MAGNETOSPHERIC ACCRETION IN TRANSITIONAL PULSARS

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26 June 2015

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J1023+0038: AN AMAZING PROBE OF ACCRETION MODELS

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

\[
\frac{\dot{P}_{\text{X-ray}}}{\dot{P}_{\text{radio}}} = 1 \pm 0.08 \\
\nu = 2.5 \times 10^{-15} \\
\dot{M} = 2.8 - 6.8 \times 10^{-5} \dot{M}_{\text{Edd}}
\]

From X-ray luminosity:
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}} \approx 0.2 
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For ms pulsar
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For ms pulsar

STAY TUNED!
MAGNETOSPHERIC ACCRETION

B field

Spin Period

Accretion Flow
MAGNETOSPHERIC ACCRETION

Accretion Flow

B field

Spin Period

$\Omega_K$

$\Omega_* > \Omega_K$

“Propeller”

Star spins faster than disc: centrifugal barrier
THE ‘CRITICAL' ACCRETION RATE

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

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

Pressure balance; \( \xi < 1 \) for rotating thin disk

Angular momentum balance; \( \eta < 1 \) describes torque efficiency

Critical accretion rate uncertain by \( \sim 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 \( R_c \))

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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)

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We can test these two models in J1023+0038!
EFFICIENCY OF PROPELLER

Propeller (MHD sims)
(Ustyugova et al. 2006; Lii et al. 2014)

Accretion Flow

Boundary Layer

$L/L_{Edd}$ vs. $(M/M_{Edd})$
J1023+0038: LIMITS ON PROPELLER SPIN

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

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**Diagram:**

- Higher accretion rate
- Thinner disk
- \( \dot{M}_c \)
TRAPPED DISC?

Tracks how well field couples to disc

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

Suggests very weak coupling

\[ \frac{\Delta r}{r} \sim 0.001 - 0.1 \]
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?