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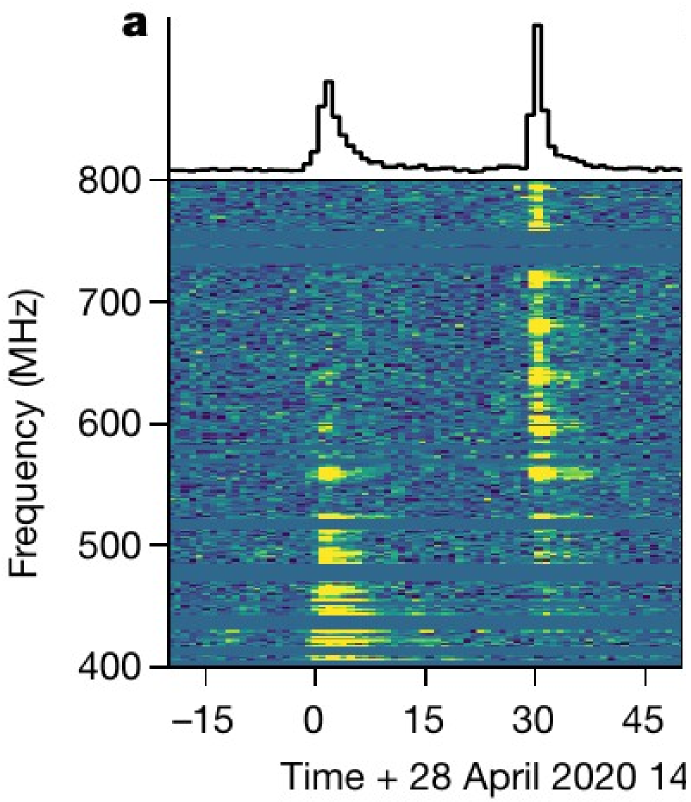
Geometrical envelopes of Fast Radio Bursts

Guillaume Voisin
LUTH, Observatoire de Paris, Université PSL – CNRS

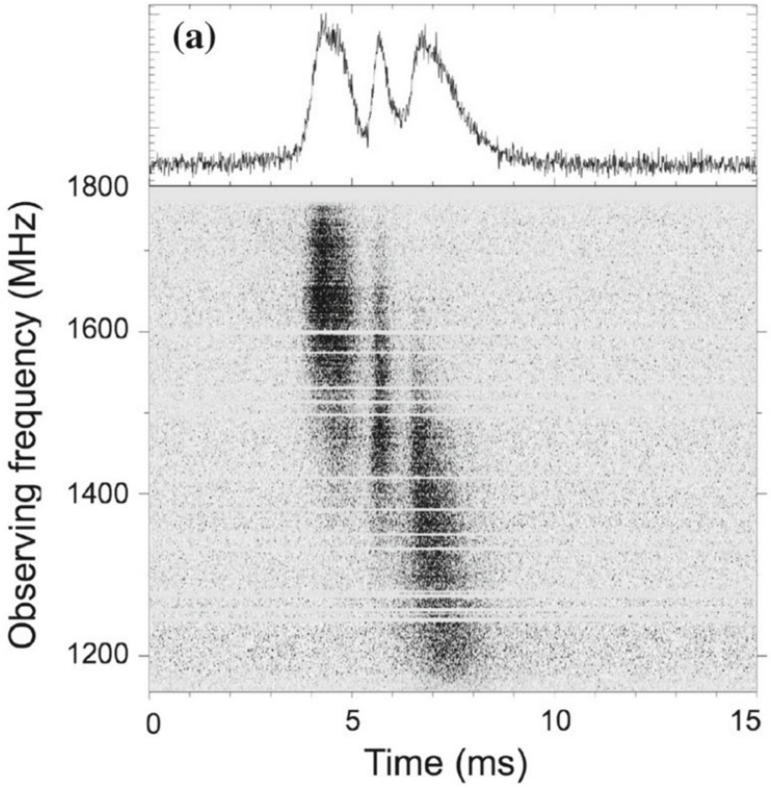
Fast radio bursts

One-off : broad-band and shorter



FRB200428, (Chime/FRB 2020b)

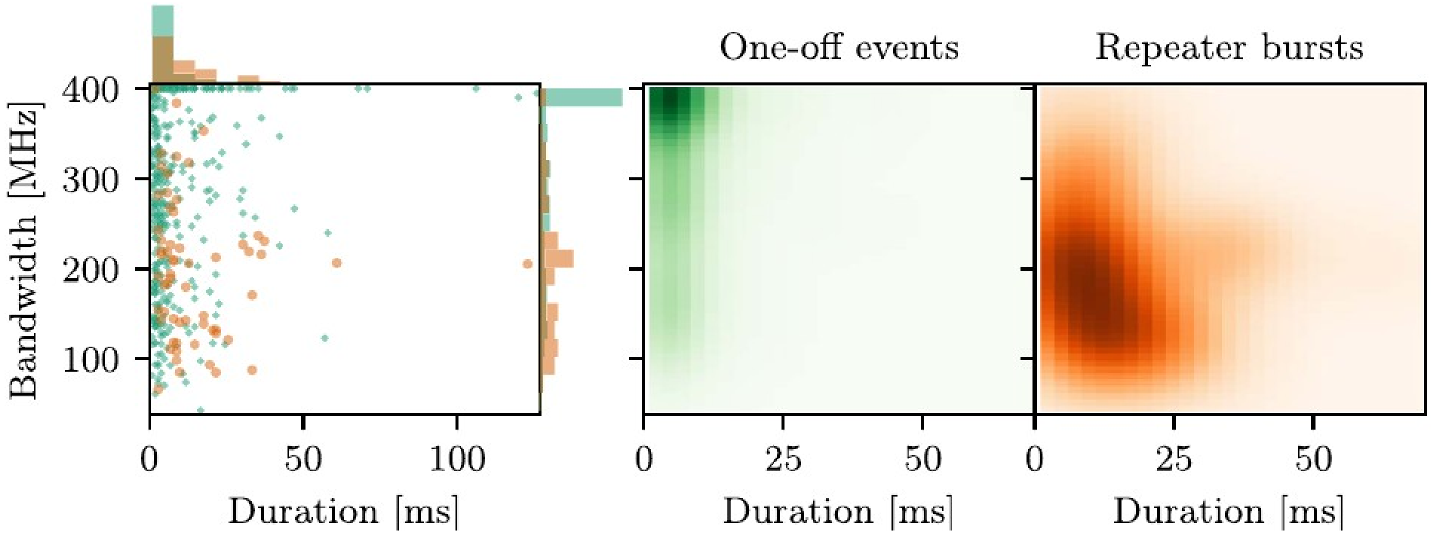
Repeaters : narrow-band, longer, downward-drifting sub-bursts



FRB121102, Hessels+18

State of the art (more or less)

- Statistical distributions: occurrence times, bandwidth/duration correlations...
- Physical constraints on observables are broadly averaged quantities: flux, duration, bandwidth, frequency drift..
- Burst morphology fitted with empirical functions (e.g. Gaussian).

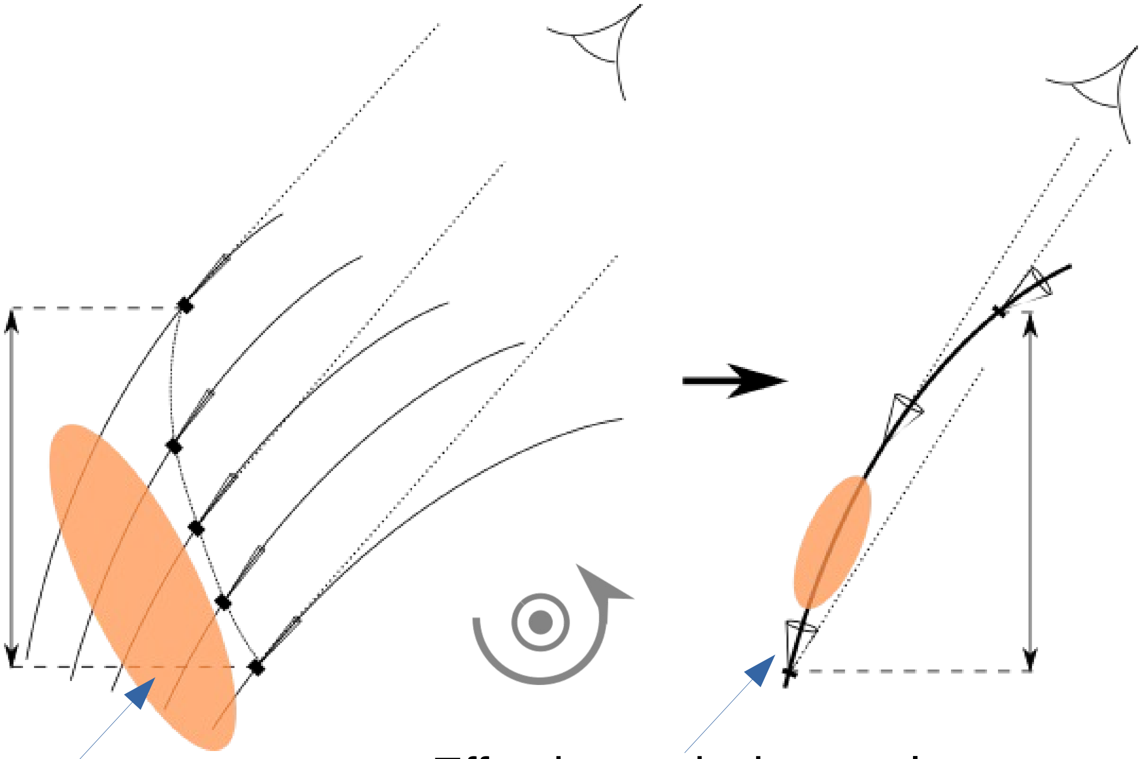


Pleunis+ 2021

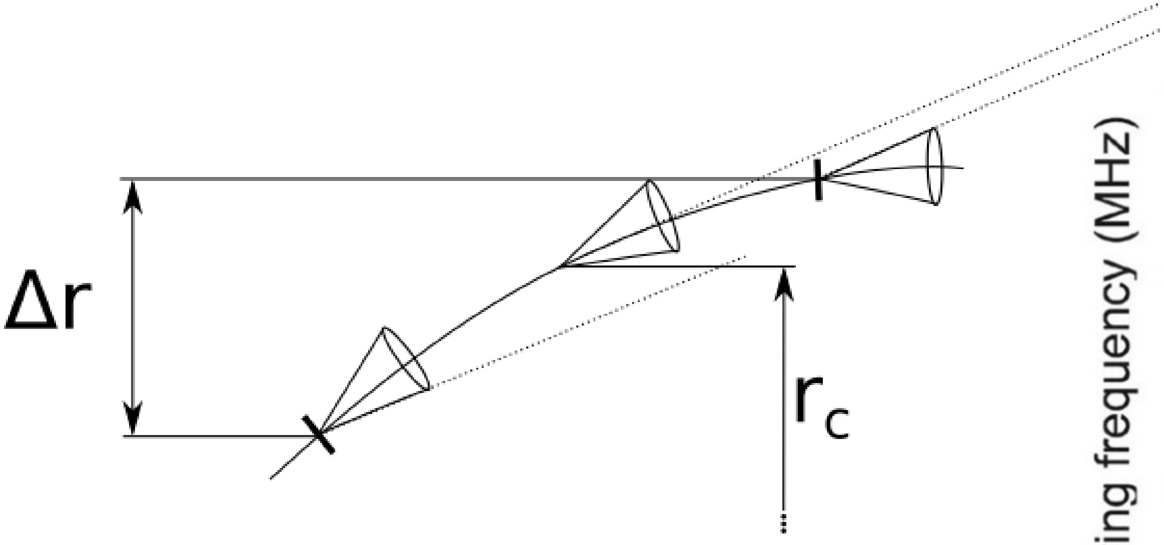
Geometrical assumptions

Hypothesis :

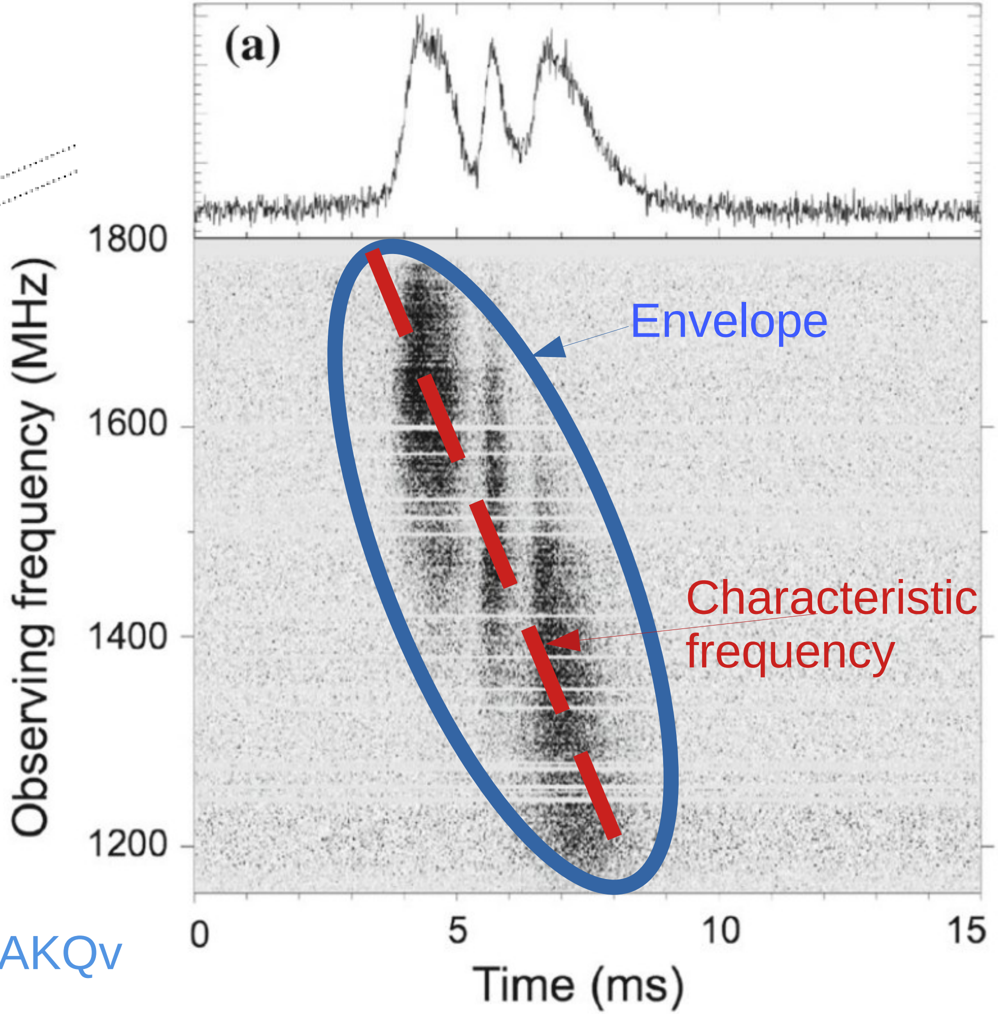
- Emission region very localized in space & time
- Emitting plasma propagating at ~c
- Source in rotating frame
- Radius-to-frequency mapping
- Polarisation: Rotating vector model



Geometric envelope



FRB121102, Hessels+18



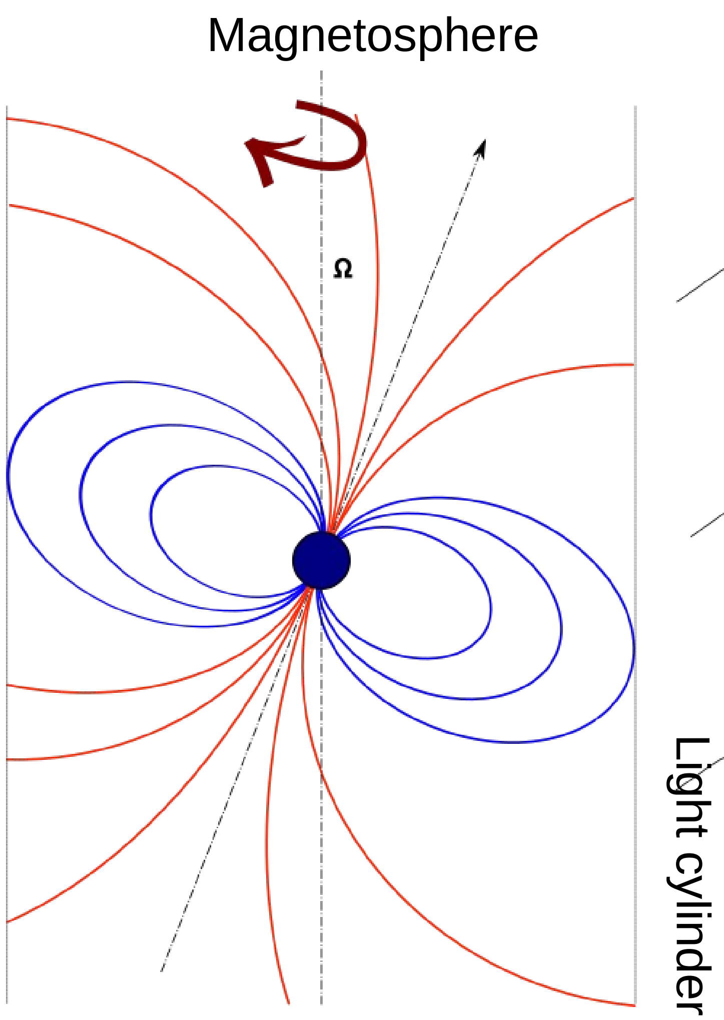
https://astrotube.obspm.fr/w/f9SxoEzzc2bBvc5KjXAKQv

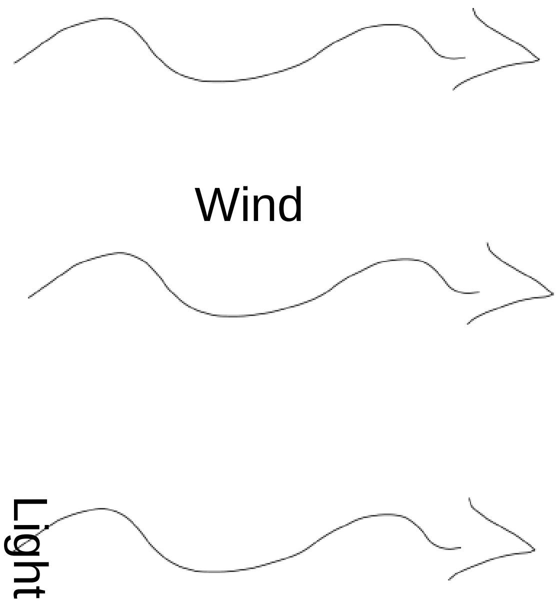
Burst model

- Intrinsic burst profile:
  ➔ Burst(t, x) = Gaussian time injection profile * Gaussian angular profile

- Observed burst = Burst (ta, f) because:
  ➔ Geometrical model maps (t, x) → (ta, f)

Global model : Neutron star magnetosphere

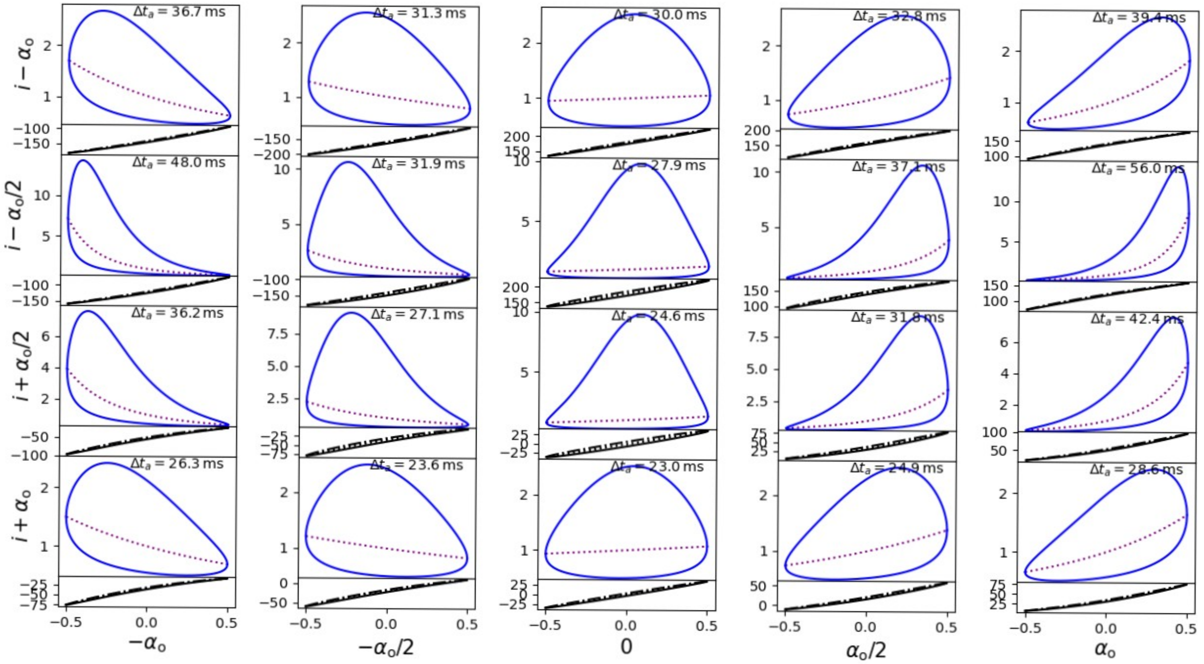




In magnetars:

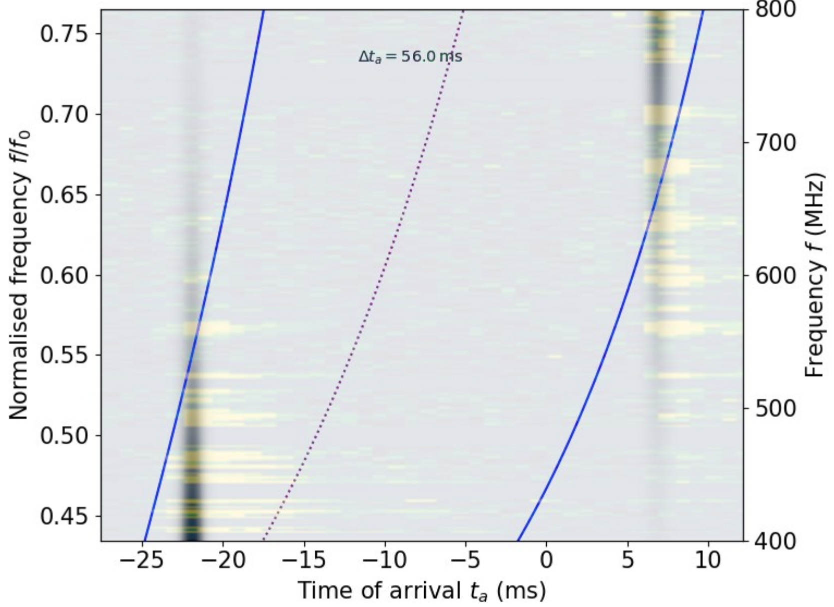
- “*Twisted magnetosphere*” : Strong toroidal magnetic field
- Magnetic field : $10^{12} – 10^{16}$ G
- *Star quakes* (responsible for magnetar flares)
- Magnetically-powered emission (vs rotation-powered for pulsars)
- Rotation period ~ few seconds for “normal” magnetars

Dipole magnetic field, Pspin=3.2sec



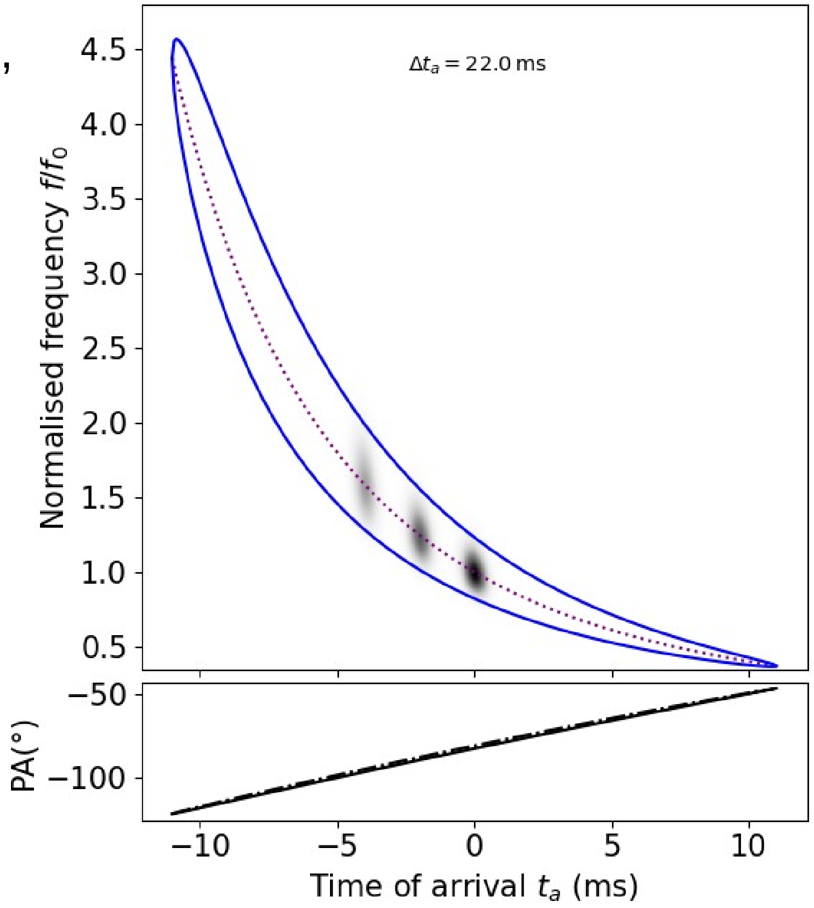
Envelopes in the polar cap region at r = 100R$_*$, Voisin2023

Modelled envelope+bursts overlaid with FRB200428 (Chime/FRB 2020b), Voisin2023

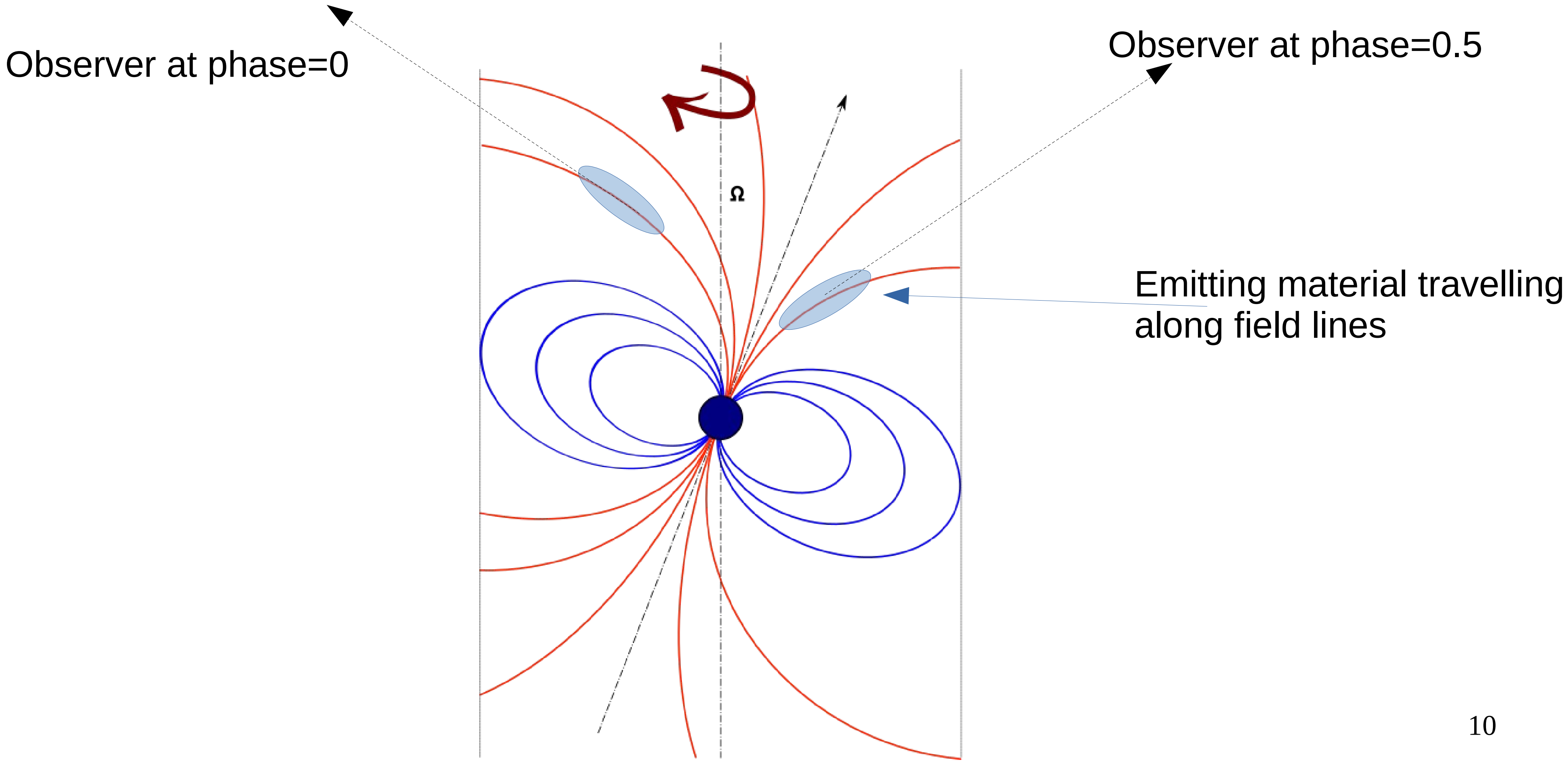


Dipole+toroidal magnetic field, Pspin=250ms

- Three bursts in envelope with Btoro = 0.5 Bdipole, (Voisin2023)
- Relative frequency drift: fdot/f ~ 110s^{-1}
- Toroidal component generically produces downward drifting sub-pulses (if strong enough)



Connecting burst morphology to spin phase



Conclusions and Outlook

- These geometrical constraints can be applied to various emission models provided locality and relativistic motion.

- Assuming propagation along magnetic field lines :
  - one-off events = dipolar polar cap geometry
  - repeaters = strong toroidal component and Pspin < 1s
  - Spin period and magnetic geometry encoded into burst morphology

- Outlook :

  Fitting simultaneously all bursts from a repeating source for global parameters such as spin period and magnetic geometry.