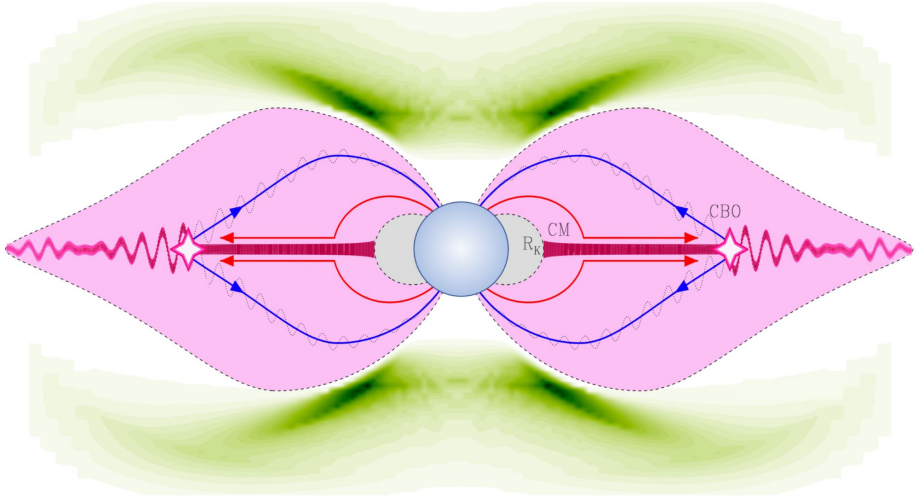
Centrifugal Breakout

Massive (B/A) magnetic stars have strong winds confined by dipolar fields that leads to rigidly rotating magnetospheres (RRMs).

Beyond the co-rotation radius, plasma builds up until:

- Centrifugal force > magnetic tension
- Reconnection injects fresh non-thermal electrons
- Efficient gyrosynchrotron emission

$$L_{\mathrm{CBO}} \propto B_p^2 R_*^{4.5} M_*^{-0.5} P_{\mathrm{rot}}^{-2}$$



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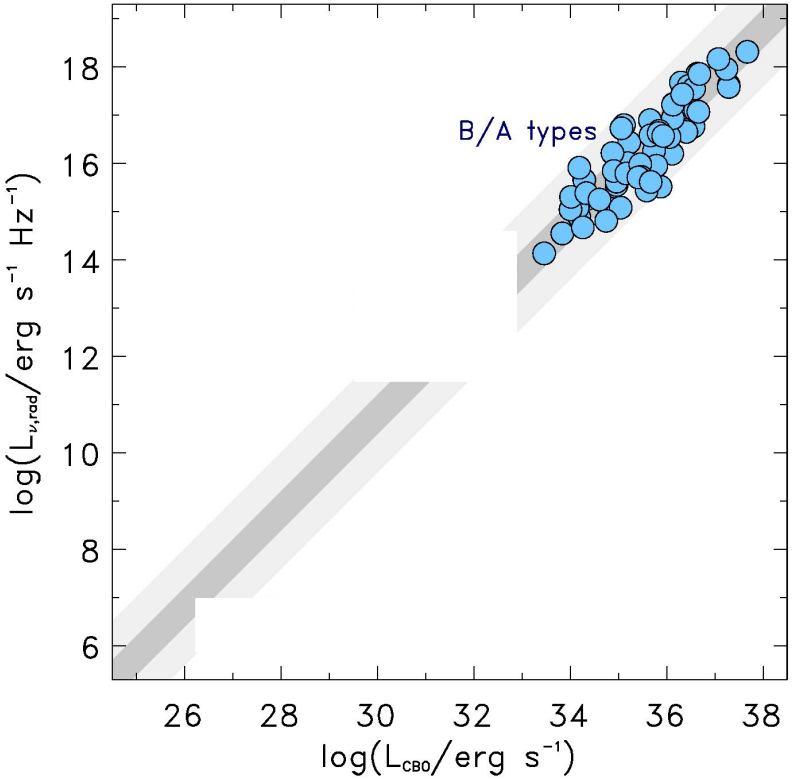
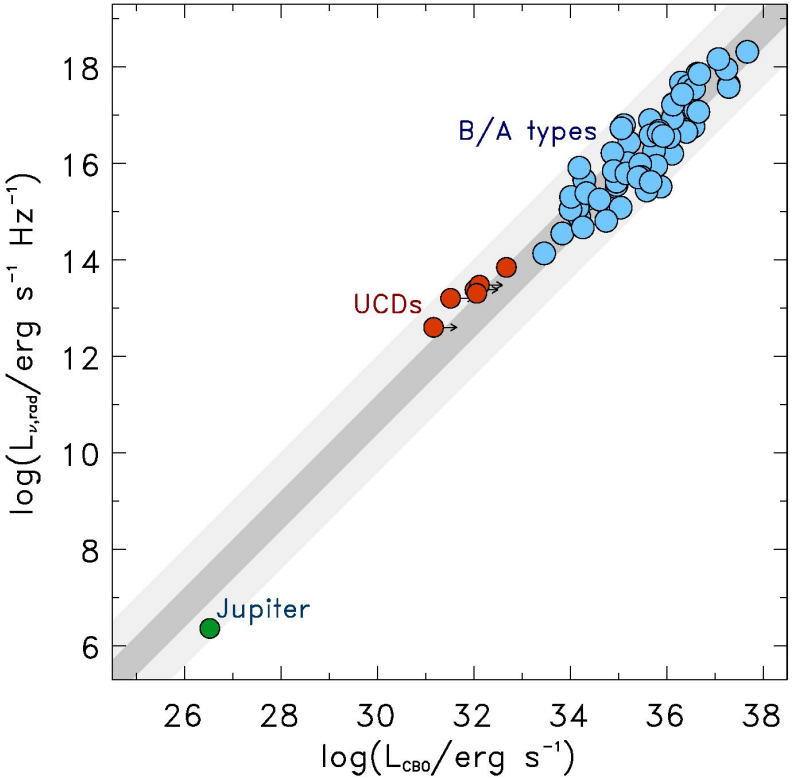


Centrifugal Breakout

How is it possible for UCDs to have the same mechanism of B/A massive stars?



UCDs SKA detection forecast

- we used the space density estimates from Best et al. (2024) and Cruz et al. (2007),
- we calculated the total UCD population within a 100 pc radius, using the 15% occurrence rate of incoherent radio emission estimates from (Kao and Shkolnik, 2024)
- this gives an expected ~12,500 radio-emitting UCDs in this volume.

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$$L_{\min} = 10^{12.7}\ \mathrm{erg\ s^{-1}\ Hz^{-1}}, \quad L_{\max} = 10^{13.6}\ \mathrm{erg\ s^{-1}\ Hz^{-1}}$$

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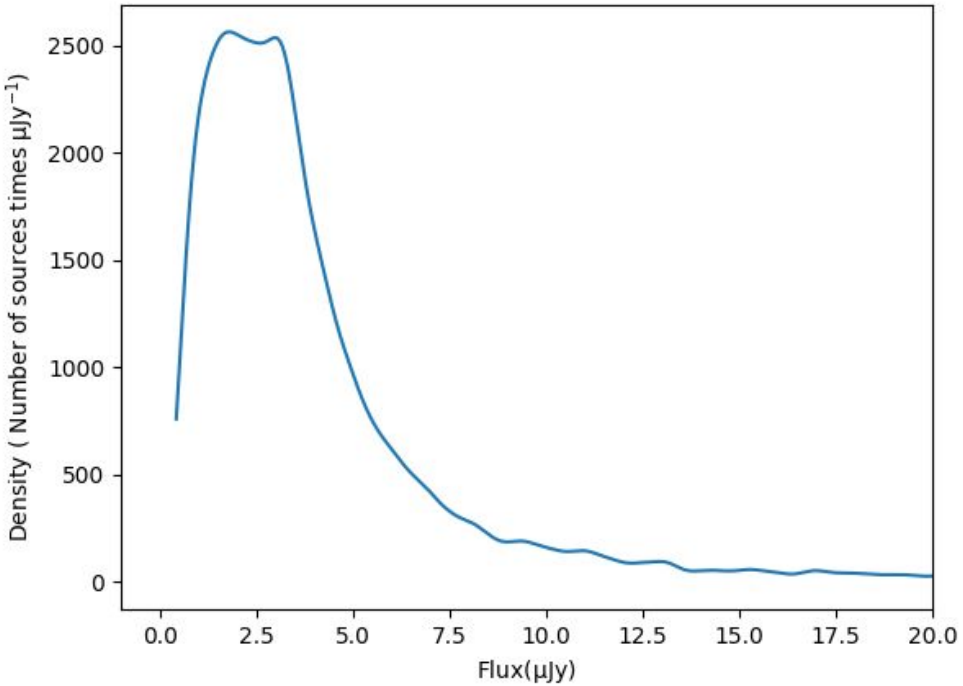

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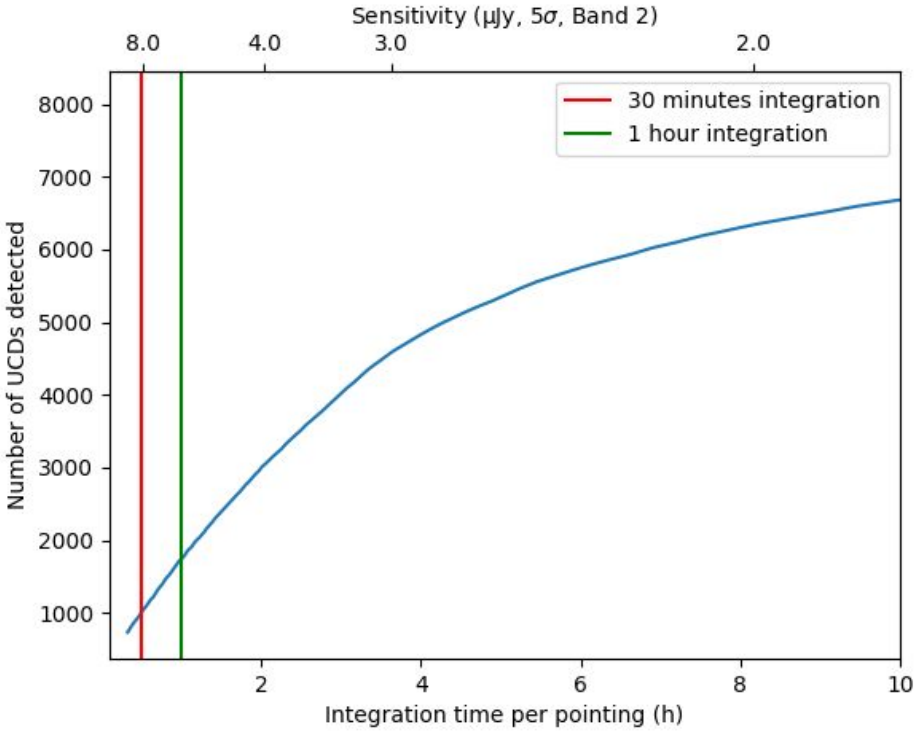
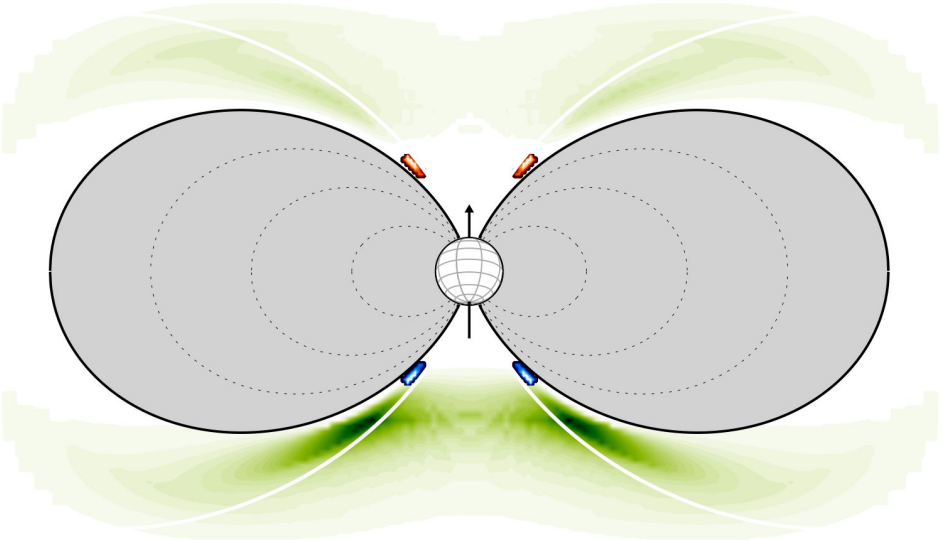


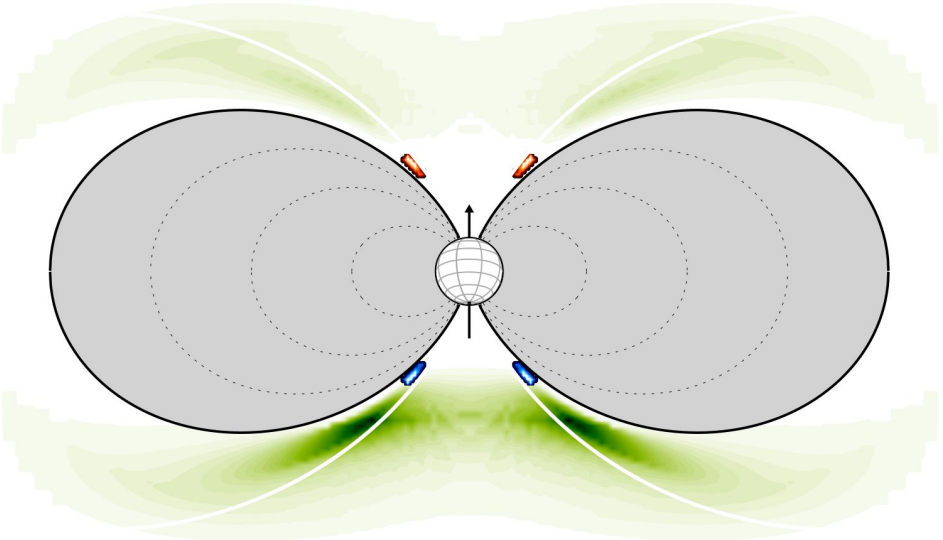
ECM Emission

Stimulated cyclotron emission process involving non-thermal electrons from a magnetised plasma



ECM Emission

We expect around 10000 detection of circularly polarised UCDs, most of them visible only during the auroral events.



Summary

- We find ordered magnetosphere within both very early type stars and very late type stars (B/A stars and UCDs);
- both type of stars can exhibit continuous incoherent emission and periodical or quasi periodical coherent emission;
- the CBO model is widely accepted to explain the origin of the incoherent emission in highly magnetic B/A stars;
- UCDs seem to follow the same relationship;
- SKA could help, by massively improving the statistics, to understand if this is the case and how it is possible for UCDs to emit via CBO