Optical & Infrared Lightcurves of Soft X-ray Transients

Charles Bailyn

Yale University

With thanks to: J. McClintock (CfA), R. Remillard (MIT), J. Orosz (SDSU), M. Buxton (Yale), Yale students and data aides R. Jain, B. Heflin, D. Maitra, S. Tourtelotte, K. Whitman, CTIO/YALO staff D. Gonzalez & J. Espinoza

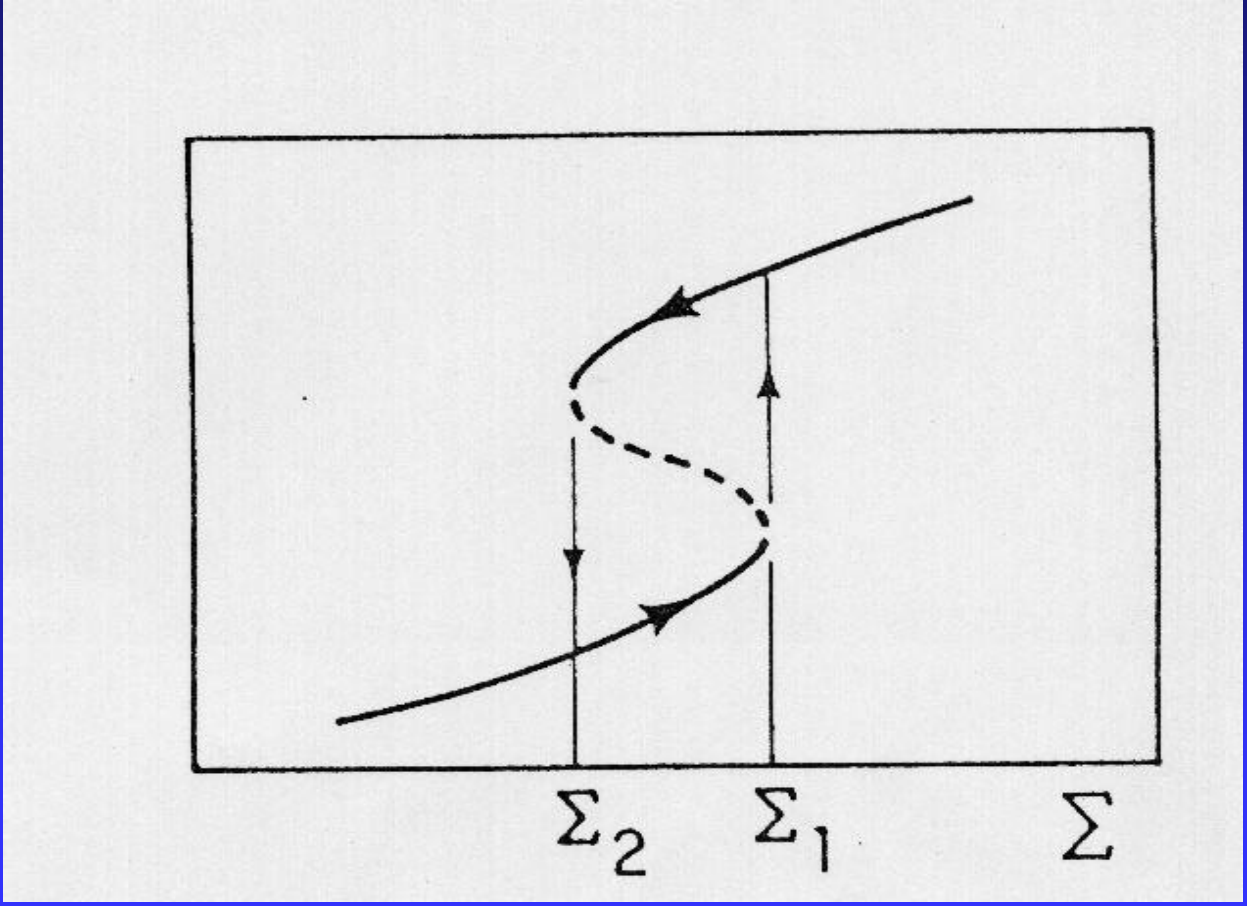
Optical and Infrared Lightcurves of Soft X-ray Transients

- Theoretical Expectations
- Observational Capabilities
- Recent data 1 – Aql X-1
- Recent data 2 – 4U1543-47
- Conclusions: outburst physics, triggers, future projects

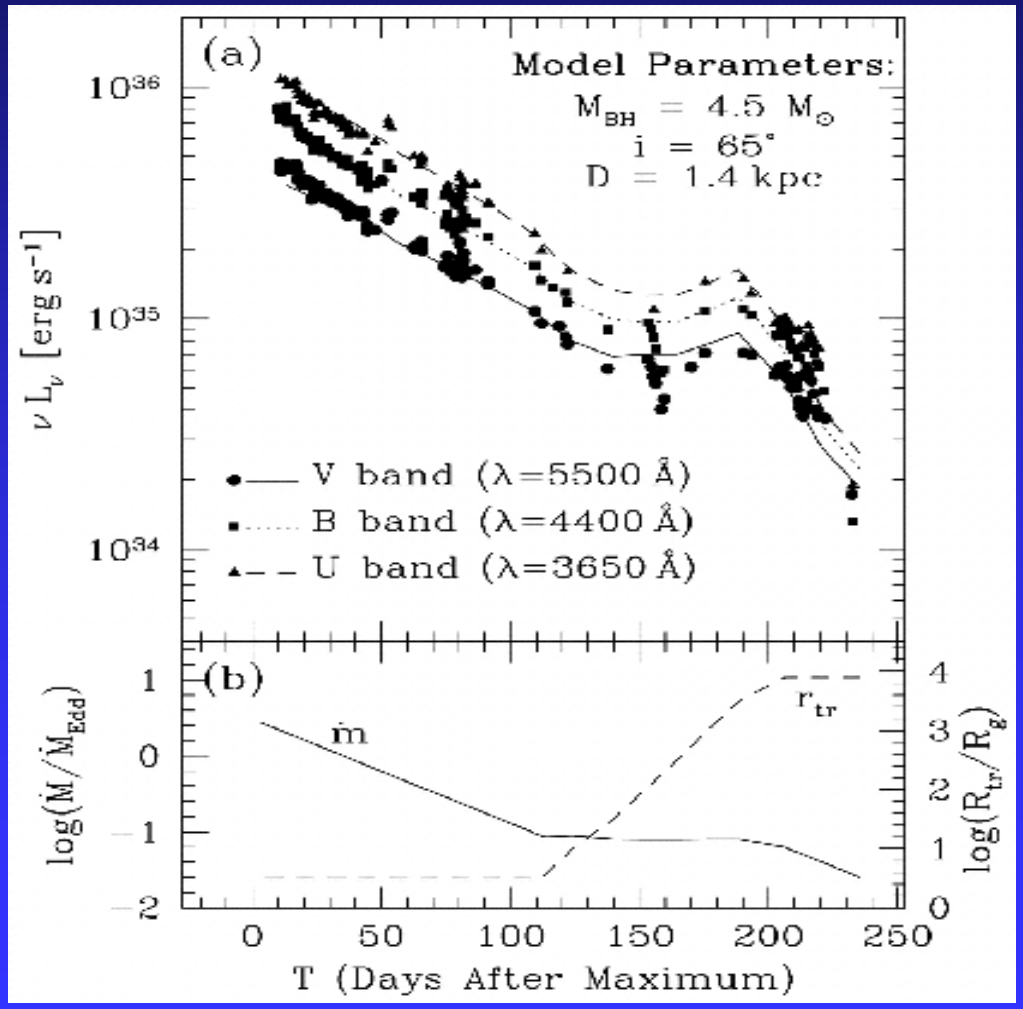
Importance of O/IR Data of (Transient) X-ray Binaries

- In quiescence, observe companion stars
  > binary parameters
- In outburst, observe outer parts of disk
  > boundary condition for inner parts of flow

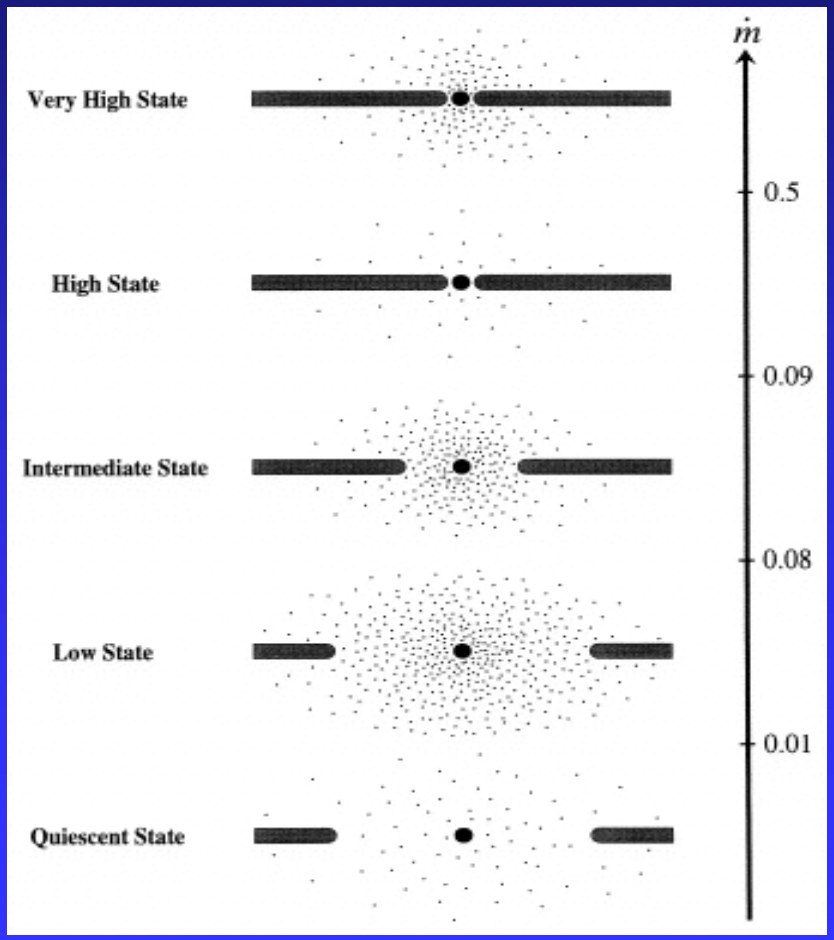
Outburst Physics I: Disk Instability Mechanism (DIM)



Outburst Physics II: X-ray Irradiation



Outburst Physics III: Two part flow



Outburst Physics IV: Expectations for Optical/IR

- Fast Rise and Exponential Decay (F.R.E.D.)
- Possible reflares
- Superposition of thermal spectra
- Optical precedes X-rays and lasts longer
- Same sequence of states in rise and fall

YALO Project (1998-2002)

- CTIO/Yale 1m
- ANDICAM dual-channel OIR imager
- Queue scheduling ideal for long-term monitoring

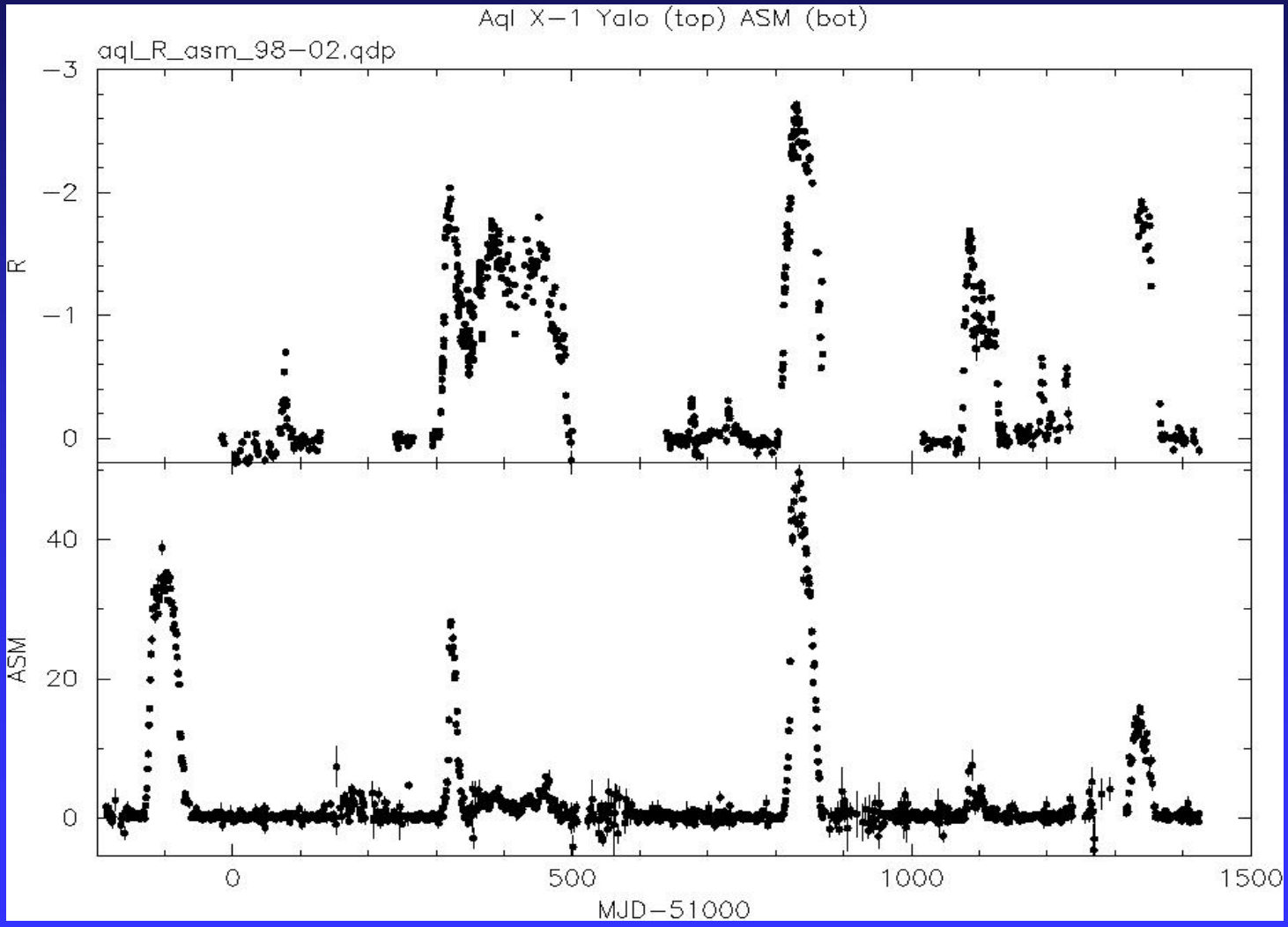
SMARTS Project 2003-2005

- 1.5m + spectrograph/IR imager
- 1.3m + ANDICAM
- 0.9m + 2KCCD (2003) followed by 1m + 4KCCD(2004)
- 0.9m + IR imager (2004?)
- Various kinds of flexible scheduling

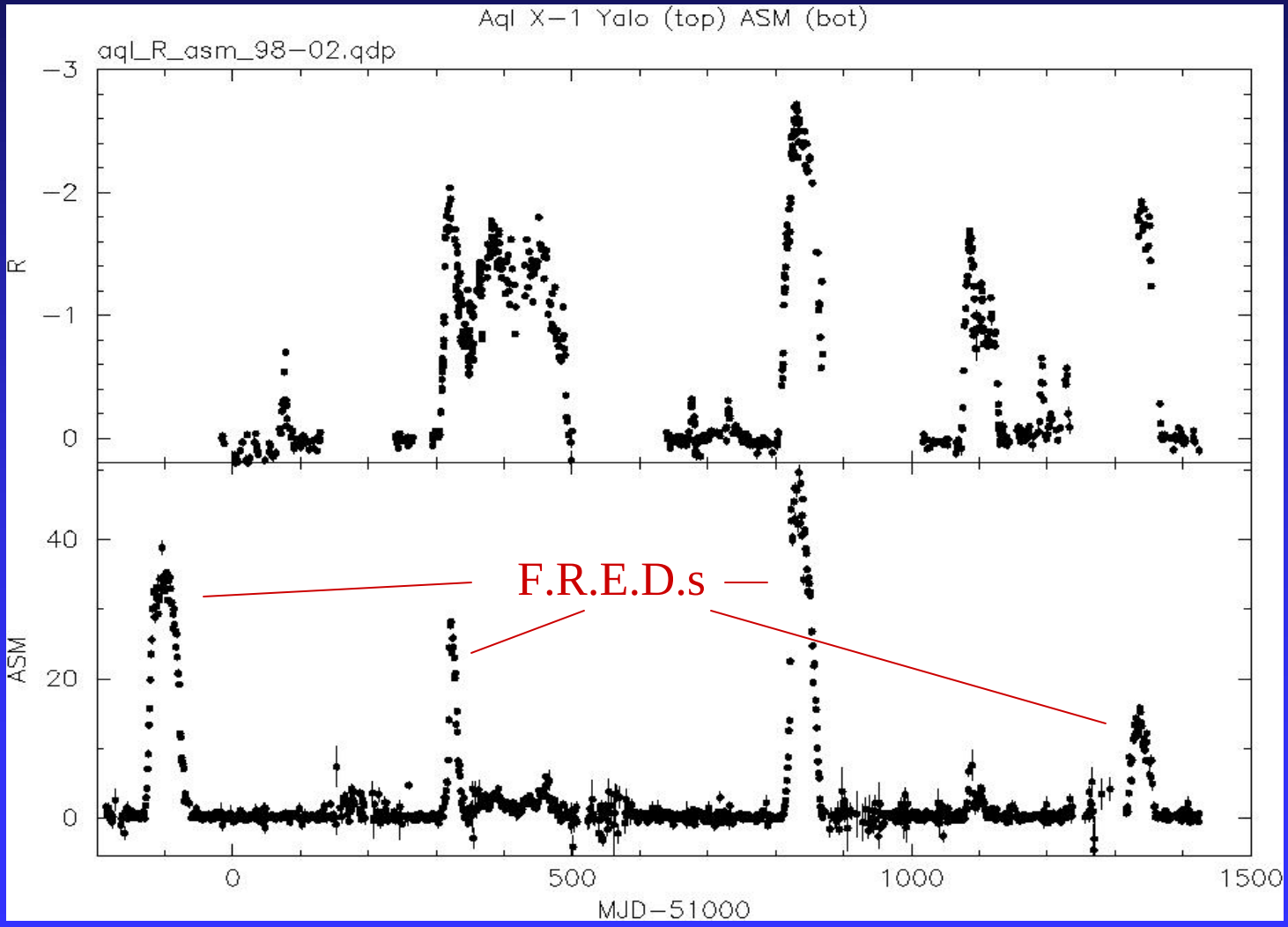
Aquila X-1

- Neutron star transient (displays bursts)
- Shortest recurrence time (~ 1 year)
- Orbital period ~ 18 hours
- Nearby neighbor ~ 2 mags brighter in quiescence
- Declination ~ 0: everyone can play!

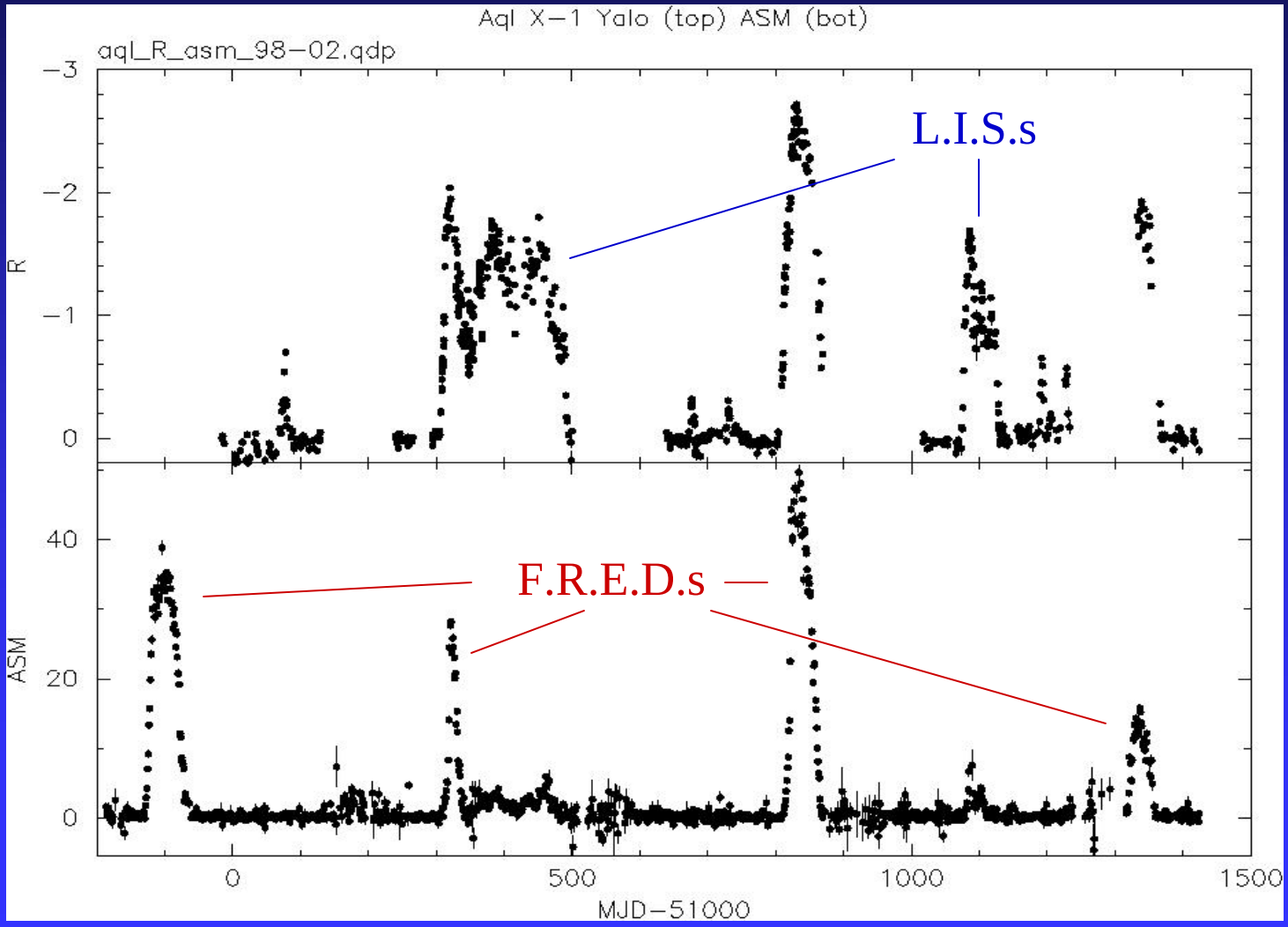
4 Years of Aquila X-1



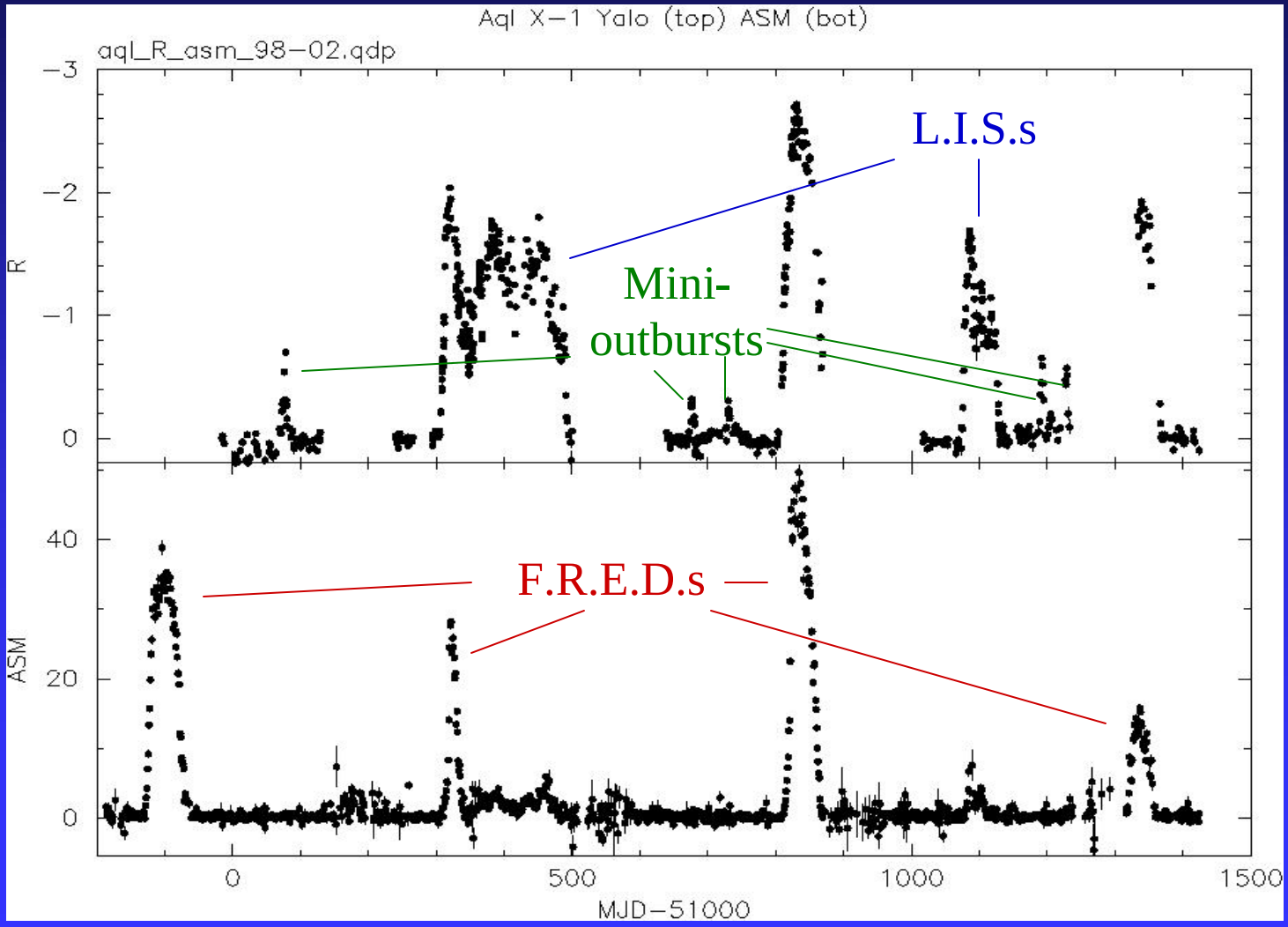
4 Years of Aquila X-1



4 Years of Aquila X-1



4 Years of Aquila X-1



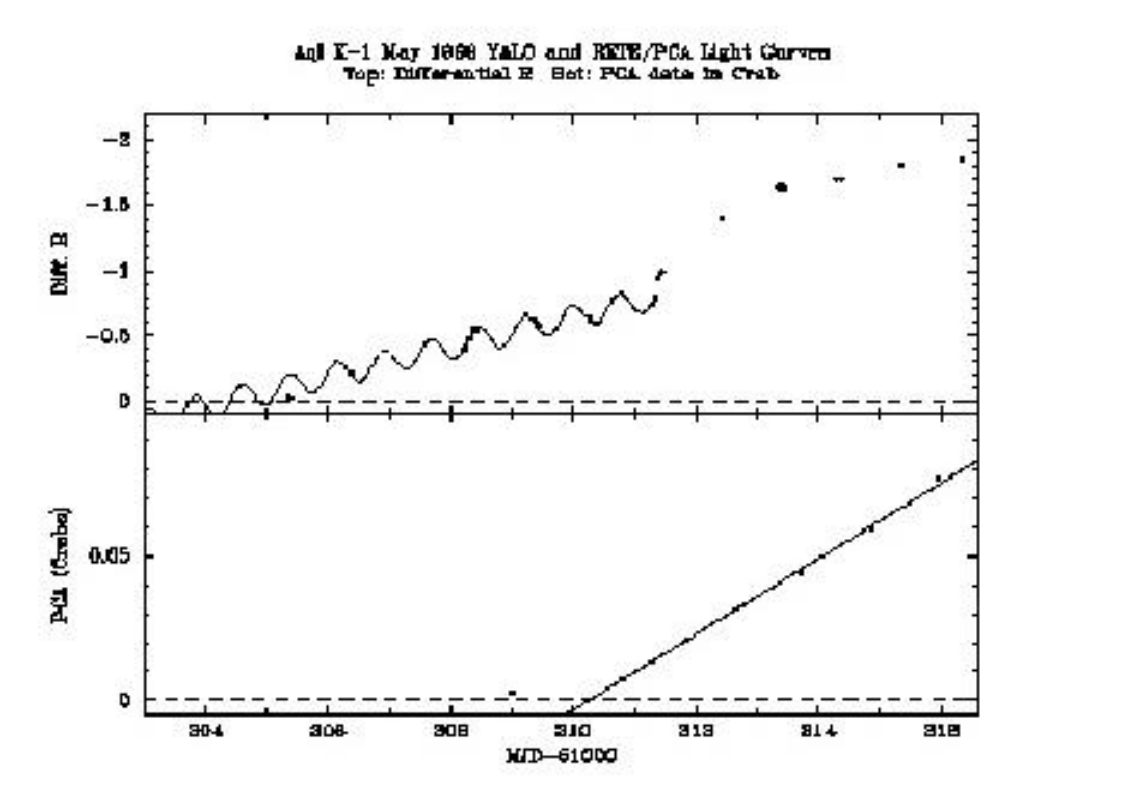
4 Years of Aquila X-1

- F.R.E.D.s – similar to expectations
- L.I.S.s – variable flux, low/hard X-rays
- Mini-outbursts – no X-ray response in ASM

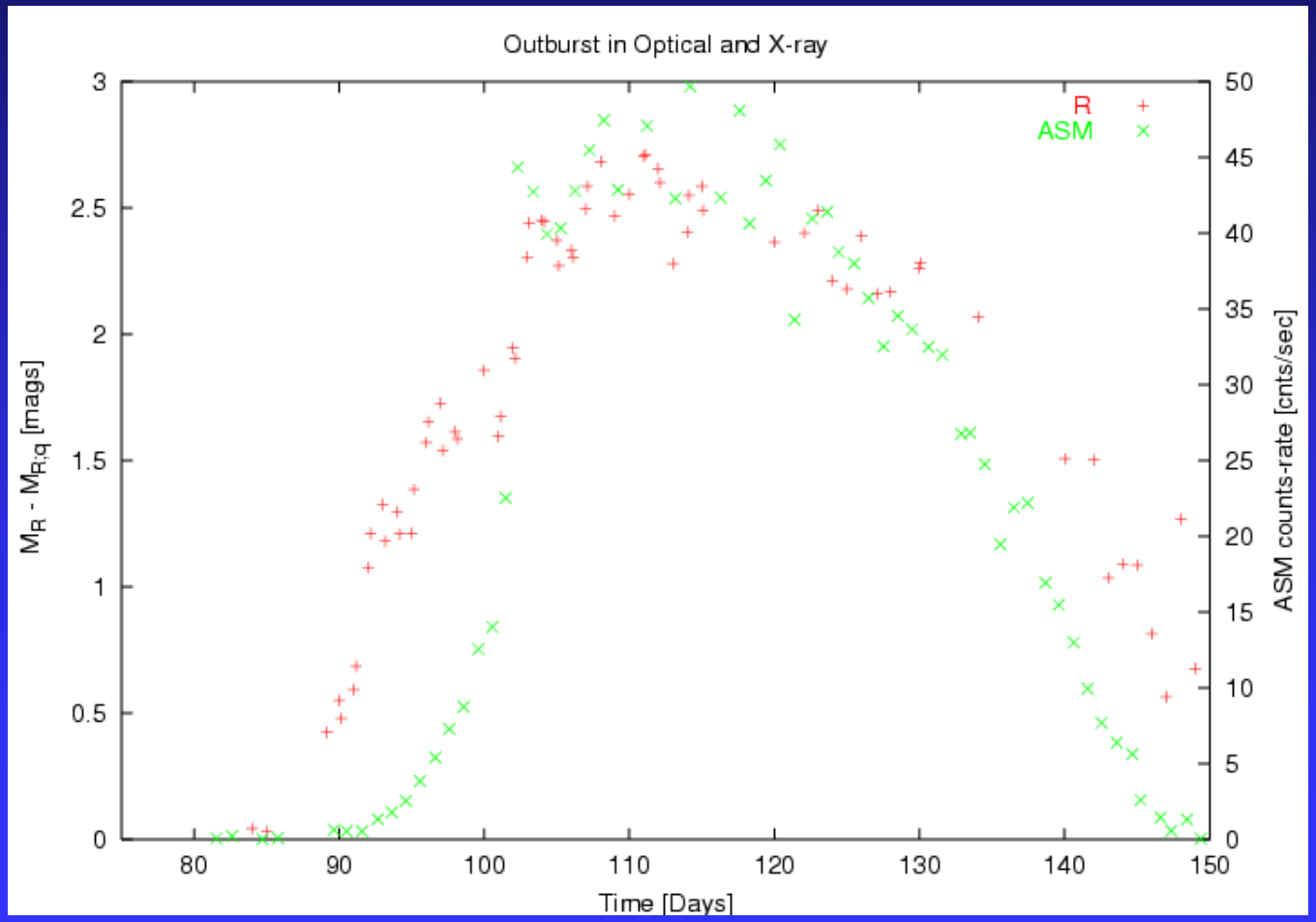
Are these due to magnetosphere? Incomplete inward disk expansion?

Do they occur in black hole candidates?

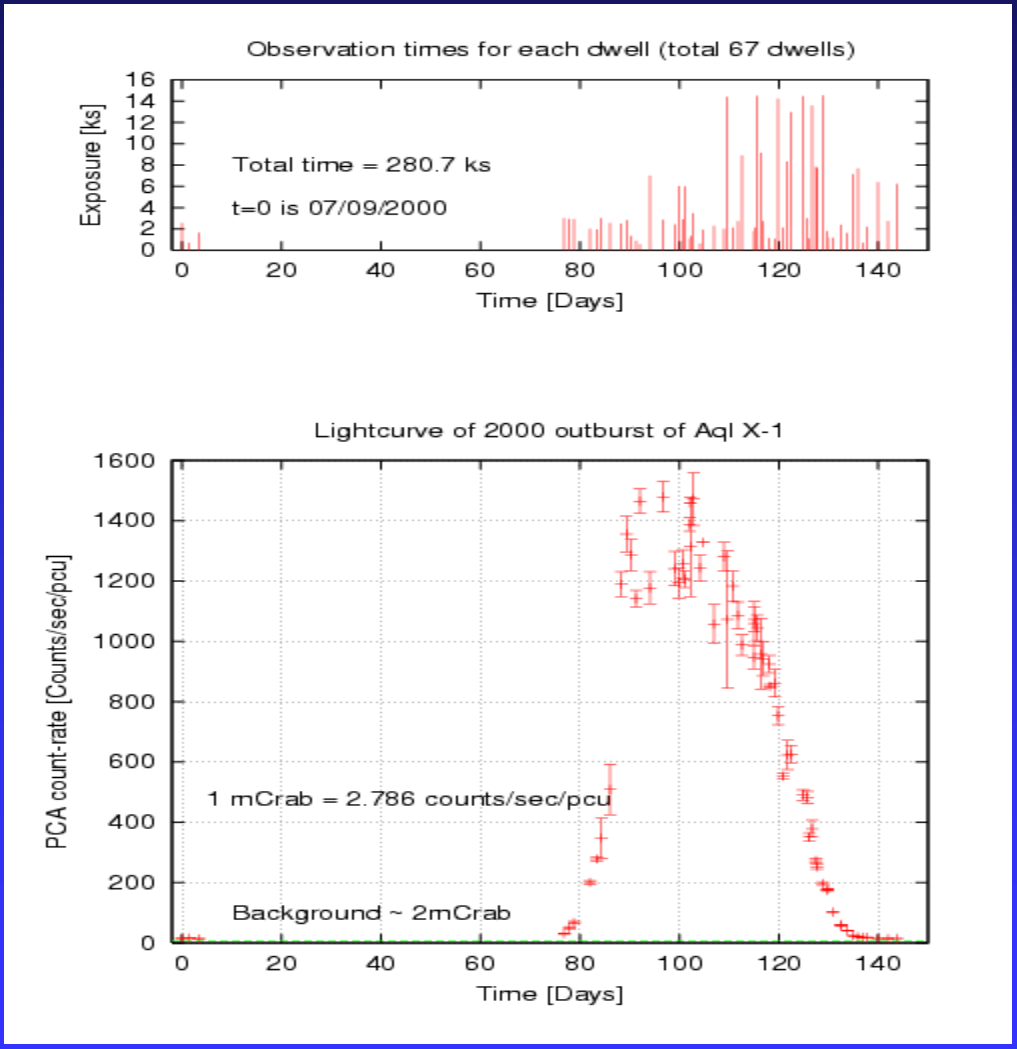
Aquila X-1: 1999 Outburst



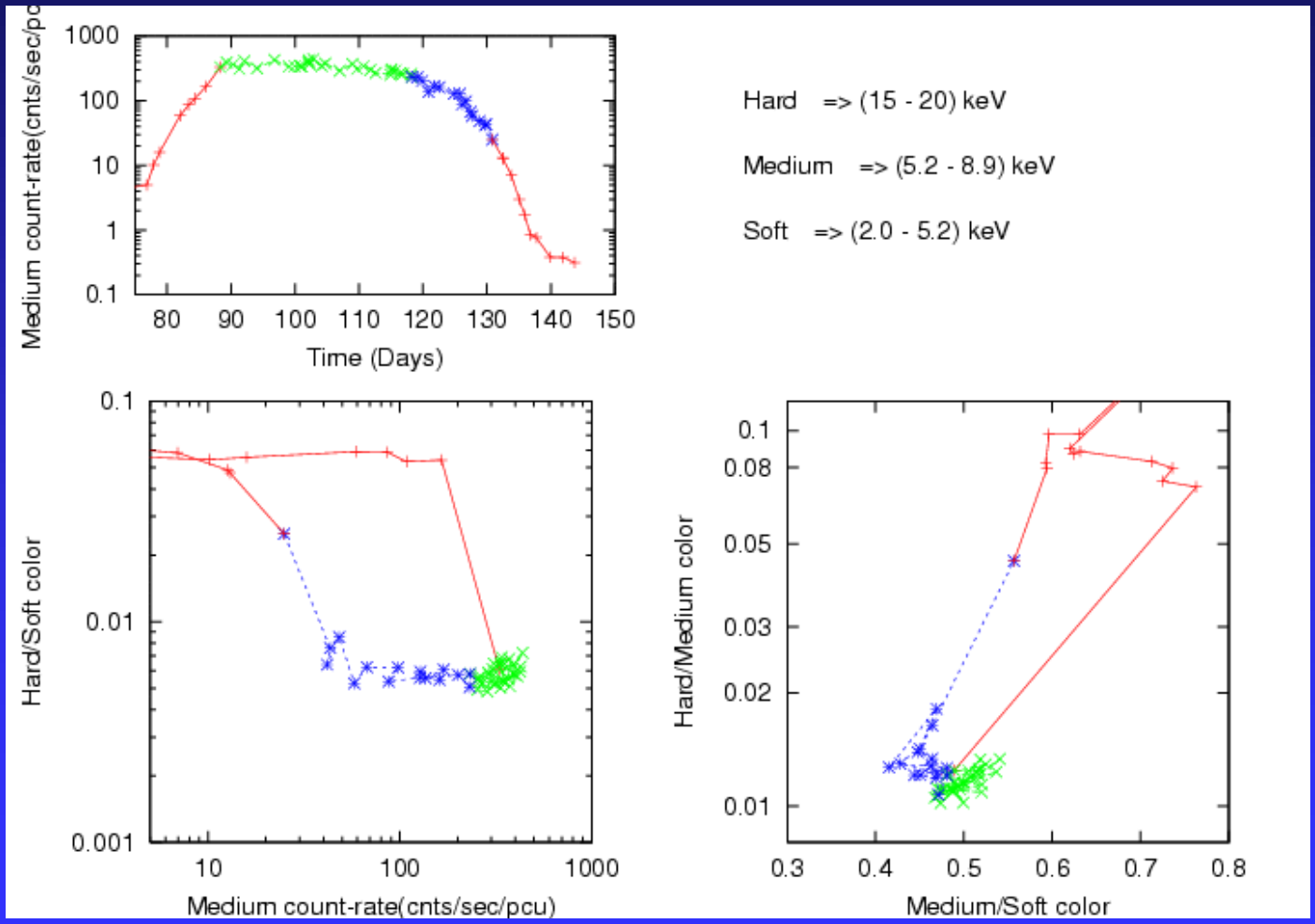
Aquila X-1: 2000 Outburst



Aquila X-1: 2000 Outburst



Aquila X-1: 2000 Outburst



Aquila X-1: 2000 Outburst

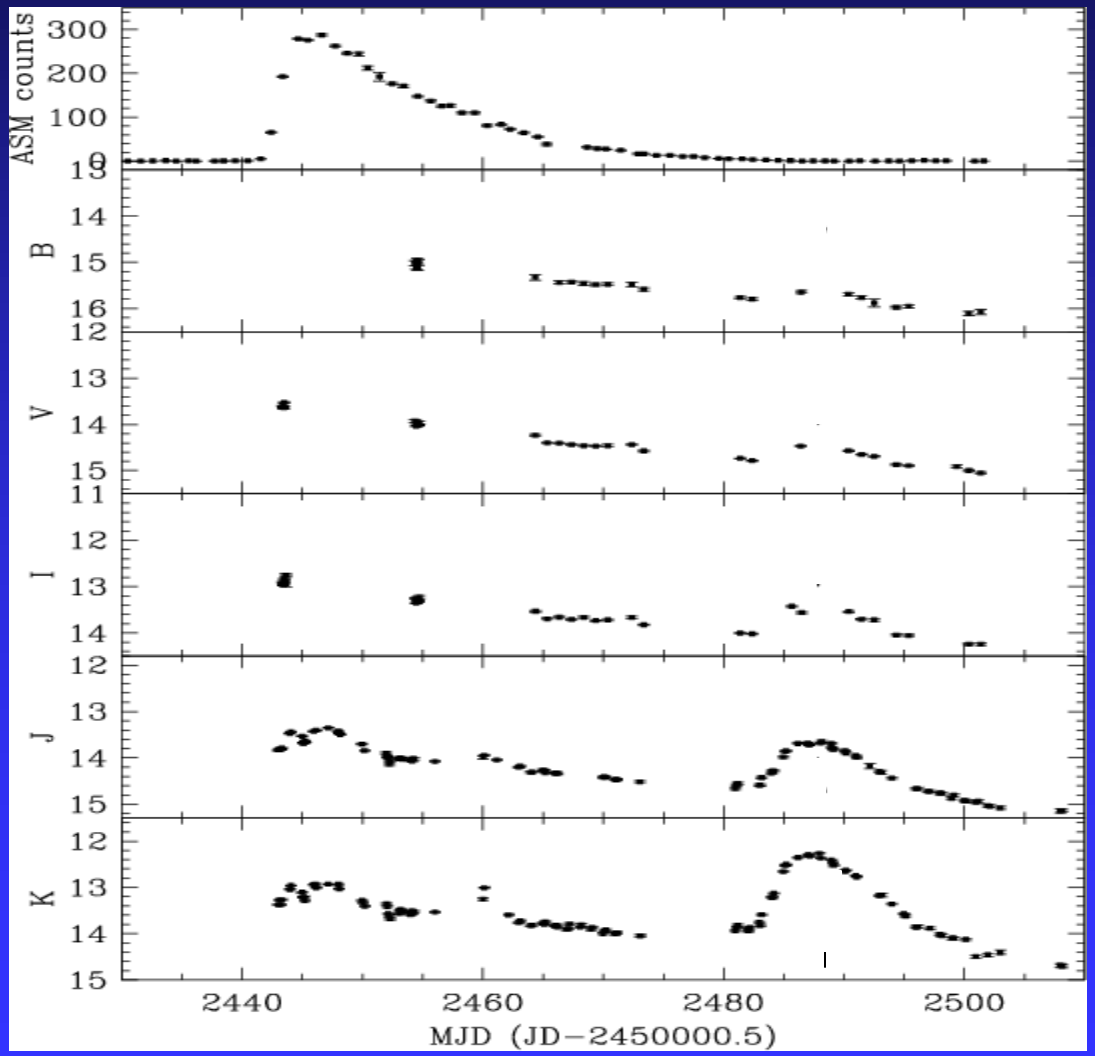
- Hysteresis in outburst morphology (also in 1999 outburst – Maccarone & Coppi)
- Slightly softer high/soft state in decline – no equivalent in outburst

Are we seeing the heated neutron star surface at the end of the outburst??

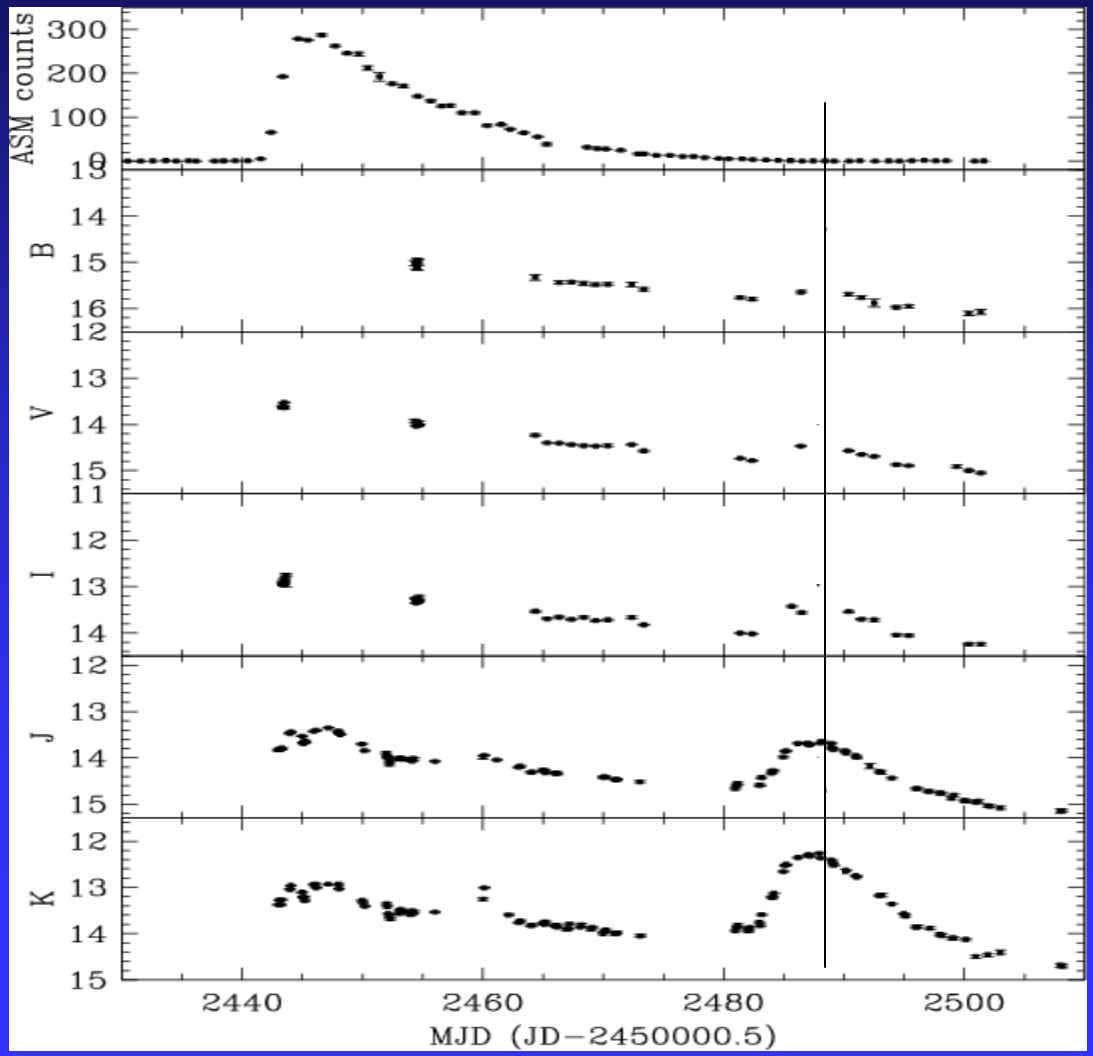
4U1543-47

- Soft X-ray transient with ~ 10 year recurrence timescale
- Low mass function and low inclination > black hole system (Orosz et al.)
- A-star companion in ~ 1 day orbit
- **OUTBURST IN SUMMER 2002!**

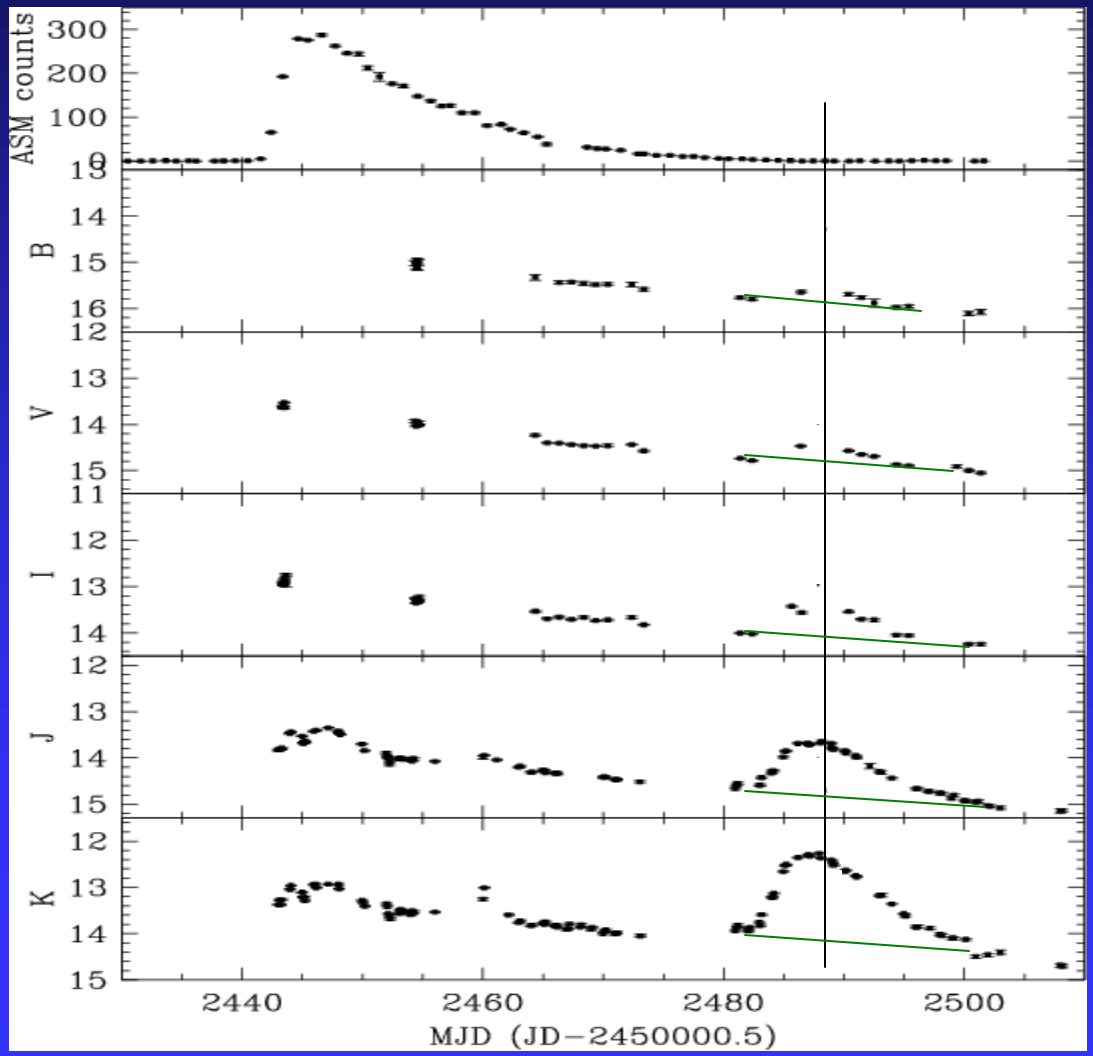
4U1543-47 in 2002



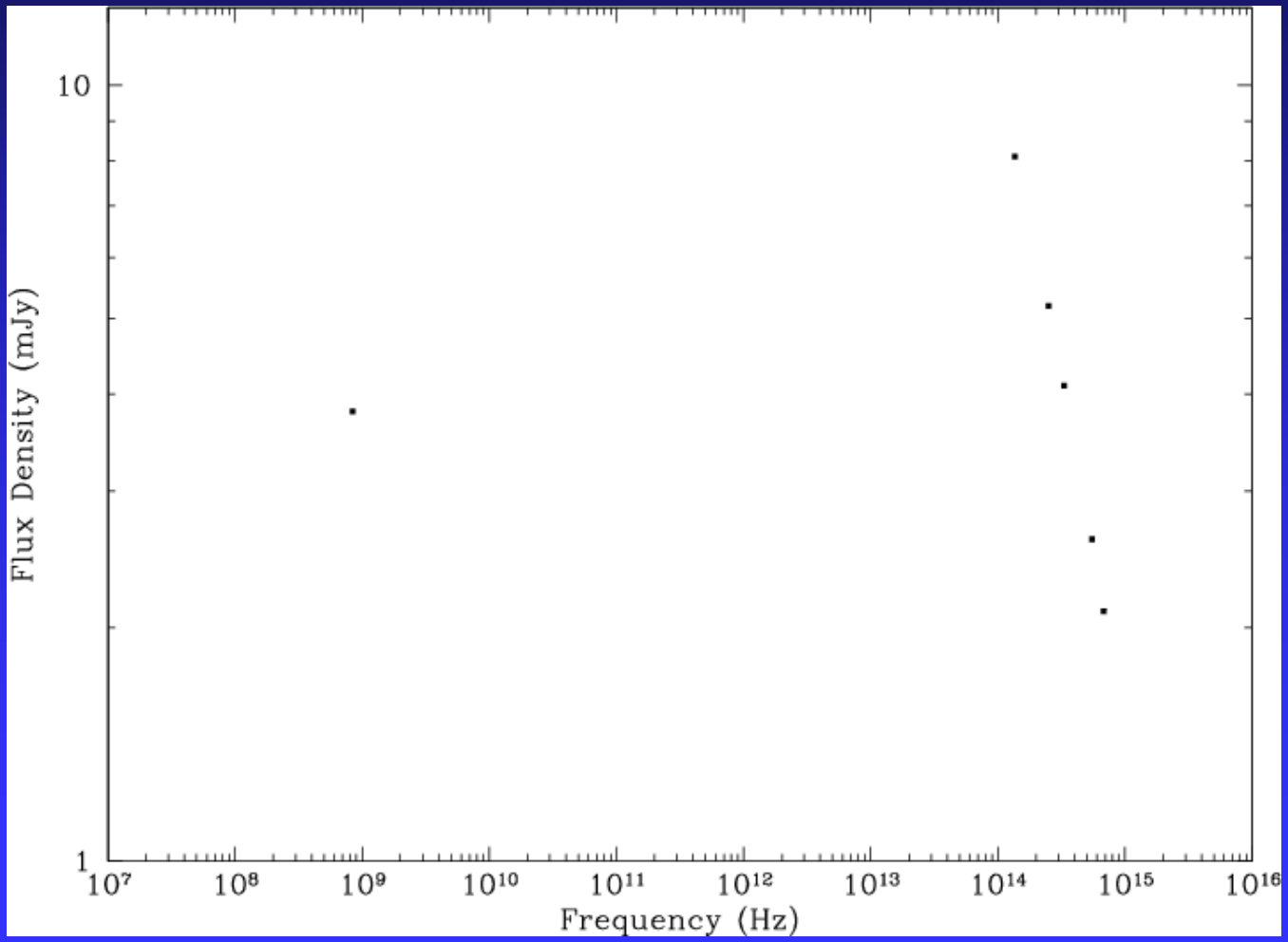
4U1543-47 in 2002



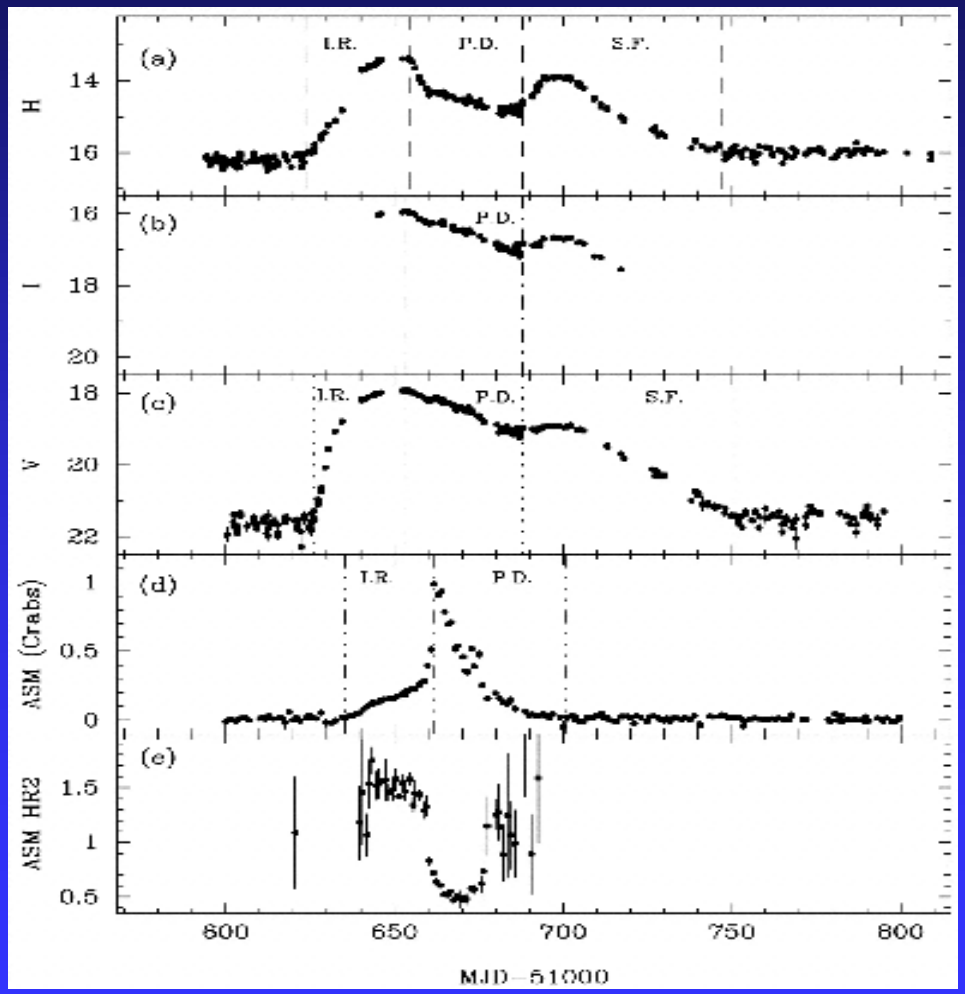
4U1543-47 in 2002



4U1543-47 in 2002



Outburst of 1550-564 in 2000



IR Dominated Re-flares

- Peak in mid-IR
- Cannot be thermal and in binary system
- Associated with (weak) radio emission
- No observable X-ray response (in ASM)
- Similar to other “optical plateaus”?
- Energetic synchrotron source??

Conclusions I: Outburst Mechanisms

- D.I.M. + irradiation + 2-part flow works for some outbursts
- L.I.S. and mini-outbursts in Aql X-1
- Hysteresis in X-ray states in Aql X-1
- IR-strong reflares in 1543-47 and 1550-564

MORE PHYSICS REQUIRED!

Conclusions II: Triggers

- Optical triggers for new outbursts
  lead time: 1 week
  especially useful for repeating outbursts
  should help to get rise as well as fall
- IR triggers for reflares
  requires real-time reduction of IR data
  detailed radio/X-ray response not yet known

Conclusions III: Future Work

- Daily SMARTS data for
  Aql X-1, GX339-4, GRS1915+105,
  Cen X-4, A0620-00, GS1124-68,
  GRO 1655-40, XTE 1550-564, 4U1543-47
  NEW SOURCES!
- Monitoring spectroscopy would be nice!
- As would short timescale photometry