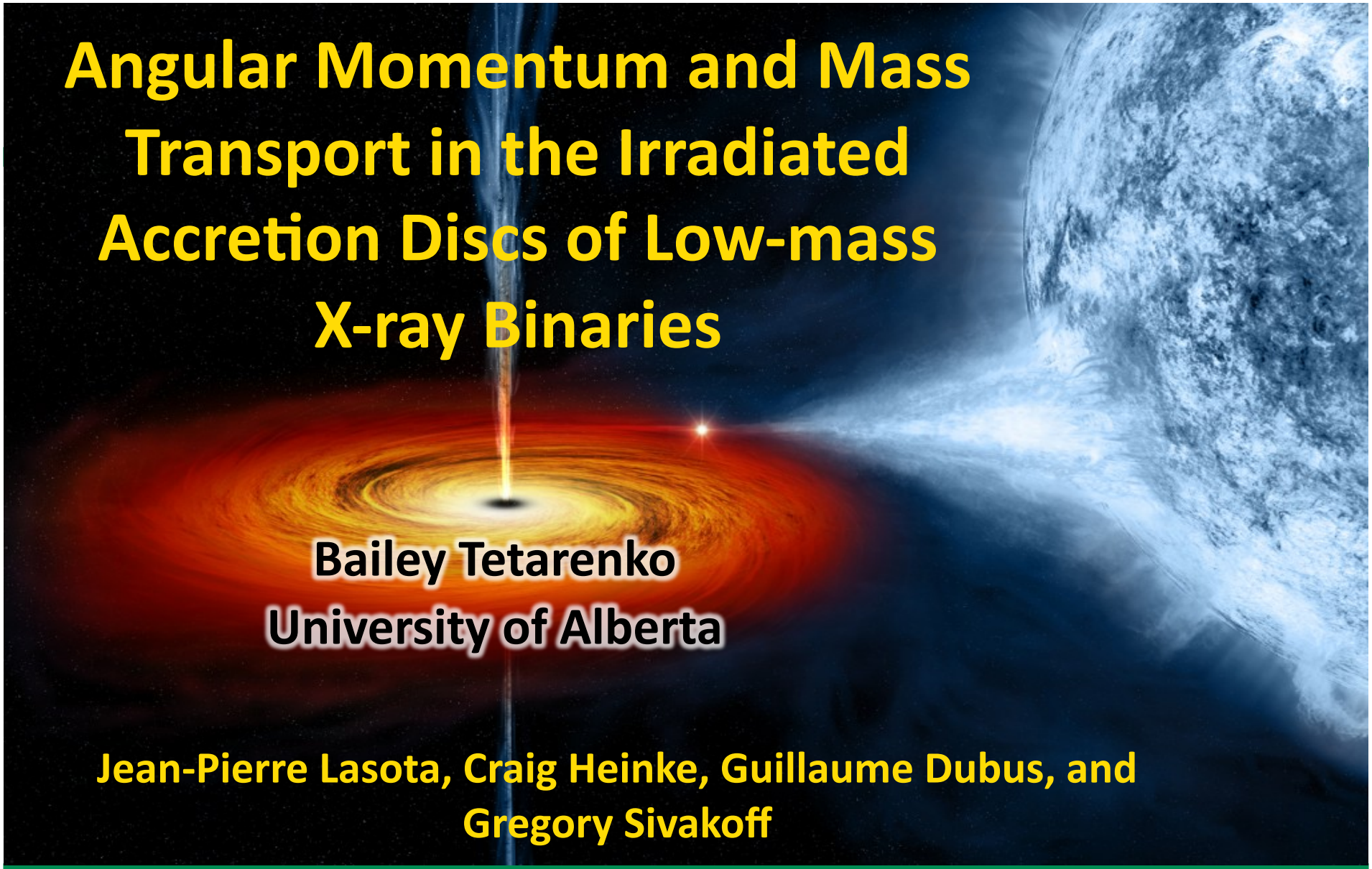
Angular Momentum and Mass Transport in the Irradiated Accretion Discs of Low-mass X-ray Binaries



Bailey Tetarenko
University of Alberta

Jean-Pierre Lasota, Craig Heinke, Guillaume Dubus, and Gregory Sivakoff

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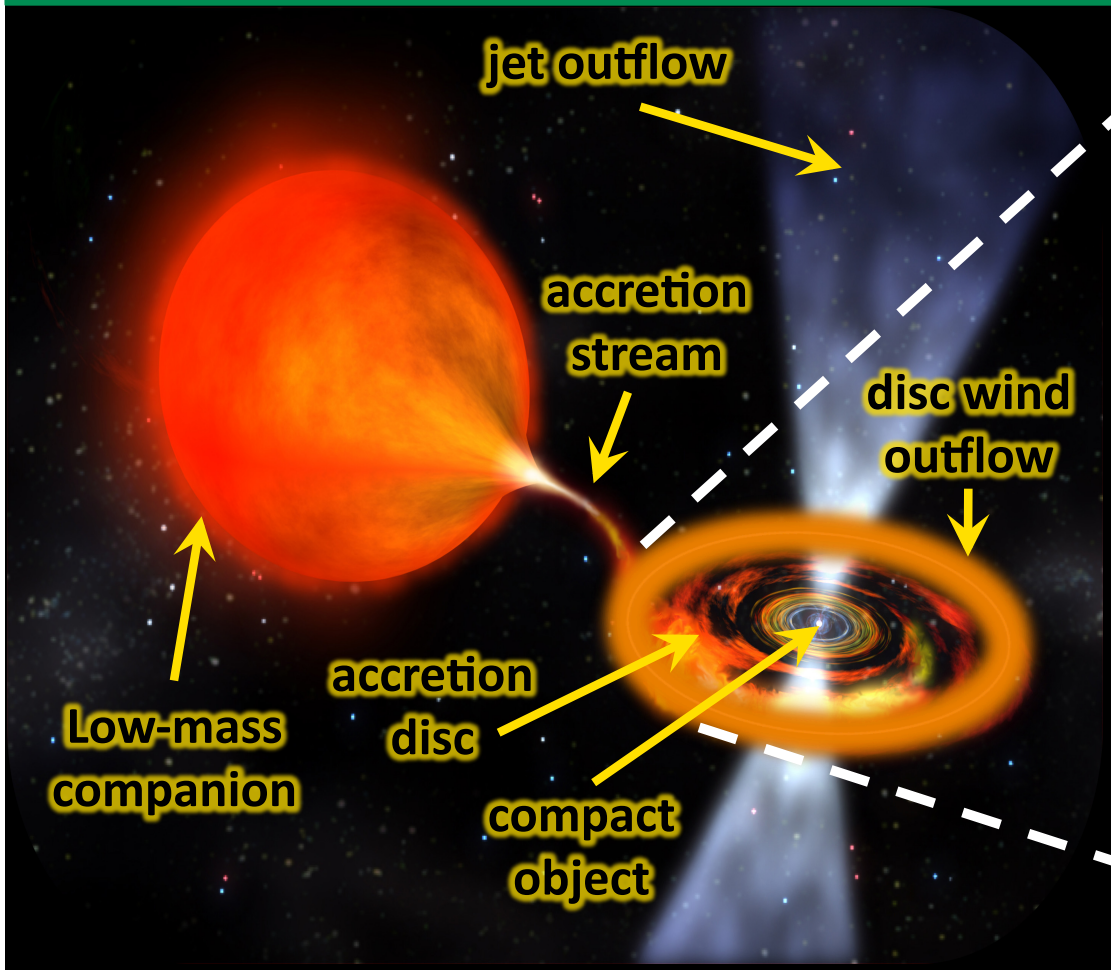
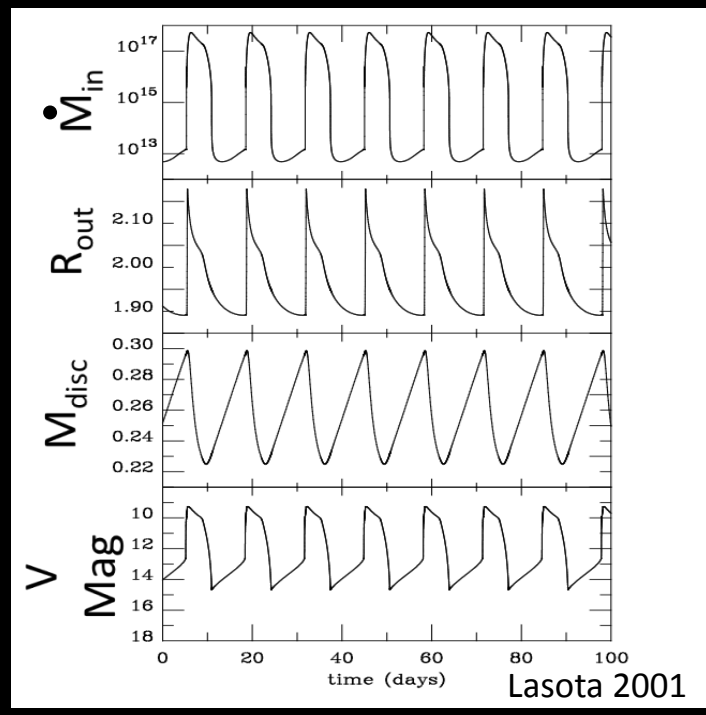
"from quiescence to outburst: when micro-quasars go wild"
Porquerolles, France, September 2017

Disc-Accretion in Compact Binaries





Lasota 2001

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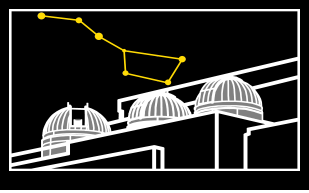
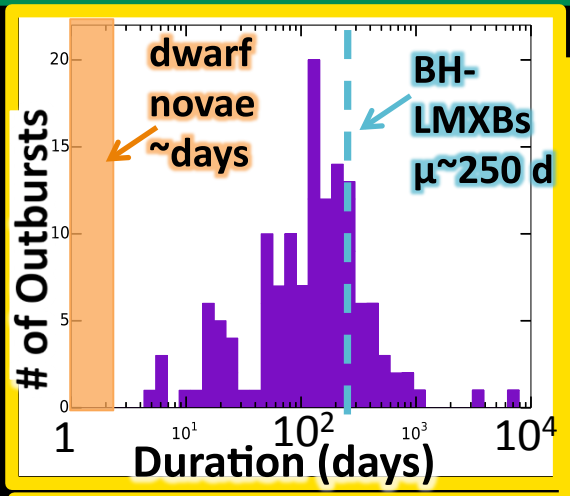
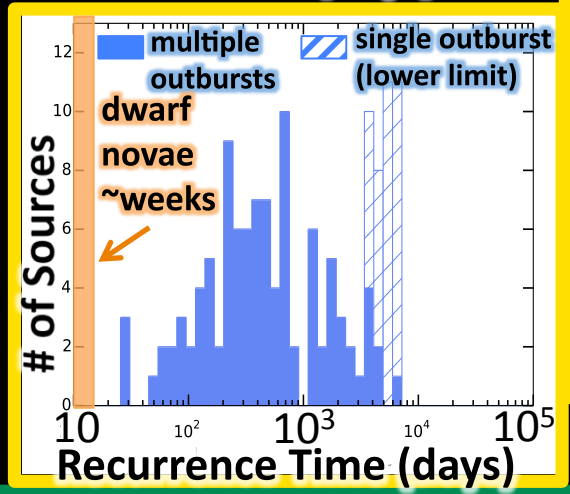


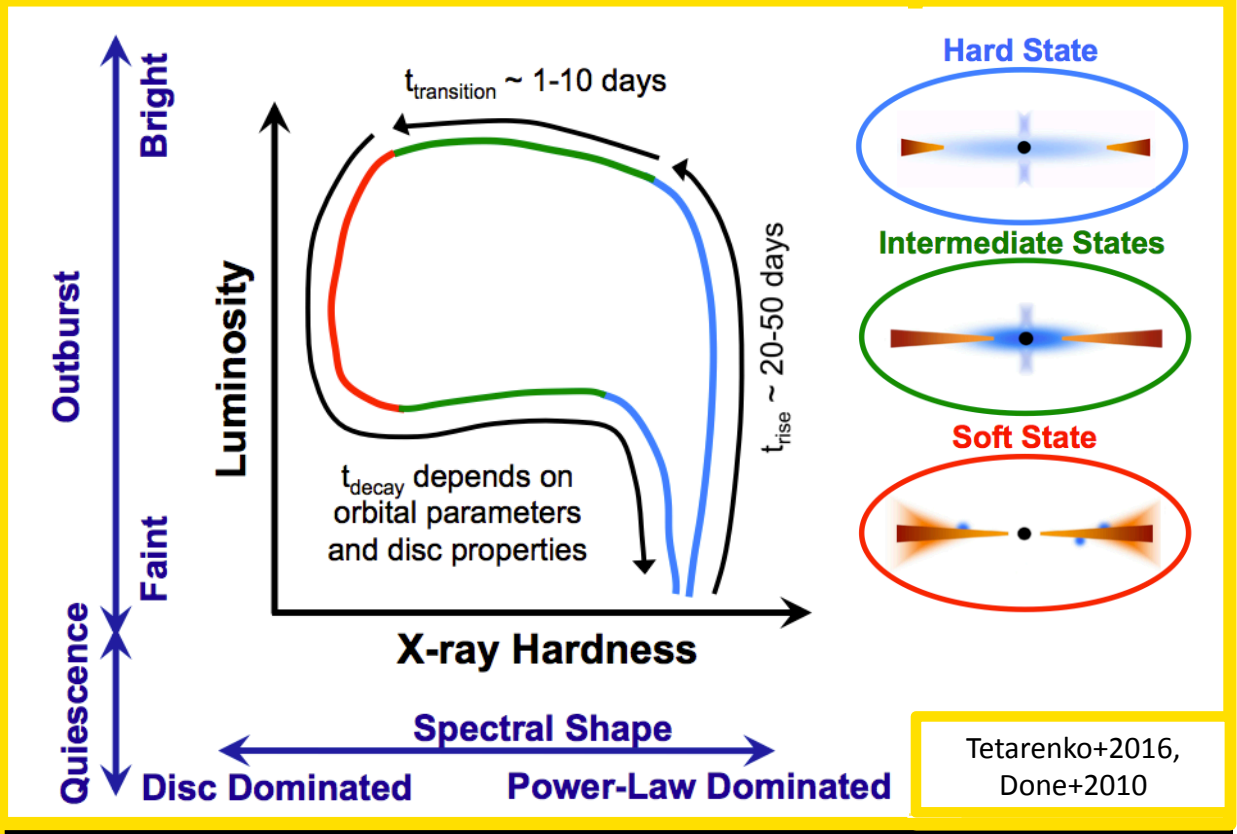
Black-hole Low-Mass X-ray Binaries

Outburst Duration



Recurrence Rate





Tetarenko+2016,
Done+2010

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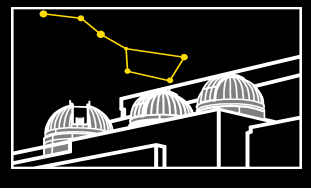
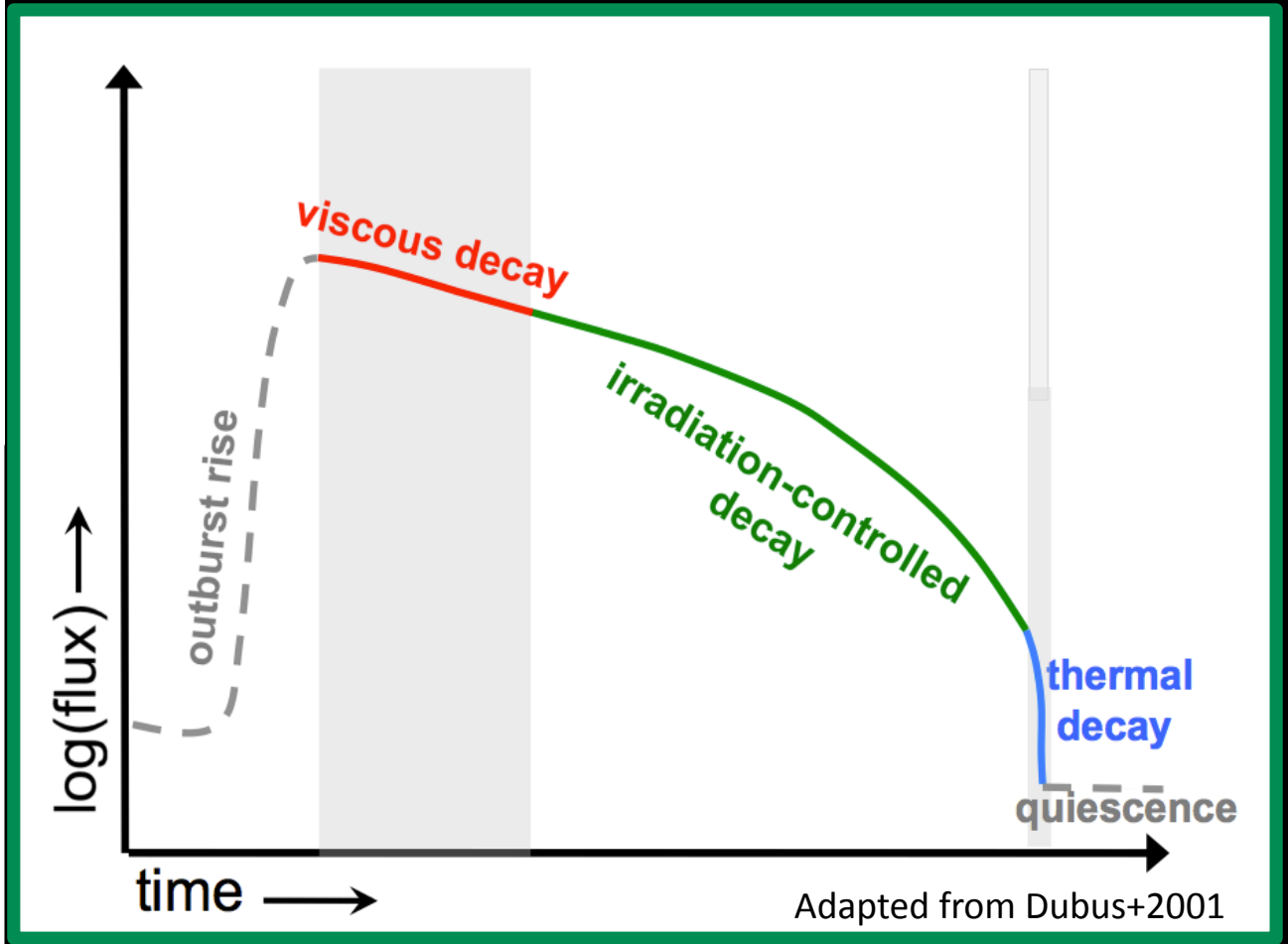
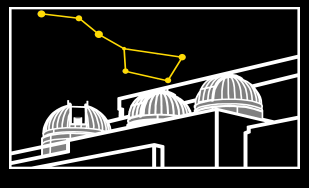


The Outburst of an Irradiated Disc Around a Stellar-mass Black-hole



Adapted from Dubus+2001

Disc-instability picture, with the additional parameter of X-ray irradiation, predicts a three stage decay in the observed light-curve



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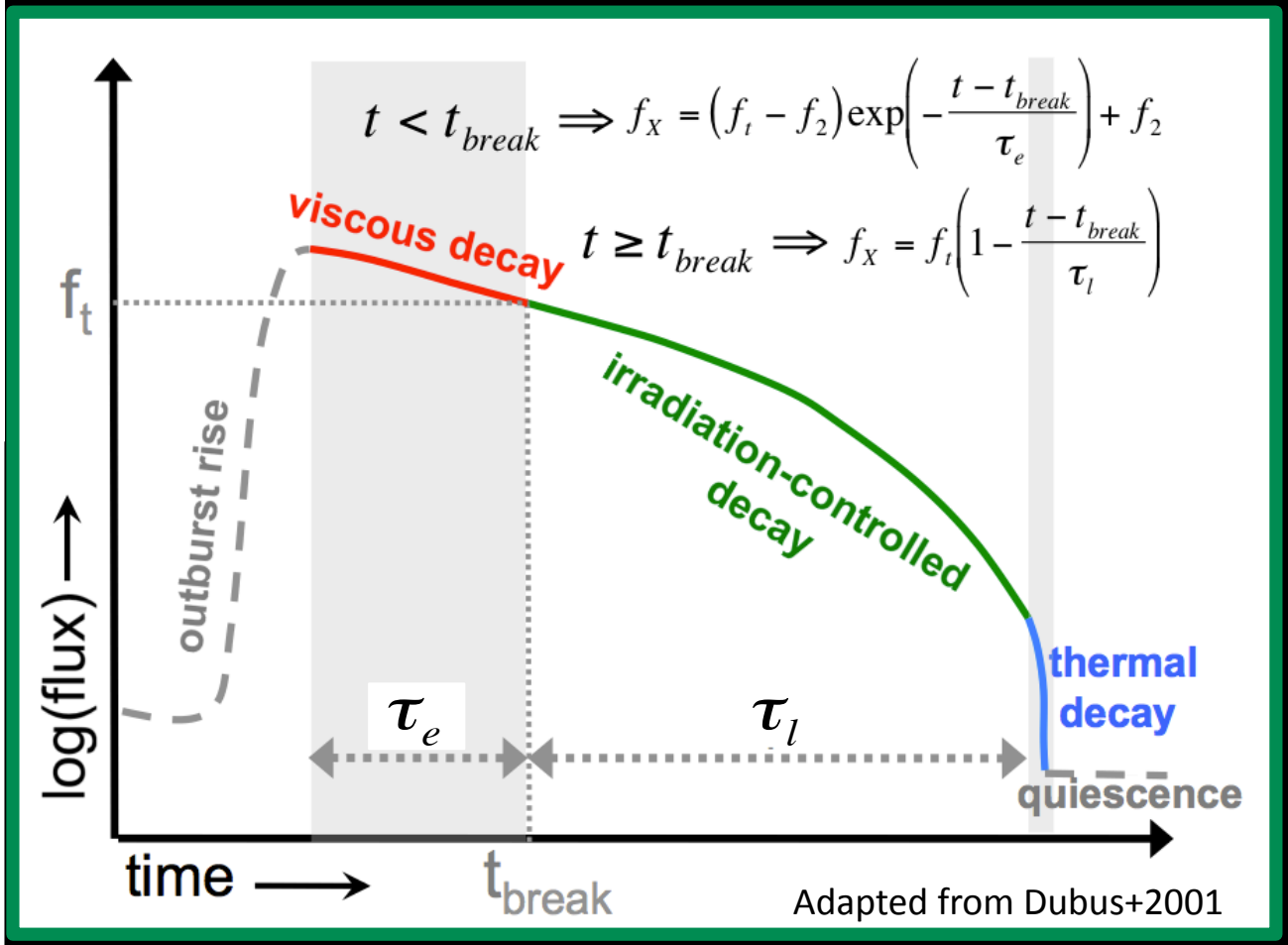
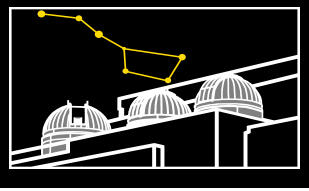
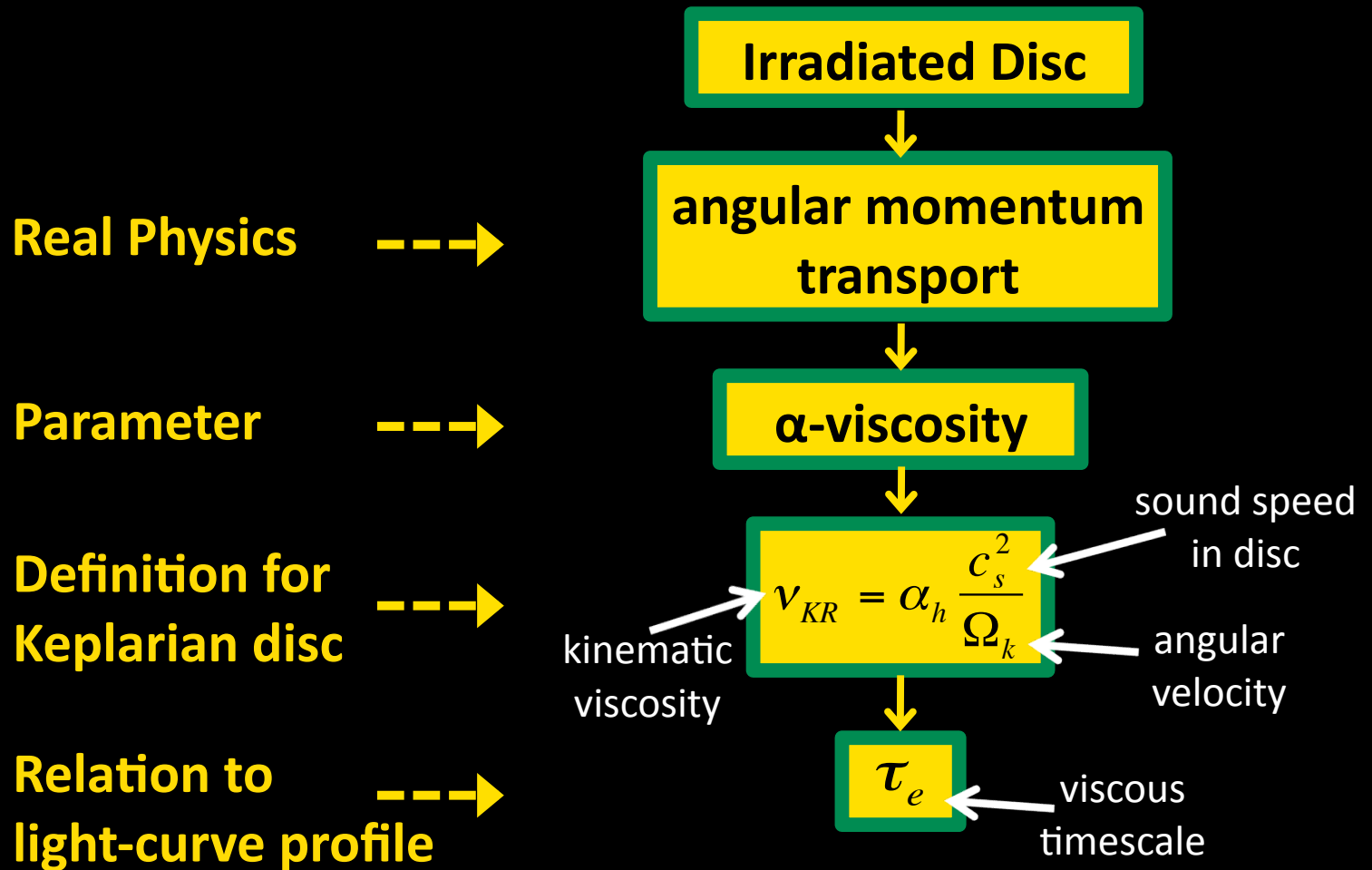
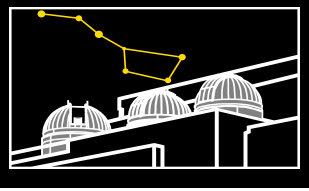


- Profile described analytically with a modified version of the "classic" King & Ritter formalism
- Five parameter analytical model fit to observed X-ray light-curves using a Markov-Chain Monte Carlo algorithm



Characterizing an Irradiated Accretion Disc





Deriving disc properties from BH-LMXB X-ray light curves

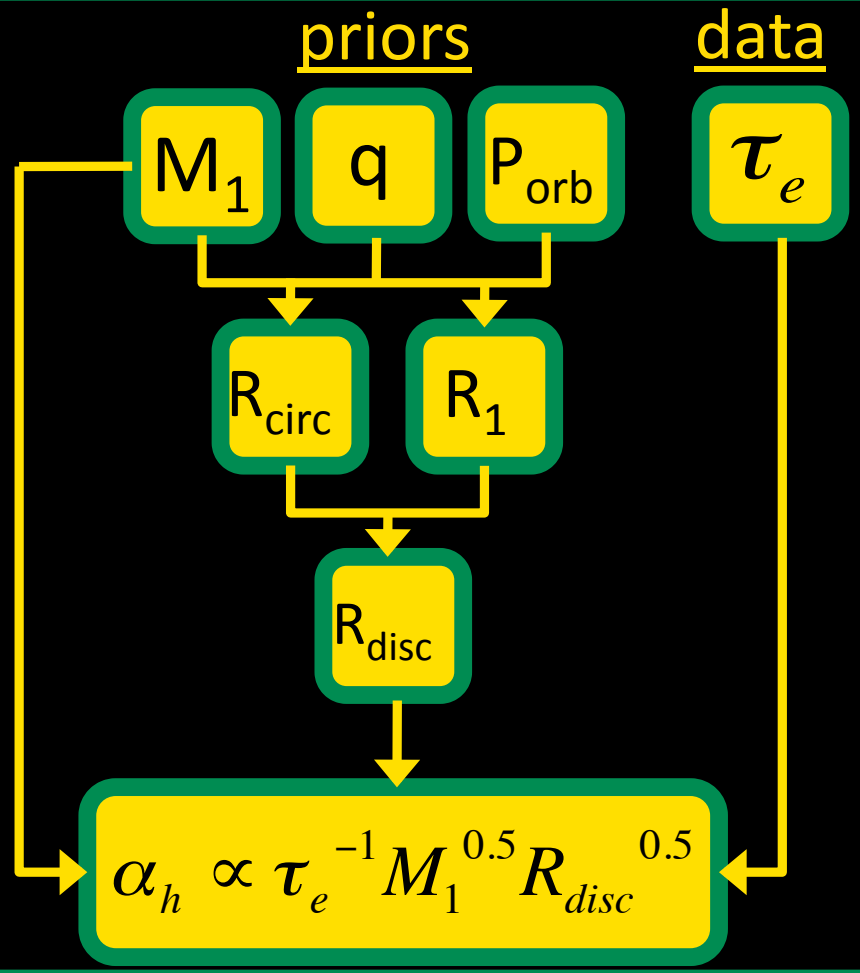
sample α-viscosity in the hot disc

↓

Bayesian hierarchical modeling

↓

A hierarchical model is a multi-level statistical model that allows one to estimate a posterior distribution by integrating a combination of known prior distributions with observed data.



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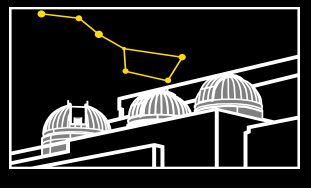

Application to the Black-hole Low-mass X-ray Binary Population of the Galaxy

The Astrophysical Journal Supplement Series, 222:15 (98pp), 2016 February
doi:10.3847/0067-0049/222/2/15

CrossMark

WATCHDOG: A COMPREHENSIVE ALL-SKY DATABASE OF GALACTIC BLACK HOLE X-RAY BINARIES

B. E. Tetarenko, G. R. Sivakoff, C. O. Heinke, and J. C. Gladstone
Department of Physics, University of Alberta, CCIS 4-181, Edmonton, AB T6G 2E1, Canada; btetaren@ualberta.ca
Received 2015 October 9; accepted 2015 November 22; published 2016 February 10

WATCHDOG
University of Alberta

www.astro.physics.ualberta.ca/watchdog

The *WATCHDOG* Resource provides:

✧ a catalog of BH and BH candidate LMXB sources in the Galaxy

✧ a complete two-decade long outburst history

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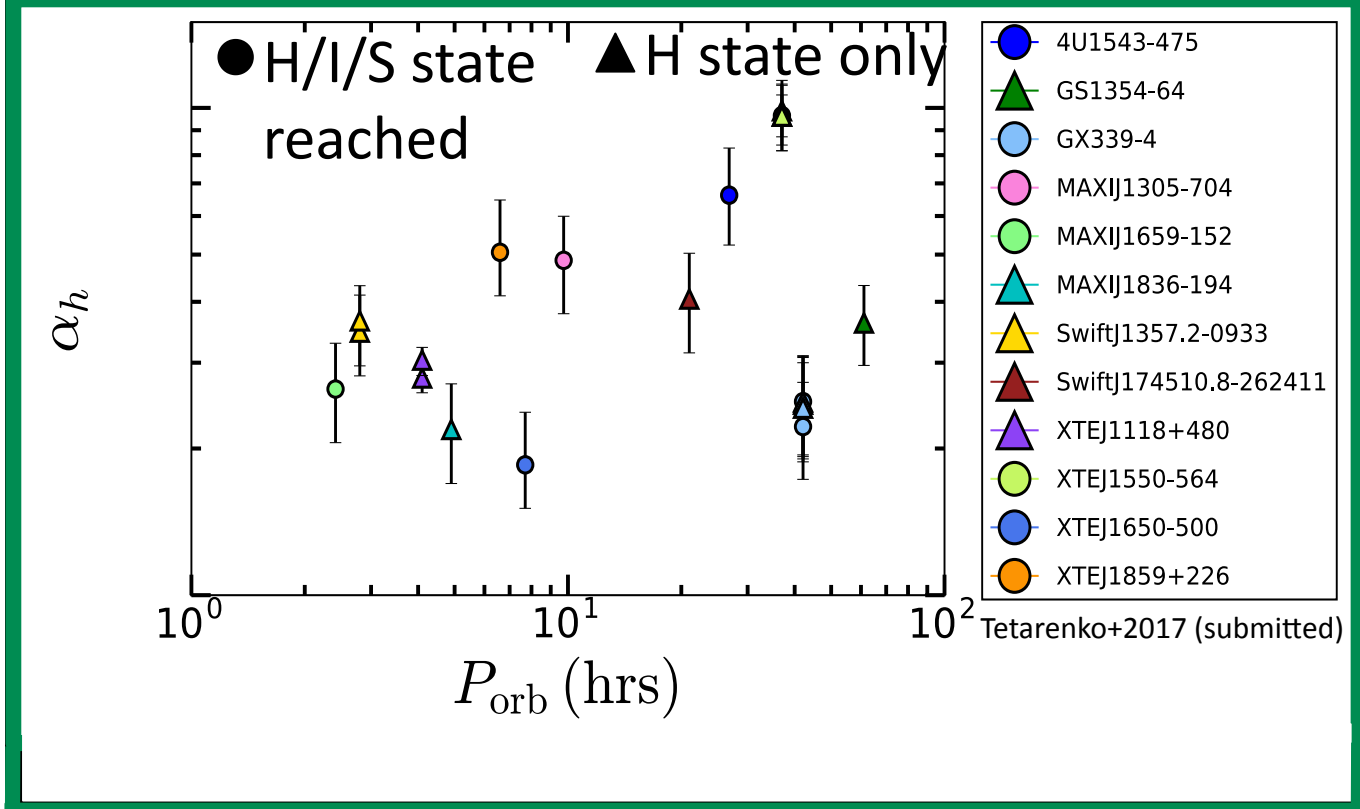
Applying the Bayesian Hierarchical Methodology to observed BH-LMXB X-ray Light Curves

α-viscosity in the outbursting discs of BH-LMXBs



- we sample $0.19<\alpha<0.99$ for 21 outbursts in 12 Galactic BH-LMXBs
- high α-viscosity derived for both canonical and failed outbursts

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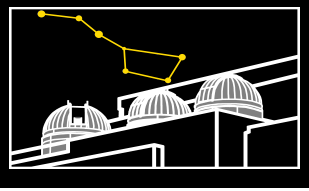

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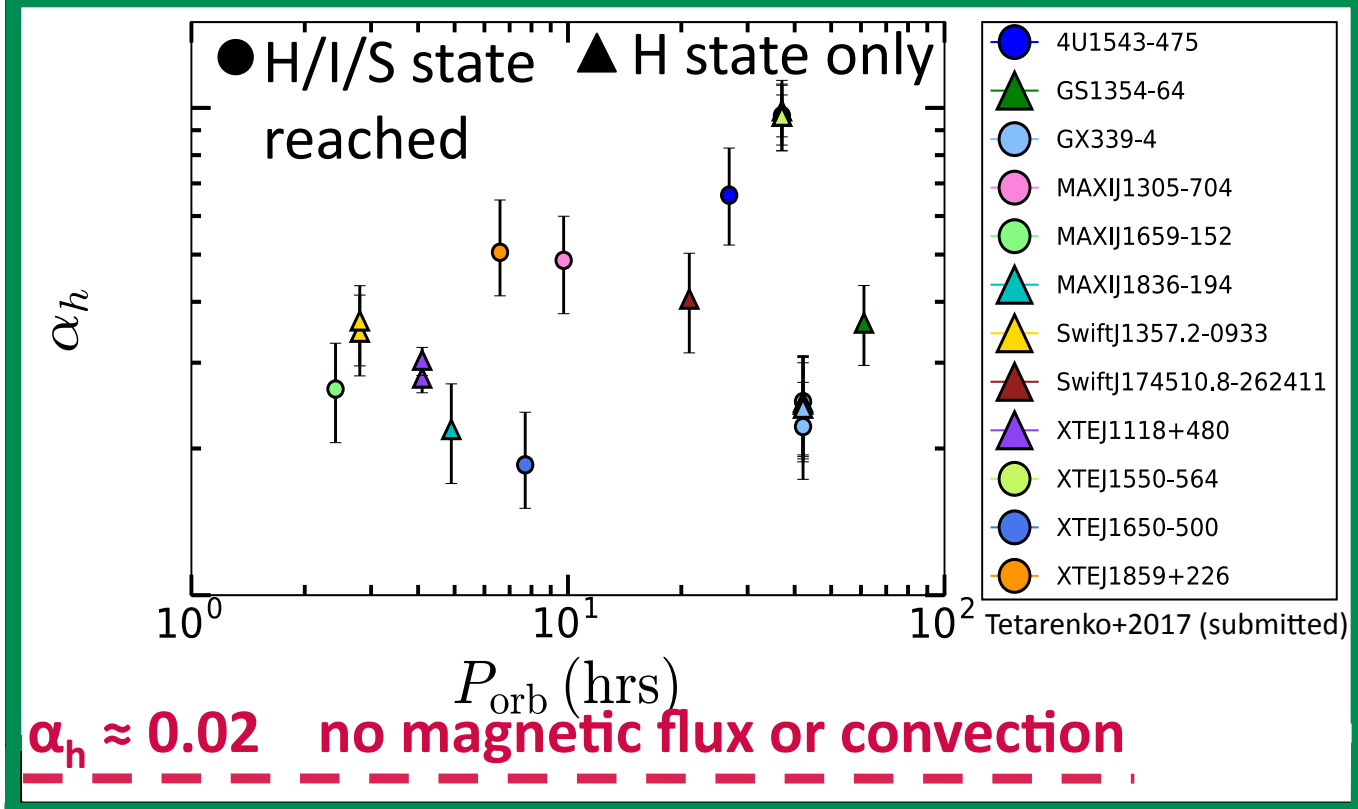

$\alpha_h \approx 0.02$ **no magnetic flux or convection**

Typically simulations of the MRI in shearing boxes yield α_h~0.02

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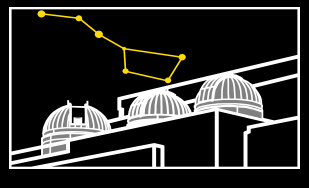

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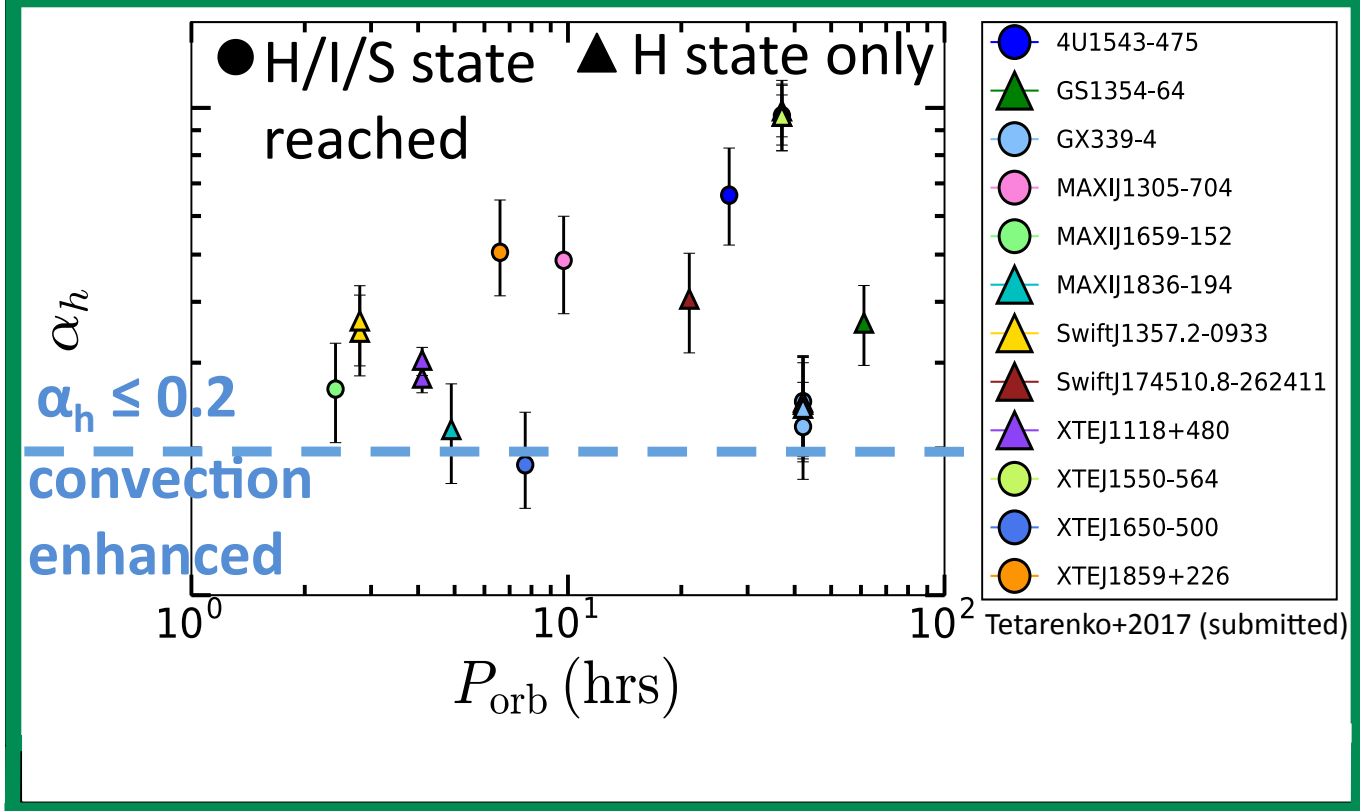

Convection can enhance this transport to α_h~0.2

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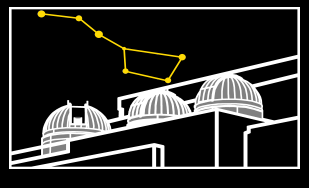

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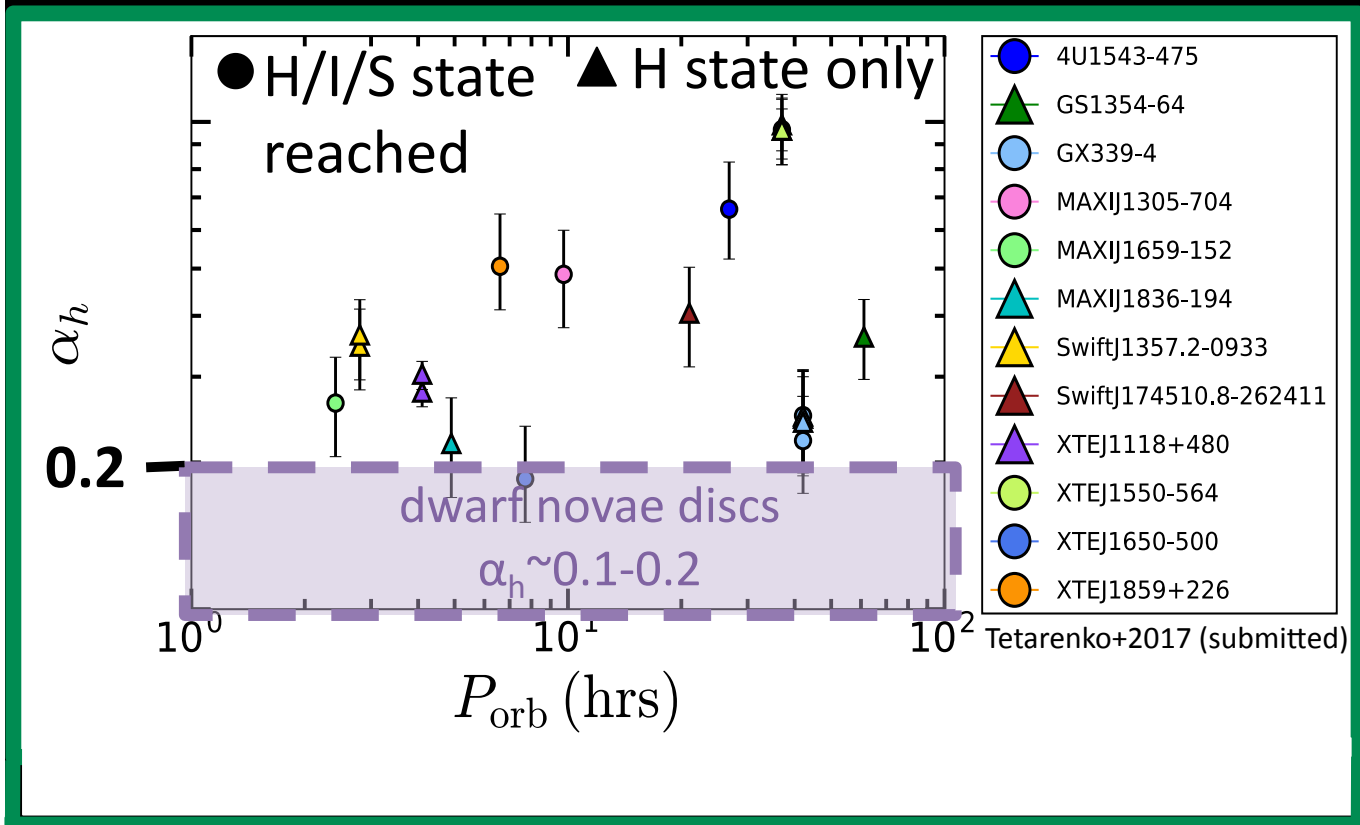
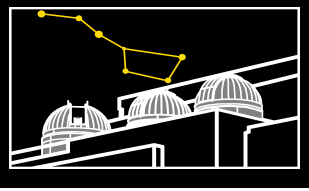


Convection enhanced transport consistent with α_h~0.1-0.2 inferred in non-irradiated dwarf novae discs



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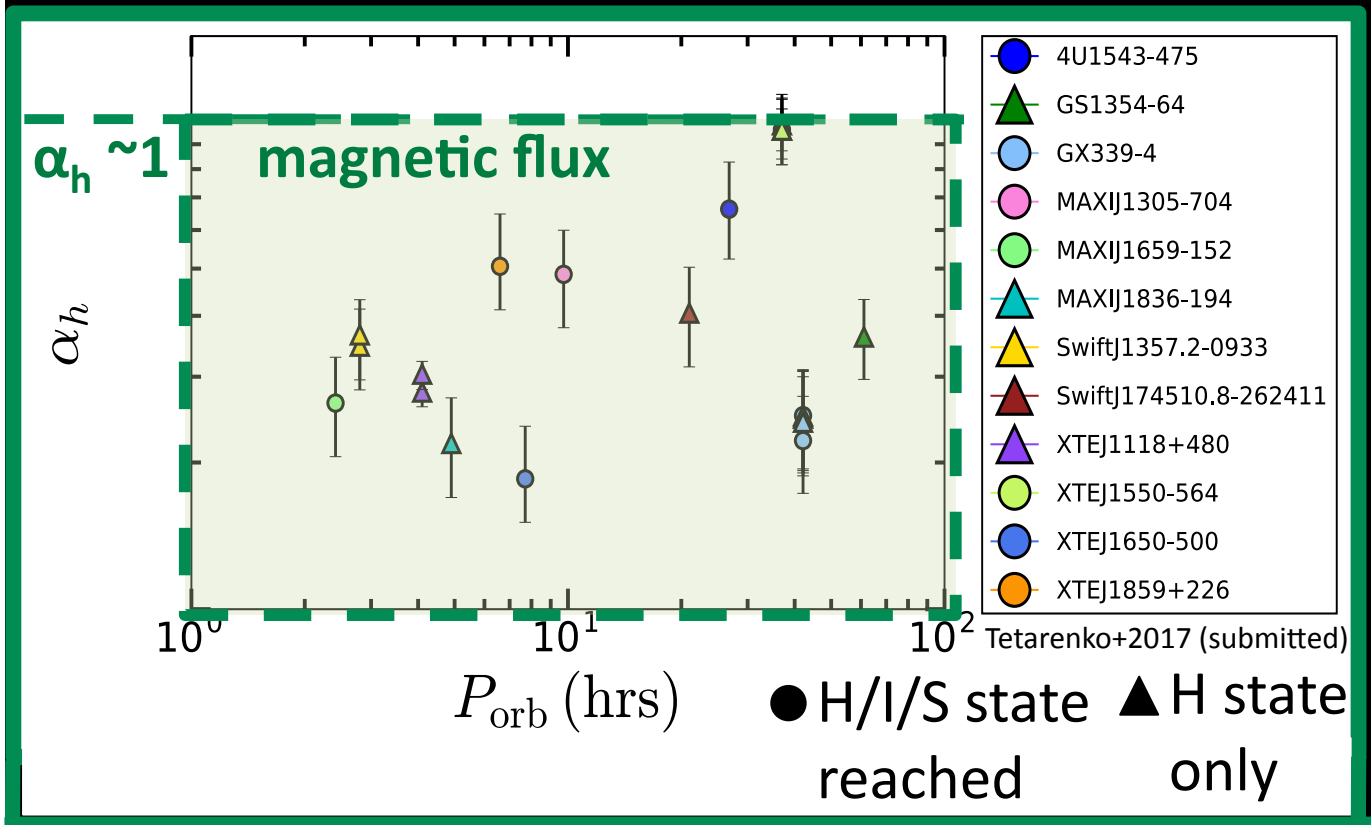

- When net magnetic flux threads shearing box, simulations can reach α_h~1
- high α-viscosity measured in BH-LMXBs indicates presence of a large-scale field in the disc, origin unknown

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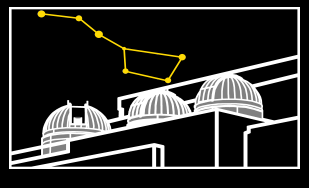
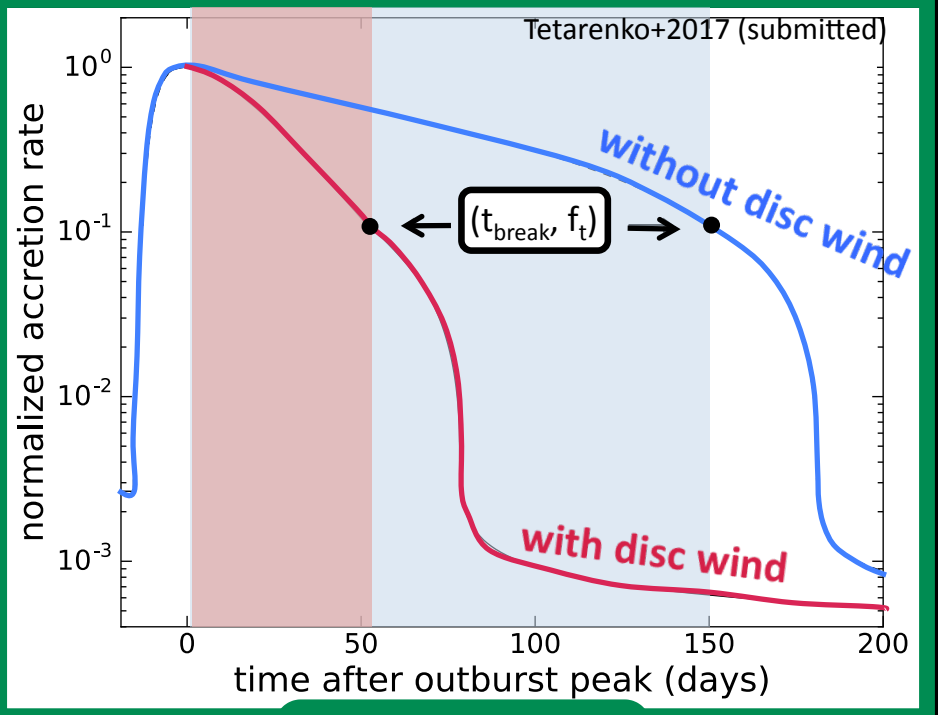


Applying the Bayesian Hierarchical Methodology to observed BH-LMXB X-ray Light Curves

- Simulations with high α_h display strong mass outflows, significantly altering the outburst light-curve

disc-wind outflow toy model



$$M_w = \varepsilon_{wind} M_c$$

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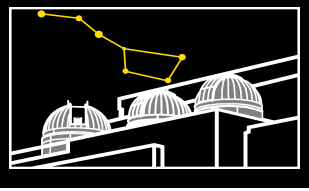
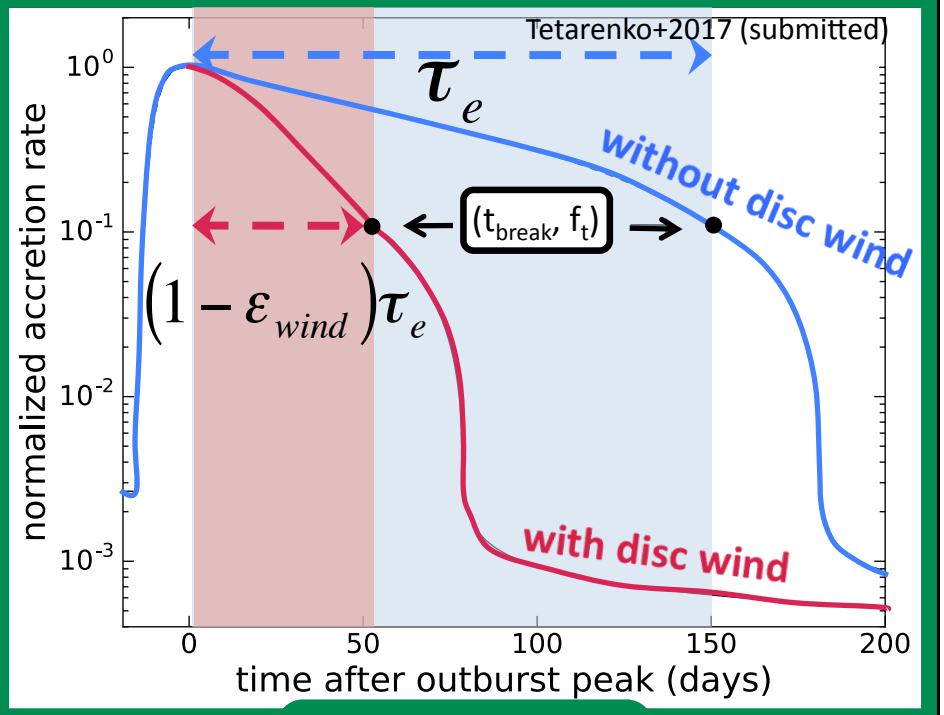


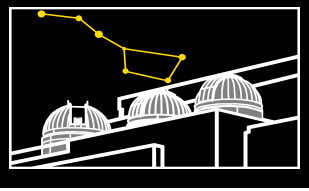
Applying the Bayesian Hierarchical Methodology to observed BH-LMXB X-ray Light Curves

- Simulations with high α_h display strong mass outflows, significantly altering the outburst light-curve

- mass loss term within irradiated disc instability model mimics effect high α_h has on the light-curve profile.

disc-wind outflow toy model



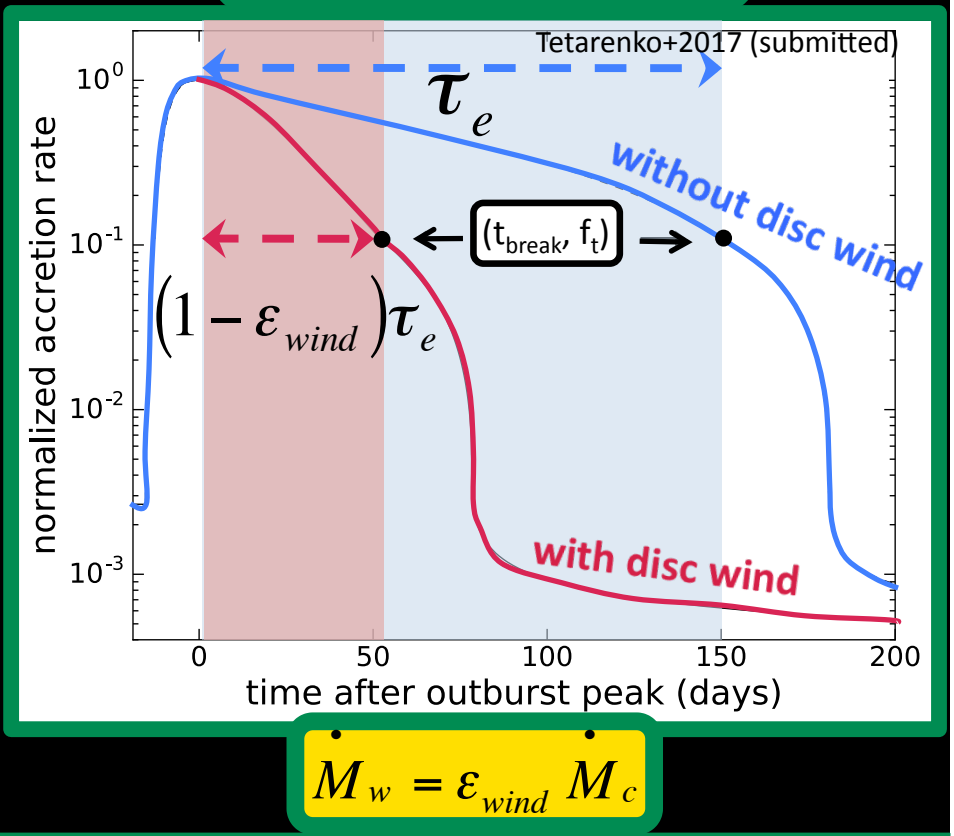


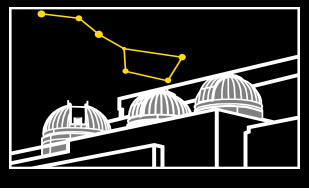
Applying the Bayesian Hierarchical Methodology to observed BH-LMXB X-ray Light Curves

- How significant are the outflows in BH-LMXB discs, given our high α_h measurements in BH-LMXB discs?

- A measurement of α_h ~1 from an observed light-curve would require ε_w~0.8 for the disc to have an intrinsic α_h ~0.2!!

disc-wind outflow toy model

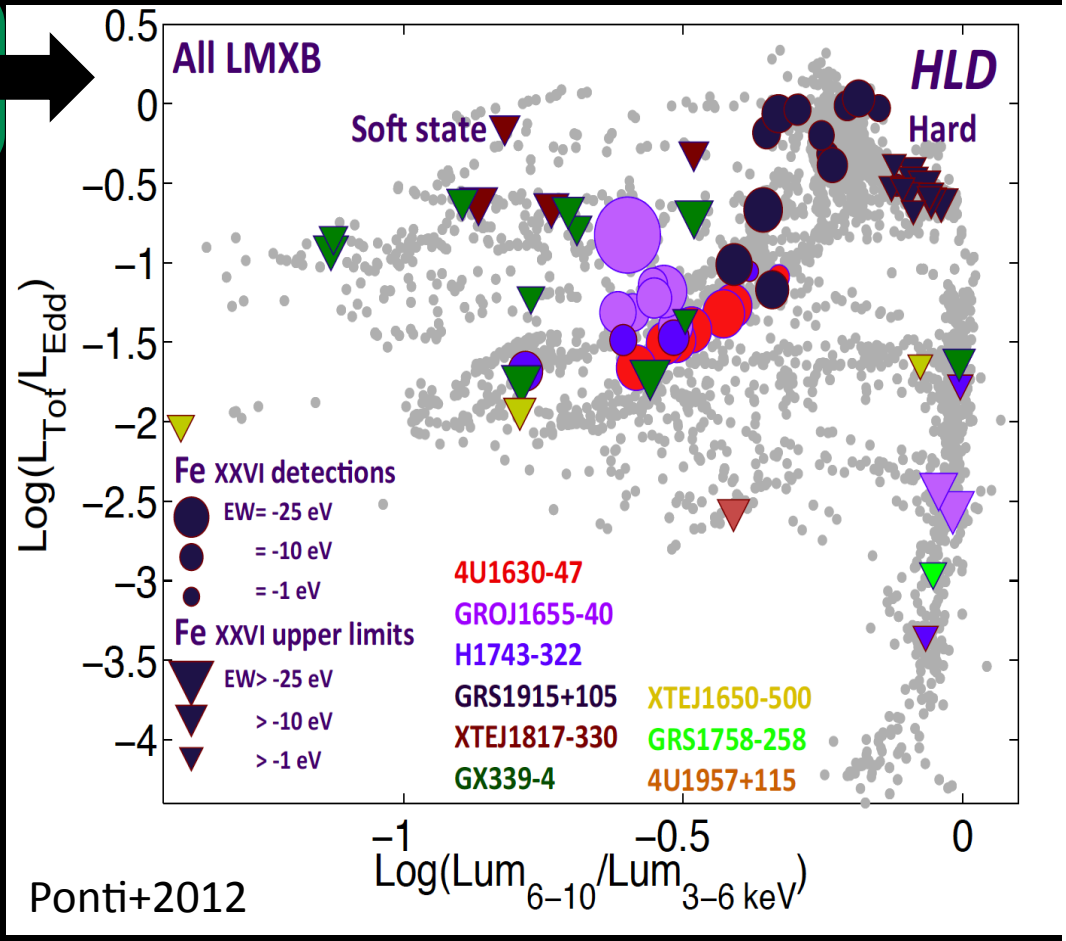




Applying the Bayesian Hierarchical Methodology to observed BH-LMXB X-ray Light Curves

disc-wind (mass) outflows detected during LMXB outbursts

Lack of correlation observed between α_h and accretion state reached implies the outflow mechanism is likely magnetically-driven, rather then thermally-driven



Ponti+2012

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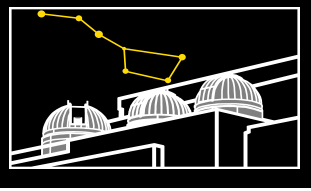
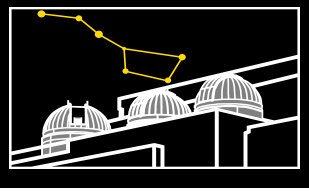


Summary

- Applying a Bayesian hierarchical methodology to the disc-instability picture, we derive α-viscosity in the irradiated discs around stellar-mass black-holes.
- First time α-viscosity has been estimated in LMXB discs.
- high α measured requires large-scale B-field threads the disc, with concurrent mass outflows shaping the outburst.
- These significant mass outflows that must exist throughout the decay are likely magnetically driven.



Important Announcement

I am currently looking for a postdoc position. If you are interested in giving me a job, please let me know!

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THANK YOU!