

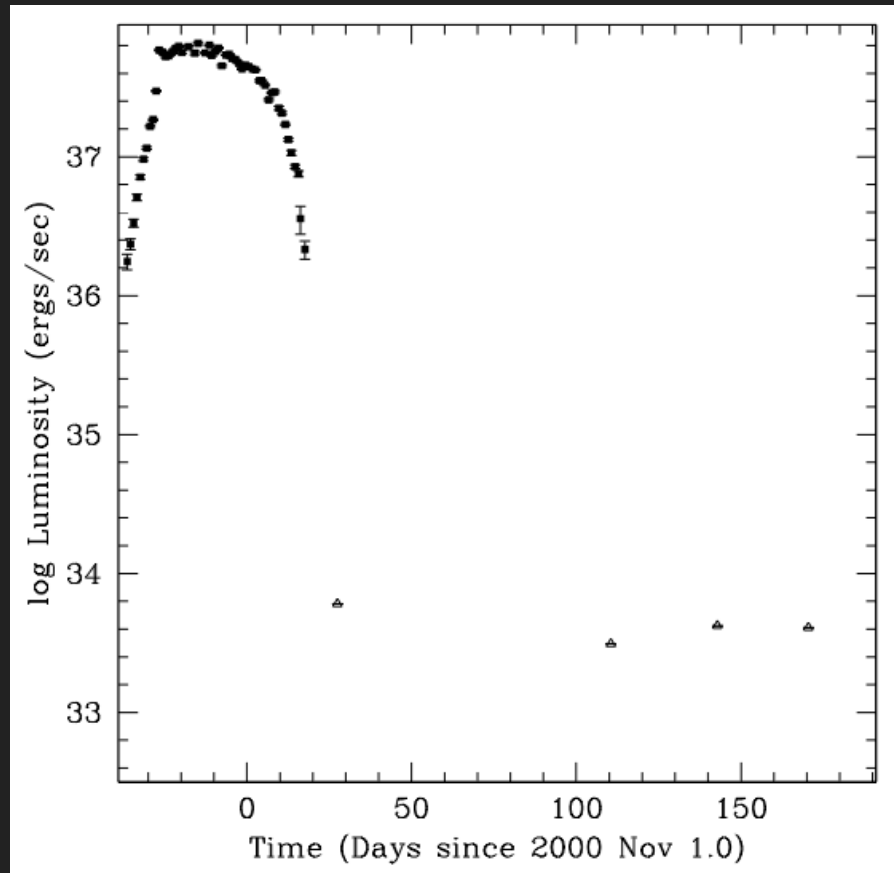
CRAIG HEINKE

CRUST COOLING OF NEUTRON STARS FOR STROBE-X

OUTBURSTS

- ▶ Energy released at surface radiated away
- ▶ Crust squishes, fuses, gives ~ 2 MeV/nucleon
- ▶ Crustal heat comes out slowly

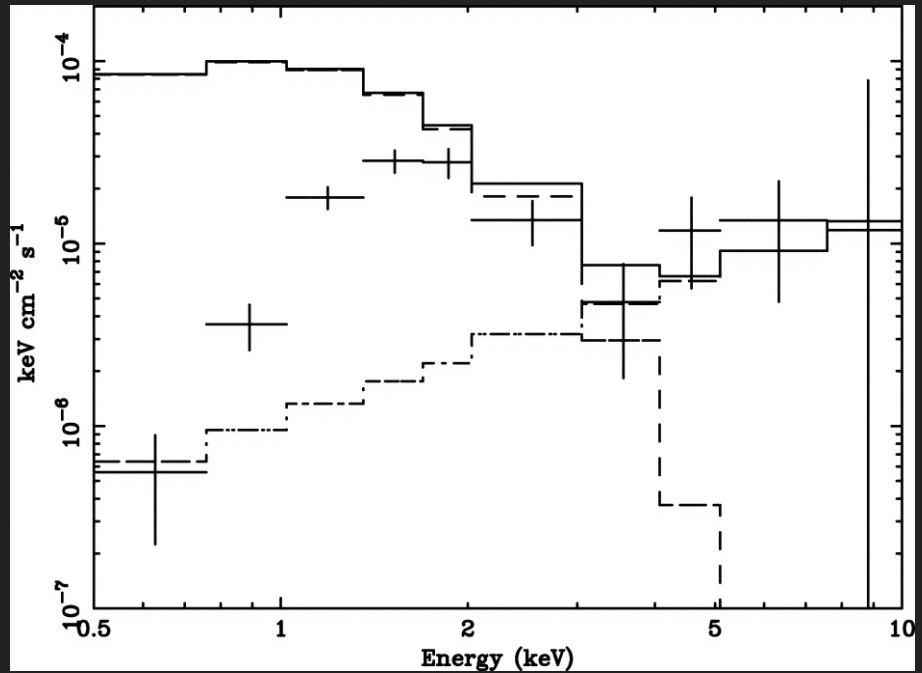
Aql X-1,
Rutledge+02



TEXT

QUIESCENT SPECTRA

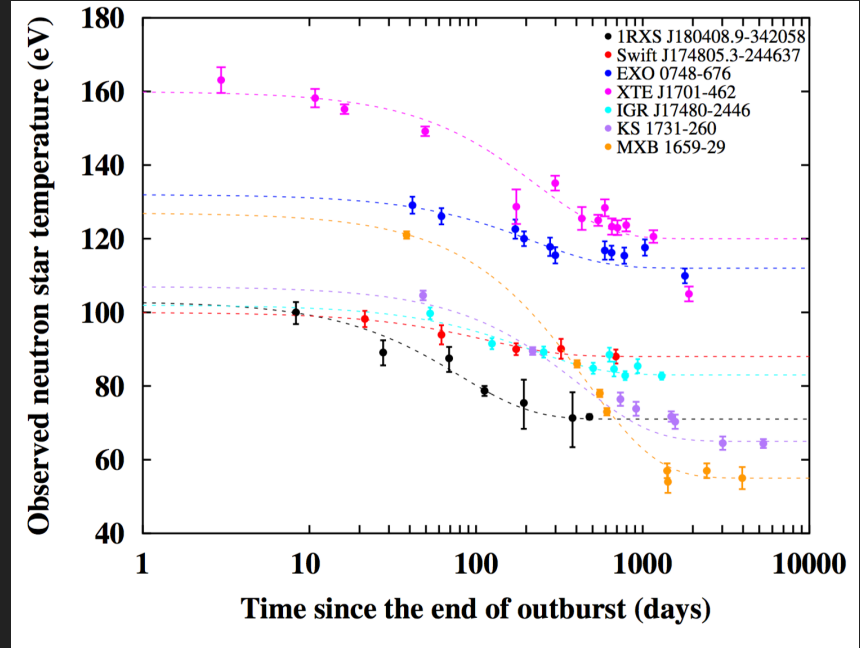
- ▶ Thermal & non thermal components
- ▶ L_x often $\sim 1e32-1e34$;
 $F_x \sim 1e-14/12$ @10 kpc
- ▶ Cosmic bg $\sim 3e-15$
(0.5-2 keV), 1' FOV



Aql X-1, Rutledge+02

OBSERVATIONS

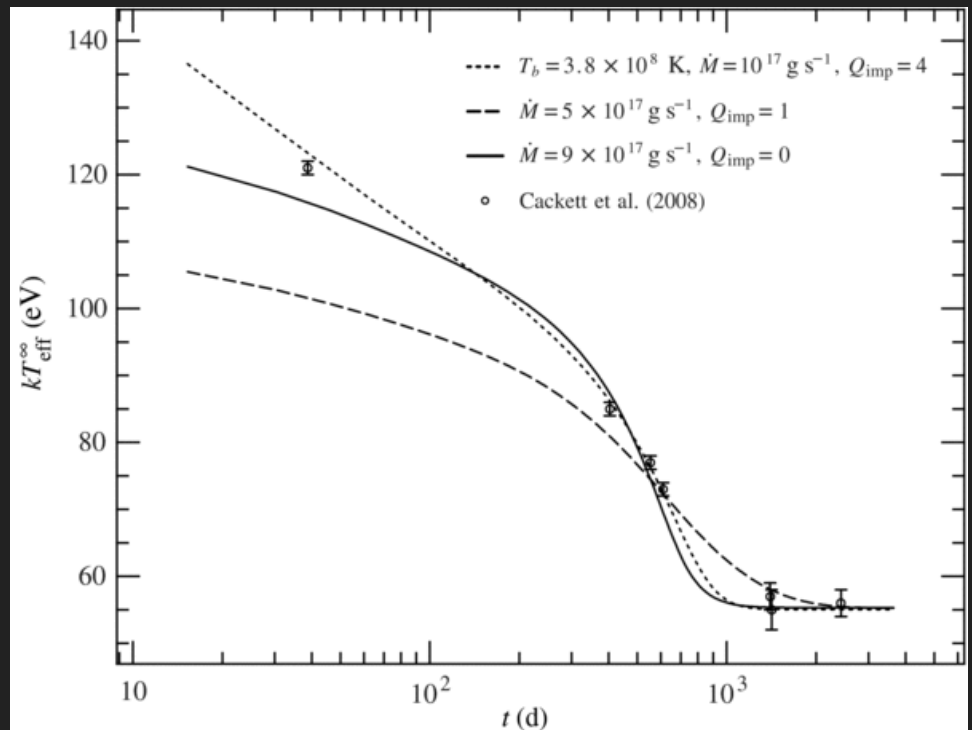
- ▶ Chandra, XMM observed NSs after long outbursts
- ▶ Heat deposited in crust, cools over few years
- ▶ Shape of curve \rightarrow physics



TEXT

FITTING CRUST COOLING CURVES

- ▶ Later times=deeper layers
- ▶ Conductivity set by impurity



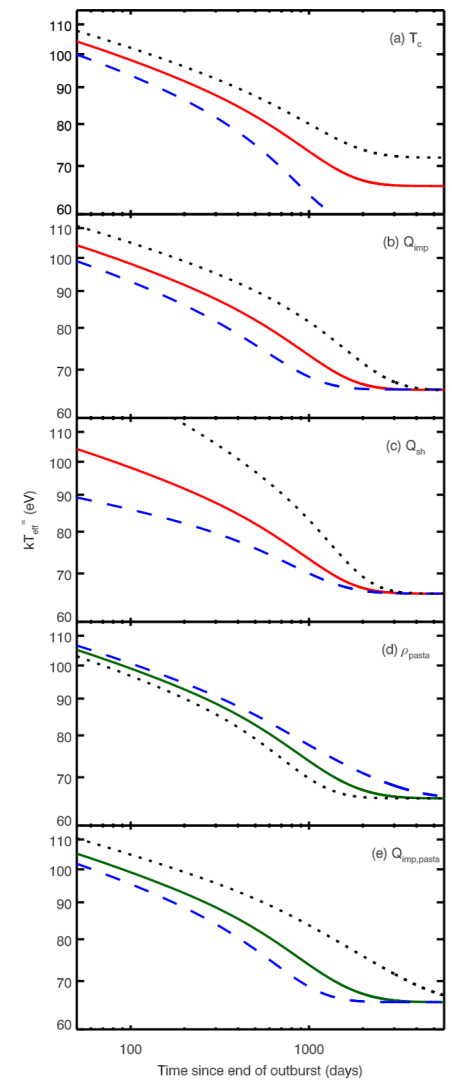
MXB 1659-29, Brown & Cumming 2009

TEXT

VARIABLES

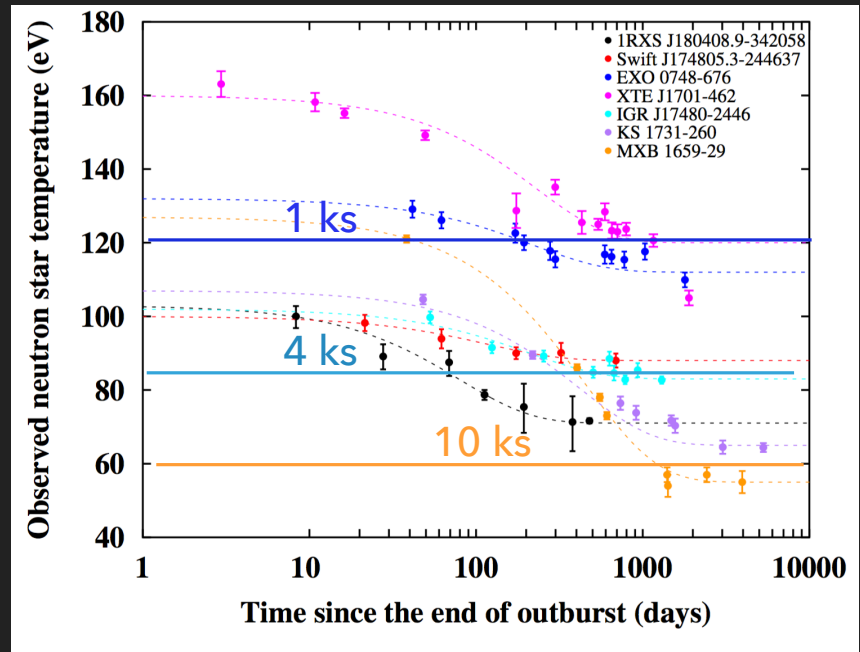
- ▶ a) Core temp; $T=7-11e8$
- ▶ b) Impurity of crust; $Q=1-10$
- ▶ c) Shallow heat; $0.6-3.5$ MeV/nucleon
- ▶ d) Transition density of pasta layer, $6-1e13$ g/cm⁻³
- ▶ e) Impurity of pasta, $Q_p=2-40$

Merritt+2017



SIMULATIONS

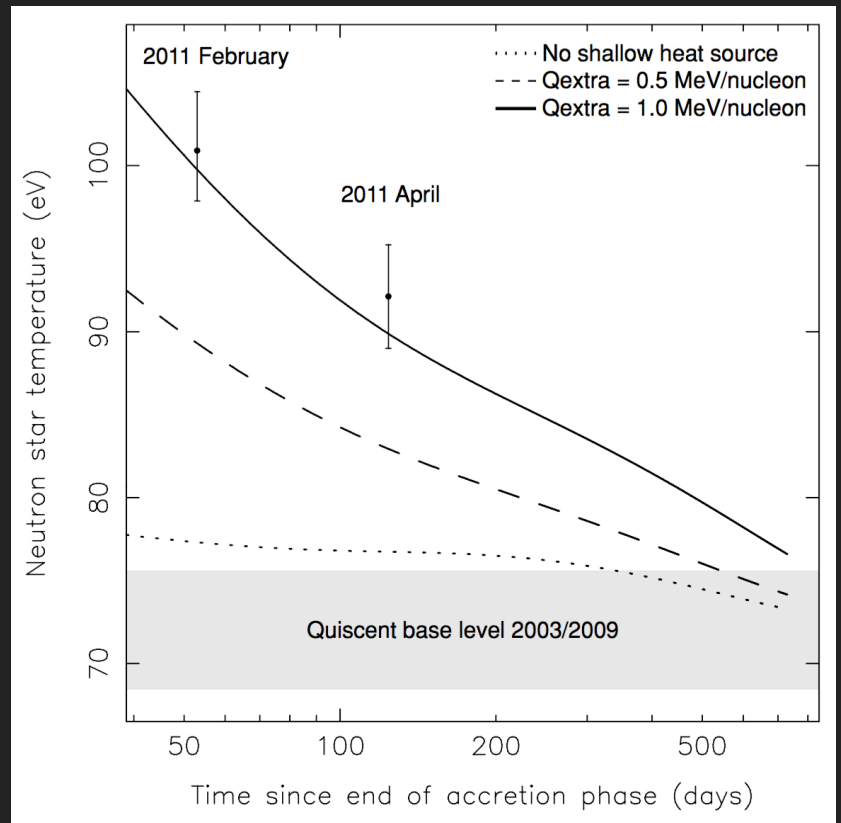
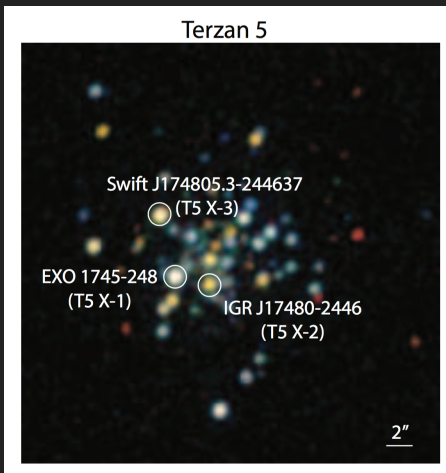
- ▶ Simulated NS atm, $N_h = 1e22$ ($2e21$ for 1659)
- ▶ Cosmic X-ray BG, for 3' field (no instr BG)
- ▶ Need 1-10 ks to get ~ 4 eV errors kT



TEXT

TERZAN 5 X-2

- ▶ Extra, shallow heating needed

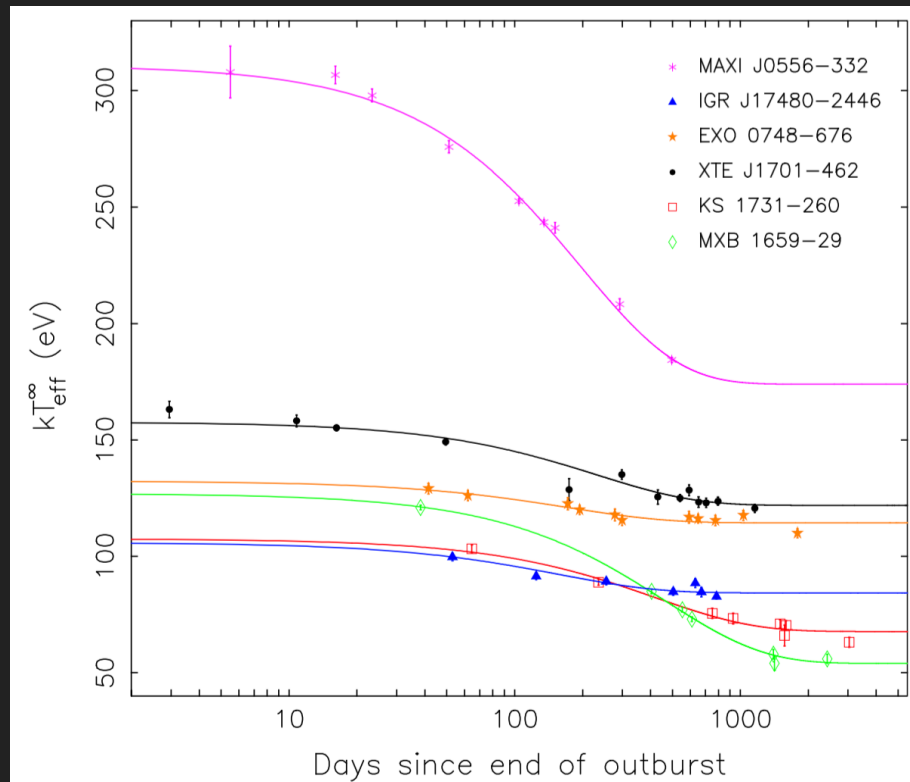


Degenaar+11, Terzan 5 X-2 cooling

TEXT

MAXI J0556-332

- ▶ Extremely hot; but history like XTE J1701
- ▶ Needs $\sim 10x$ more heating; how??
- ▶ Superburst?
- ▶ Crust convection?

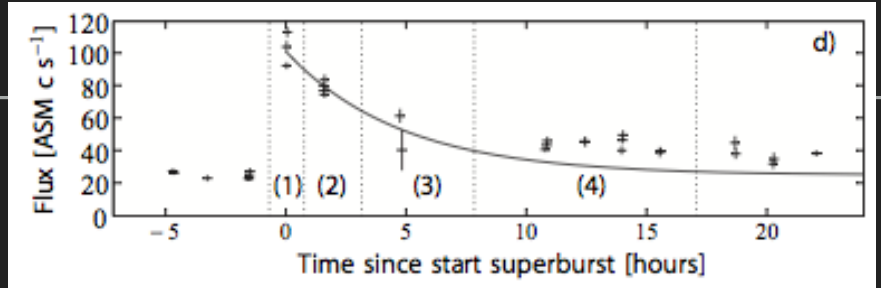


Homan+14

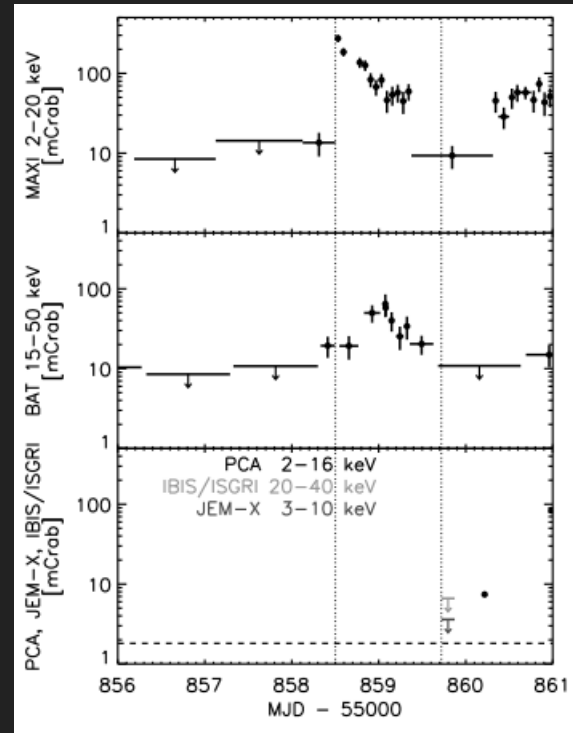
TEXT

SUPERBURSTS

- ▶ Last 5+ hours
- ▶ Burning of C?
- ▶ Aim to catch all Galactic superbursts?
- ▶ Understand trigger, recurrence, effect on crust



Keek+08



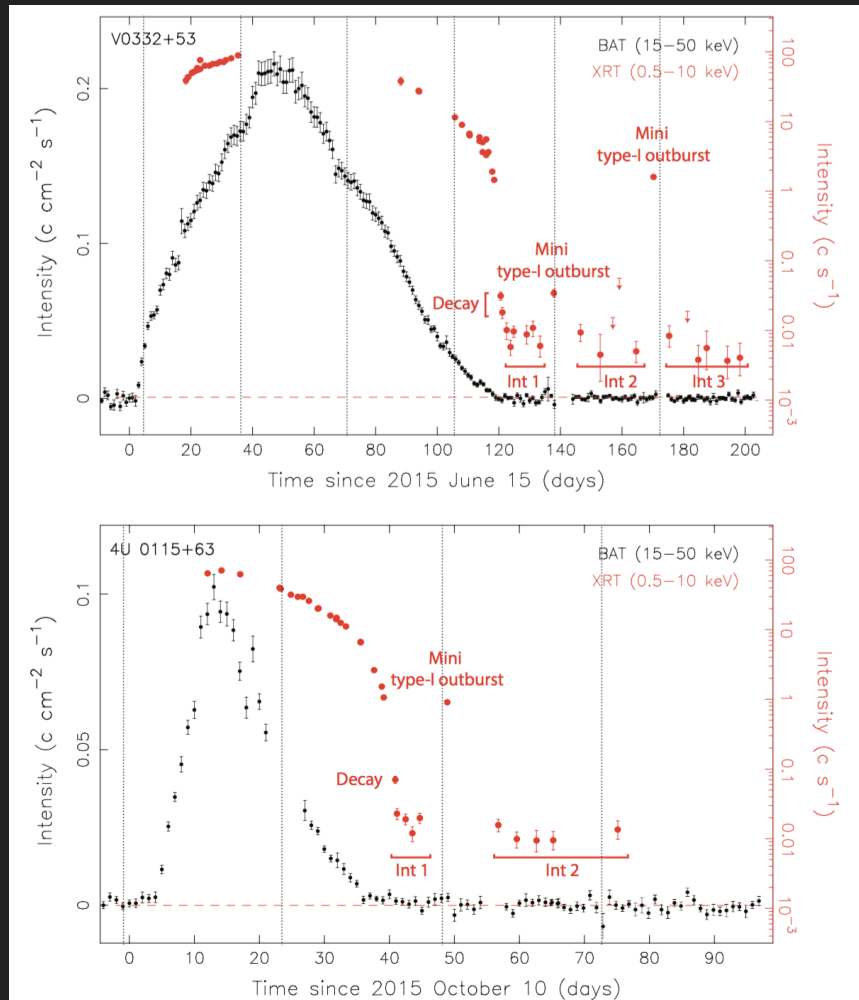
Altamirano+12

TEXT

HIGH-MASS X-RAY BINARIES

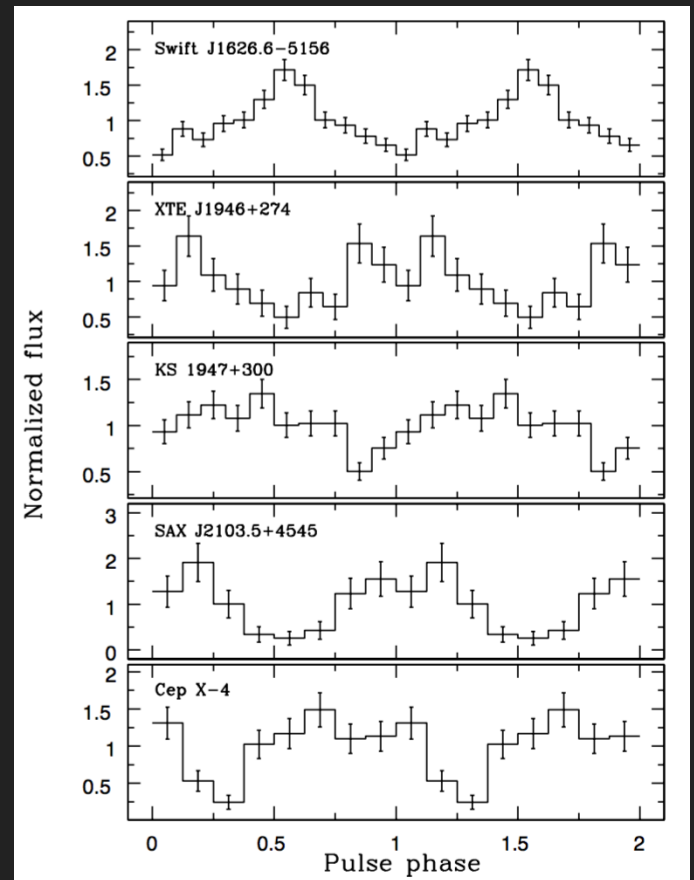
- ▶ Young, high-B NSs accreting Be star wind
- ▶ Major outbursts, cooling
- ▶ Often low-level accretion

Wijnands+16



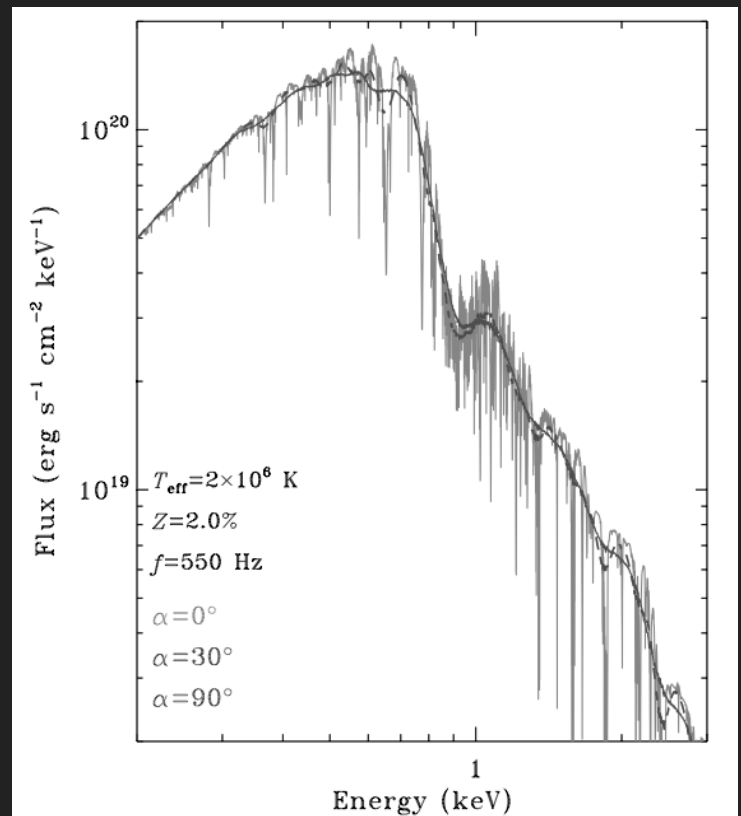
NATURE OF QUIESCENT FLUX

- ▶ Propeller regime:
accretion retarded
- ▶ Search for quiescent pulsations



CONTINUED ACCRETION?

- ▶ Elements stratify in ~ 30 s
- ▶ Accretion-pow $L_x < \sim 1e33$, H floats to top
- ▶ Higher $L_x \rightarrow$ solar abund, spectral change
- ▶ Hints (Rutledge+02); need larger eff. area, more obs!
- ▶ Direct z measurement!!



Rutledge+02a

TEXT

KEY GOALS

- ▶ Monitor cooling, constrain crustal physics
- ▶ Determine shallow heat deposit in crust
- ▶ Solve mysteries of superbursts
- ▶ Catch mixed-element atmospheres, measure Z

SUGGESTIONS

- ▶ Daily monitoring of outbursts
- ▶ WFM: monitor whole sky for superbursts
- ▶ Aim to slew $>10-15$ degrees/minute, maximize targets
- ▶ Keep XRCA FOV small ($<1'$), cosmic (& detector) bg low
- ▶ Ability to trigger within $\sim 1-2$ hrs from WFM, observe superbursts