# MAGNETOSPHERIC ACCRETION IN TRANSITIONAL PULSARS

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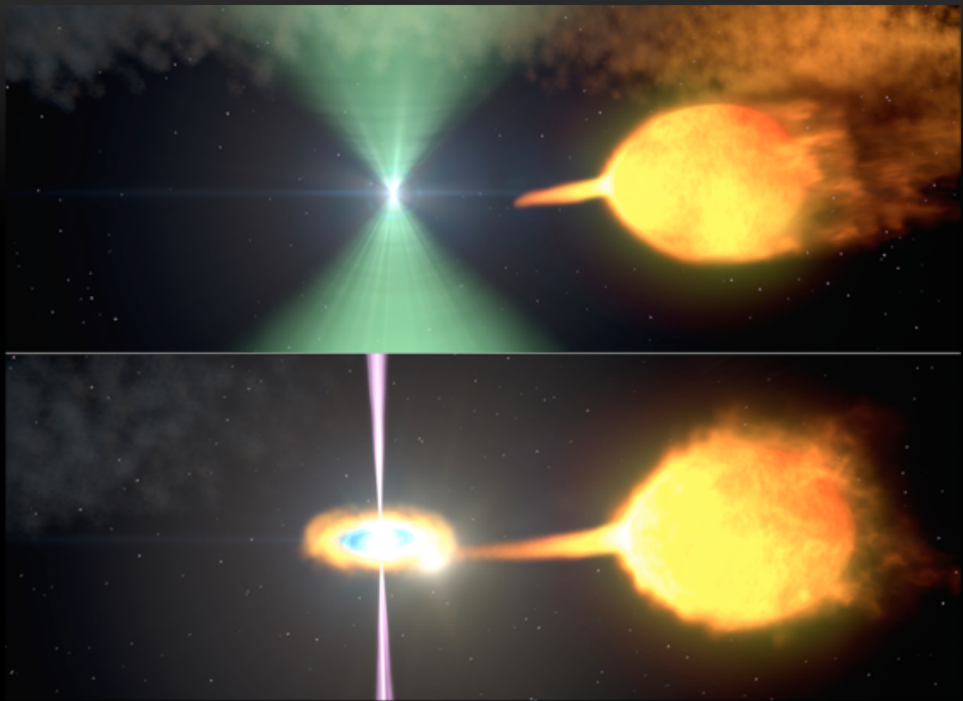
# J1023+0038: AN AMAZING PROBE OF ACCRETION MODELS



NASA

- Low accretion state: propeller?, radiatively-inefficient?)
- Known B, $P_*$
- Known timing solution
- Reasonable estimate of accretion rate

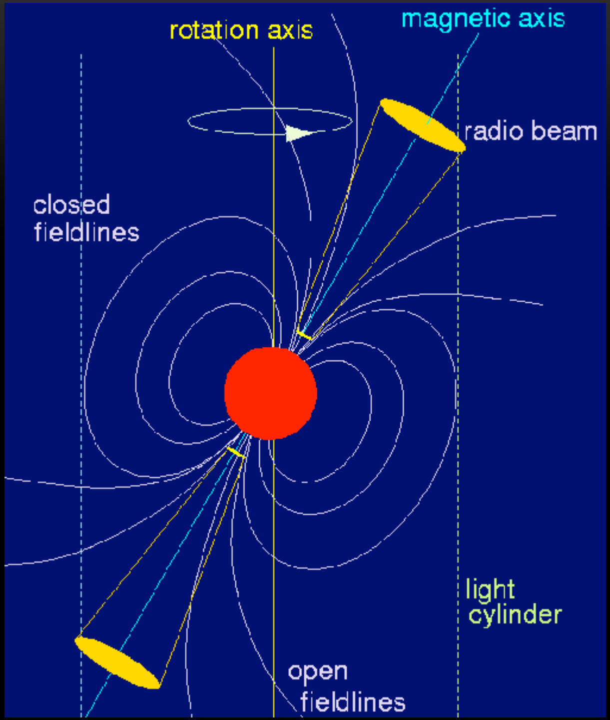
$$\dot{P}_{\mathrm{X-ray}} = \dot{P}_{\mathrm{radio}}(1 \pm 0.08)$$

$$\dot{\nu} = 2.5 \times 10^{-15}$$

**From X-ray luminosity:**

$$\dot{M} = 2.8 - 6.8 \times 10^{-5} \dot{M}_{\mathrm{Edd}}$$

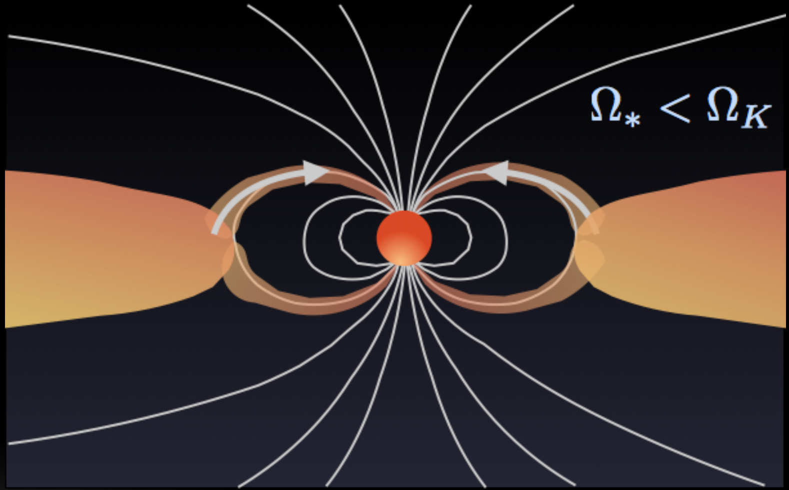
# HOW DOES PULSAR WIND STAY ON!?




- Pulsar wind shielded from disc ?
- Open field line region *should* be ~5 times larger in accreting state
- How strong is radio outflow?

$$\frac{R_{LC}}{R_c} = \sqrt{\frac{R_g}{R_c}} \simeq 0.2$$

For ms pulsar



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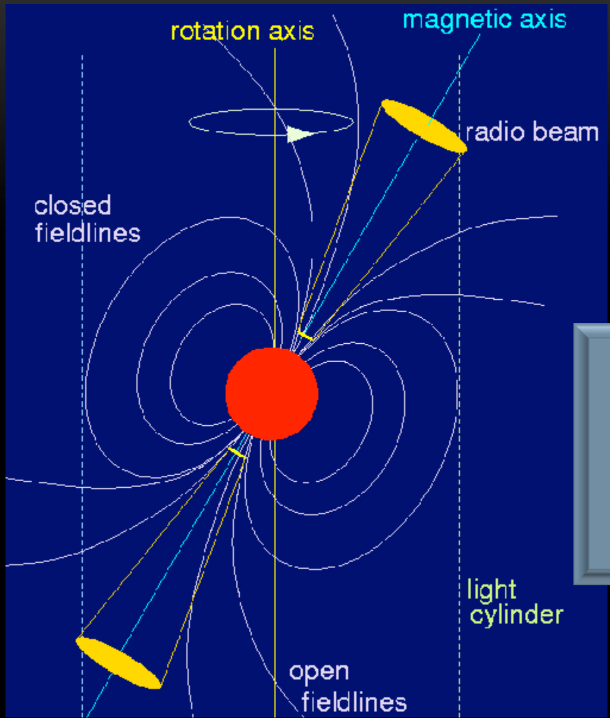


- Pulsar wind shielded from disc ?
- Open field line region *should* be ~5 times larger in accreting state
- is radio outflow?

STAY TUNED!

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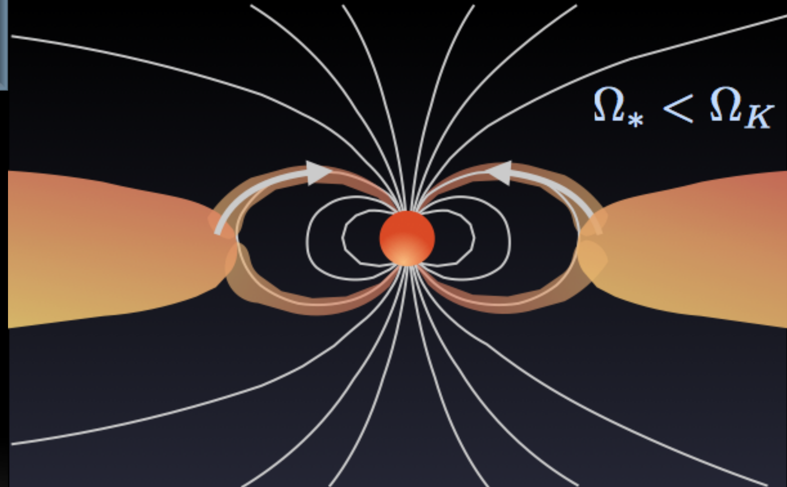

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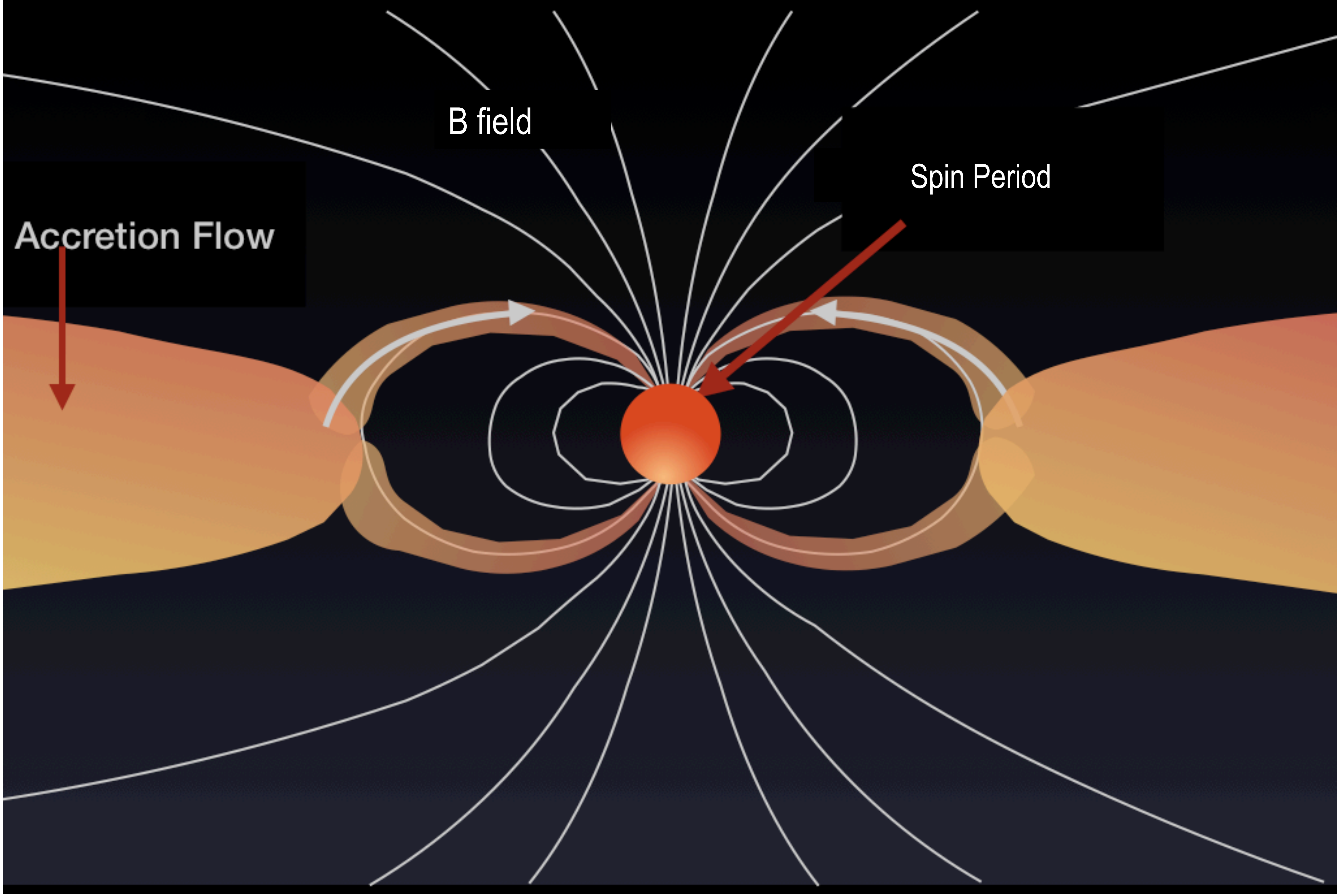

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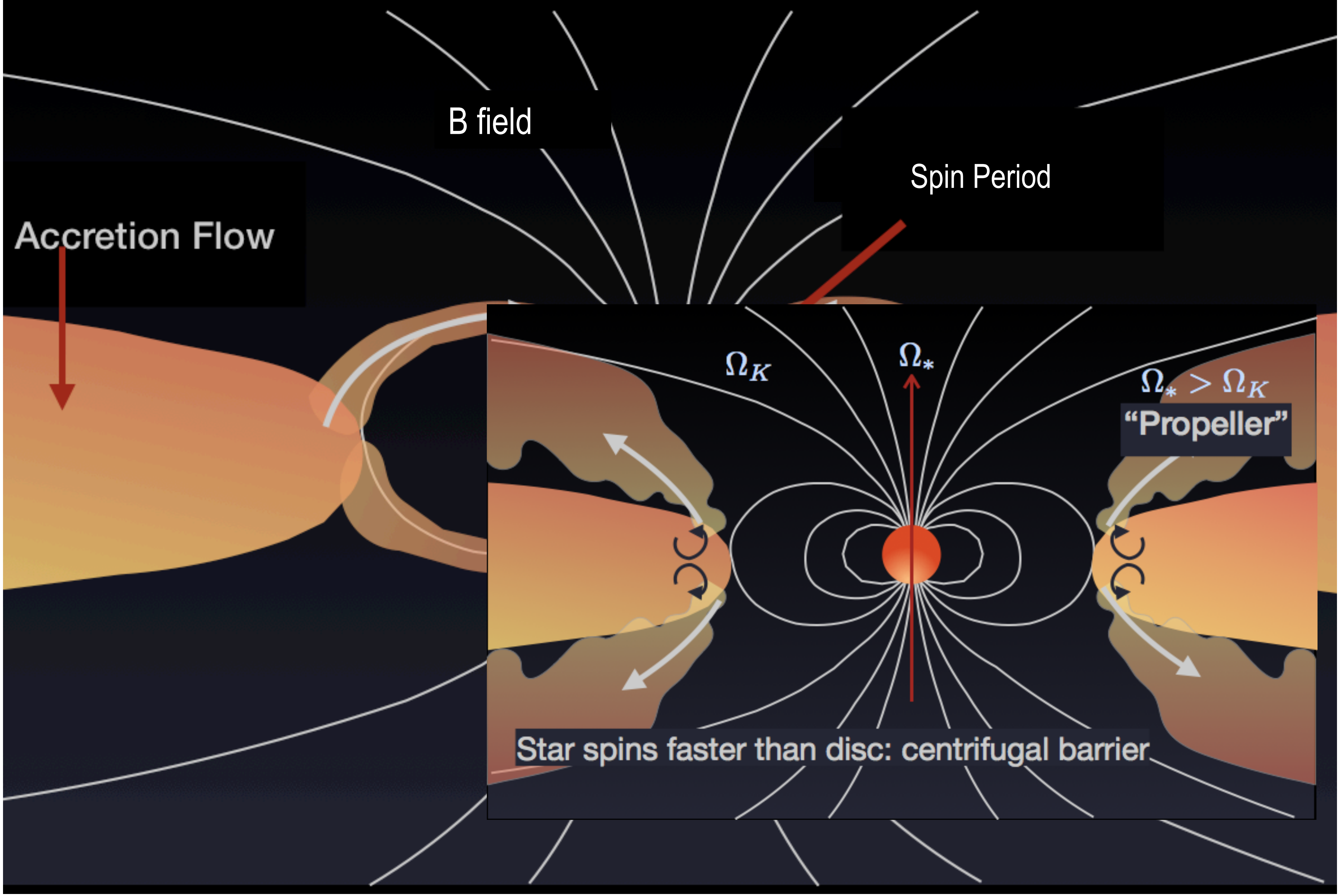


# THE 'CRITICAL' ACCRETION RATE

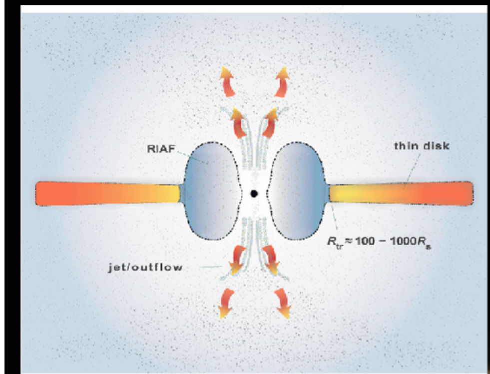
$$\dot{M}_c = \frac{\xi}{\sqrt{2}} r_c^{-7/2} \mu^2 (GM)^{-1/2}$$

pressure balance; ξ < 1 for rotating thin disk

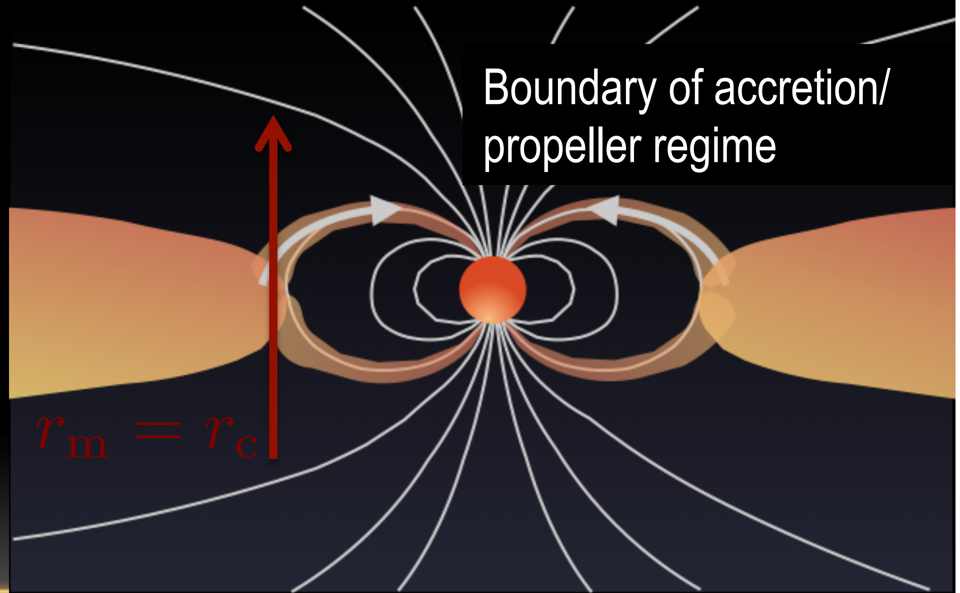
$$\dot{M}_c = \frac{\eta \mu^2}{8\Omega_*} r_c^{-5}$$

Angular momentum balance; **η** < 1 describes torque efficiency

**Critical accretion rate uncertain by ~40**

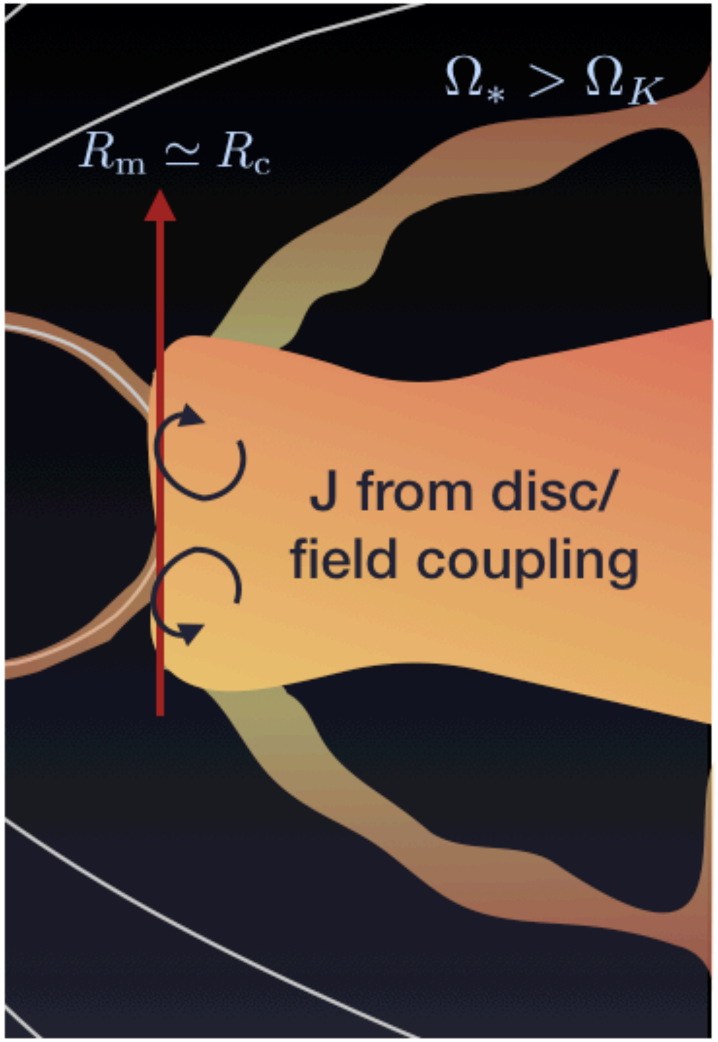



Radial inflow vs. disk-like: RIAF constraint




Boundary of accretion/ propeller regime

# A PROPELLER DOESN'T HAVE TO FORM




- ($r_m$<1.3 $r_c$): angular momentum not enough to expel most gas in outflow (weak propeller)
- gas piles up in disc
- accretion onto star continues
- "Trapped disc" (inner edge trapped near $R_c$)

*[Spruit & Taam 1993, D'Angelo & Spruit 2010,2011,2012]*

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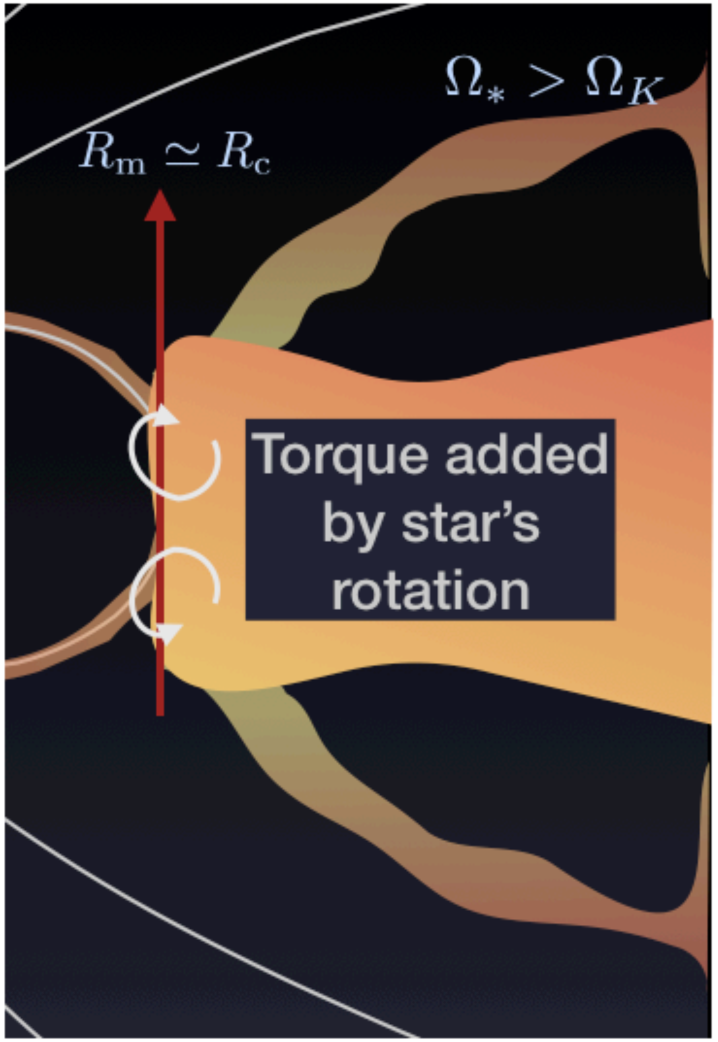


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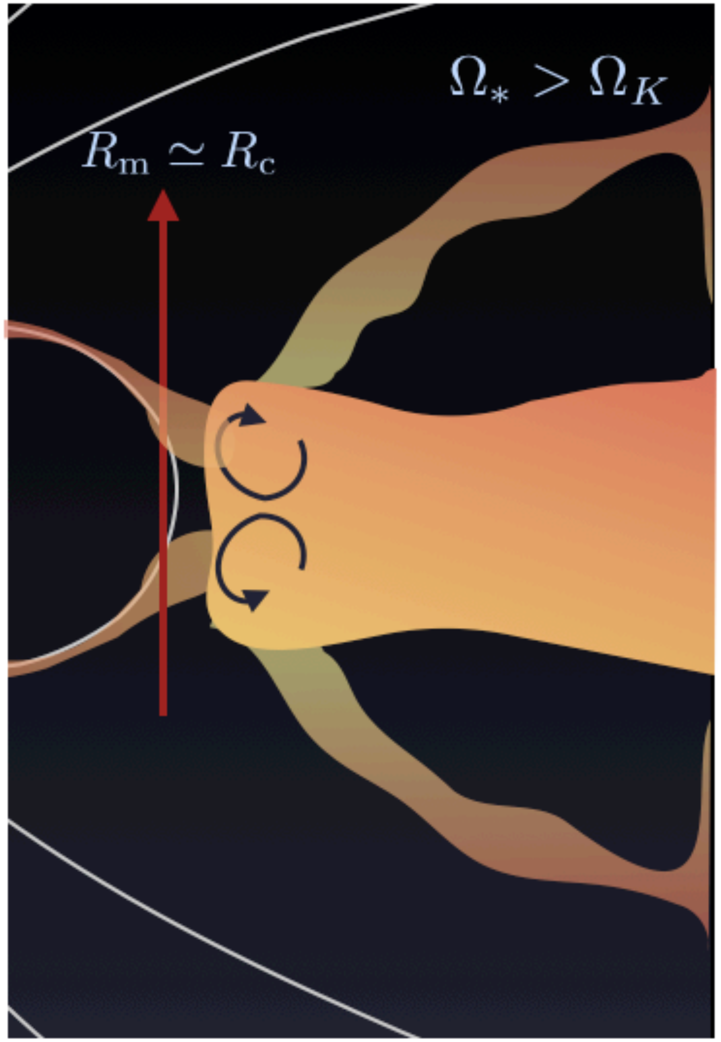


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# A PROPELLER DOESN'T HAVE TO FORM


- Accretion on to star can cease completely without expelling disc
- "Dead Disc" (Shakura & Sunyaev, 1977)

*[Spruit & Taam 1993, D'Angelo & Spruit 2010,2011,2012]*

| Propeller | Trapped disc |
| --- | --- |
| Strong outflow dominates | Weak outflow; gas accretes |
| **Narrow range** of $\dot{M}$ produce pulsations | **Pulsations** to low accretion rates |
| **Accretion flow** dominates emission | **Stellar surface** dominates emission |
| Luminosity drops rapidly as accretion rate declines | Luminosity drops gradually |

| **Propeller** | **Trapped disc** |
|---|---|
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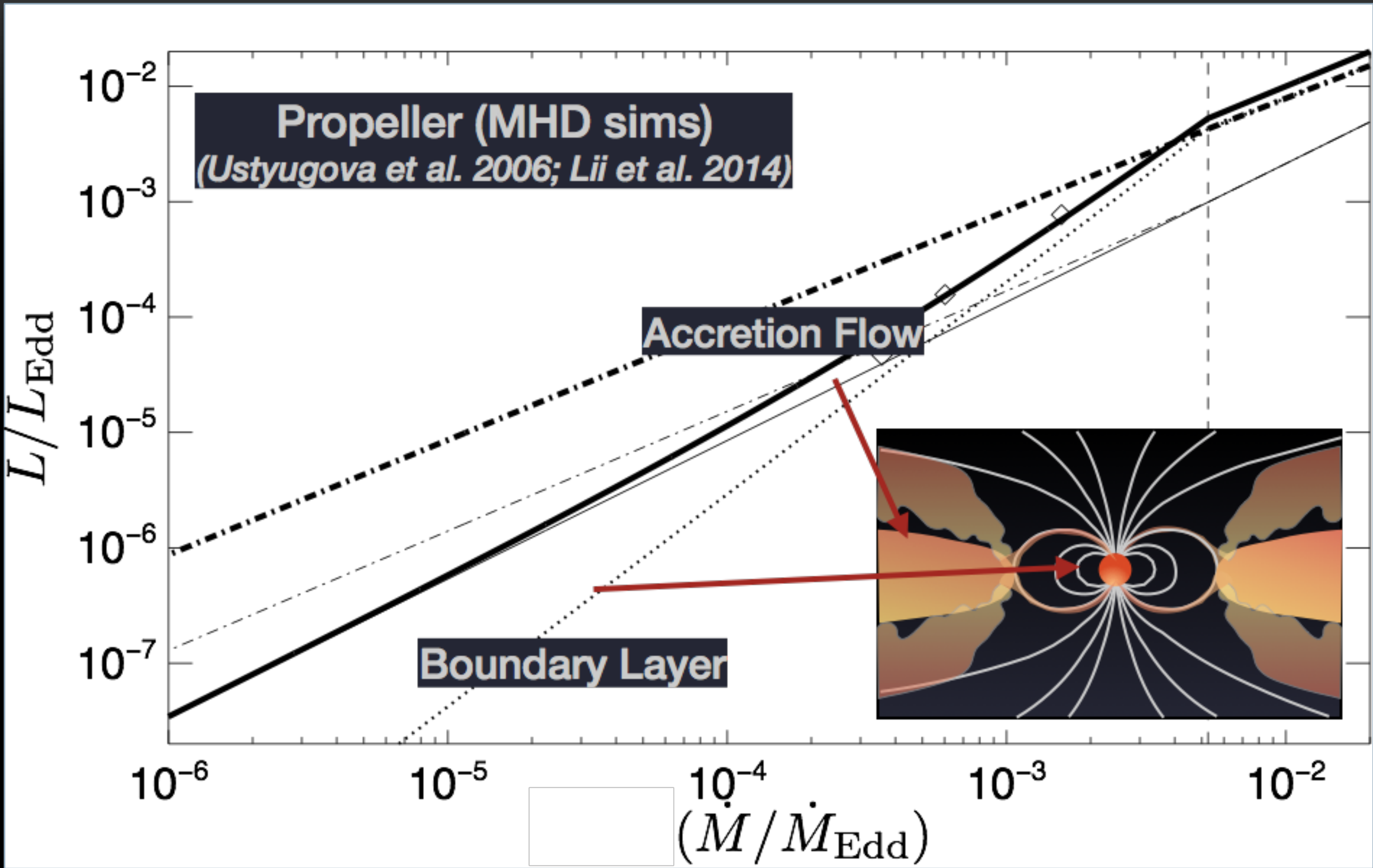
We can test these two models in J1023+0038!

# EFFICIENCY OF PROPELLER



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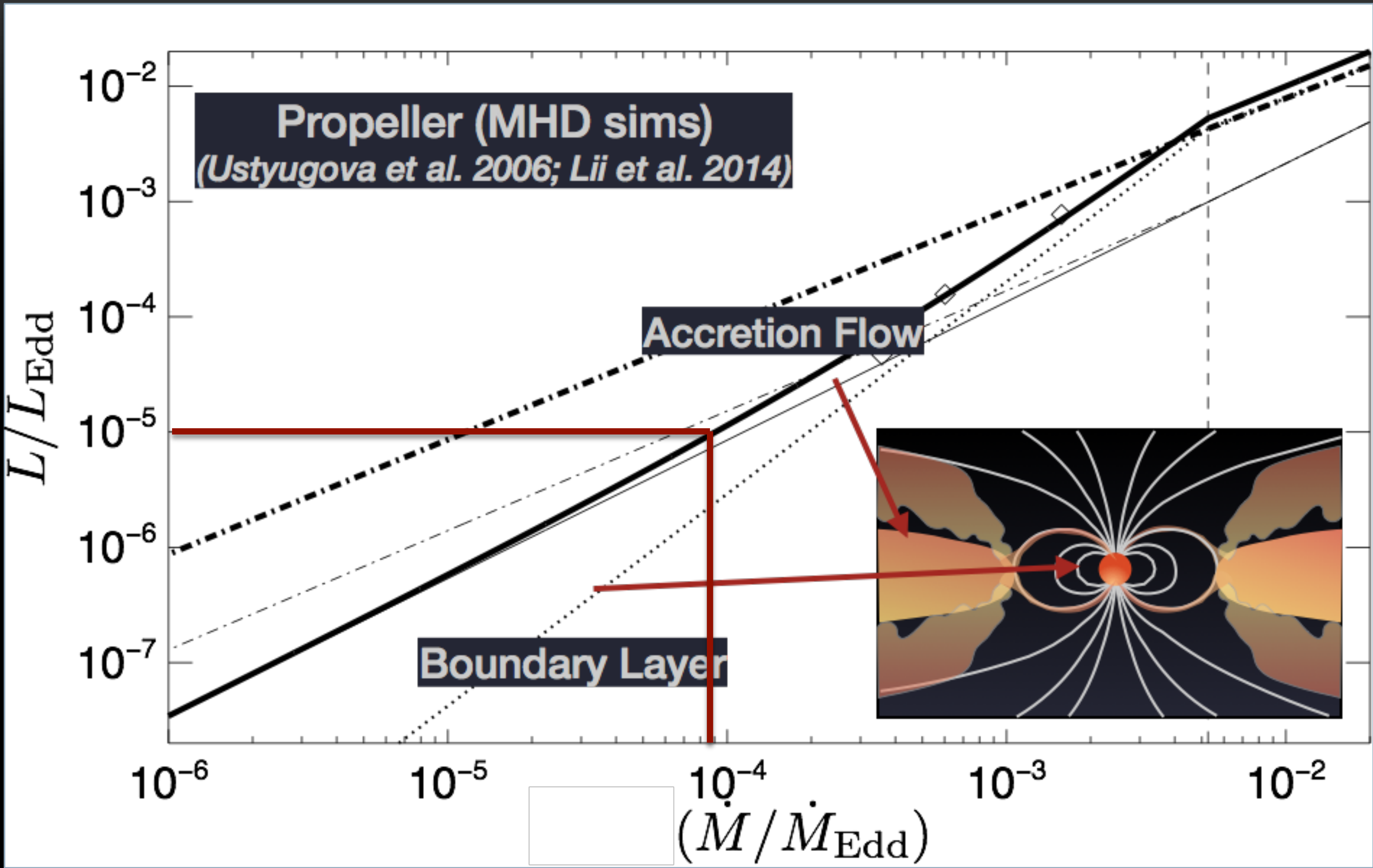

# J1023+0038: LIMITS ON PROPELLER SPIN

$$\dot{\nu} = 2.5 \times 10^{-15}$$

| | |
|---|---|
| $\frac{\dot{M}}{\dot{M}_{\rm c}} = 9 \times 10^{-4}$ <br> $\dot{\nu} = 7{\times}10^{-15}$ | $\frac{\dot{M}}{\dot{M}_{\rm c}} = 2 \times 10^{-3}$ <br> $\dot{\nu} = 17$ |
| $\frac{\dot{M}}{\dot{M}_{\rm c}} = 0.09$ <br> $\dot{\nu} = 1.2$ | $\frac{\dot{M}}{\dot{M}_{\rm c}} = 0.03$ <br> $\dot{\nu} = 0.5$ |

Higher accretion rate $\dot{M}$

thinner disk $\dot{M}_{\rm c}$

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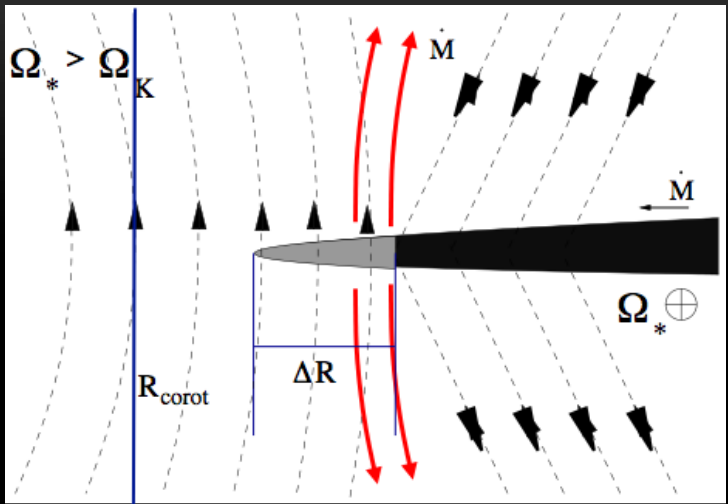
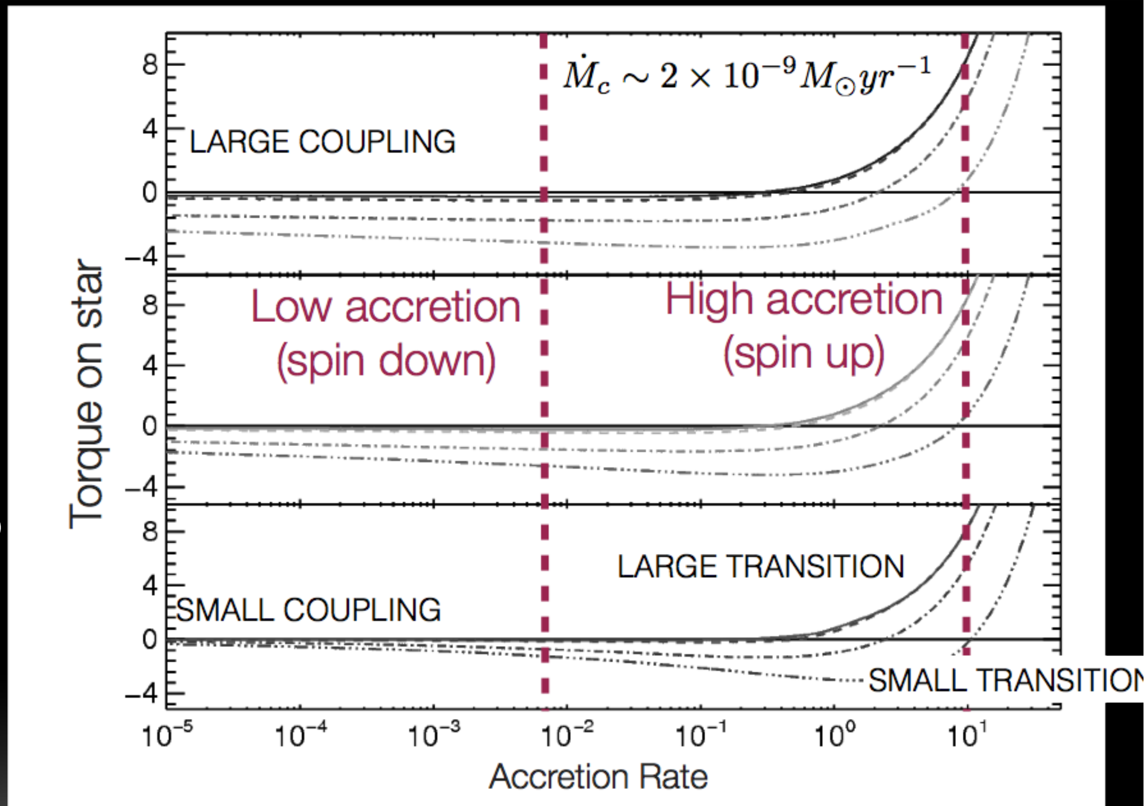
# TRAPPED DISC?




$$\frac{\Delta r}{r} \sim 0.001 - 0.1$$




Tracks how well field couples to disc

$$\dot{\nu} = 0.03 - 120 \times 10^{-15}$$

Suggests *very weak coupling*

# CONCLUSIONS

- Transitional MSPs offer strong constraints on magnetospheric accretion models
- Spindown identical to dipole case
- Propeller predicts *larger* spindown than constrained
- Trapped disc can work, on edge of parameter space
- Might be underestimating magnetic fields of typical pulsars?
- Something else?