Magnetosphere – accretion disk interaction in X-ray binaries

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Outline

- Introduction
- Uncertainties: the magnetosphere
- Jan's work on magnetic links connecting the magnetosphere to the accretion disk
- Our work on the evolution of ultracompact X-ray binaries

Introduction: accreting magnetic stars

- Various types:
  - protostars
  - cataclysmic variables
  - X-ray binaries

Important because:

- Accretion
- Spin regulation
- Disk structure

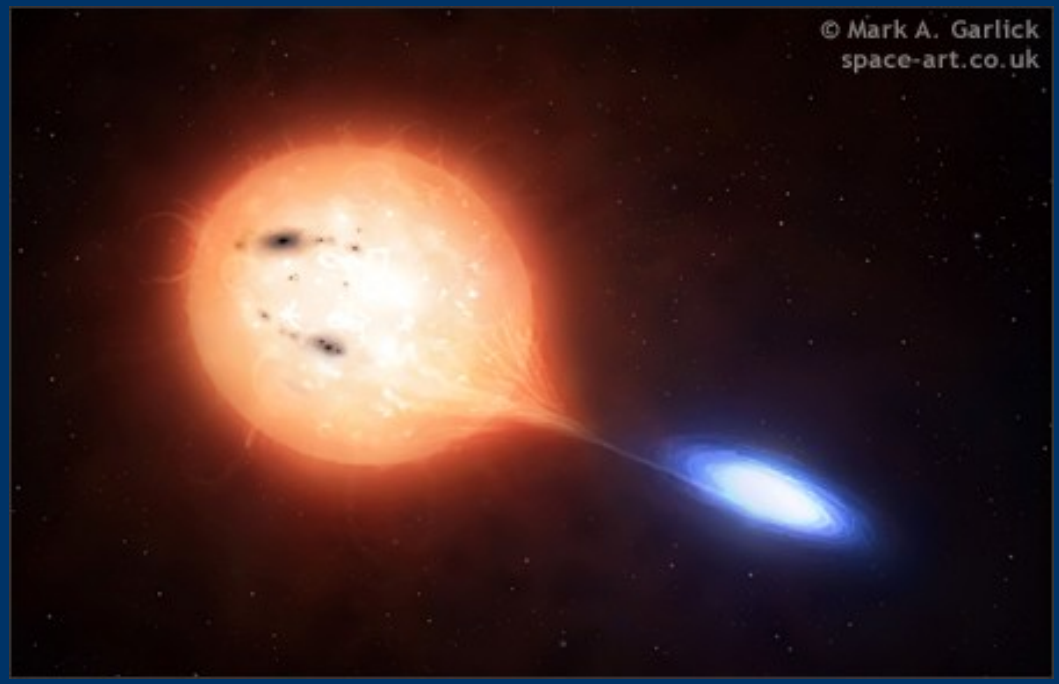


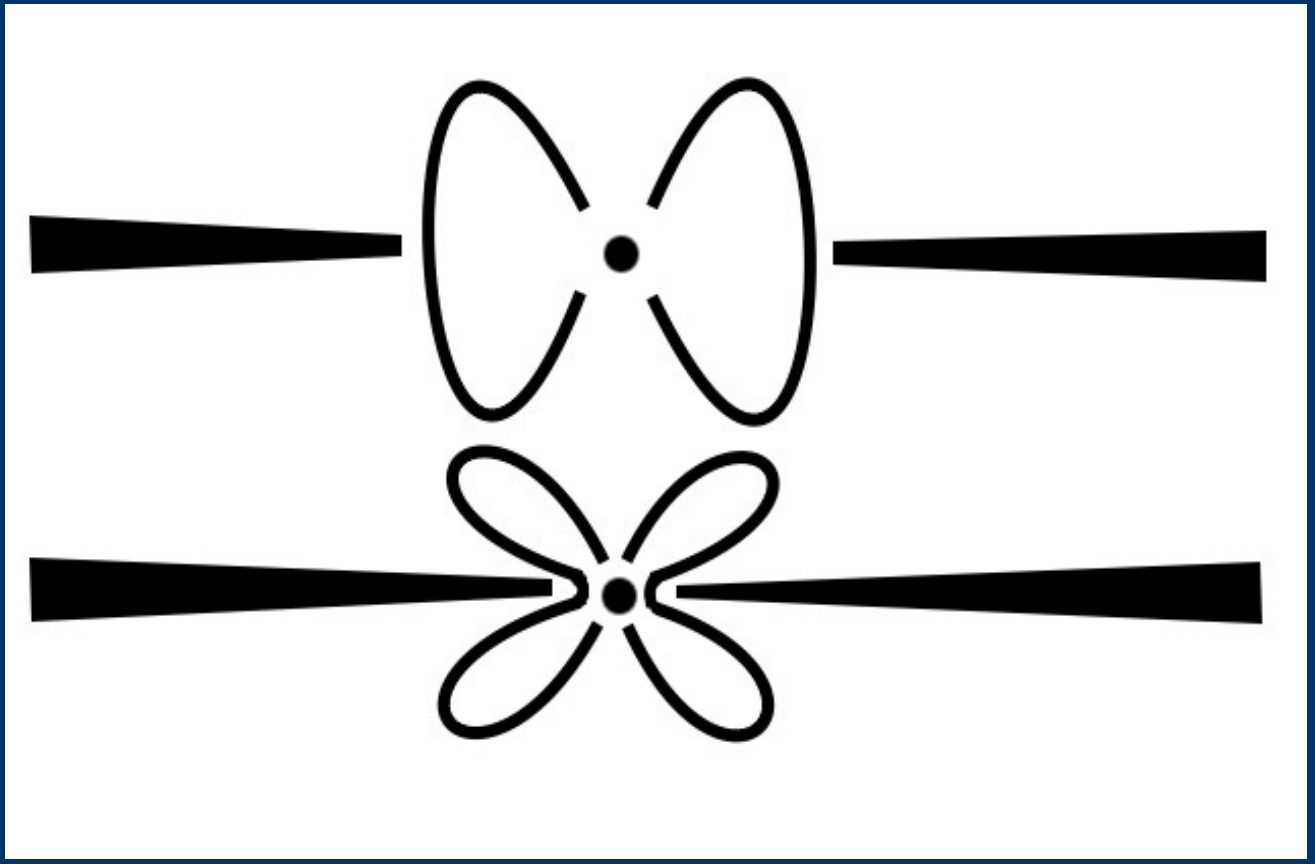
Image credits: Mark A. Garlick

The magnetosphere – a simple picture

- Geometry: spherical accretion vs. disk accretion

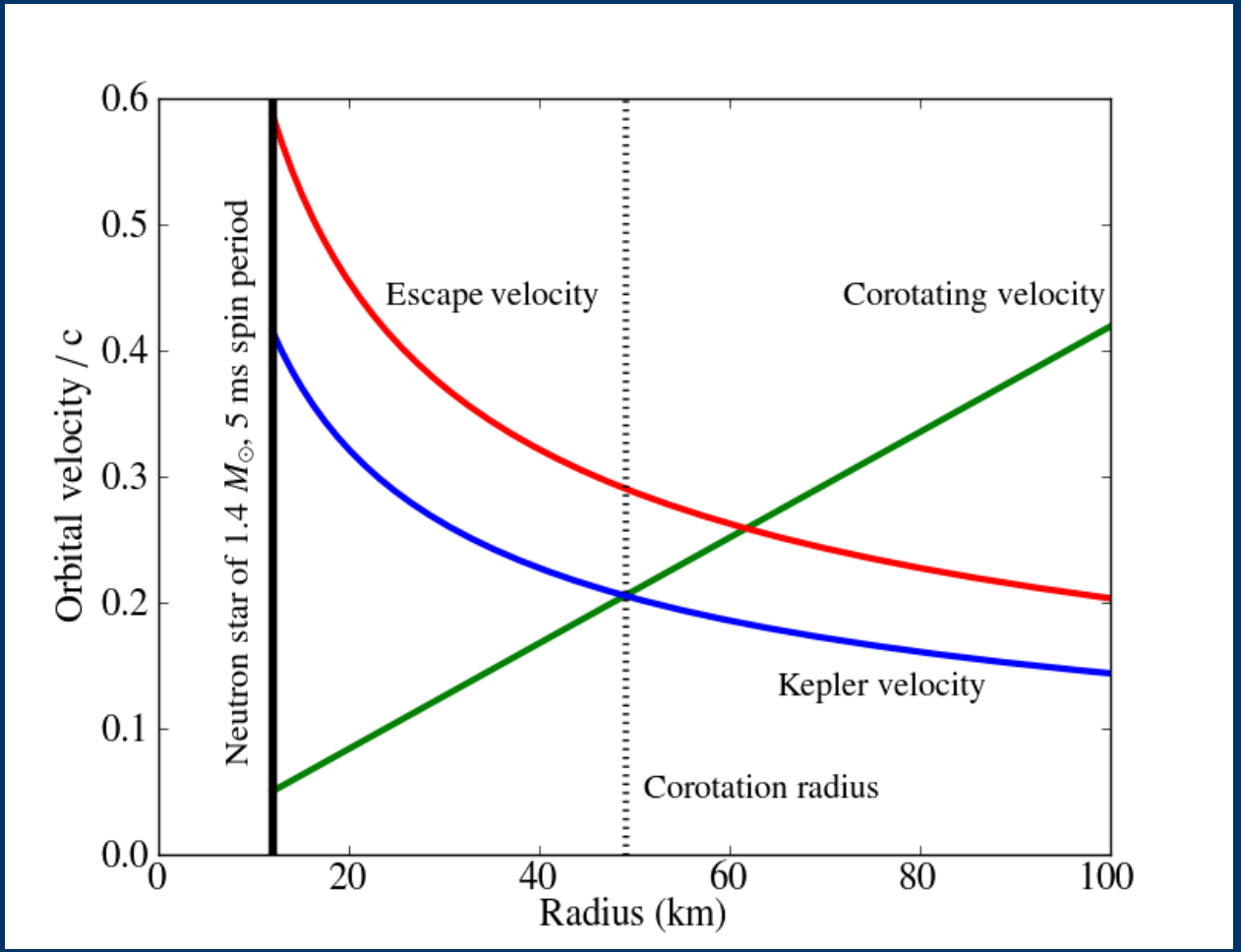
- Field dominates spherically infalling gas

- Disk dominates field



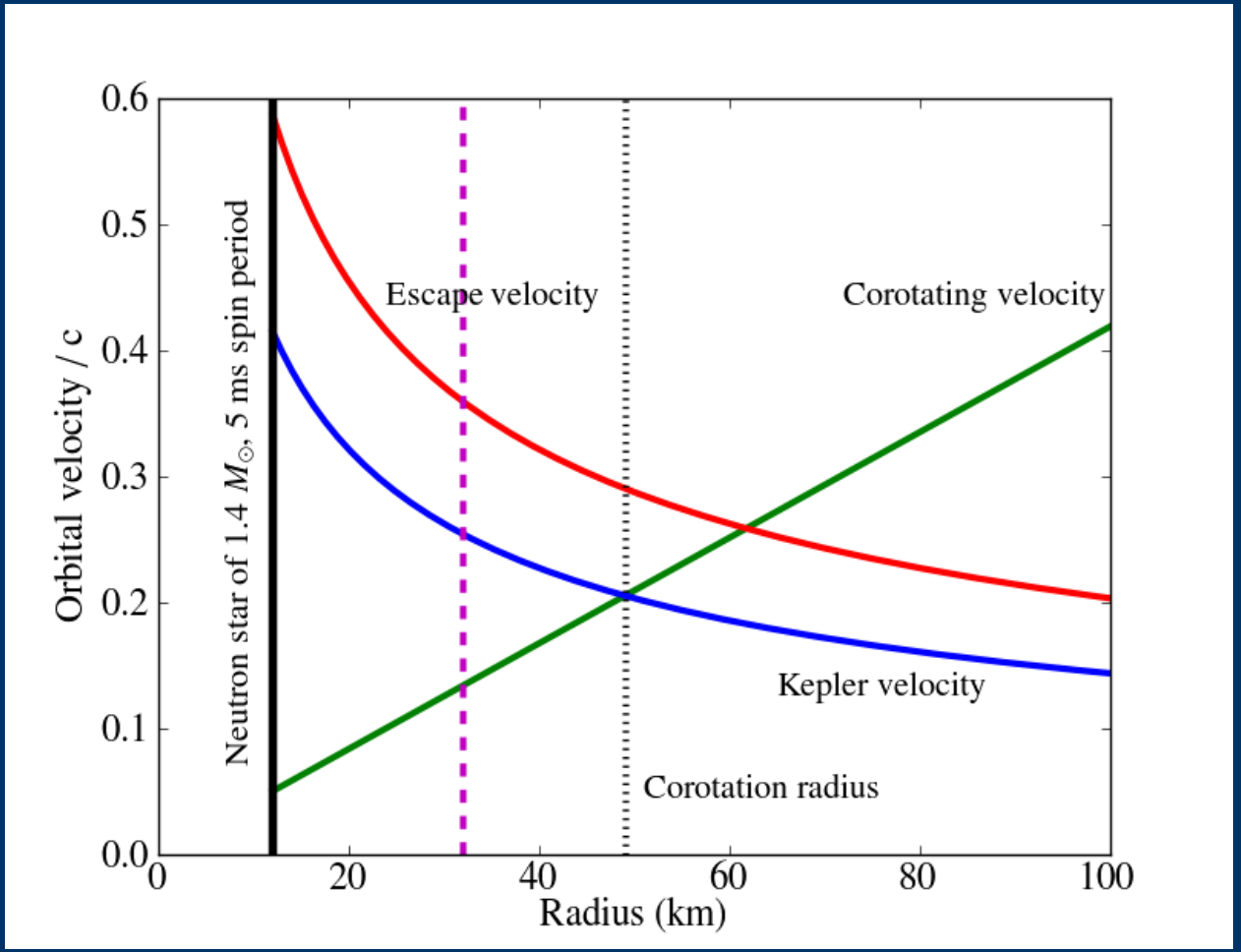
Velocities – a simple picture

- Field lines can move either slower or faster than disk matter



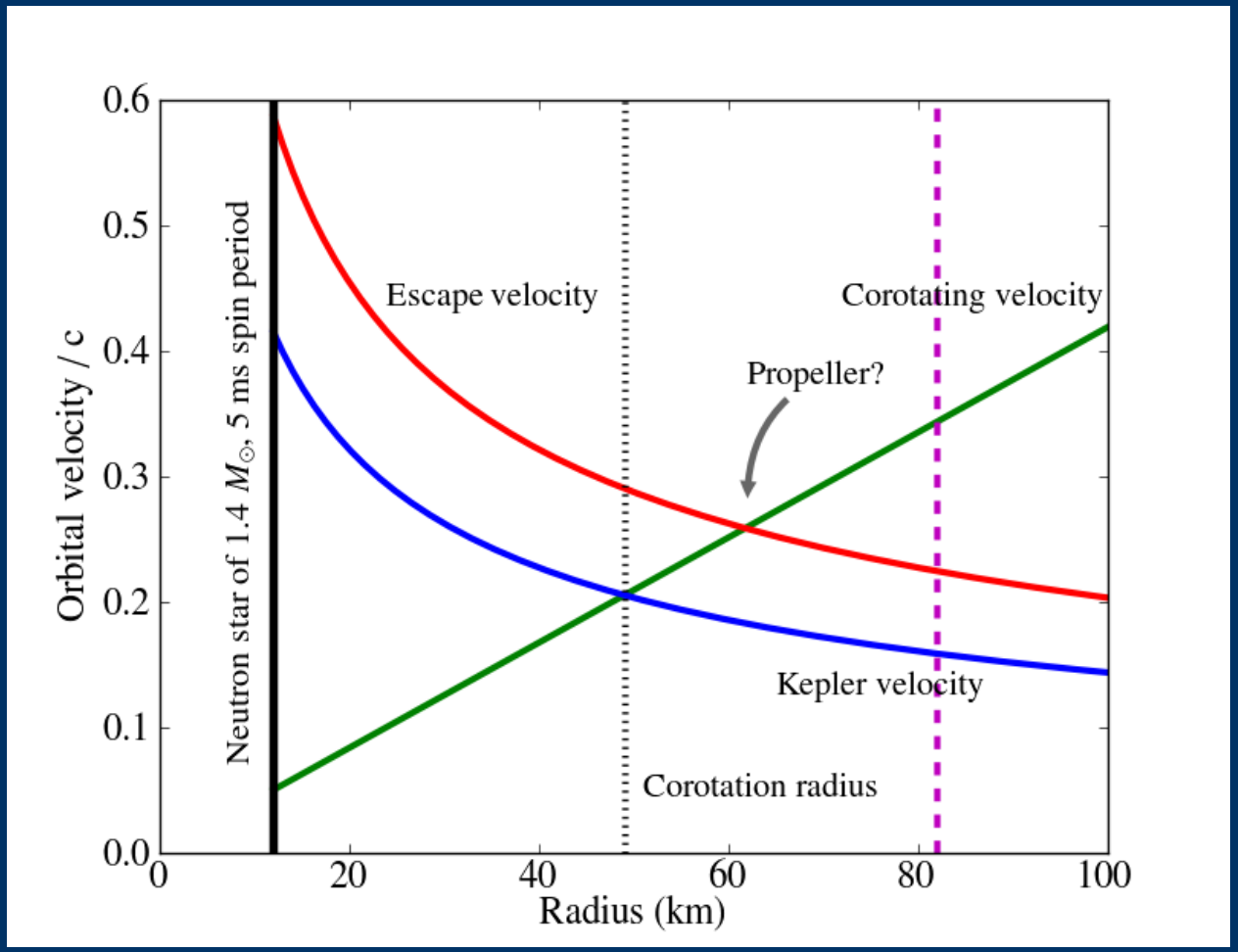
Velocities – a simple picture

- Field lines can move either slower or faster than disk matter
- Spin up



Velocities – a simple picture

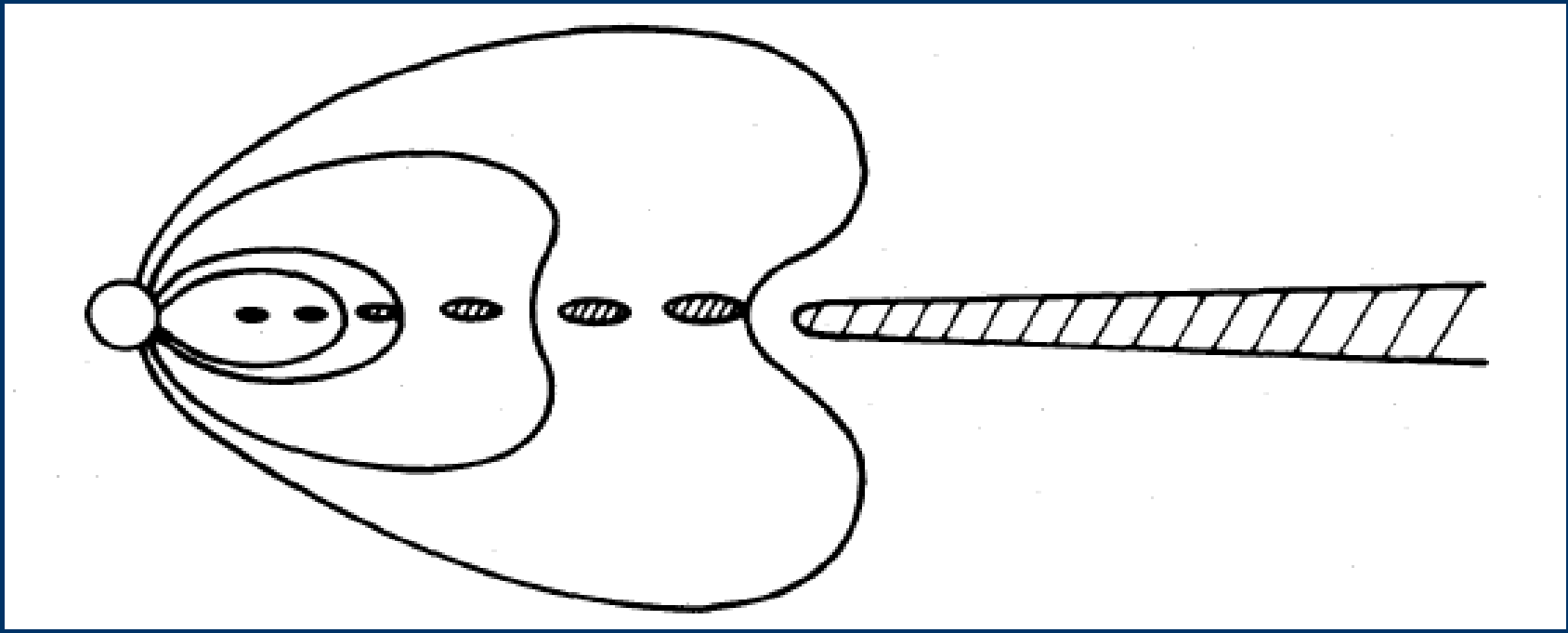
- Field lines can move either slower or faster than disk matter
- Spin down



Complications

Selection of Jan's work (with J.J. Aly)

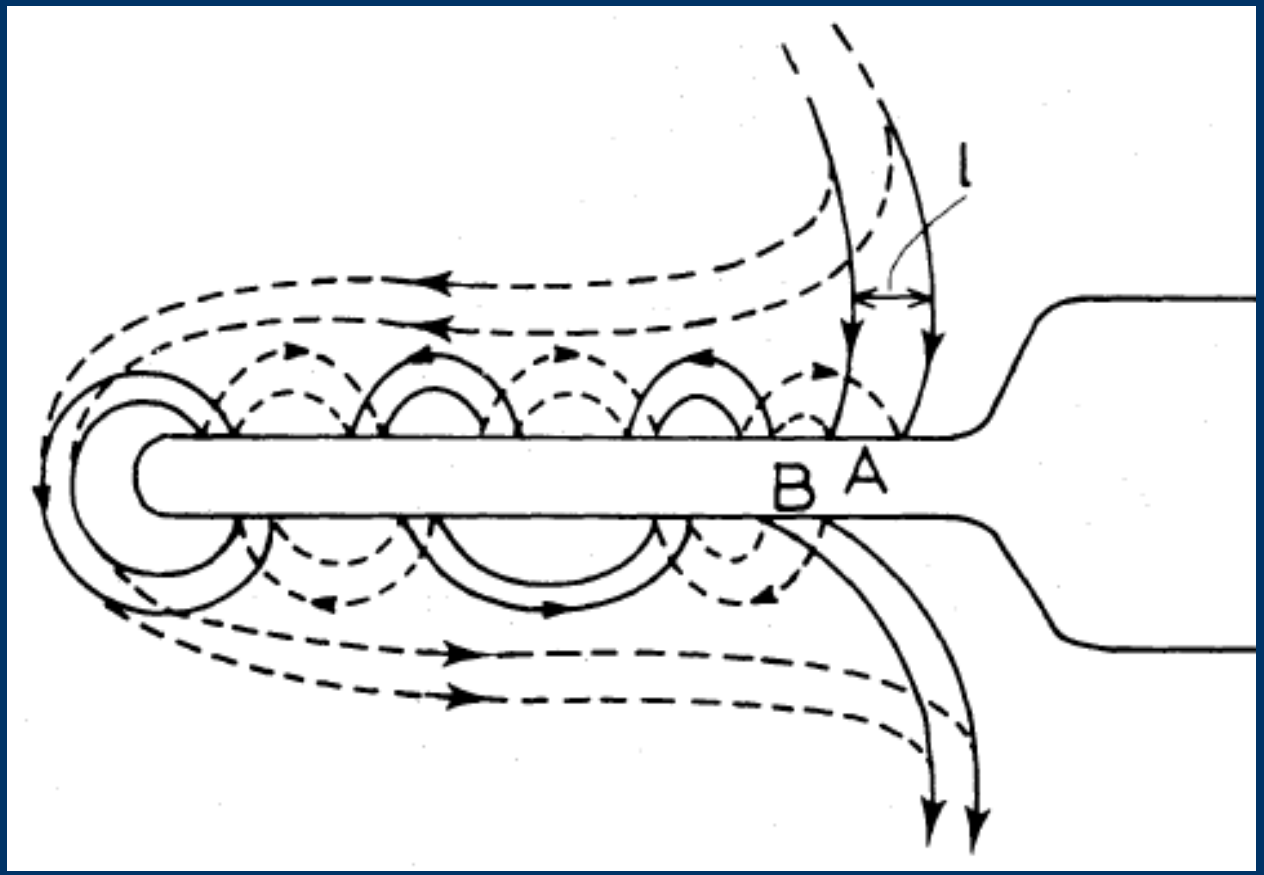
- Inside corotation radius: blob accretion
- Angular momentum transport



Aly & Kuijpers 1990 A&A, 227, 473

More work by Jan: Magnetic flares

- Connections between the stellar field and the disk field
- Differential rotation causes shear and reconnections



Aly & Kuijpers 1990 A&A, 227, 473

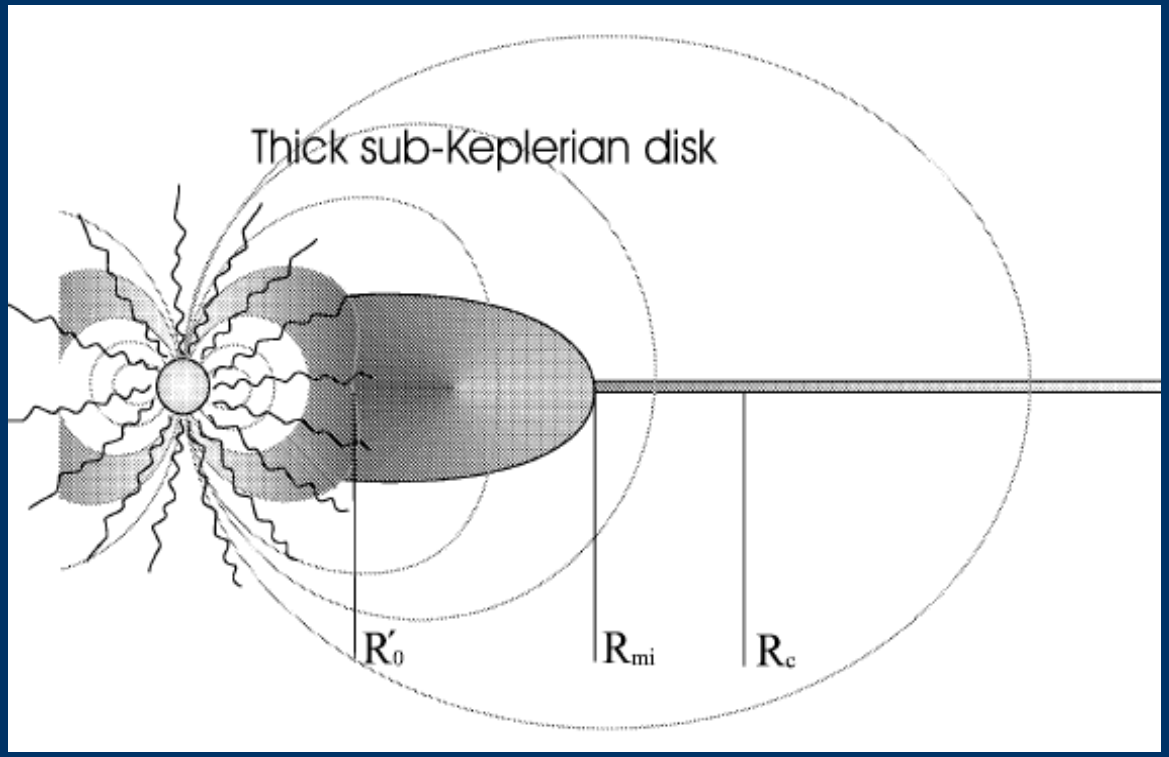
Two other models

- Andersson et al. 2005: high accretion rate model

  Radiation pressure

- D'Angelo & Spruit 2011
  (arXiv:1102.3697)

  Trapped disk, mainly for strong magnetic field



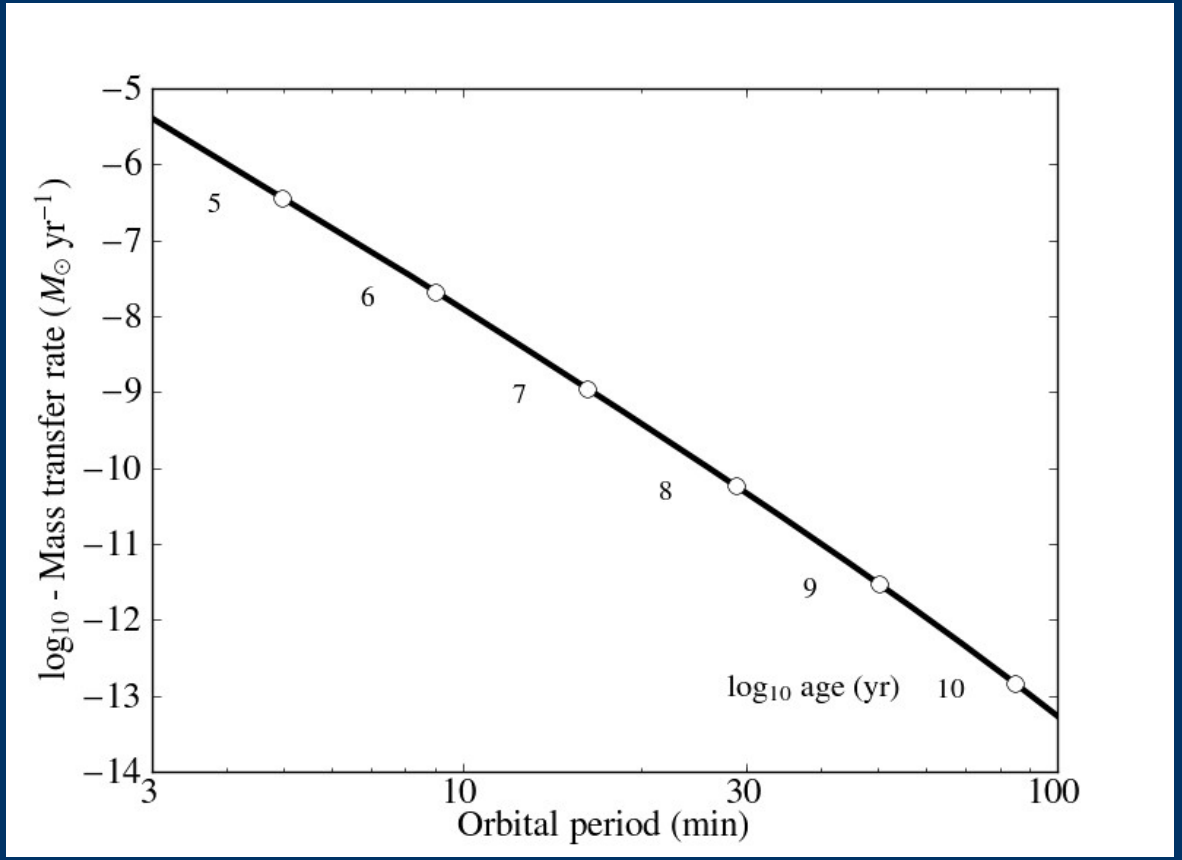
Andersson et al. 2005 MNRAS, 361, 1153

Recent work with Jan, and
G. Nelemans, R. Voss, M. Wood:

ultracompact X-ray binaries (UCXBs)

What are ultracompact X-ray binaries?

- UCXB: Roche-lobe filling white dwarf losing mass to a neutron star
- Gravitational wave radiation forces mass transfer
- Donor and orbit expand with time



Understanding UCXB evolution

The problem:

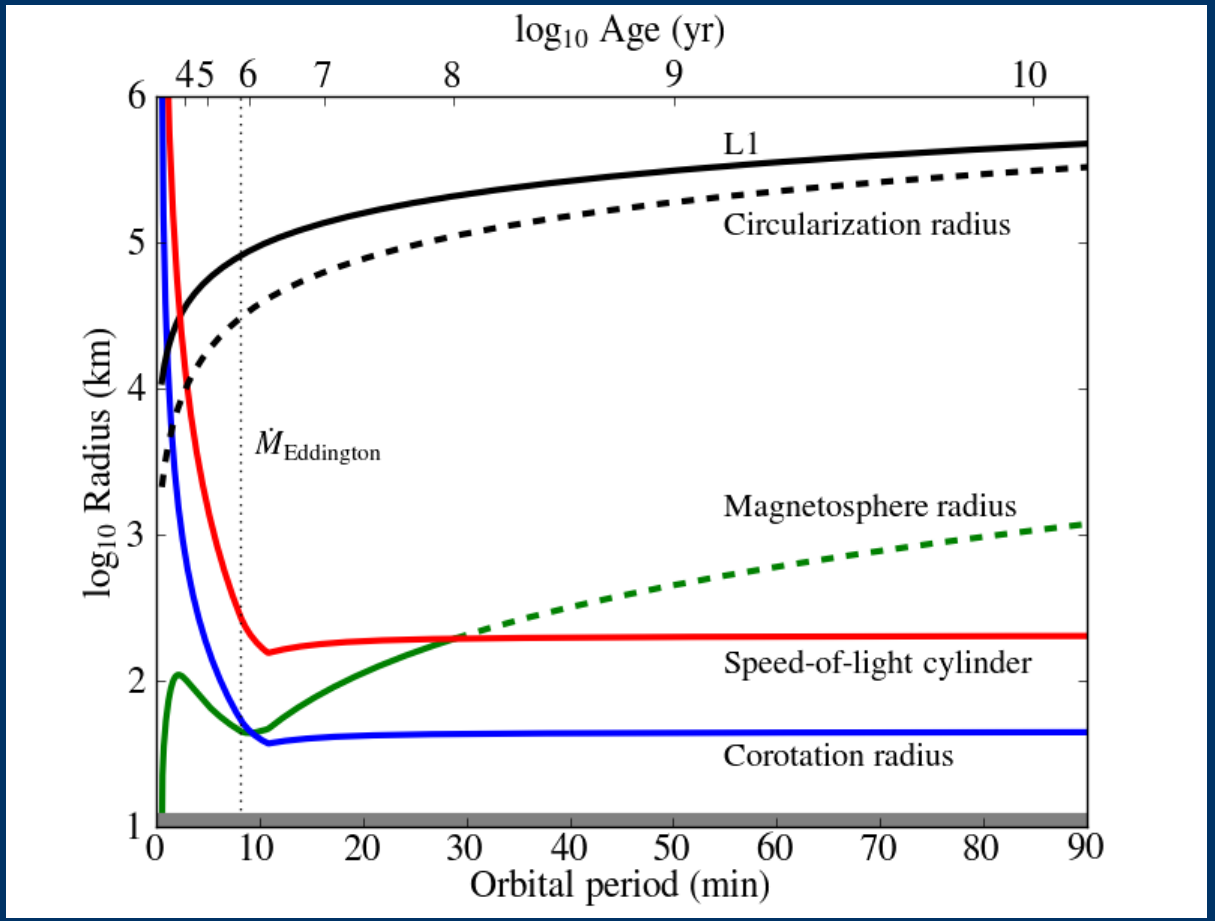
- Our population synthesis model overpredicts the number of visible UCXBs

Possible explanations:

- UCXBs are destroyed at a very low mass ratio
- UCXBs become (often) invisible at a very low mass transfer rate → propeller effect?

UCXB accretion disk evolution

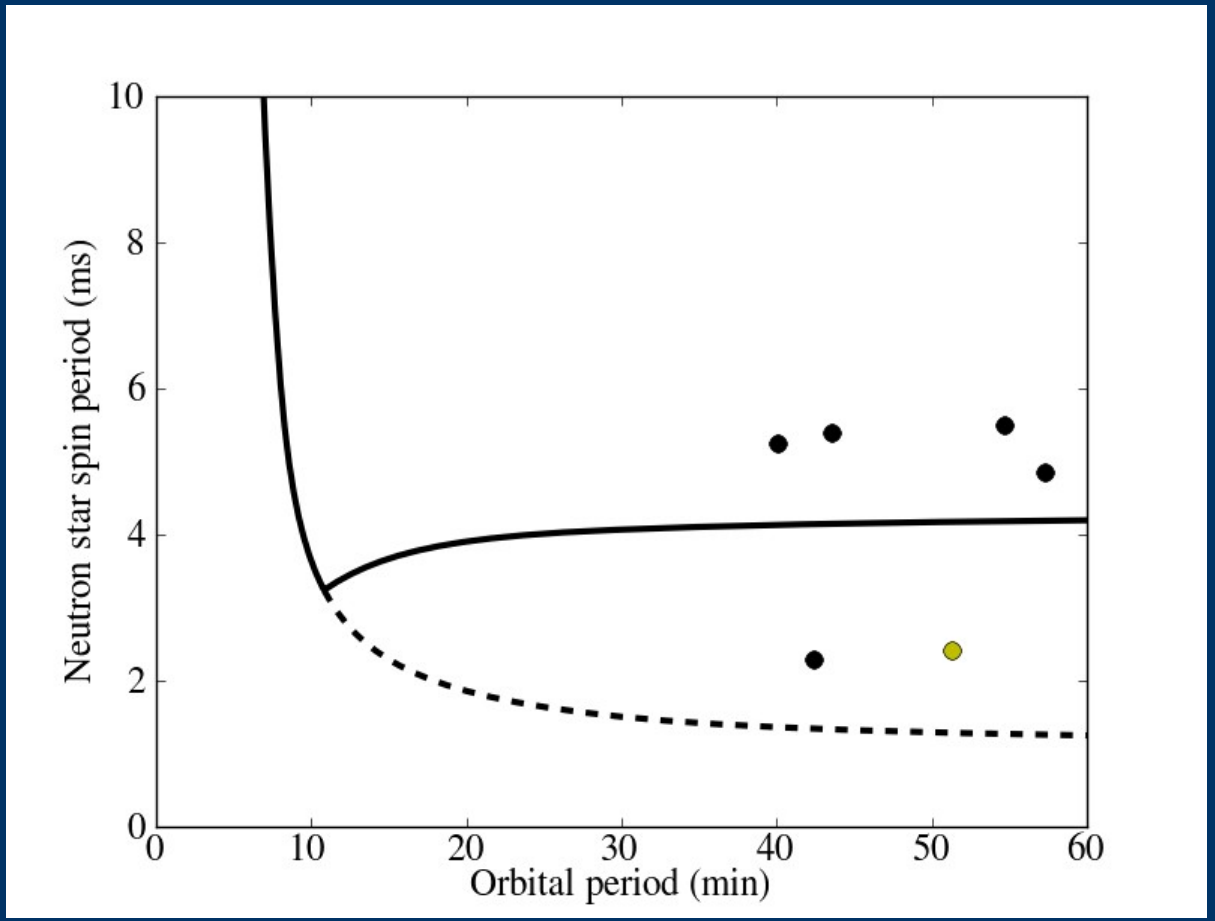
Propeller effect may reduce or stop accretion, but only if the magnetosphere is large enough



Residual equatorial B-field = $10^{8.5}$ G

UCXB accretor spin evolution

Comparison with the sample of known millisecond pulsars in UCXBs



Residual equatorial B-field = $10^{8.5}$ G