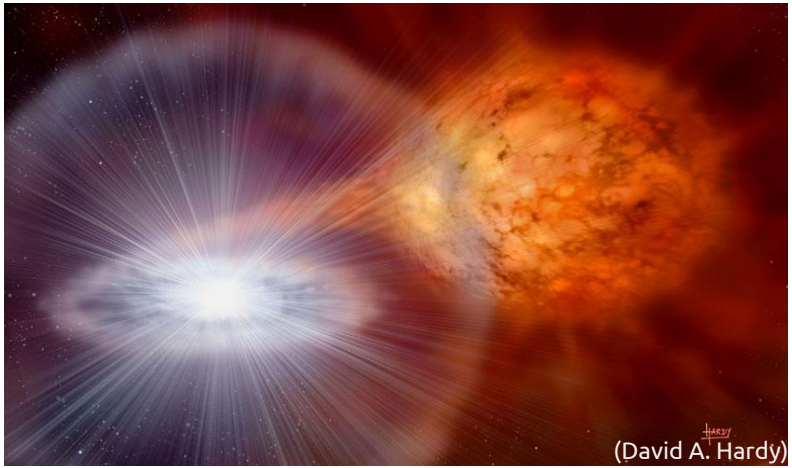
Neutron star parameter estimation with grids of X-ray burst models



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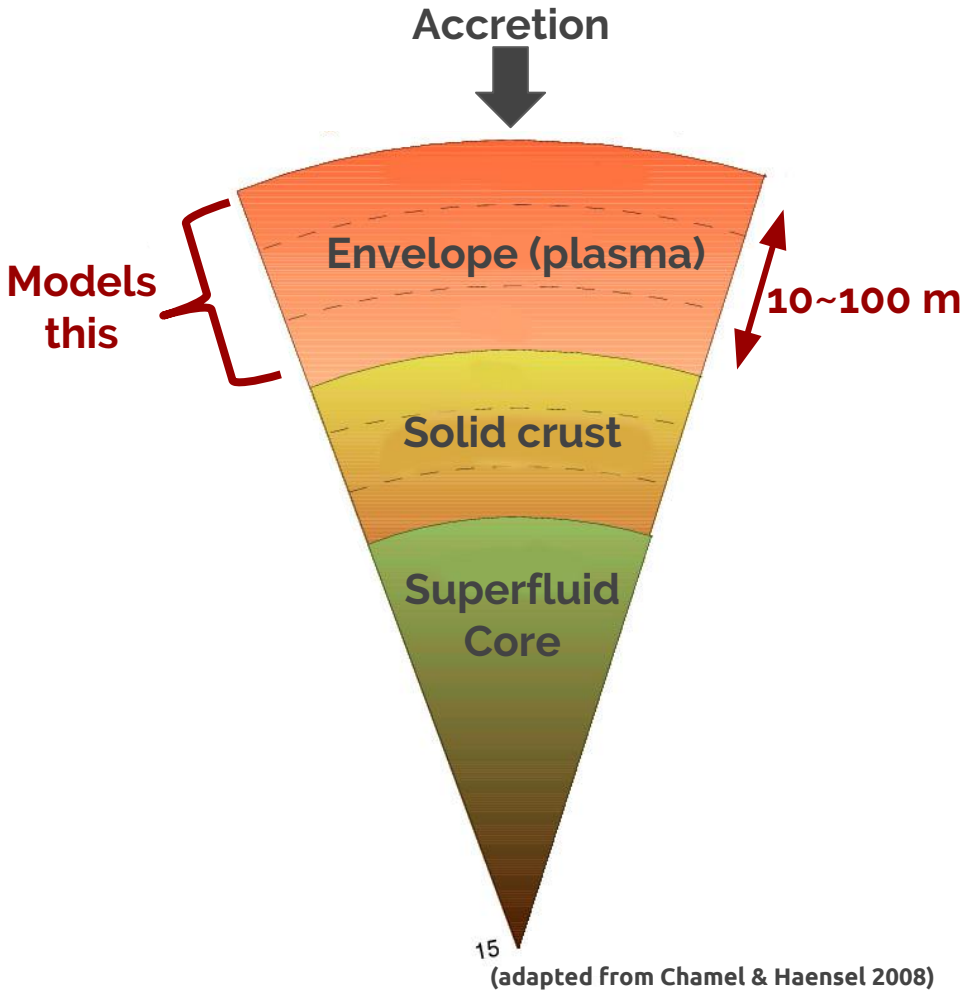
Modelling

KEPLER Code:

- 1D stellar hydro
- Adaptive nuclear network
- Simulates the envelope



(adapted from Chamel & Haensel 2008)

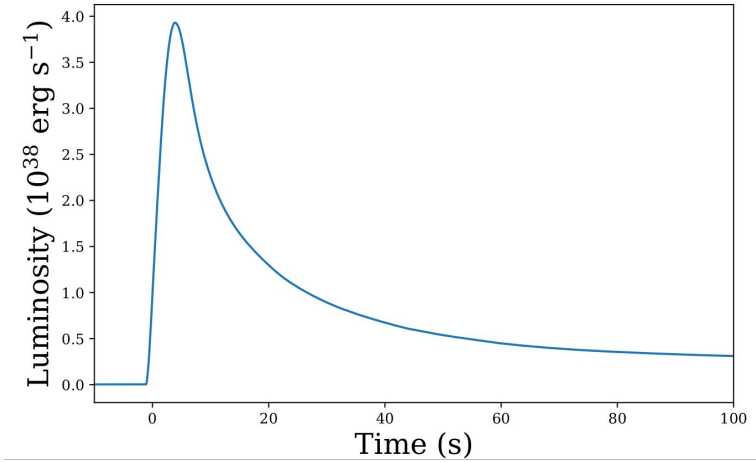
Modelling

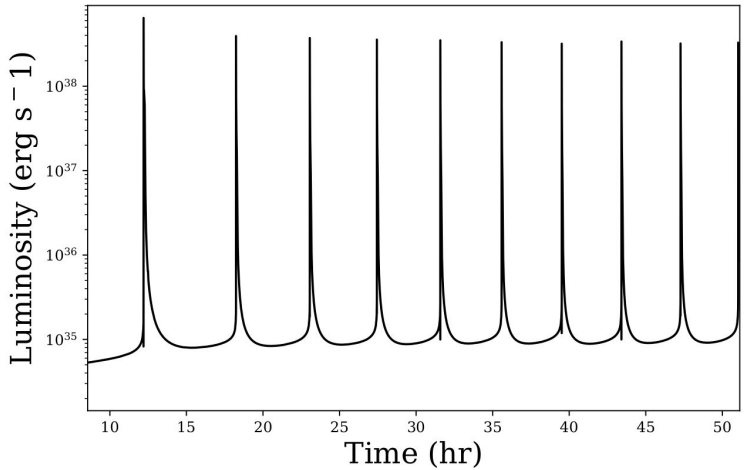
KEPLER Code:

- 1D stellar hydro
- Adaptive nuclear network
- Simulates the envelope

Burst properties:

- Peak luminosity
- Energy
- Recurrence time





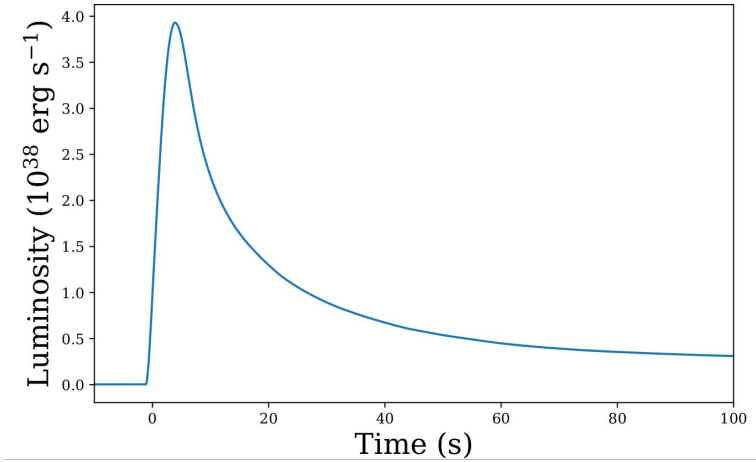
Modelling

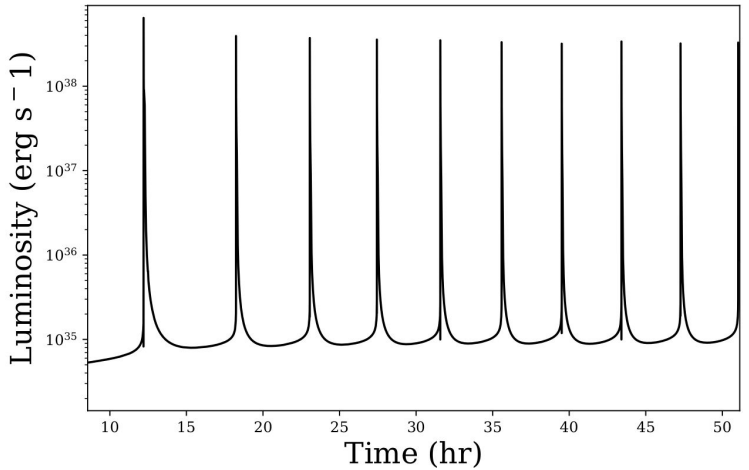
KEPLER Code:

- 1D stellar hydro
- Adaptive nuclear network
- Simulates the envelope

Parameters:

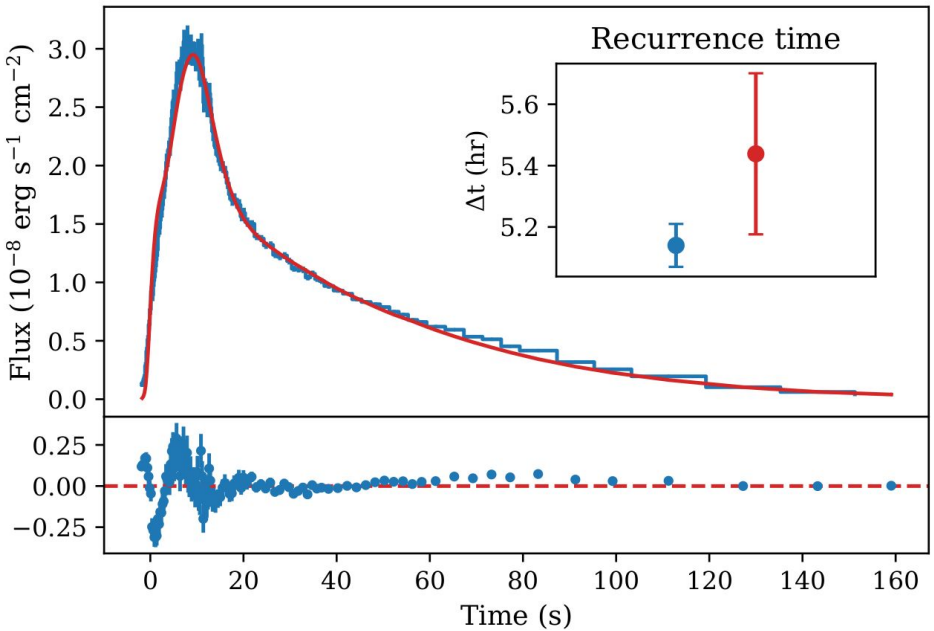
- Accretion rate
- Fuel Composition (^{1}H, Z_{CNO})
- Surface gravity
- Crust heating
- etc.





Matching observations

GS 1826-24 (the “clocked burster”)



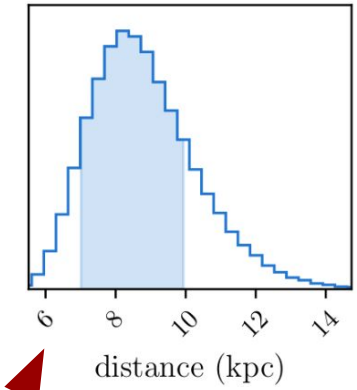
(WORK IN PROGRESS)

Matching observations

Lacking systematic model fitting:

- Many parameters (some unexplored)
- Have some good fits, but are they the only/best ones?
- How can we actually constrain system properties with our models?

Matching observations



Lacking systematic model fitting:

- Many parameters (some unexplored)
- Have some good fits, but are they the only/best ones?
- How can we actually constrain system properties with our models?

Markov chain Monte Carlo (MCMC)

- Optimises model fit
- Also provides likelihood distributions (i.e. uncertainties)

One problem...

The individual models are too expensive

- Takes days to compute
- Need to evaluate thousands/millions of times

One problem...

The individual models are too expensive

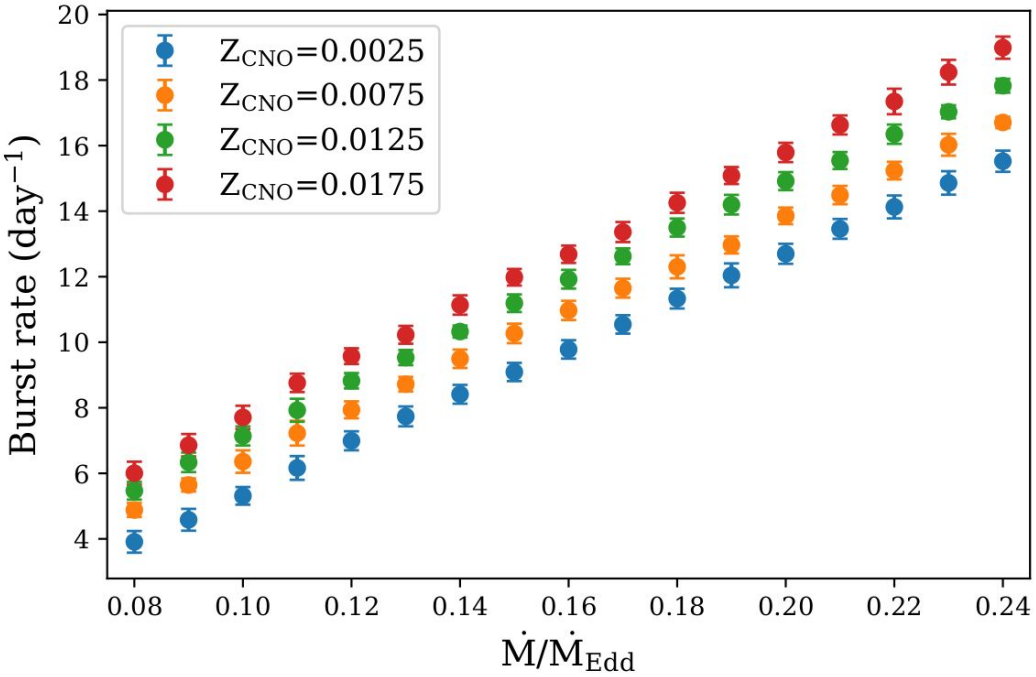
- Takes days to compute
- Need to evaluate thousands/millions of times

Needs to take < 1 human lifetime (preferably < 1 phd)

Model database

Tabulate burst models

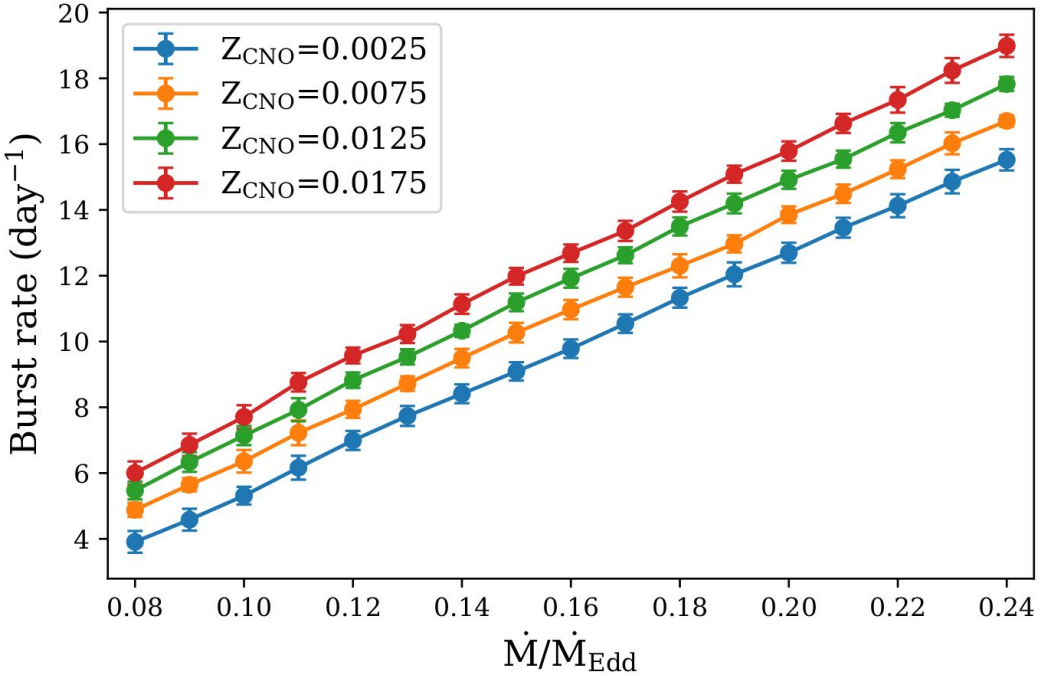
- Burst rate
- Fluence
- Peak luminosity



Interpolate between models

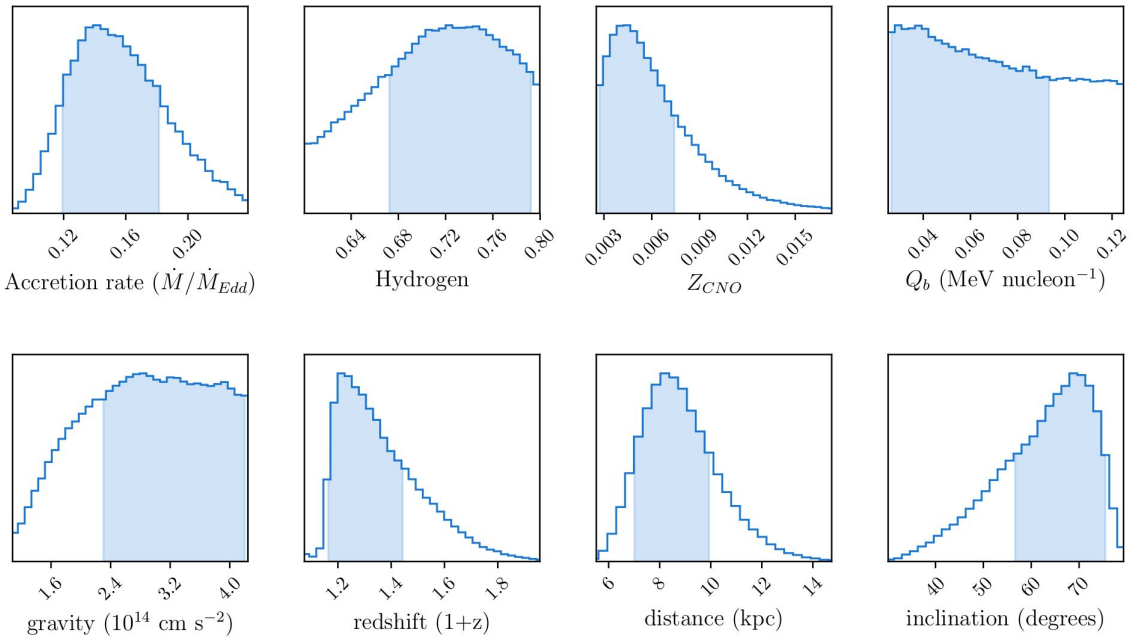
Bursts vary smoothly

- Use interpolation
- Cheap to evaluate
- Days ⟶ ms



MCMC

Feed into MCMC, give it data to match

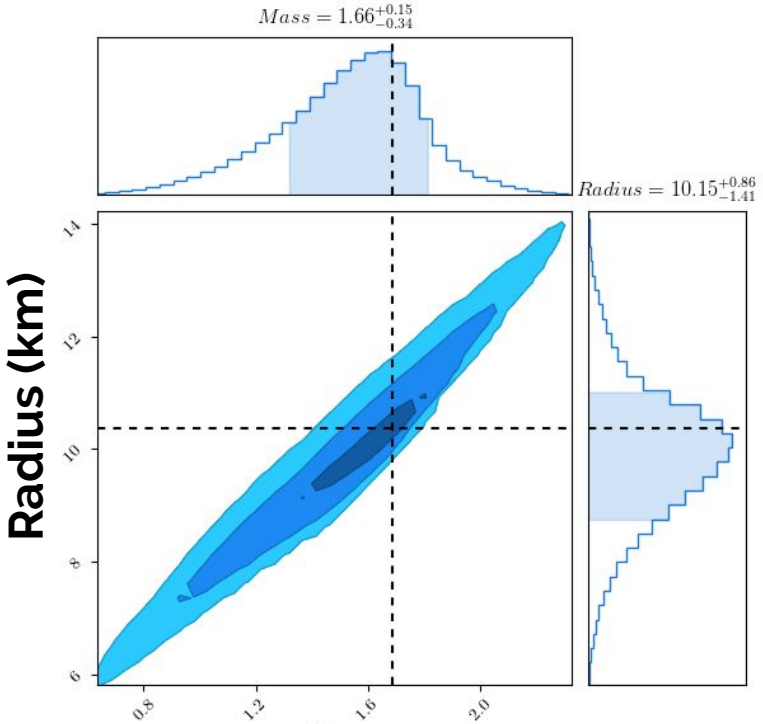


(WORK IN PROGRESS)

NS mass and radius

Everyone's favourite NS property

- Each model has a fixed gravity
- But can still choose mass and radius
- Affects model fitting due to gravitational redshifting

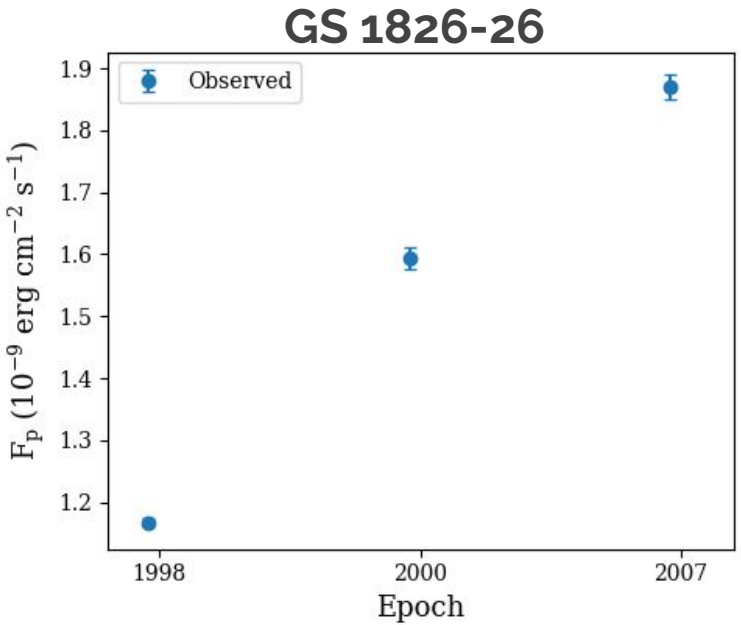


(WORK IN PROGRESS)

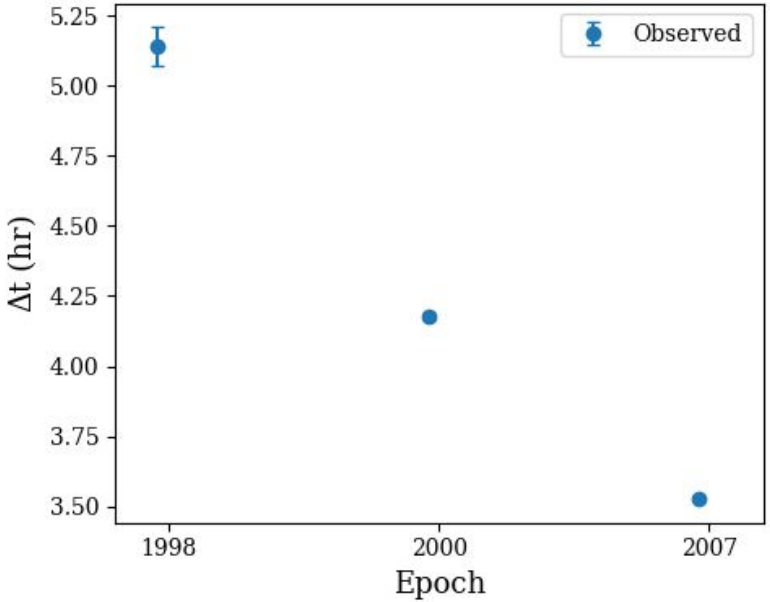
Multi-epoch matching

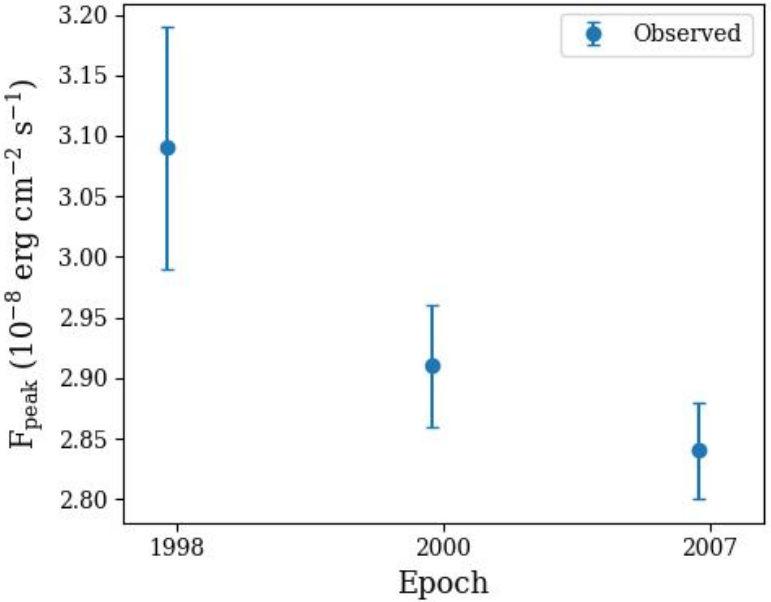
The same system at different accretion rates

- Vastly tightens constraints
- Breaks degeneracies
- Rules out some models
- See **Meisel 2018**

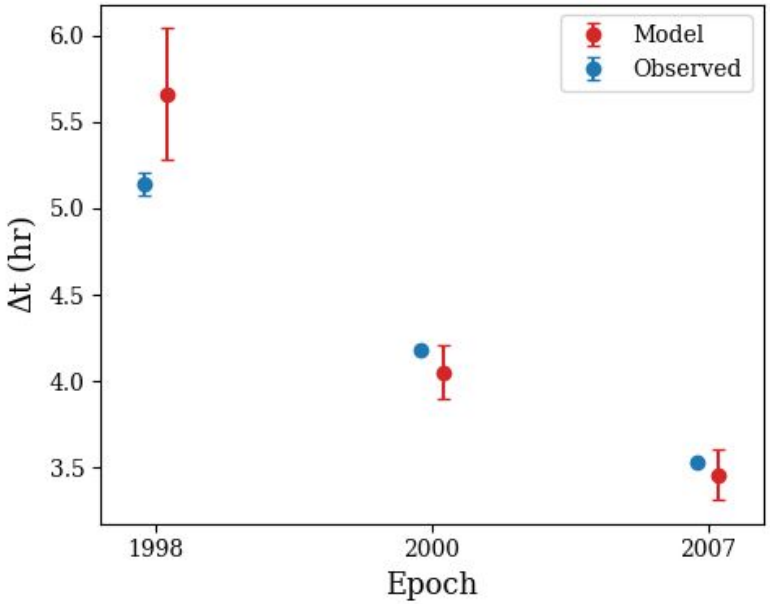


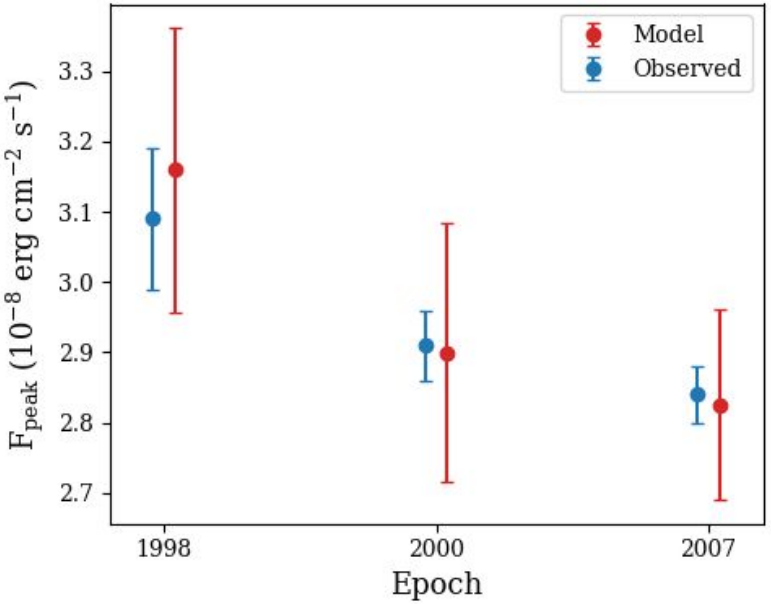
Multi-epoch matching





Multi-epoch matching

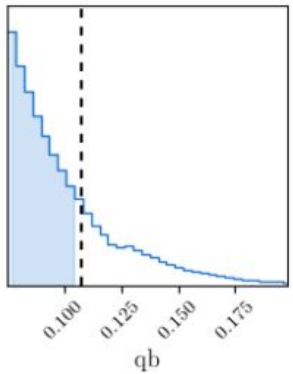




(WORK IN PROGRESS)

Open problems

- **How to interpolate across lightcurves?**
- **Dependence of anisotropy on disc models?**
- **Priors on mass and radius?**
- **MCMC keeps wanting minimum crust heating?**



Outlook

Extending burst model-fitting:

- Comprehensive model library
- Determine best match, with likelihood distributions
- Constrain system properties
- Apply to more observed bursting systems