



International  
Centre for  
Radio  
Astronomy  
Research

# Jets from neutron stars

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Collaborators: Greg Sivakoff, Adam Deller, Dave Russell, Tom Russell, Rob Fender, Aquib Moin, Simone Migliari...



Curtin University



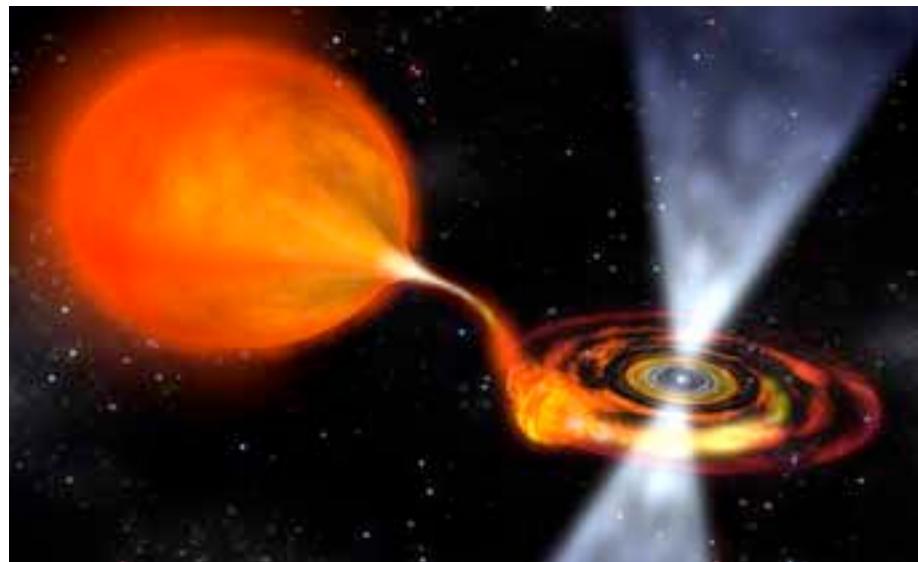
THE UNIVERSITY OF  
WESTERN AUSTRALIA

## Jet launching

- Effect of depth of gravitational potential well
- Role of stellar surface
- Role of stellar magnetic field
- Effect of spin
- Can jets have bulk motions exceeding escape speed from accretor?

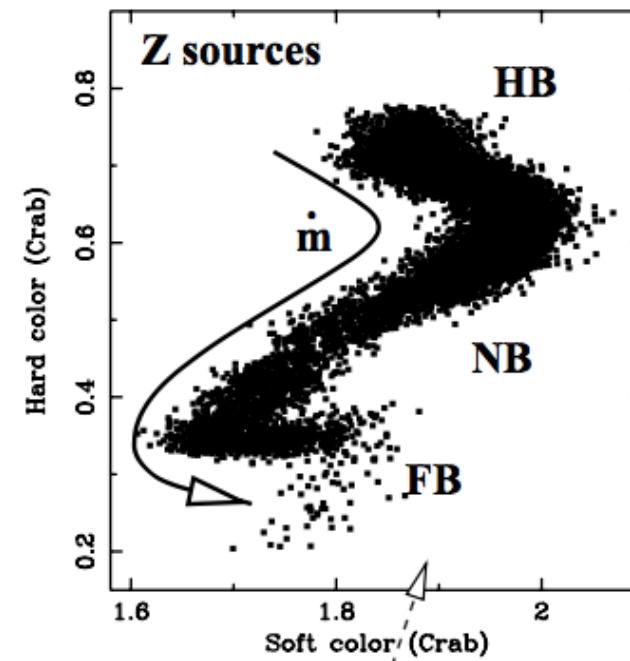
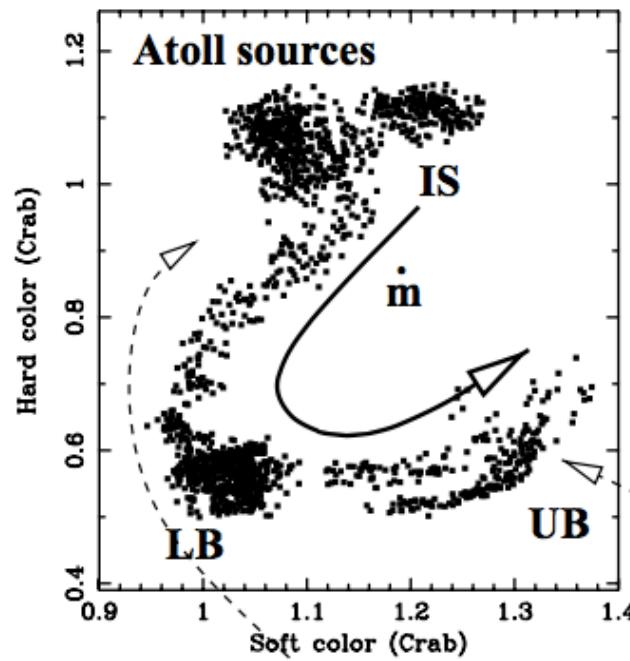
## Complications

- Faster evolution
- Lower peak flux densities



# The ‘zoo’ of accreting NSs

Low-magnetic field NSs show different accretion “states”



‘Hard’ atoll sources    ‘Soft’ atoll sources

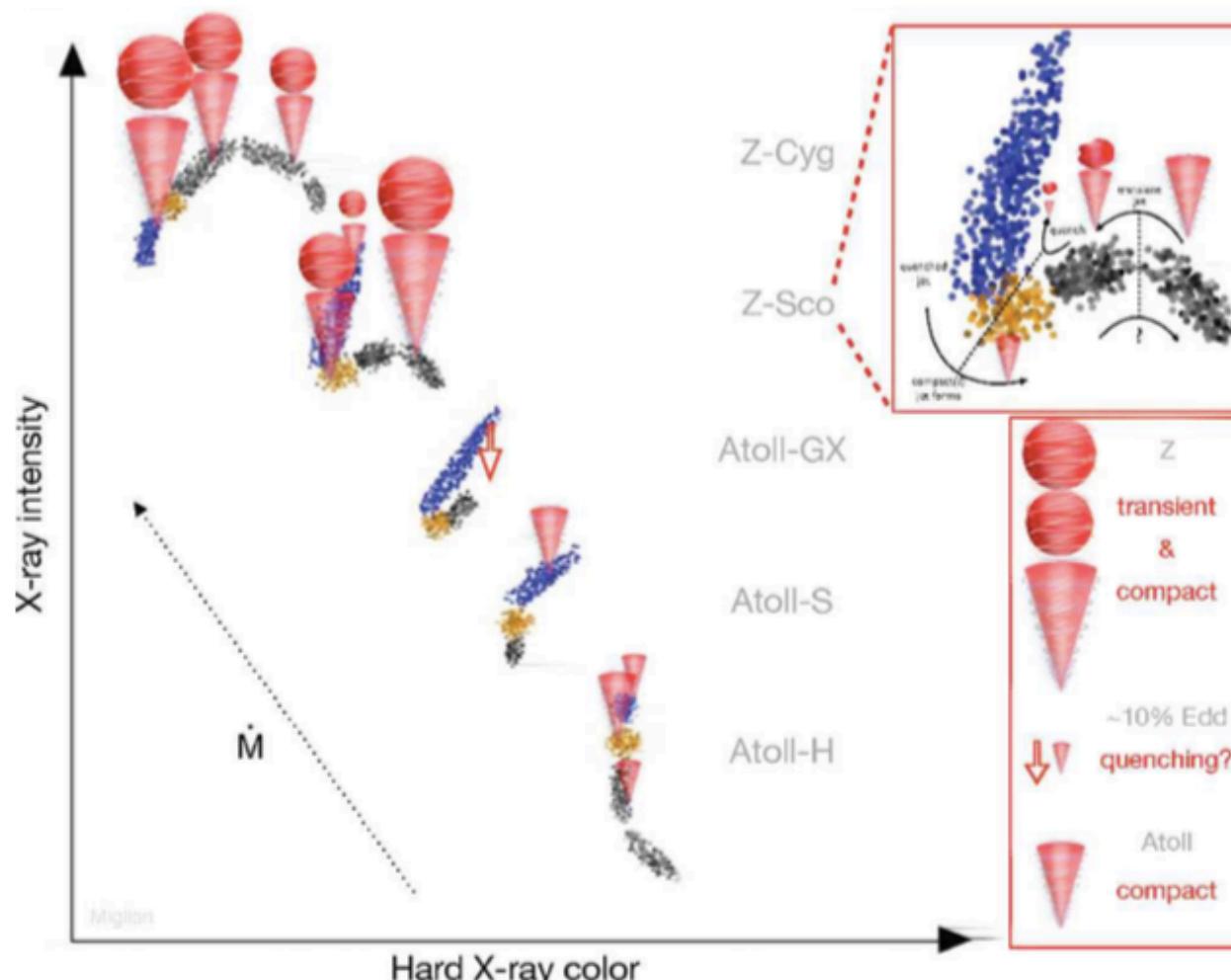
**Luminosity / Eddington**

‘Z’ sources

Migliari & Fender (2006)

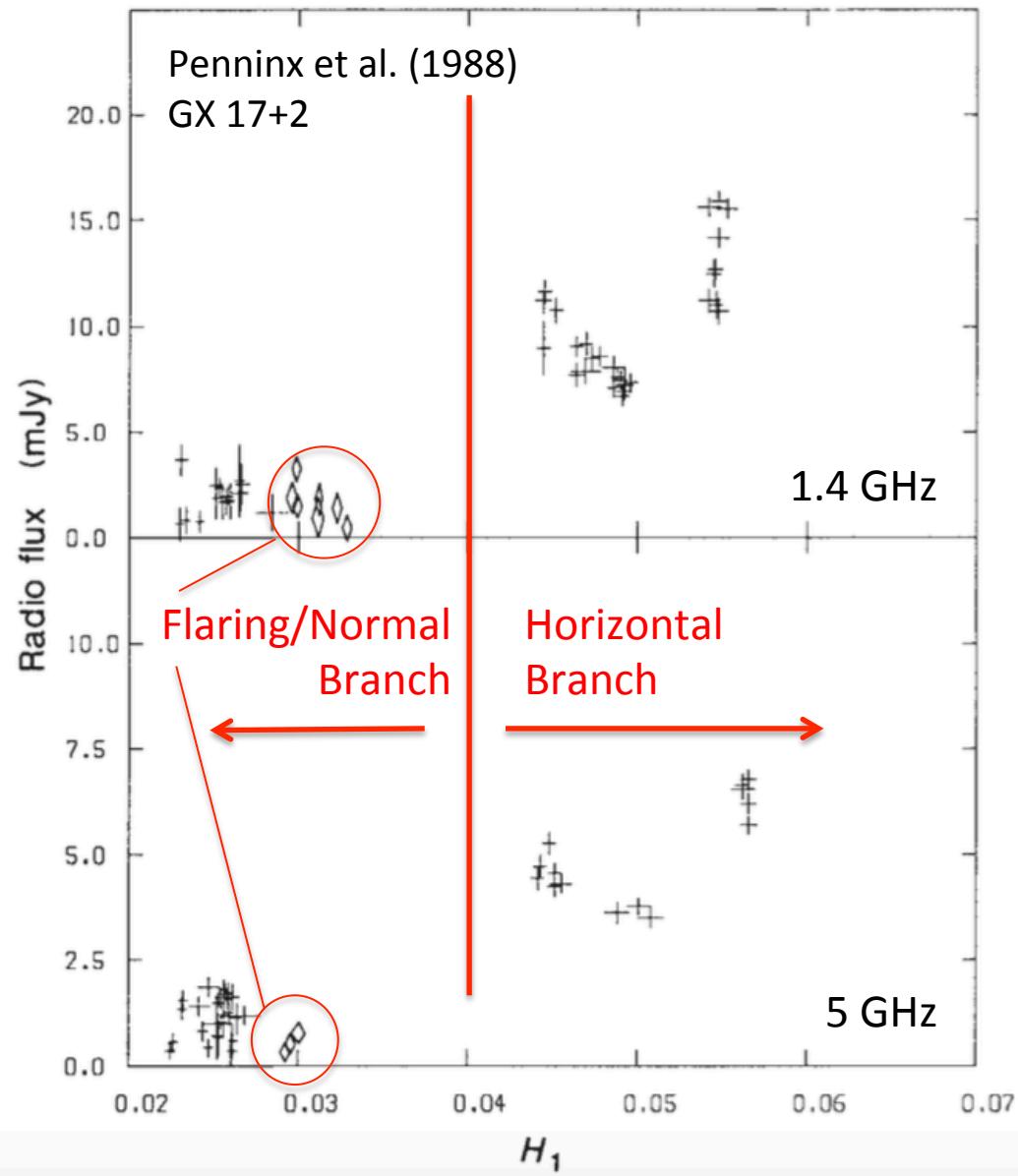
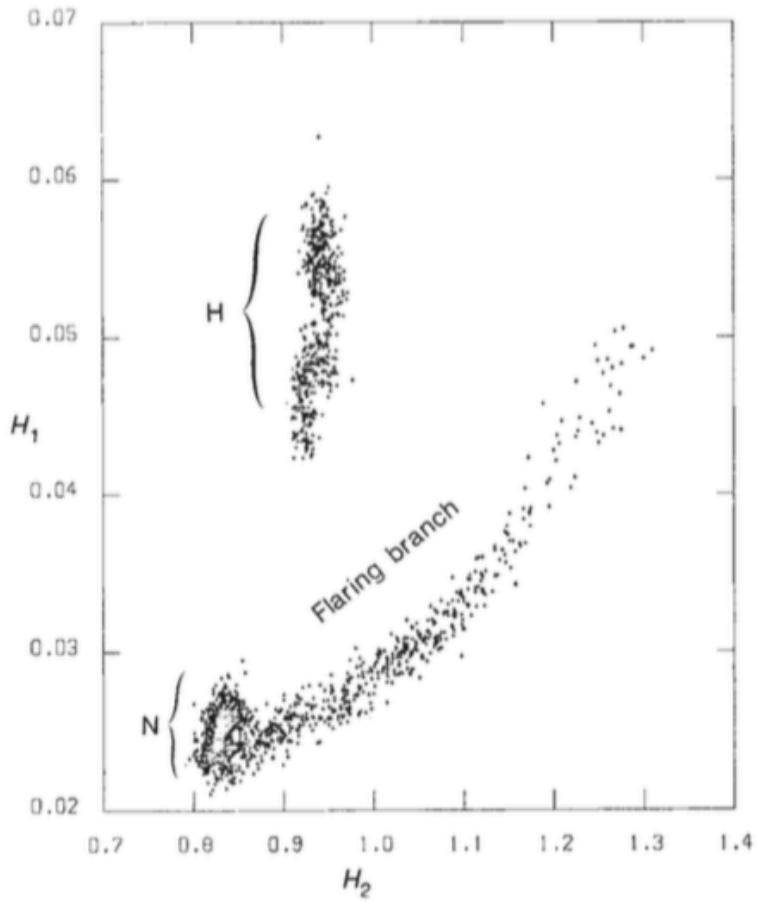
# The ‘zoo’ of accreting NSs

States are a function of mass accretion rate



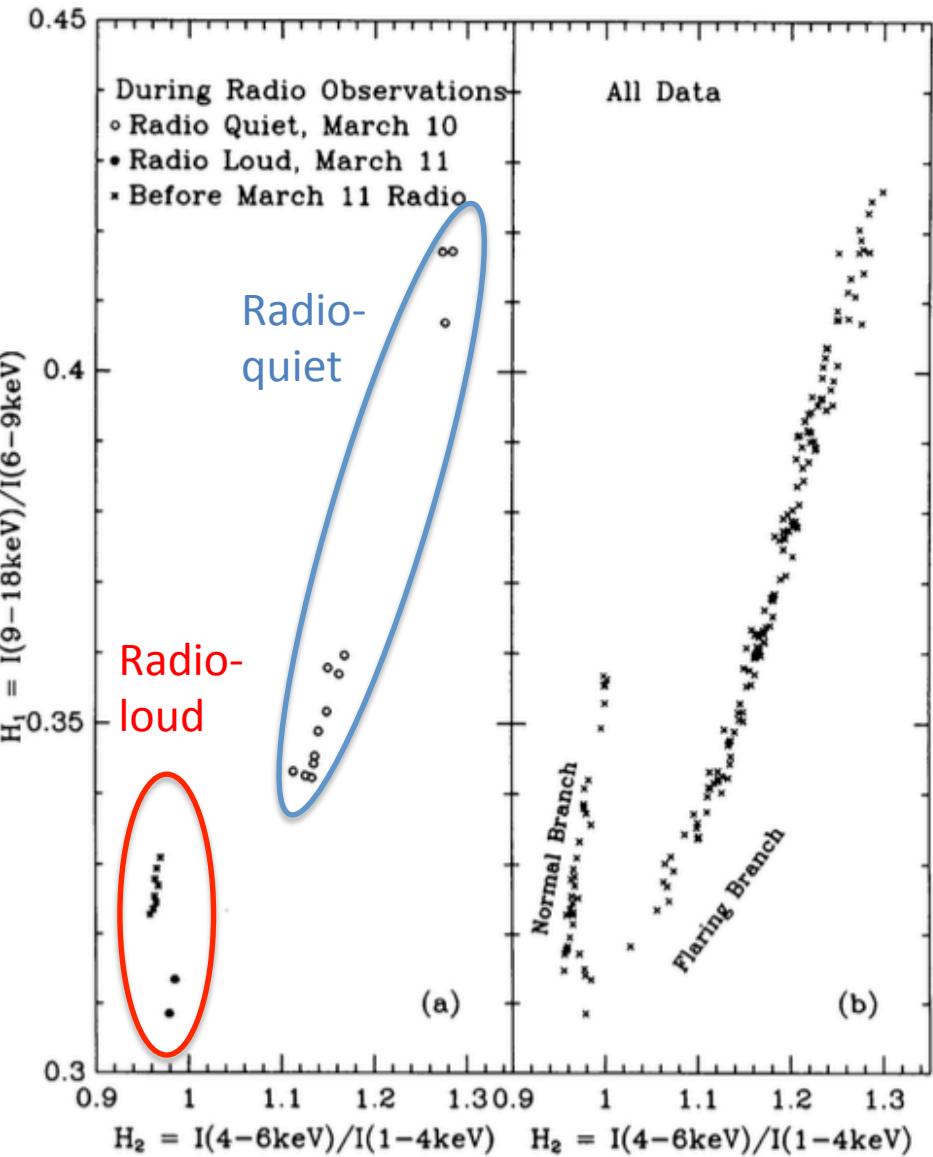
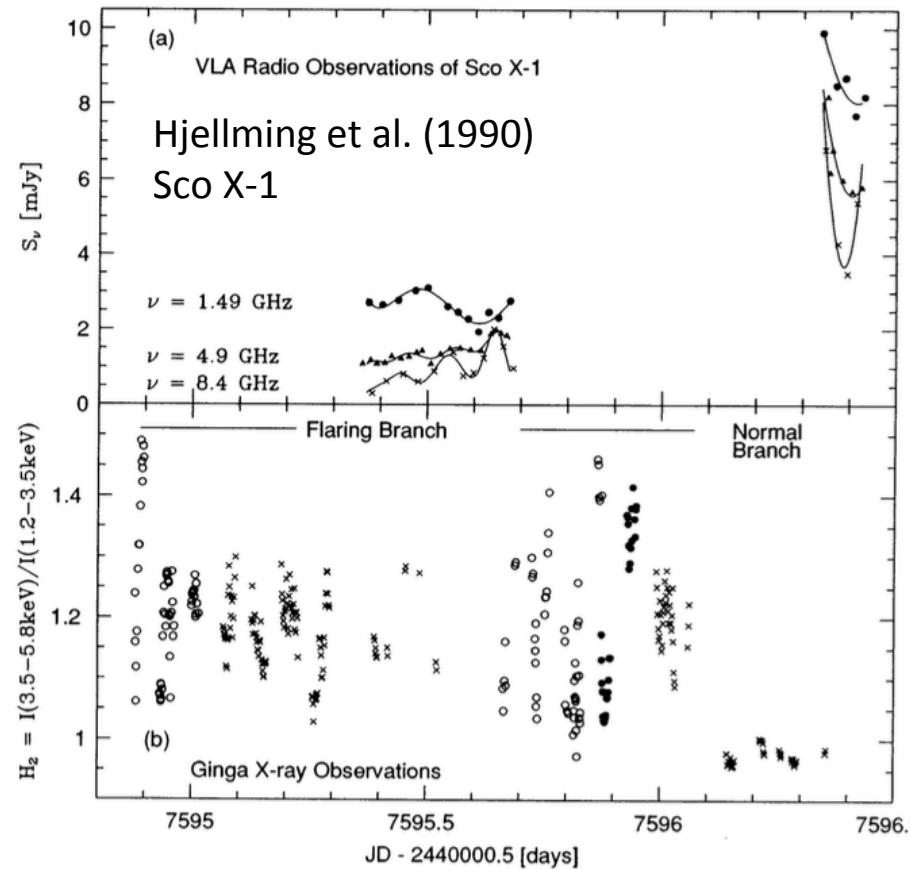
# Z-sources: radio/X-ray coupling

## Radio emission a function of X-ray state



# Z-sources: radio/X-ray coupling

## Radio emission a function of X-ray state

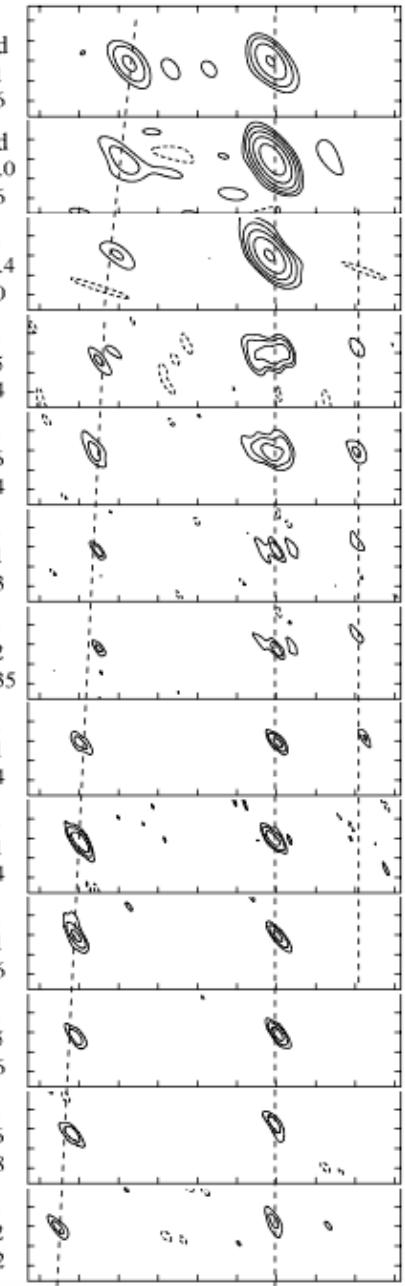
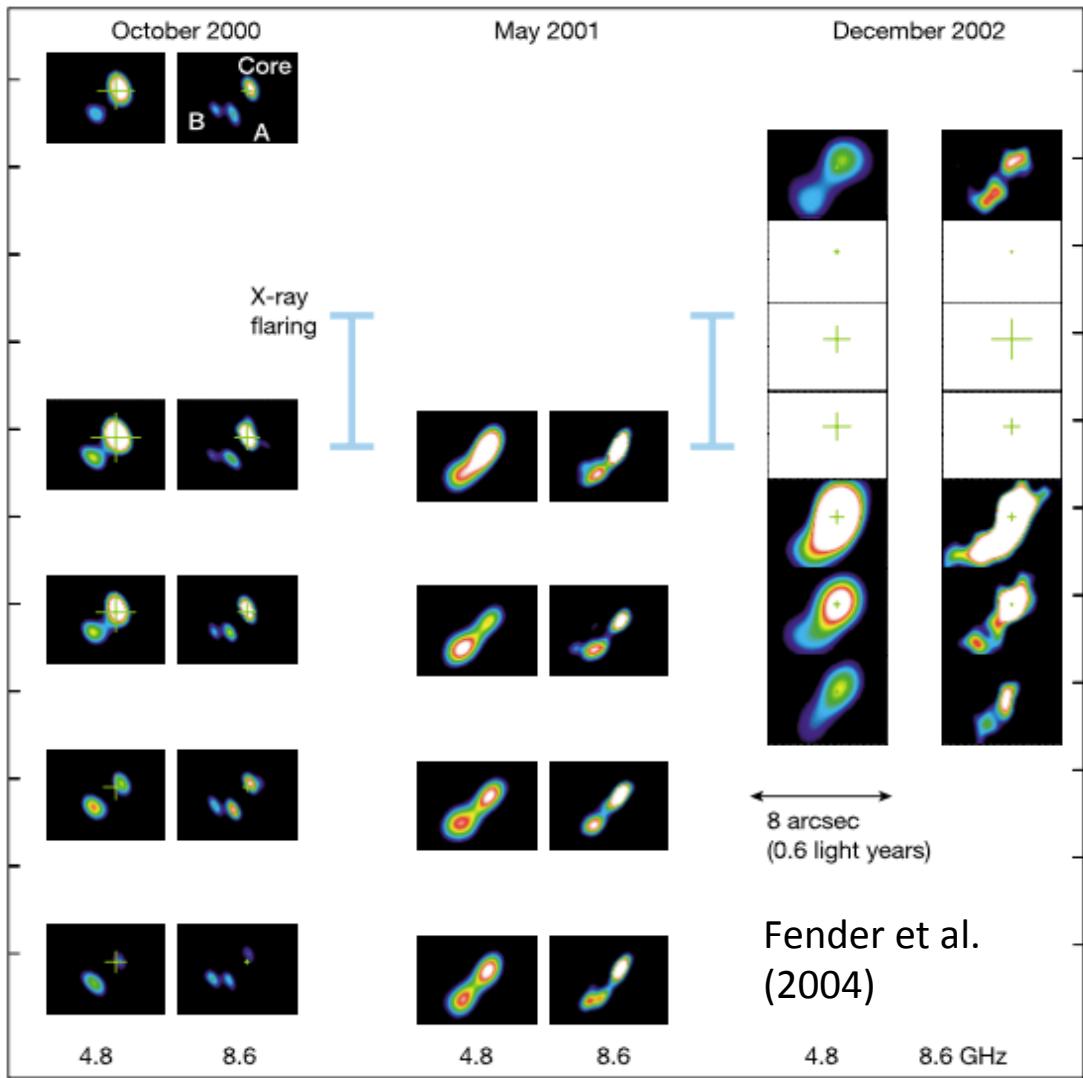




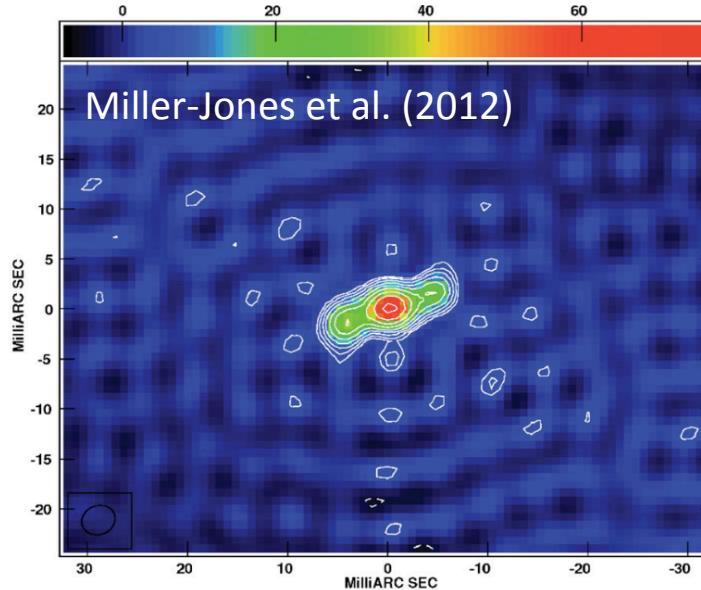
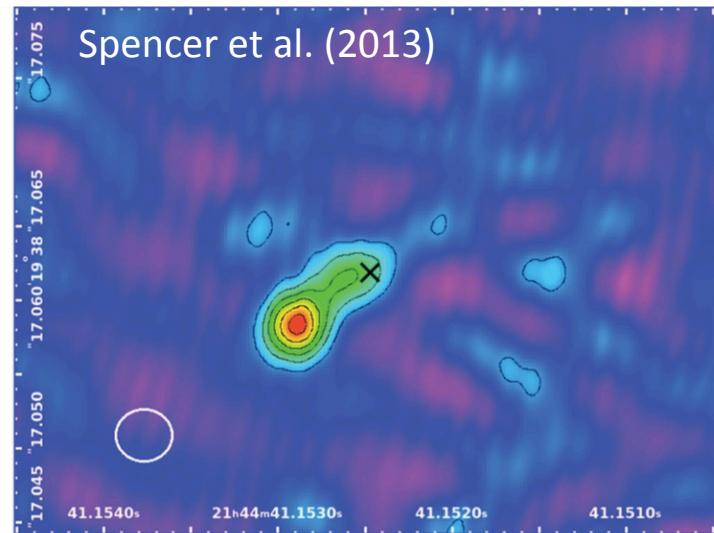
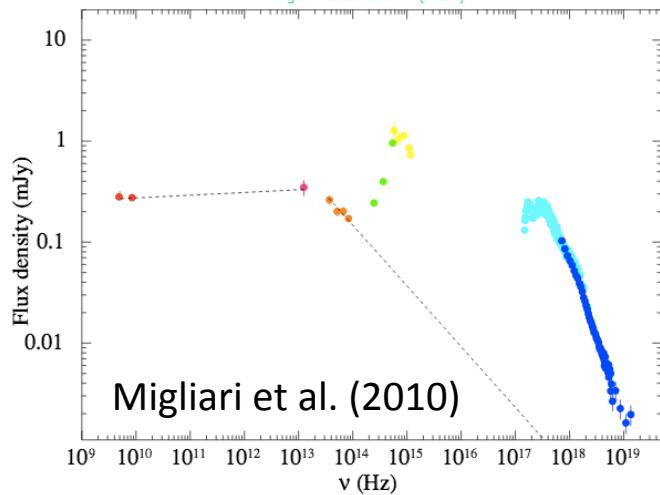
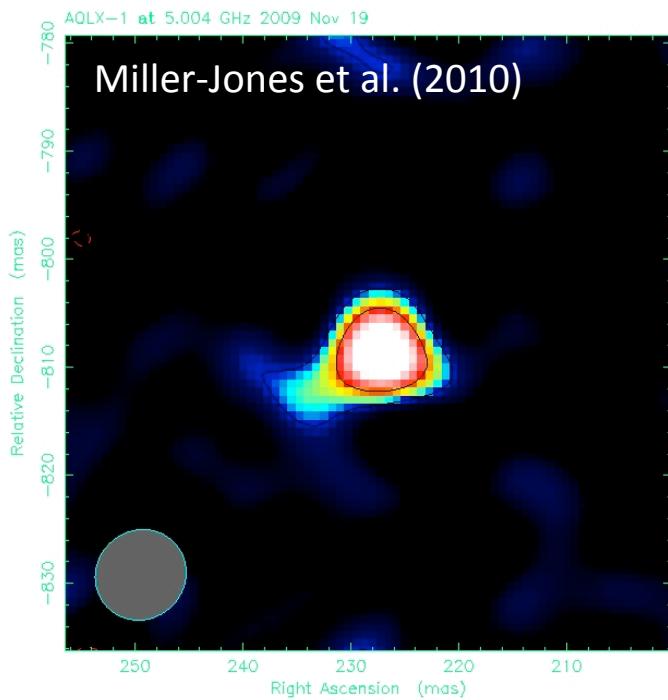
# NS do have jets!

Fomalont et al. (2001)

MJD 51342



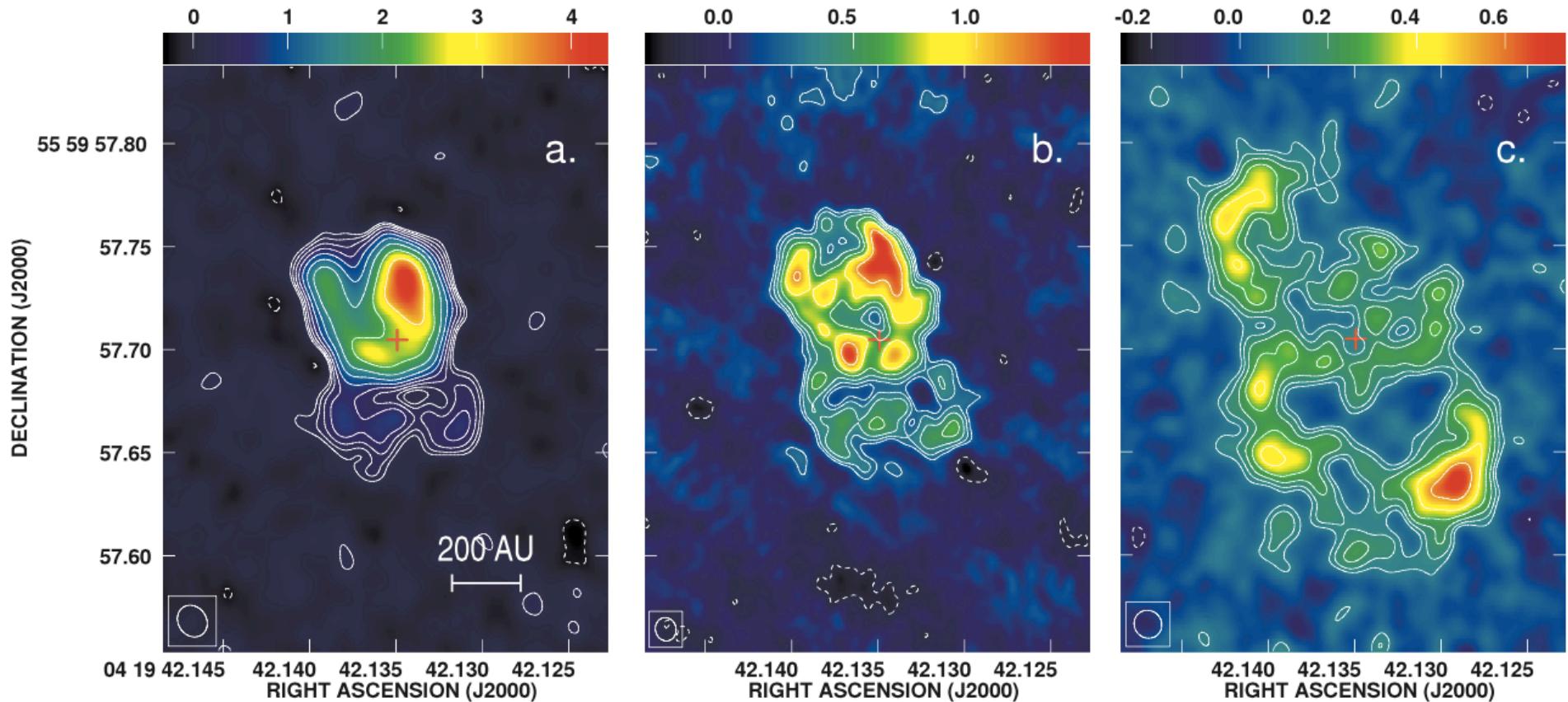
# NS do have jets!



# But not everything is a jet...

## CI Cam

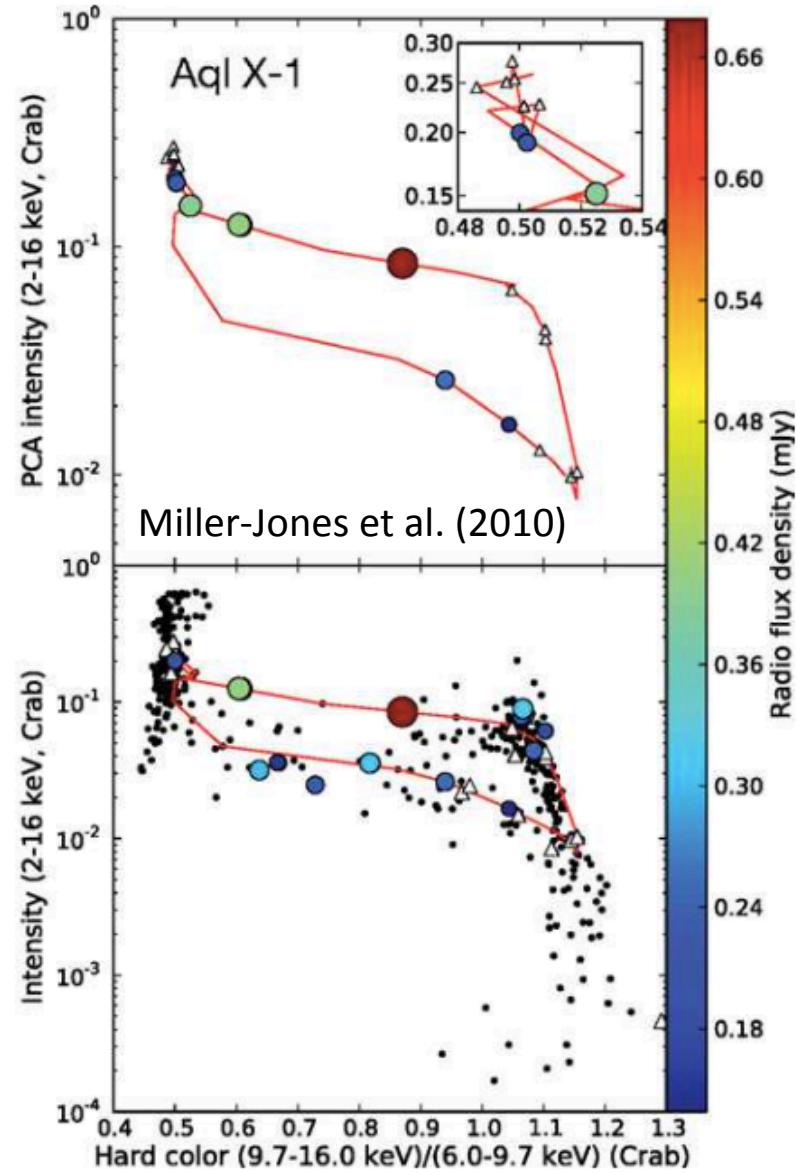
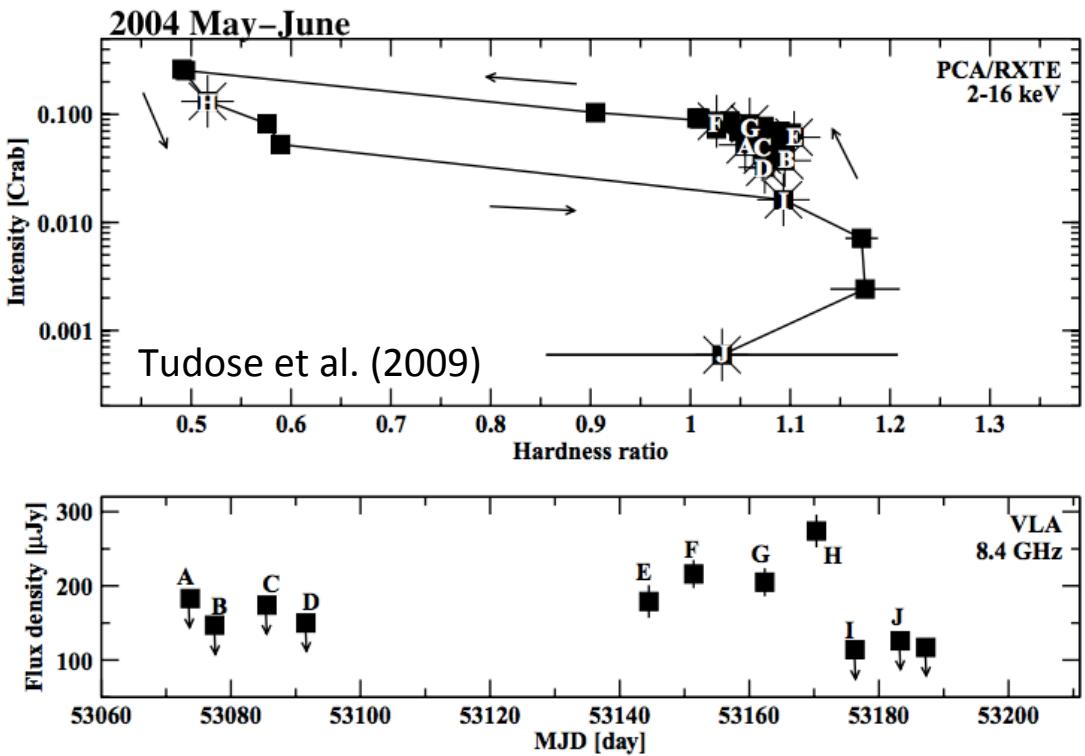
- Jet runs into dense surrounding medium and is smothered



# Atoll sources: HIDs

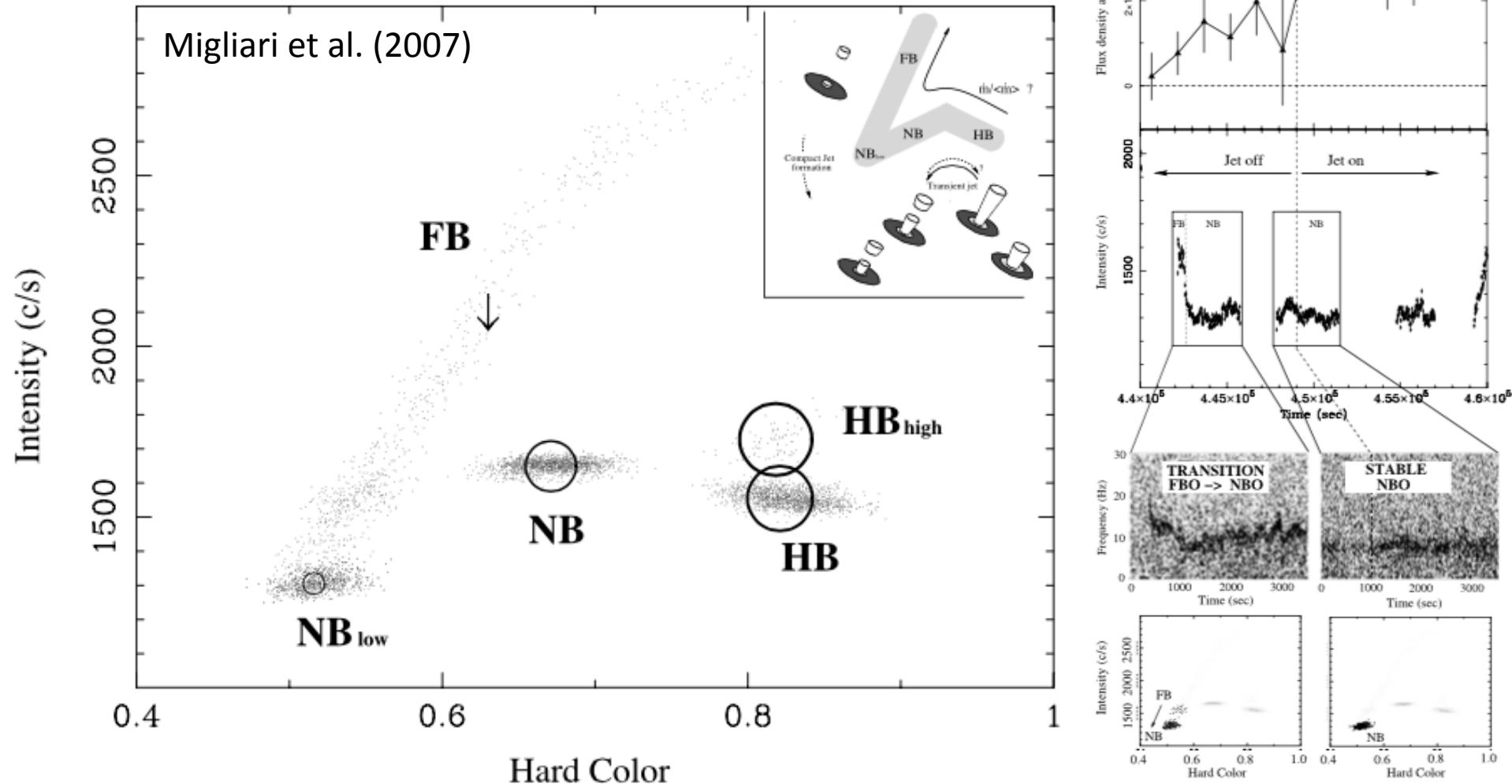
## Similar HIDs to black holes

- Compact jet emission in hard state
- Quenching in soft state

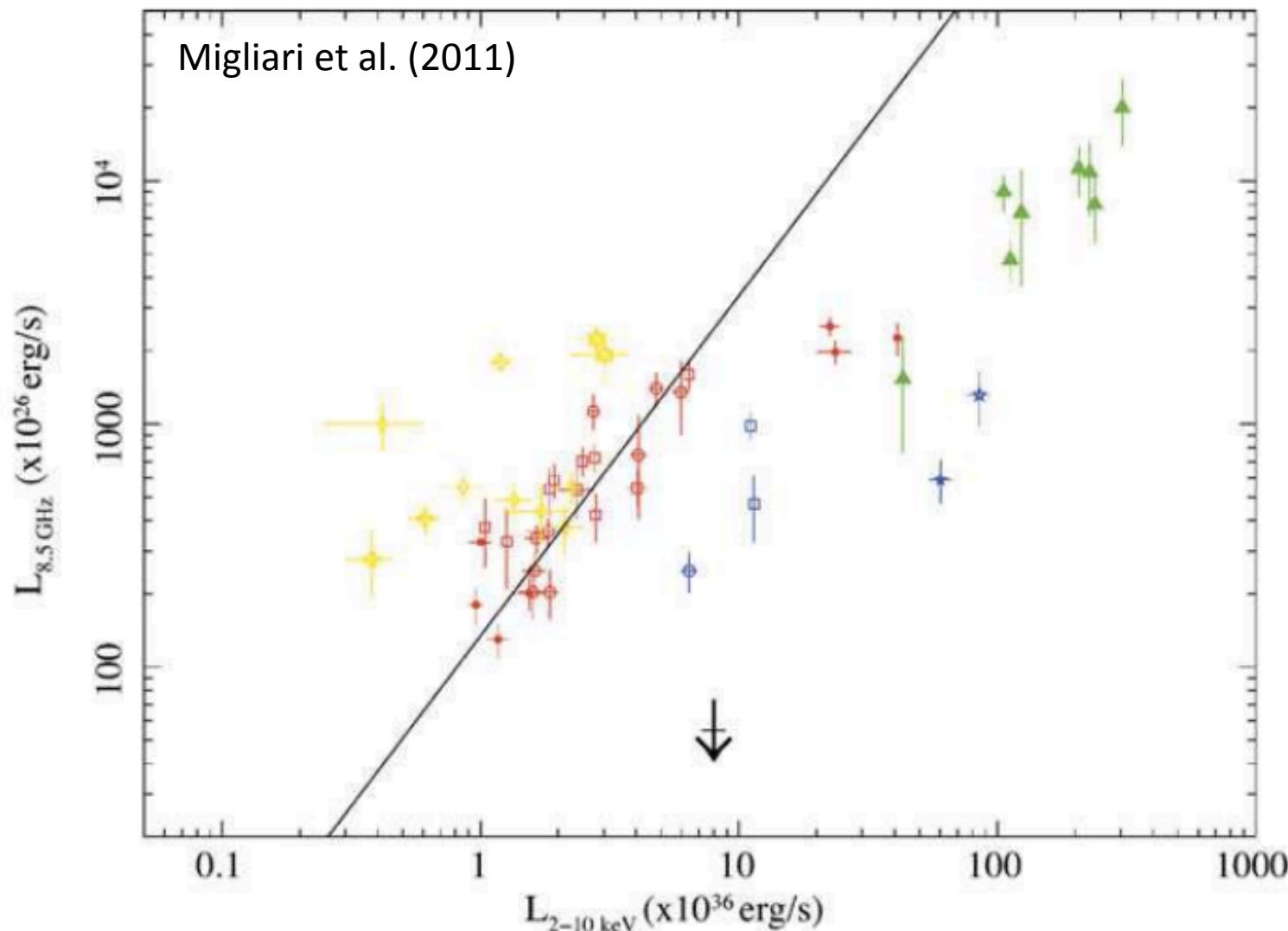


# Jet switches on after state transition

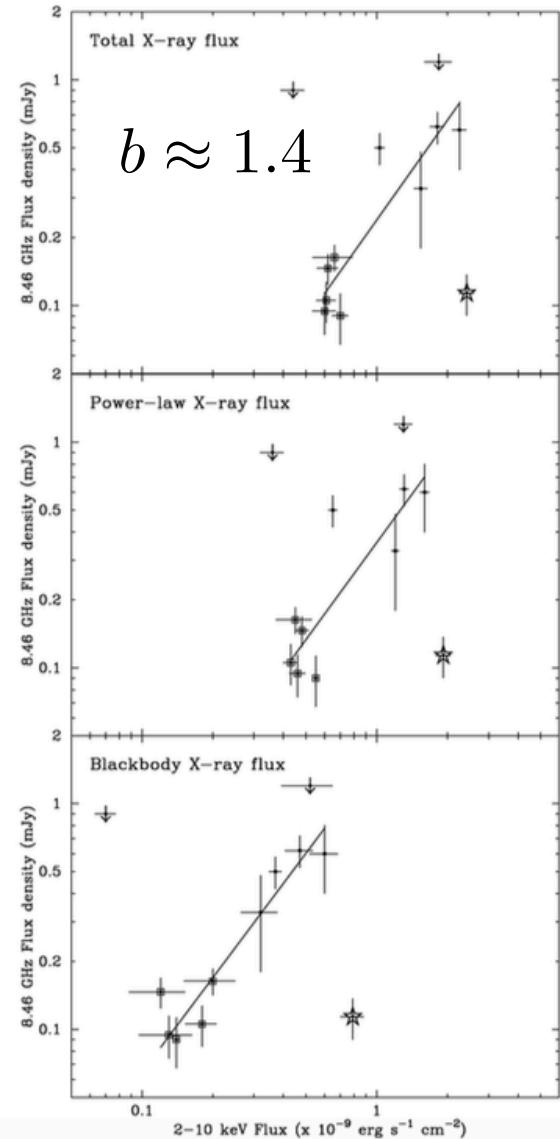
## Timing signature as jet turns on



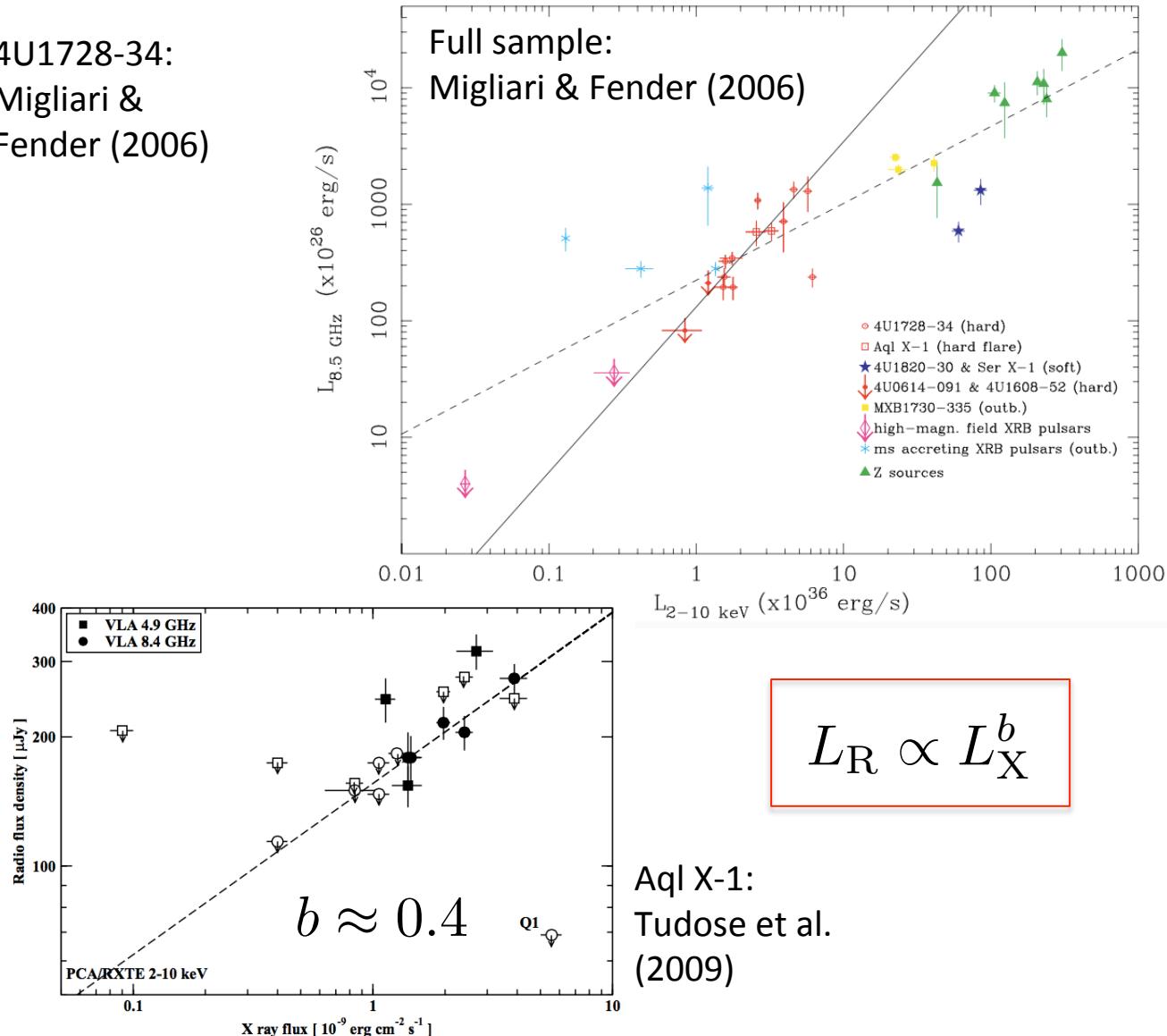
# Soft state quenching: some but not all



# Radio/X-ray hard state correlations



4U1728-34:  
Migliari &  
Fender (2006)

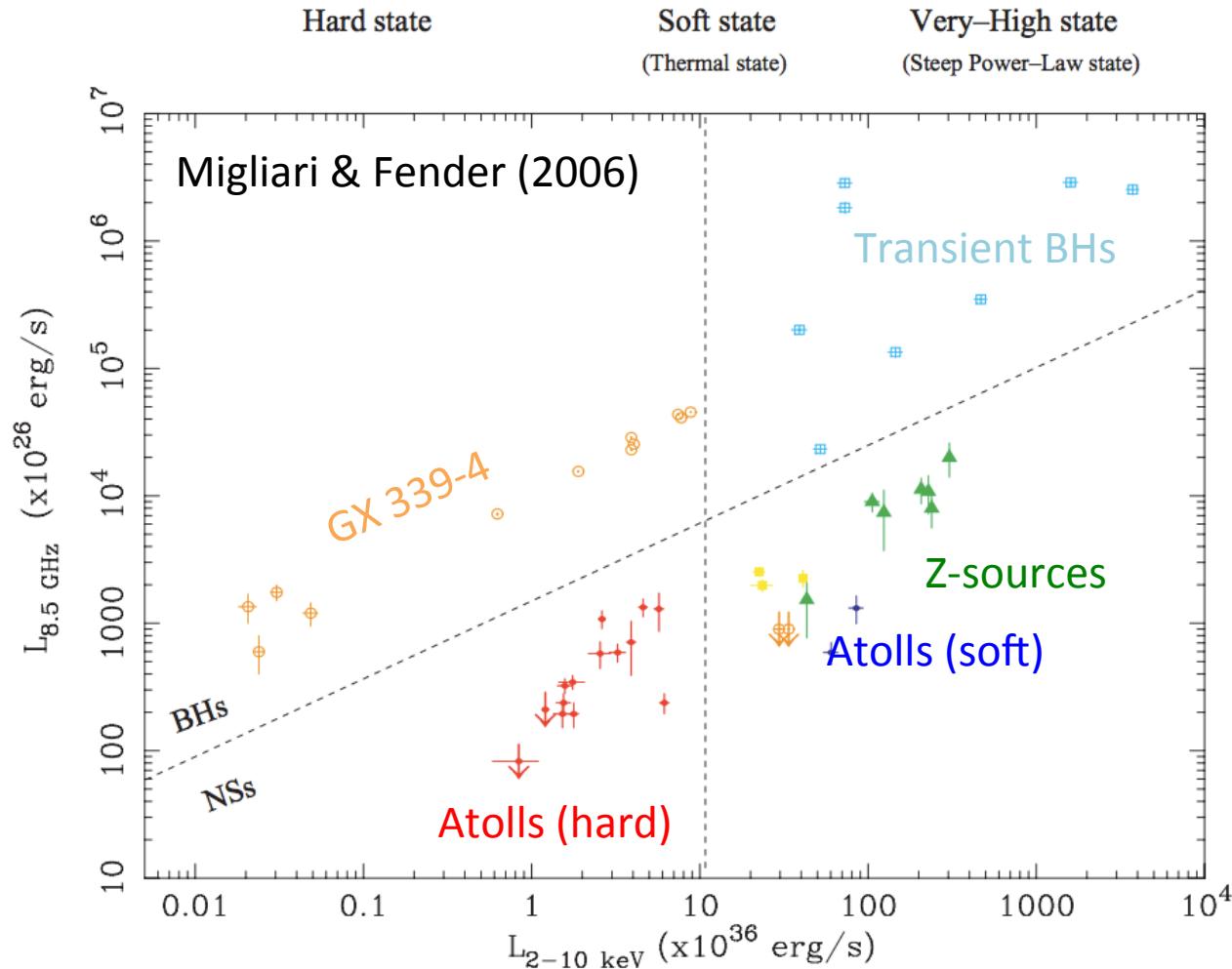


Aql X-1:  
Tudose et al.  
(2009)

$$L_R \propto L_X^b$$

# Neutron stars vs black holes

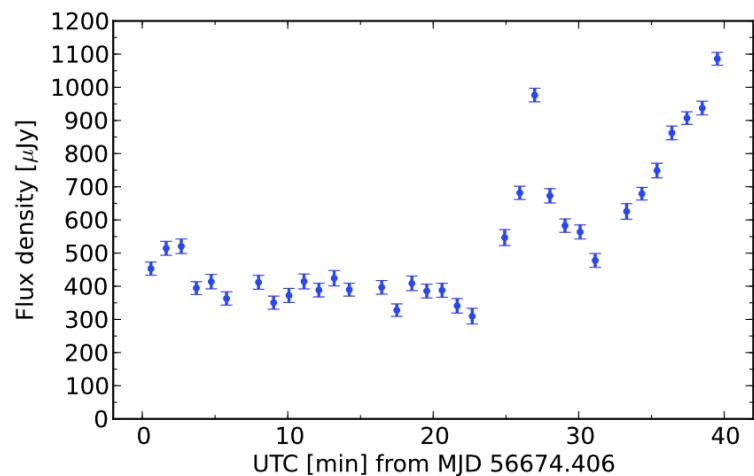
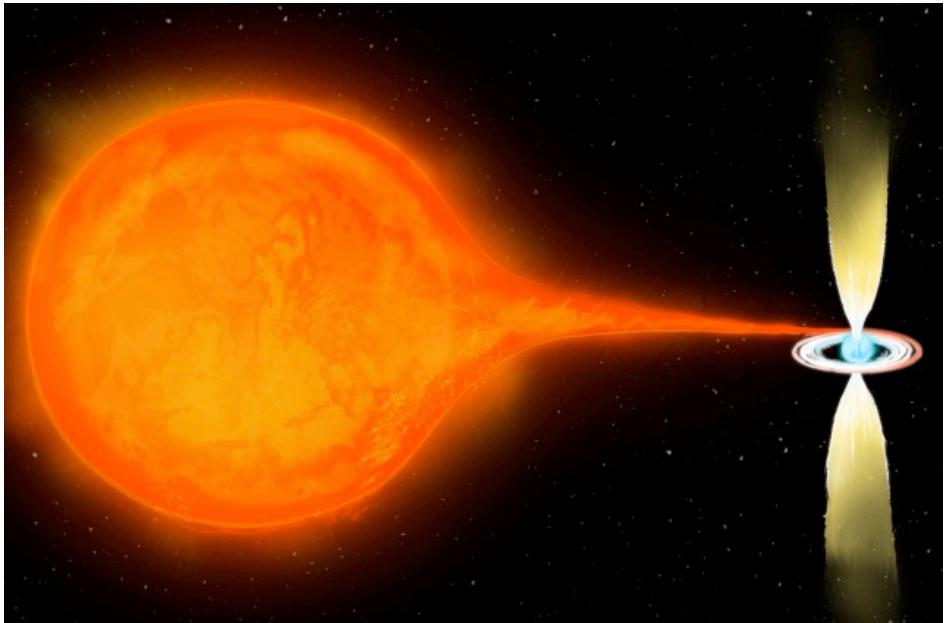
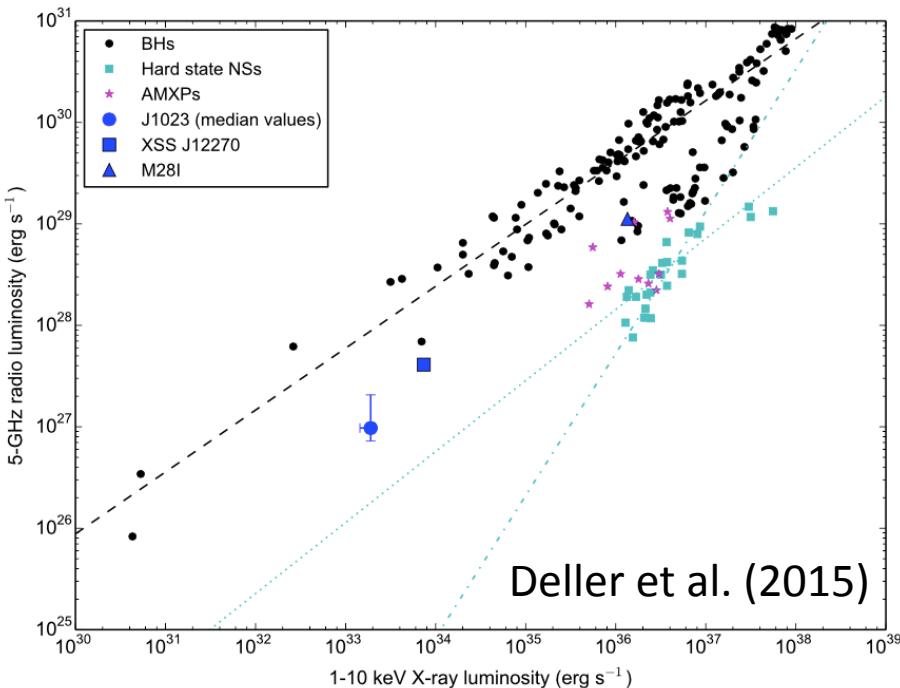
Neutron stars systematically fainter in the radio



# Transitional MSPs

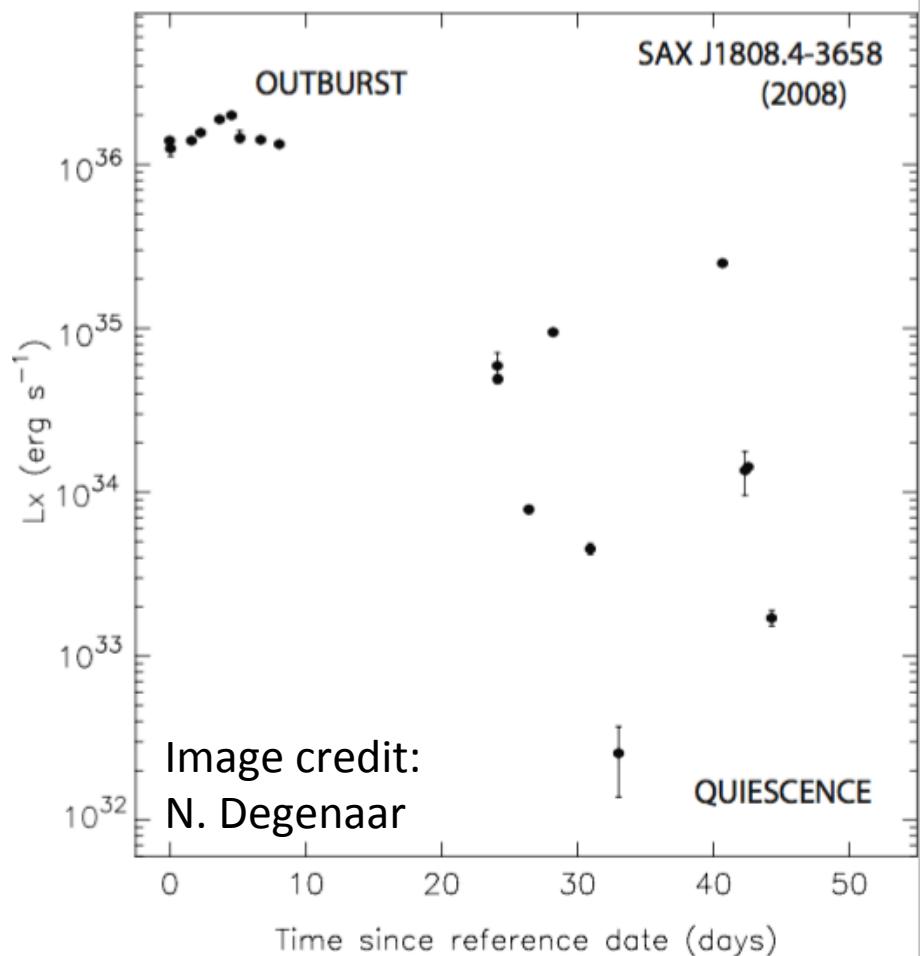
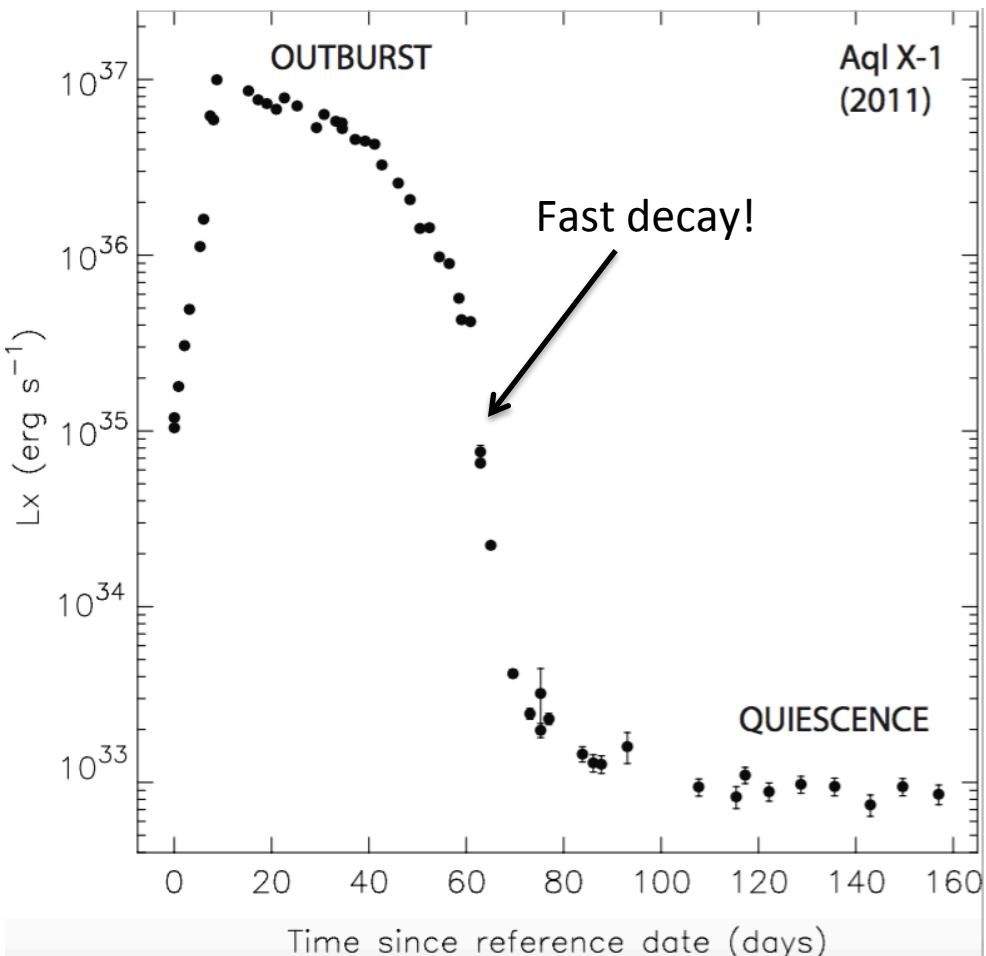
## Accreting state

- No pulsations
- Variable radio emission
- Flat spectrum
- Radio-loud



# Sampling the right $L_X$ is hard

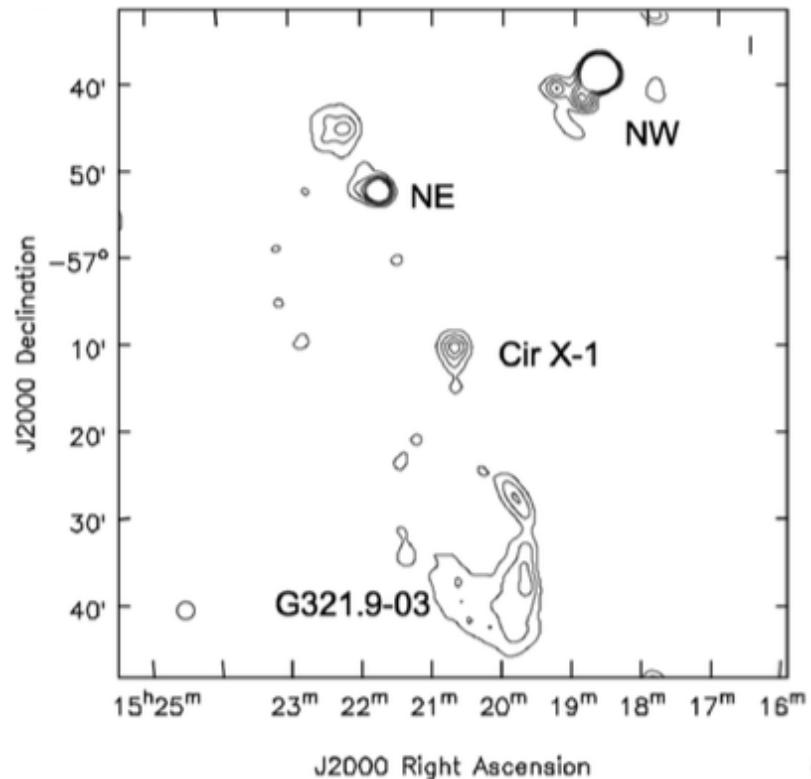
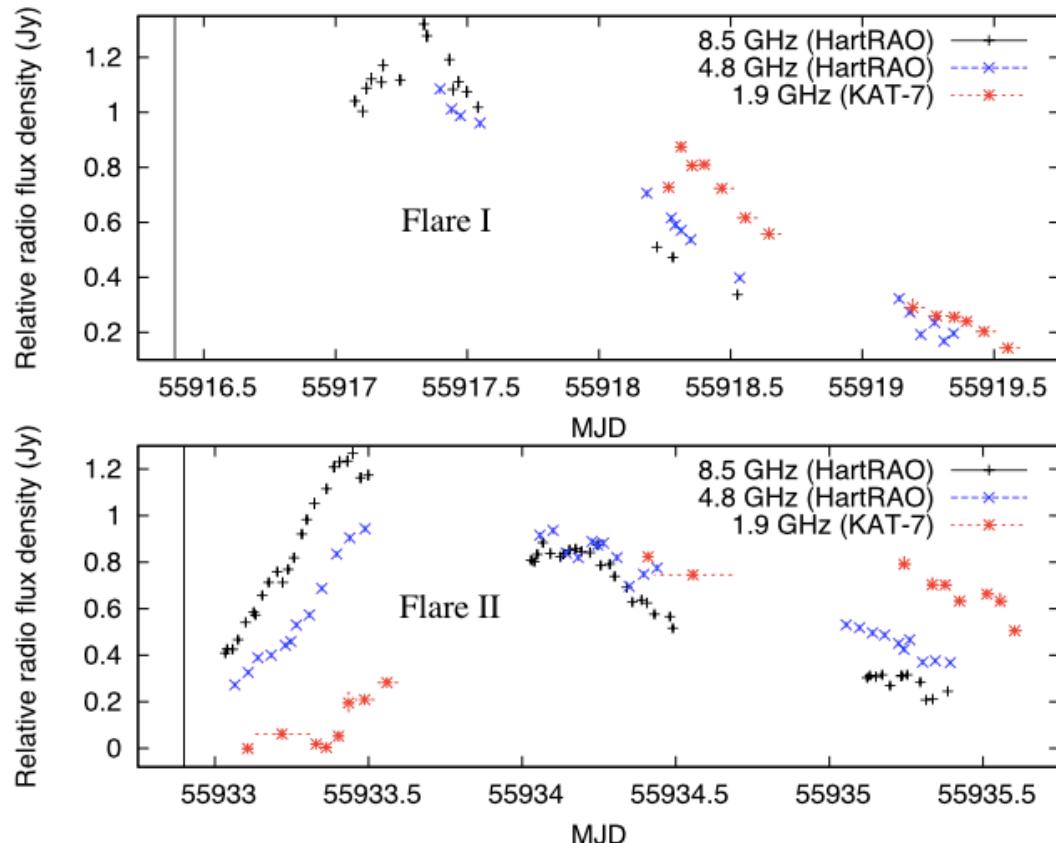
Decay over correct range is rapid (~days)



# Initial results from KAT-7

## Strong radio flaring in Cir X-1

- Temporally resolving the flaring events



Armstrong et al. (2013)

# Outlook – MeerKAT and SKA1-mid

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- Atoll sources:
  - Dedicated monitoring of an outburst (disc/jet connection)
  - Deep limits on radio quenching in soft state
  - High-cadence monitoring during outburst decays
- Z-sources:
  - How/when does jet turn on/off during state transitions
- Transitional millisecond pulsars
  - What makes them launch jets?
  - How do they compare to atoll source NSs and BHs?
- General
  - Role of NS spin?
  - Role of NS magnetic field?