B-Fields in Massive Stars

Norbert Langer
Uni Bonn / MPIfR Bonn

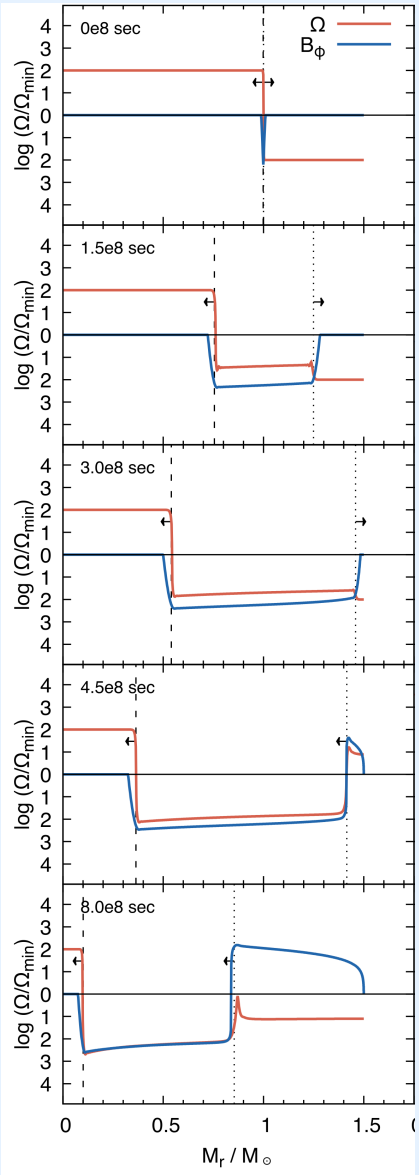
B-fields and stellar evolution

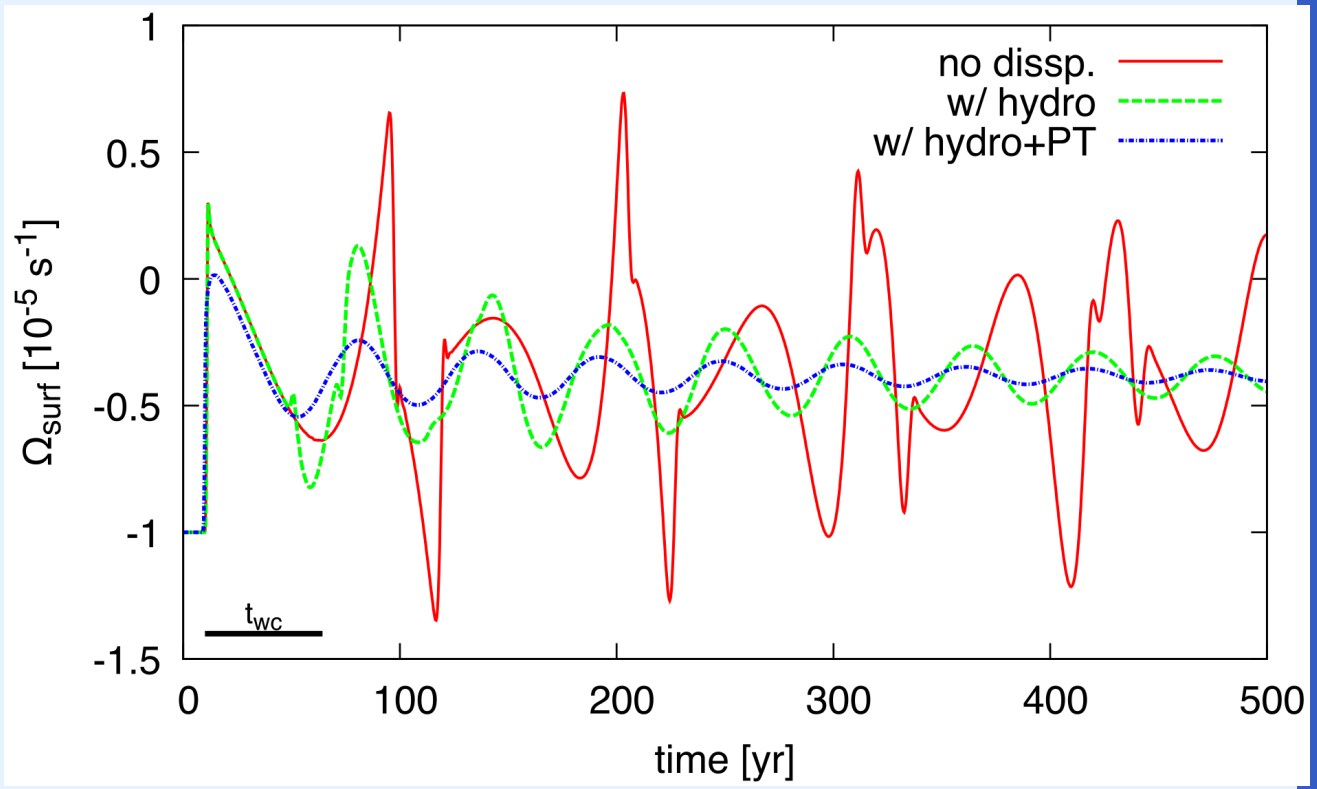
- Maxwell's equations? NO: $\tau_{\rm nuc}$, 1D
- mean-field MHD equations Brandenburg 2018

  1D averages, rot. symmetry
  eqs for evolution of $B_{\rm toroidal}$ and $B_{\rm poloidal}$

  Potter+ 2012, Takahashi+ 2021

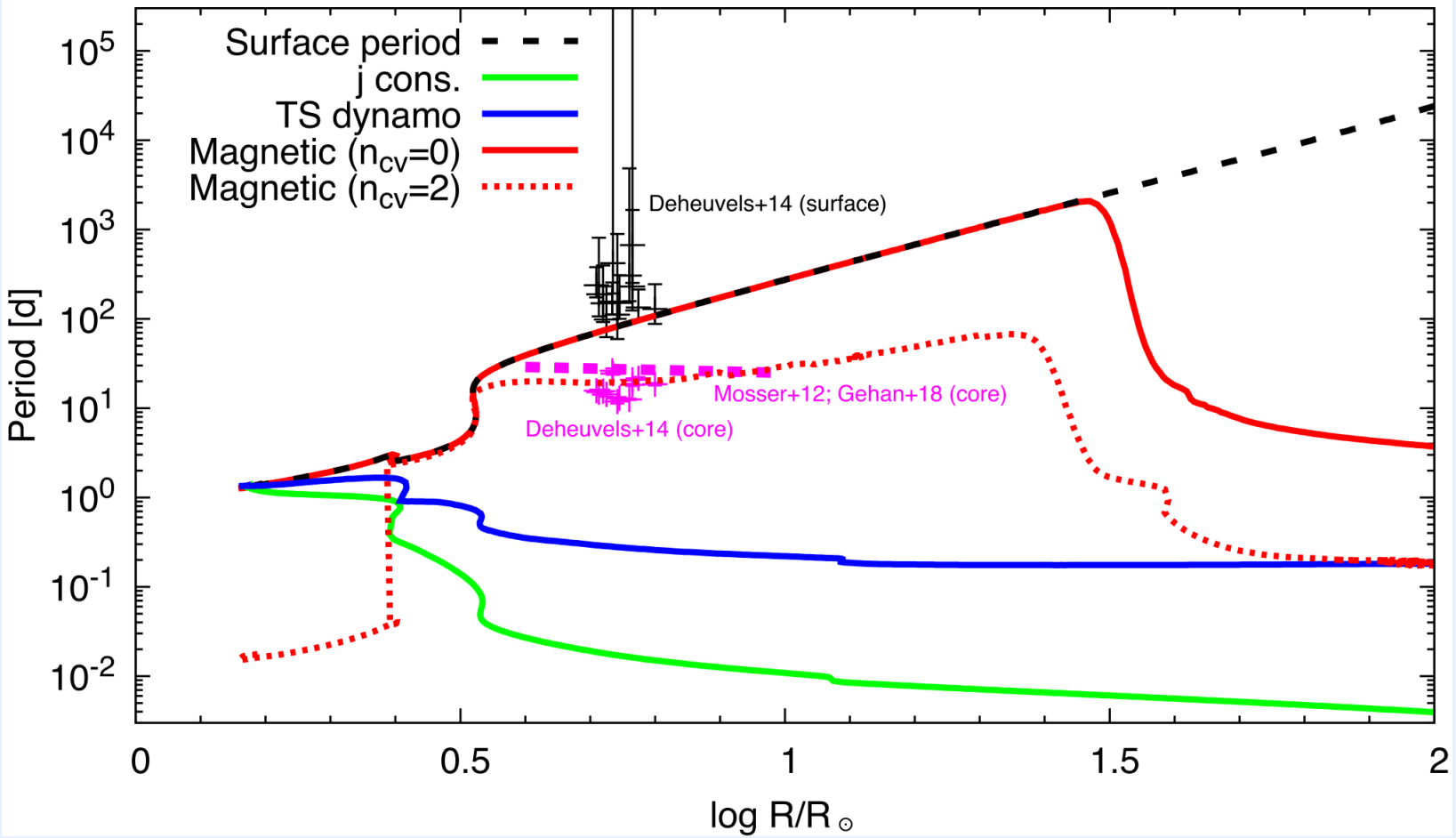
Magneto-sonic oscillation





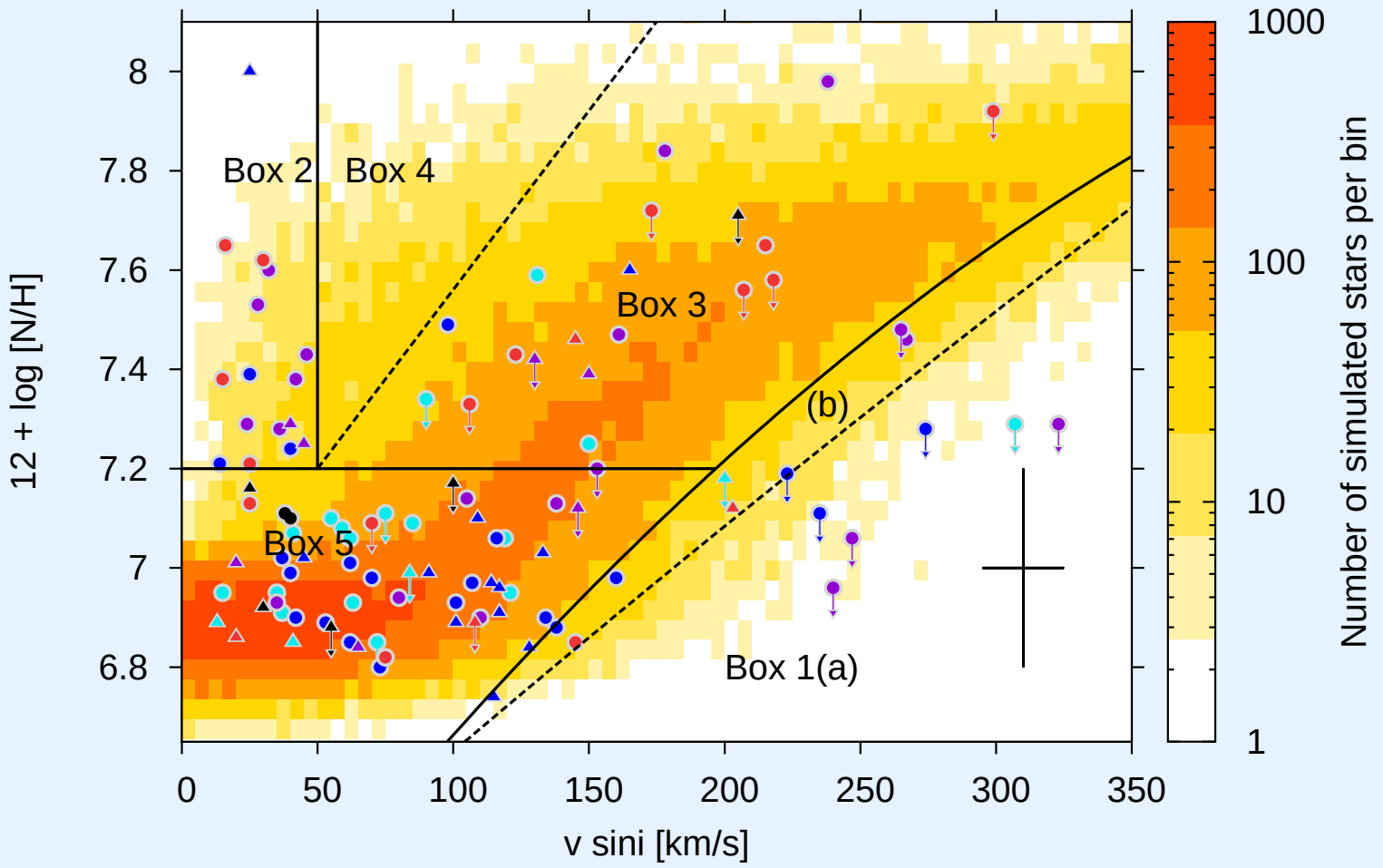
Takahashi+ 2021

Moagneto-sonic oscillation



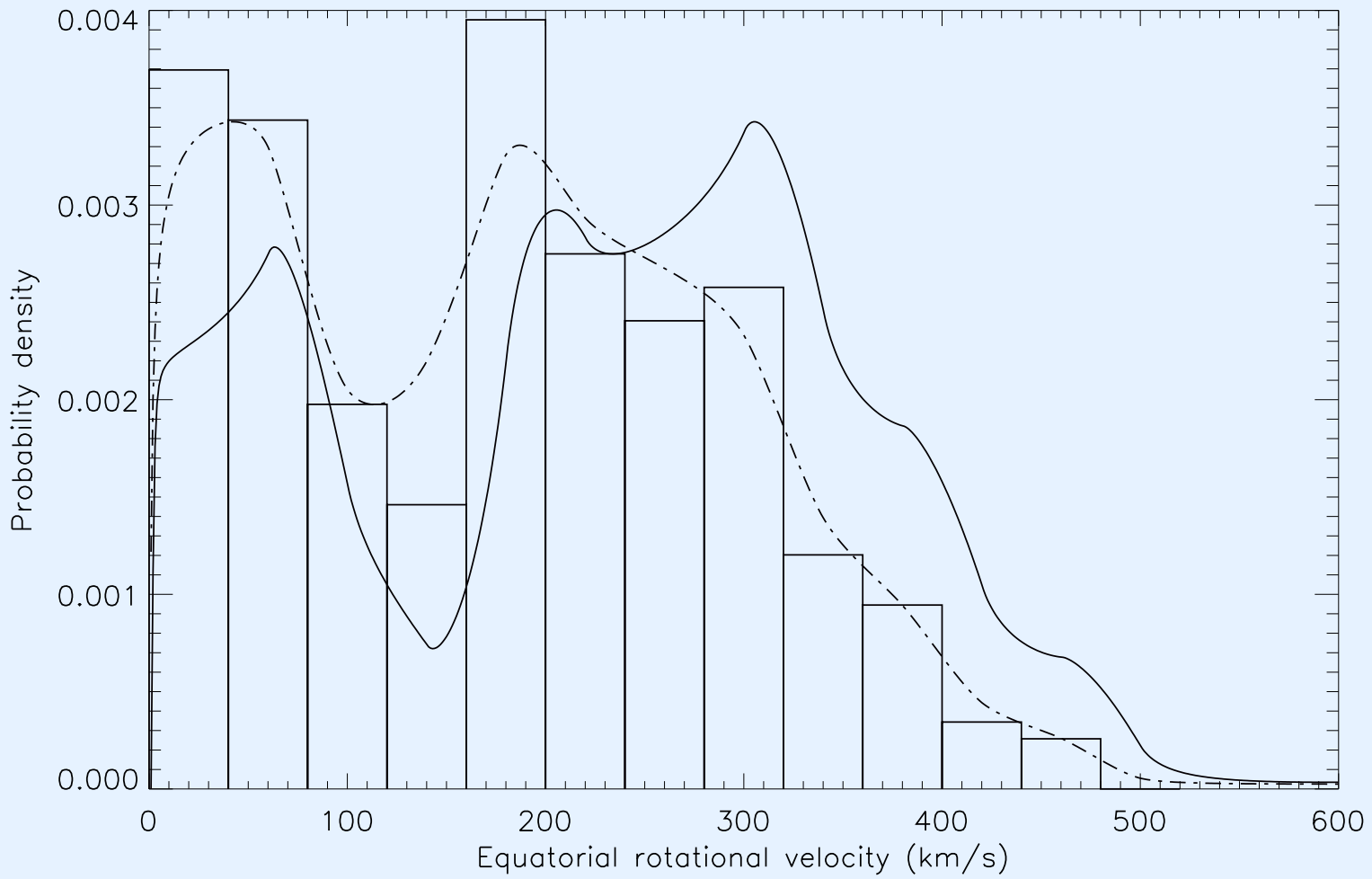
Takahashi+ 2021

Observational constraints: BV stars



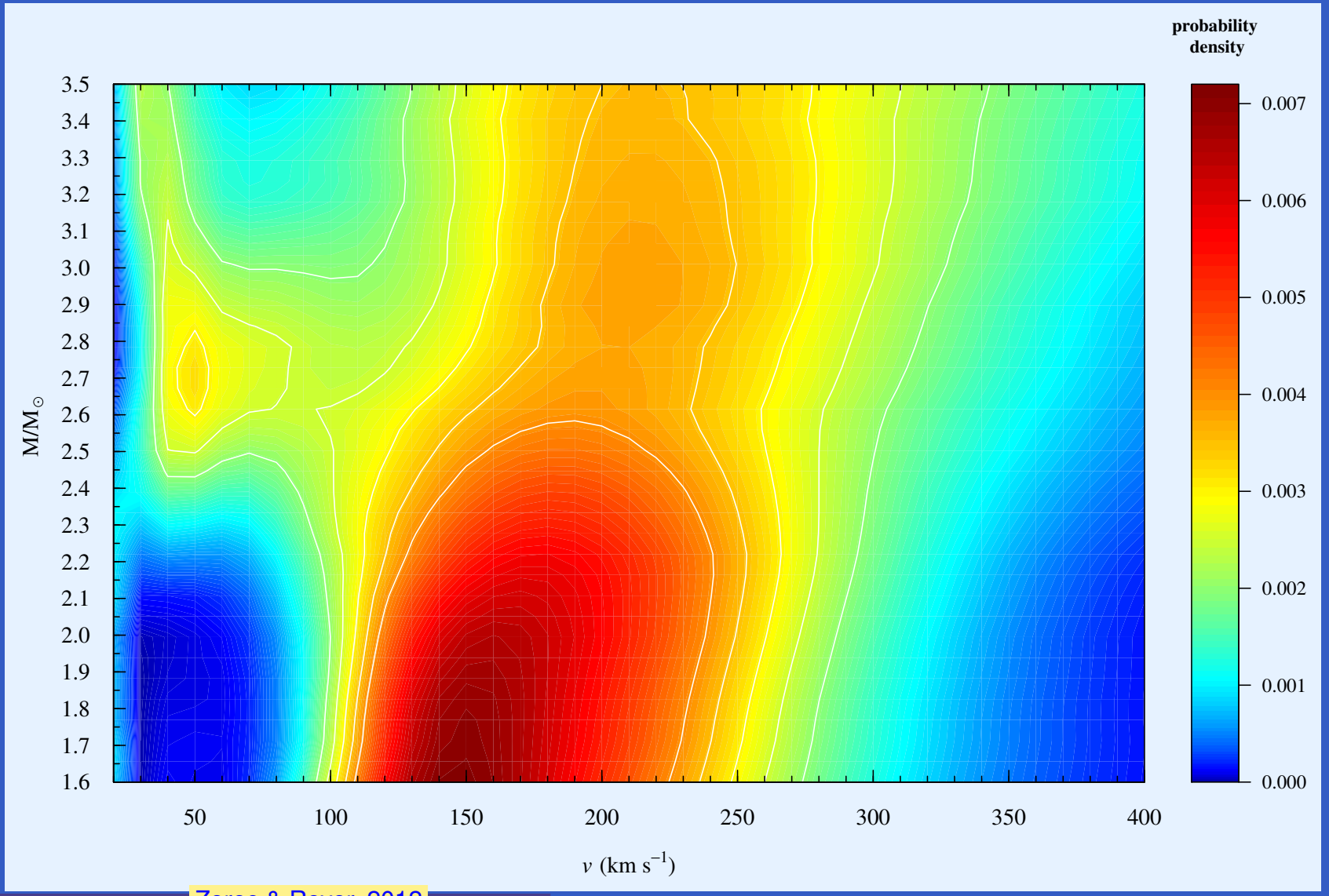
Brott+ 2011

The rotation rates: early BV stars



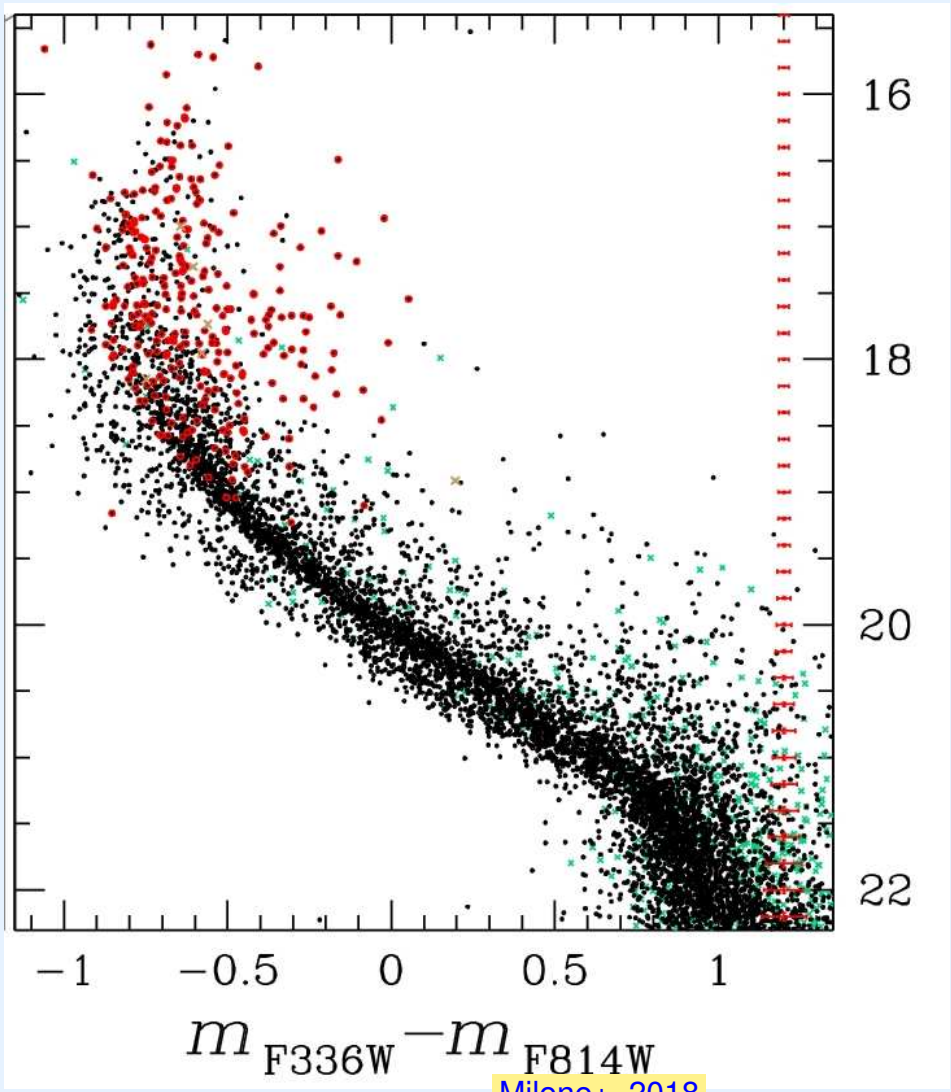
Dufton+ 2012

The rotation rates: A stars



Zorec & Royer, 2012

HST photometry: NGC 1850

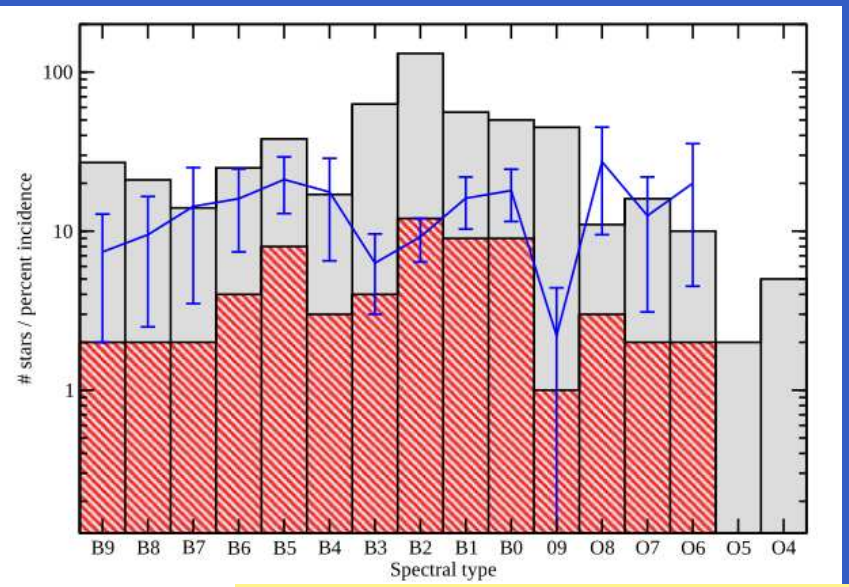


Milone+, 2018

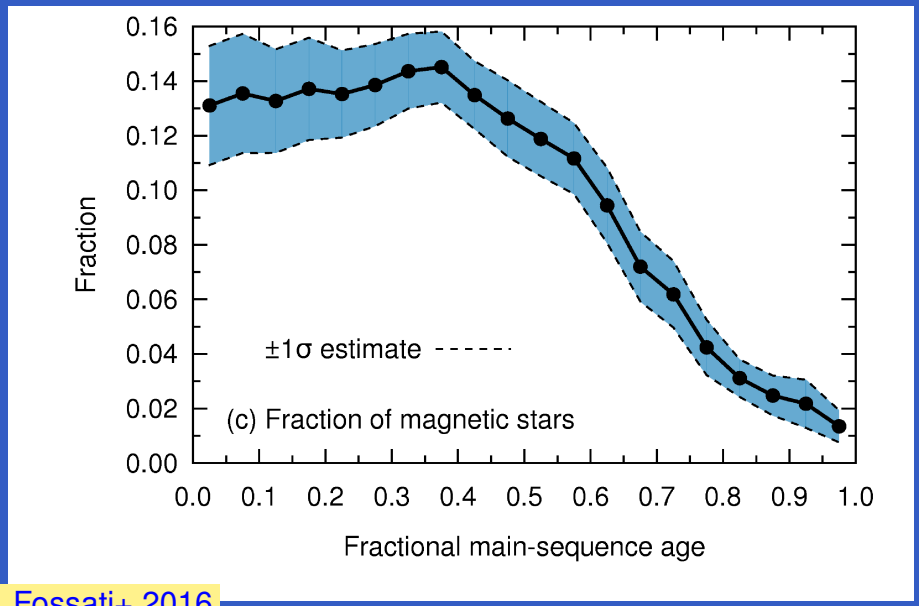
$\Rightarrow$ pre-MS merger

Tokovinin & Moe 2020; Wang+ 2022

Magnetic stars are fewer than slow rotators



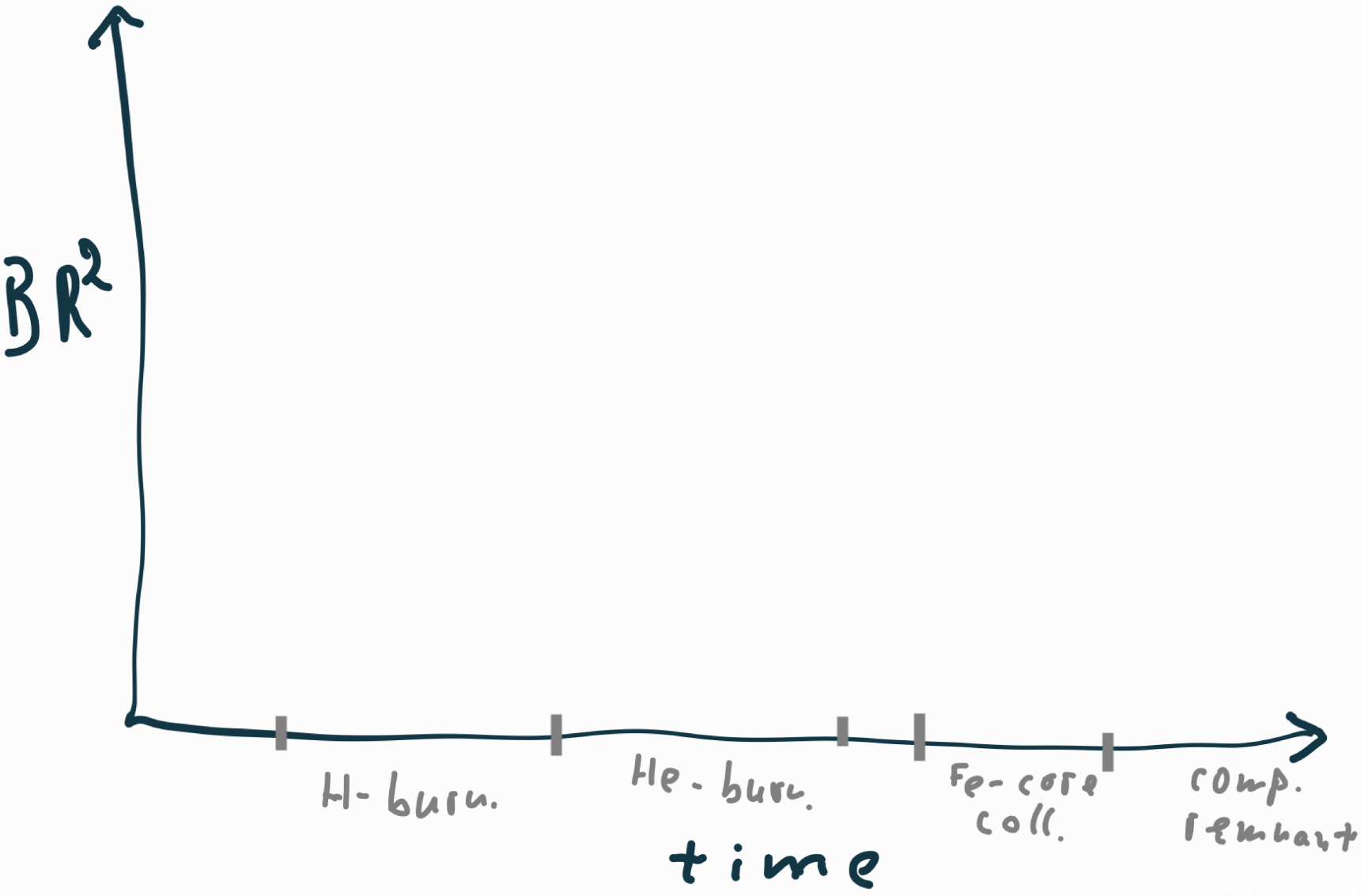
Wade+ 2014



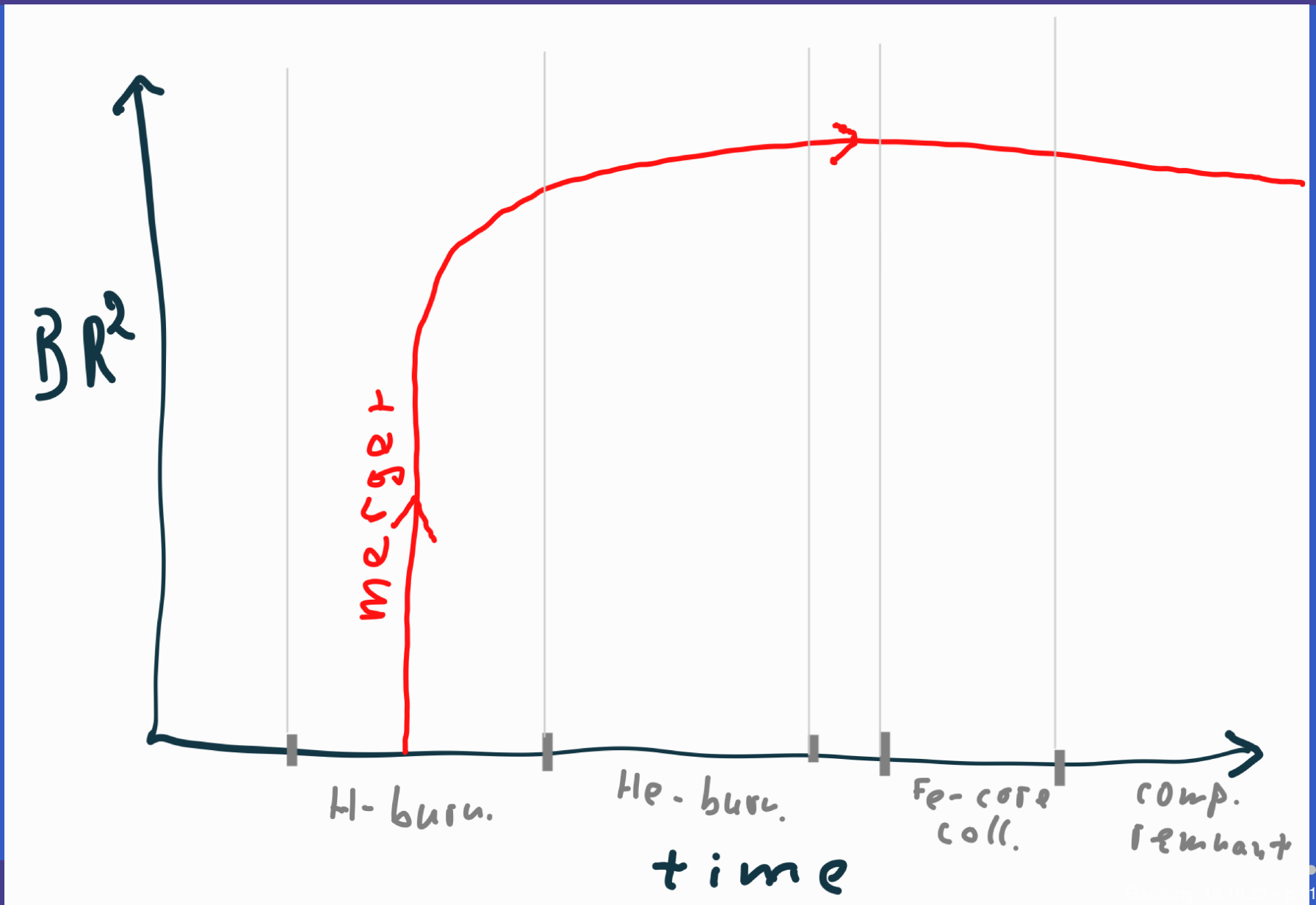
Fossati+ 2016

→ B-fields might decay on nuclear timescale

B-field evolution



B-field evoltion



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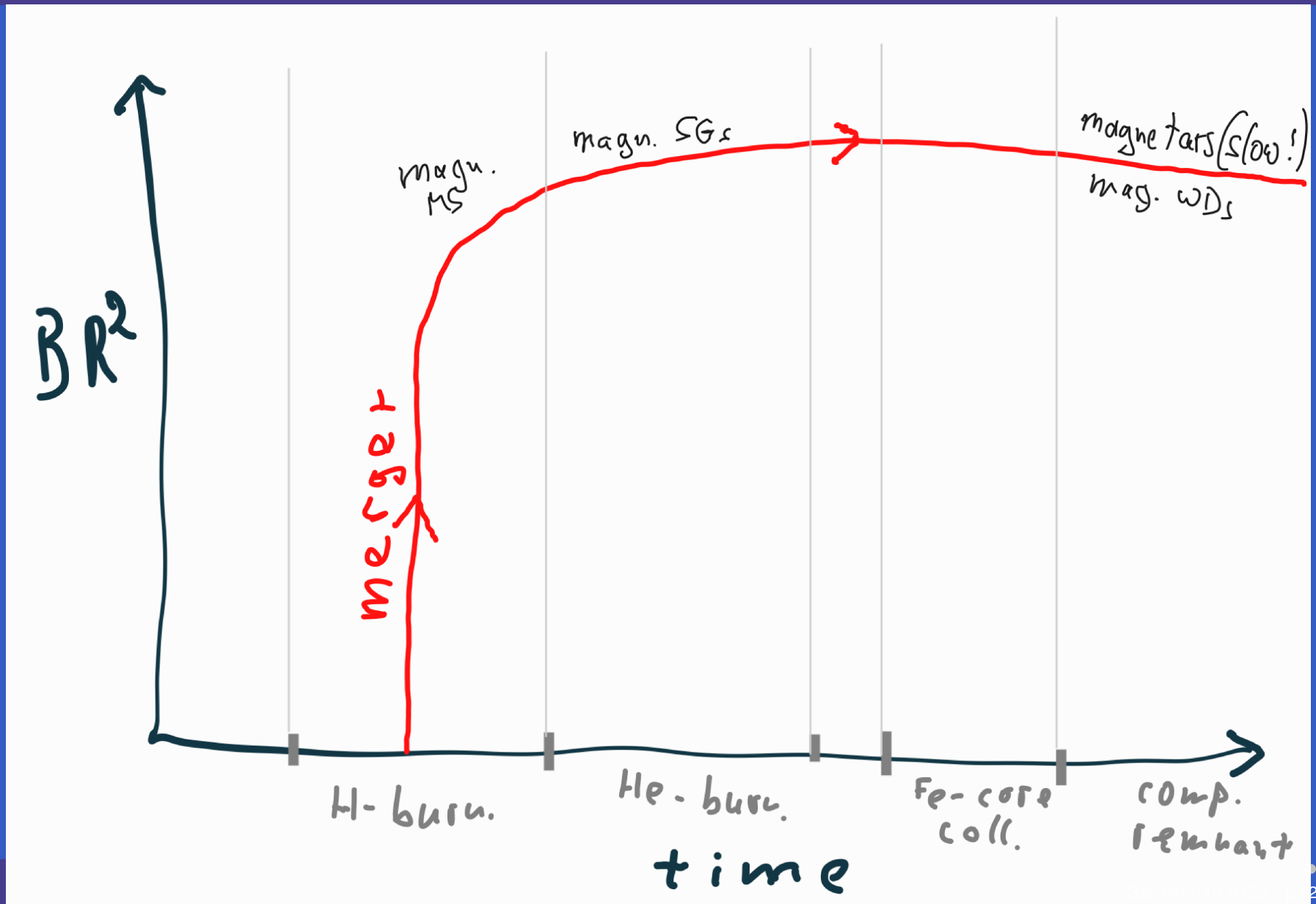

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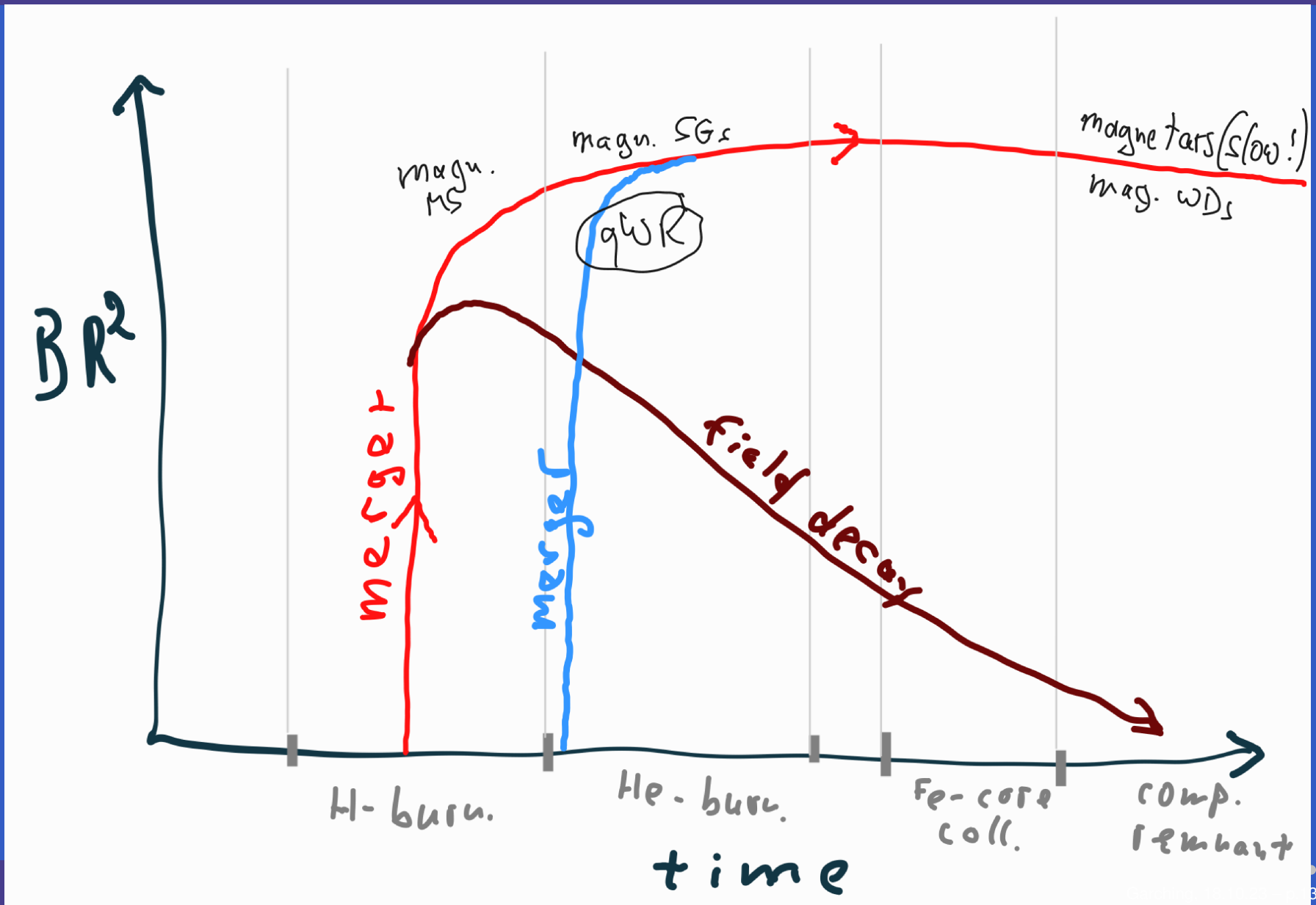
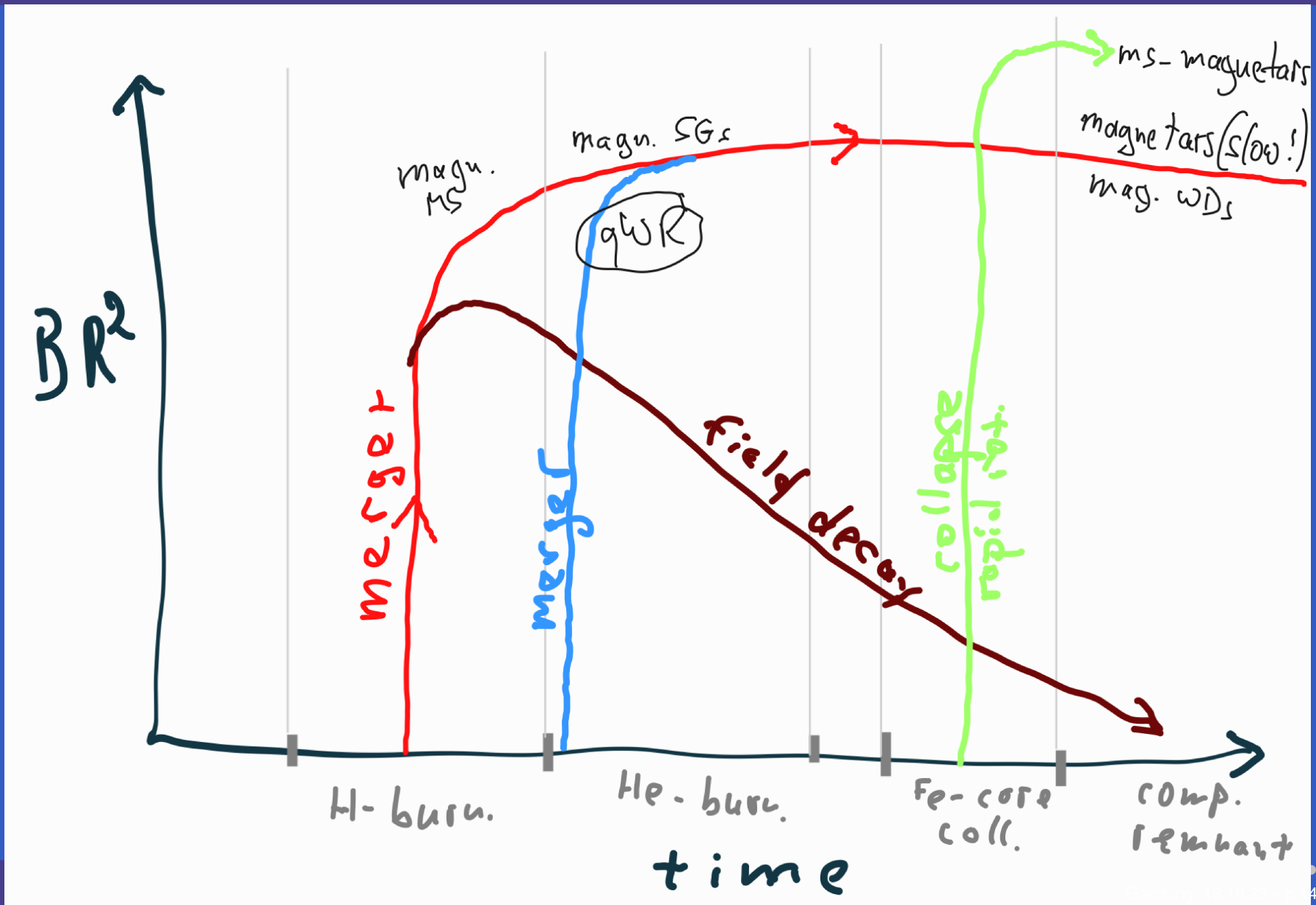


B-field evoltion



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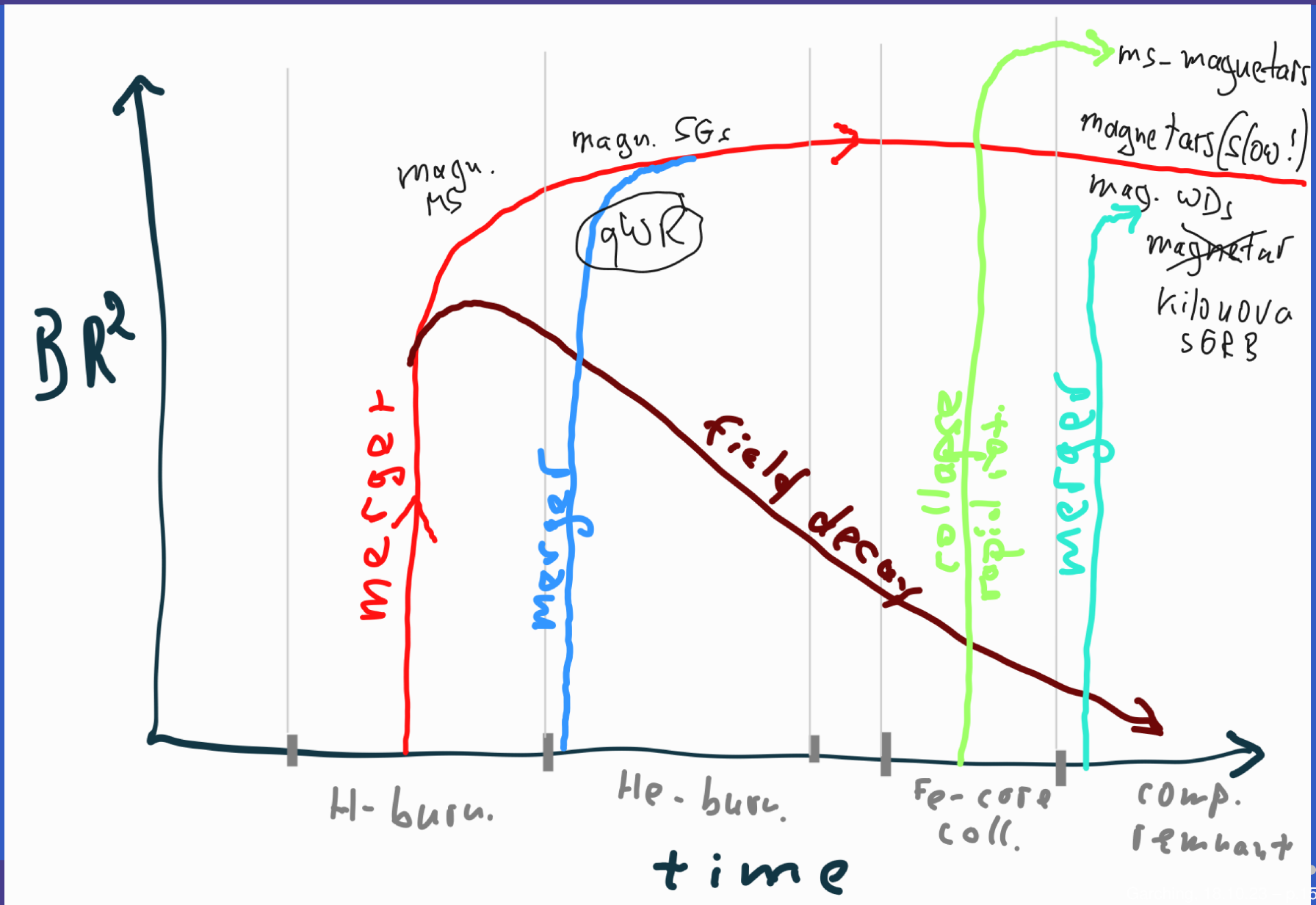

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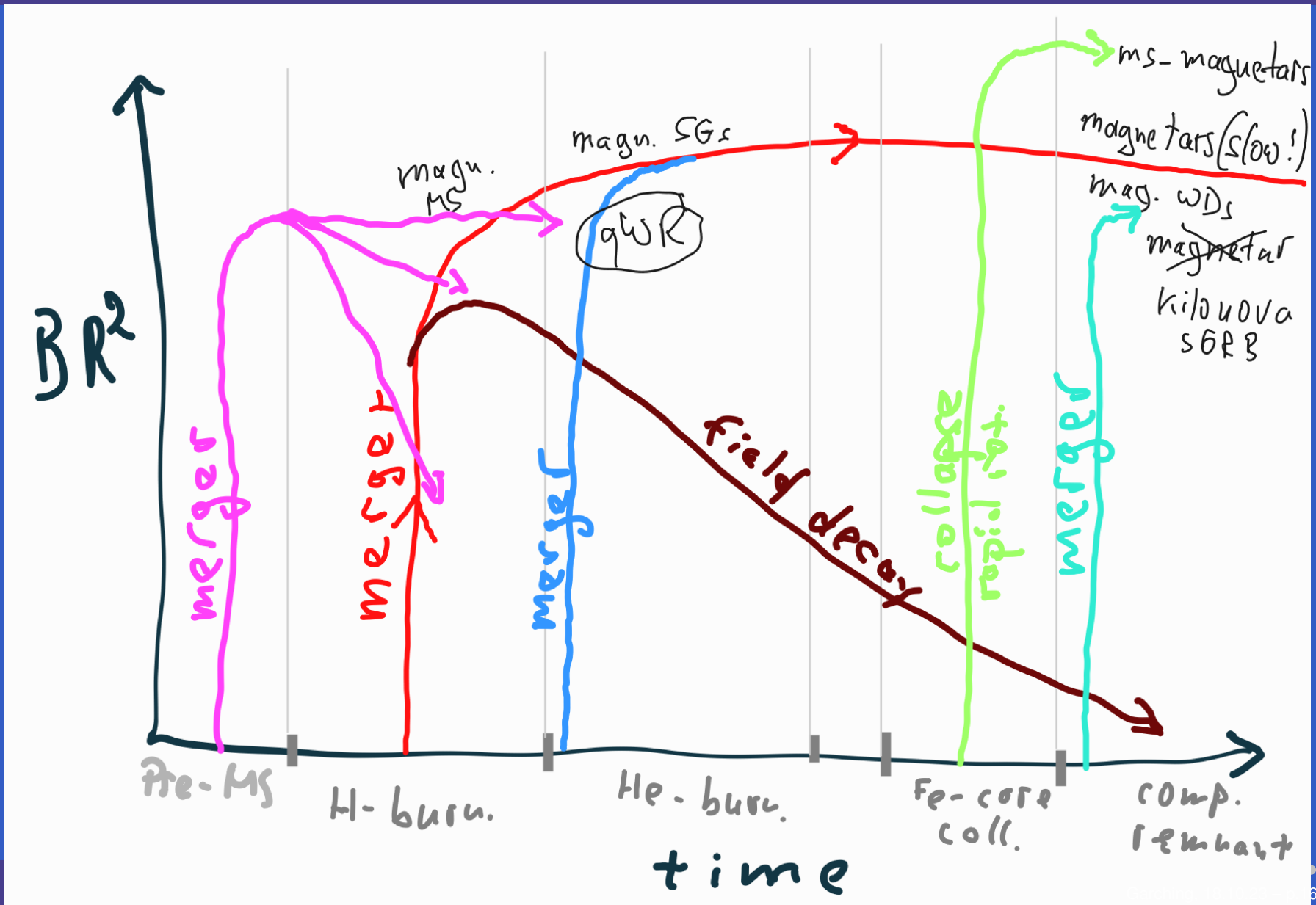

Conclusions

- pre-MS merger! $\rightarrow$ B-fields? $\rightarrow$ magnetic Herbig stars
- MS & post-MS merger channels work (e.g., τ Sco; qWR)
- field decay? not always: slow magnetars; but needed
- core collapse channel: ms-magnetars? (rare!)
- population synthesis should tell $\rightarrow$ e.g., which channel dominates magnetic WDs