Cataclysmic Variables are significant radio emitters

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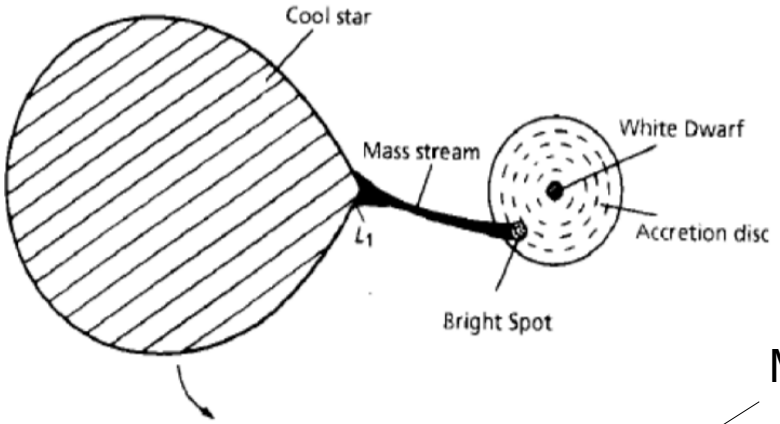
Contents

(Rough & idealized) CV classification



Cataclysmic Variables (CVs)

Novae

Magnetics

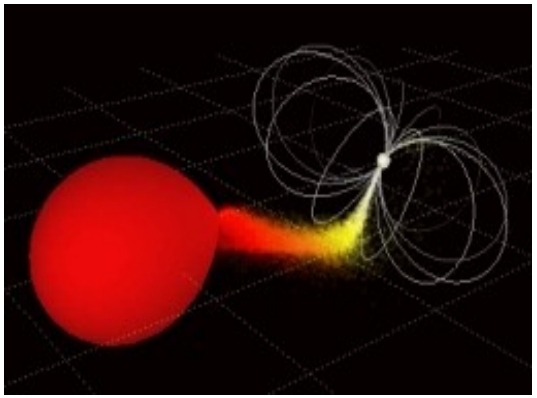
Non-magnetics
($B \lesssim 10^6$ G)

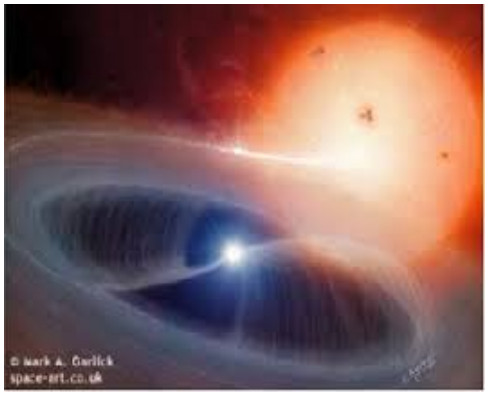
Polars
($B \gtrsim 10^7$ G)

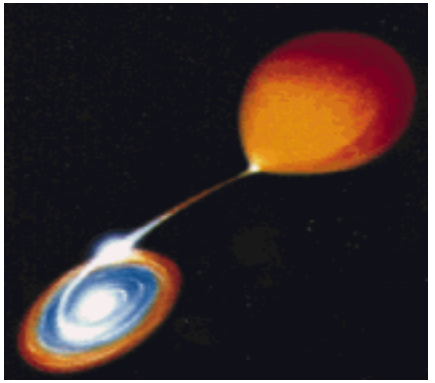
Intermediate Polars
($10^6 \lesssim B \lesssim 10^7$ G)

Dwarf Novae

Novalikes

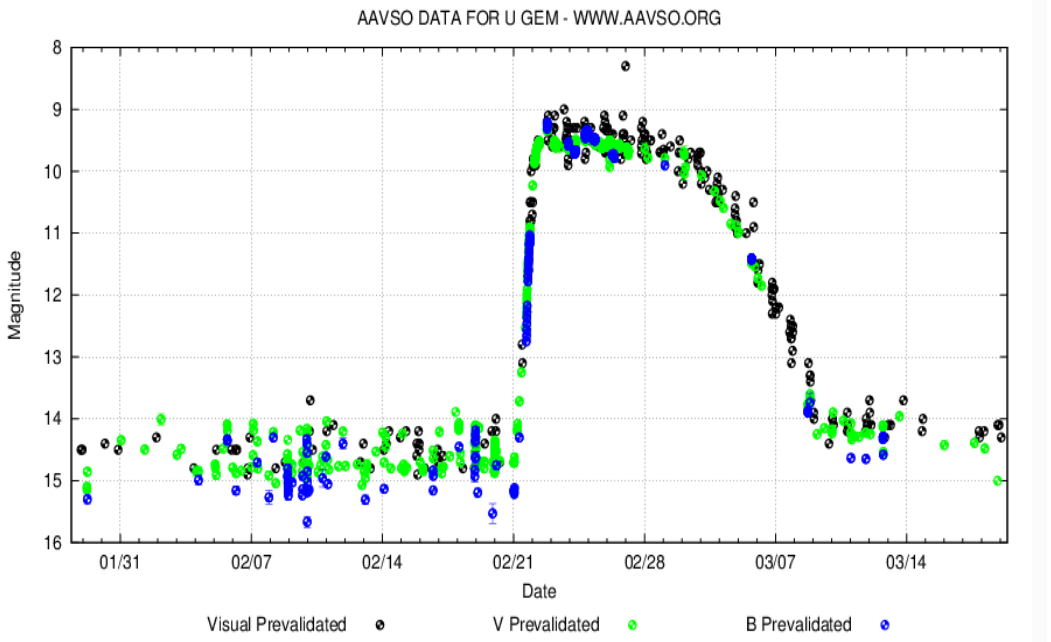






Dwarf Novae (DN) and Novalikes

DN:



Novalikes: **No outbursts**

Early radio observations of CVs

Non-magnetic CVs (Prior to 2008)

- 1980s: Large number of surveys[1,2,3,4]
- Only 2 detections out of 50 observations (Benz et al. 1996)
- Only three were detected: SU UMa[1], [2]EM Cyg, and [3]TY Psc
- CVs were not detected in follow-up observations
- Proposed emission mechanisms: Thermal, synchrotron, gyrosynchrotron or cyclotron mazer

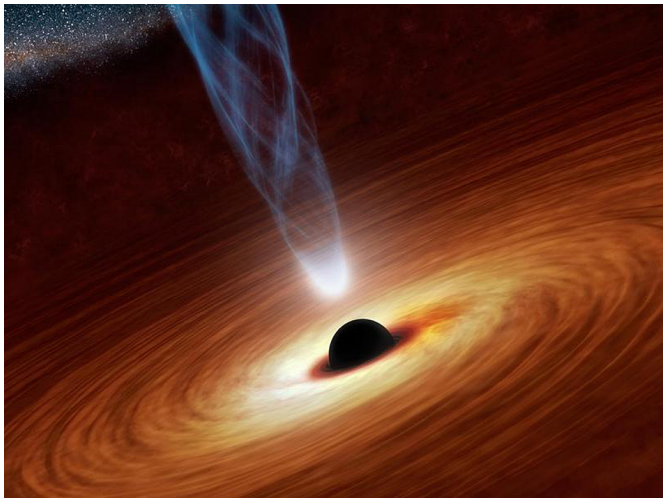
Magnetic CVs

- Large number of surveys
- 8 CVs out of 20 (Mason & Gray 2007)
- Only AM Her[6], AR UMa[7] and AE Aqr[8] are persistent radio emitters
- Proposed emission mechanisms: Synchrotron, gyrosynchrotron or cyclotron mazer

[1]Benz et al. 1983, [2]Benz & Gudel 1989, [3]Turner 1985, [4](Cordova 1983, Fuerst et al. 1986, Echevarria 1987, Nelson & Spencer 1988), [5](Dulk et al. 1983, Bastian 1987, Beasley et al. 1994), 6(Chanmugam & Dulk 1982, Dulk et al. 1983, Mason & Gray 2007), [7]Mason & Gray 2007, [8](Bookbinder & Lamb 1987, Bastian et al. 1988, Abada-Simon e al. 1993, Meintjes & Venter 2005)

Jets?

- Jets have been found in manner of classes of accreting objects
- BUT Currently CVs are commonly considered to be an exception to this rule
- (Jets have been detected in nova outbursts e.g. Sokoloski et al. 2008)
- CVs currently prohibit a universal link between accretion and ejection
- This has been used to constrain jet launching models (e.g. Soker & Lasota 2004).



Prediction for a jet

Körding et al. 2008:

- Compared the outbursts of DN and XRBs
- Showed that they progress through the same outburst states
- **Proposed that we should see a transient jet and associated radio flare on the rise to outburst**
- Concluded that previous radio observations of DN were taken at the wrong time

Prediction for a jet: SS CYG

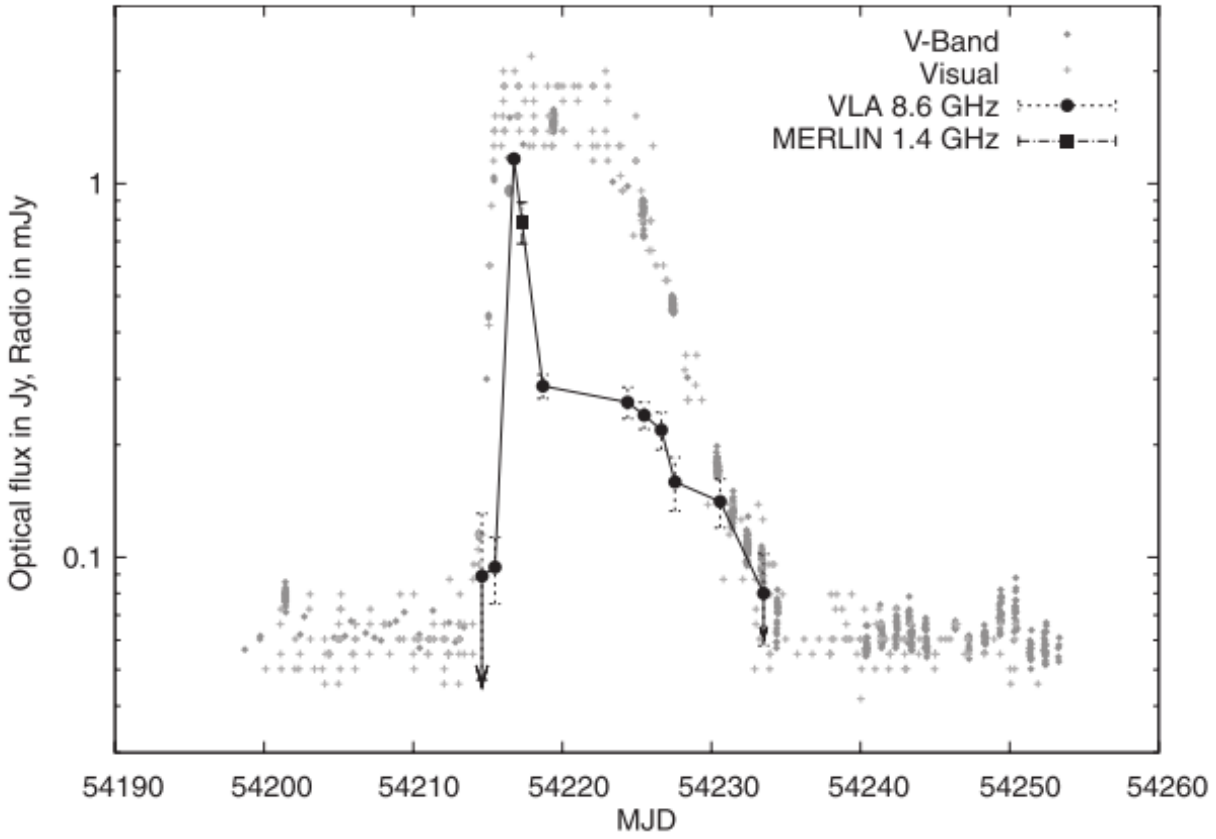


Figure 2 of Körding et al. (2008), showing SS Cyg's 1.1 mJy flare at 8.5 GHz on the rise to outburst

Prediction for a jet: SS CYG

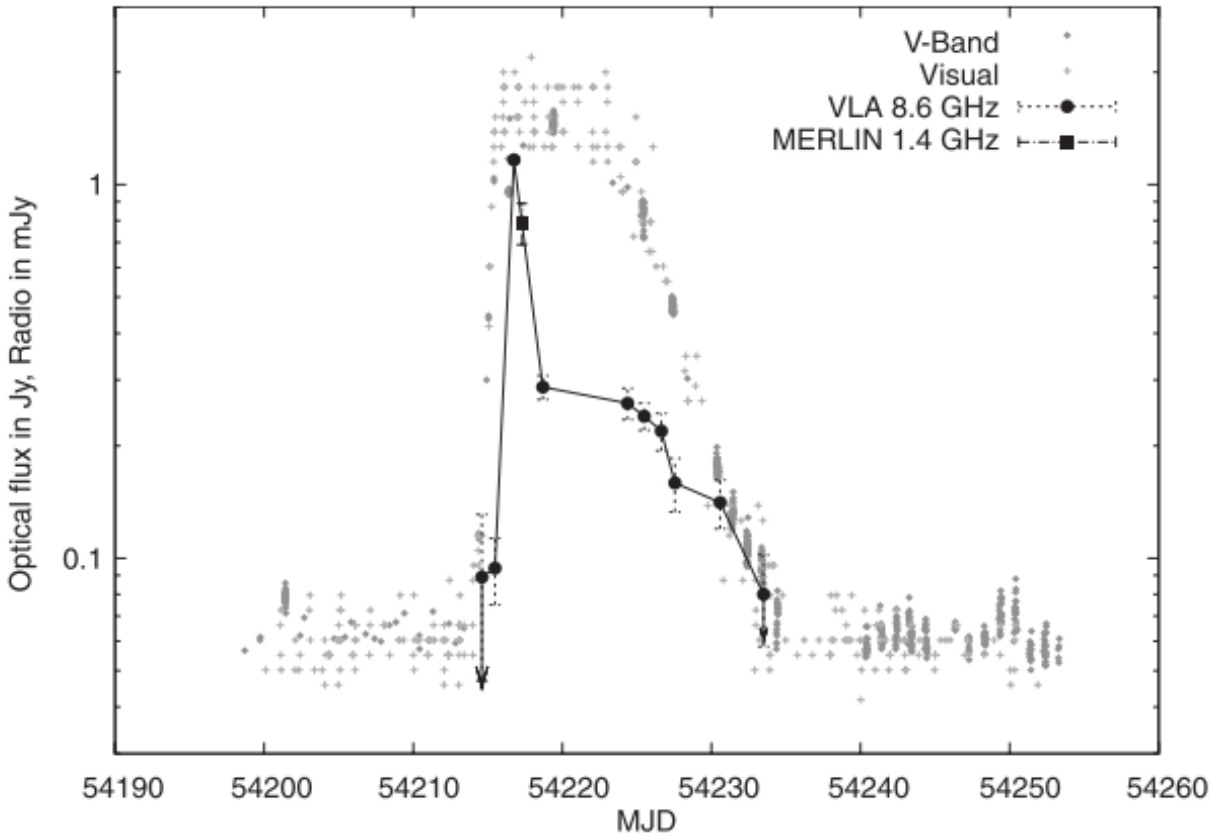


Figure 2 of Körding et al. (2008), showing SS Cyg's 1.1 mJy flare at 8.5 GHz on the rise to outburst

- **Conclusion: optically thick synchrotron emission from a jet**
- Behaviour confirmed by Miller-Jones et al. (2010)

Subsequent radio observations

- Detected V3885 Sgr (Körding et al. 2011):
  0.16 ± 0.01 mJy at 5.5 GHz
  0.11 ± 0.02 mJy at 9 GHz

- Non-detections (Körding et al. 2011) for:
  IX Vel <0.6 mJy
  AC Cnc <0.05 mJy

- Non-detection for VW Hyi:
  <45 μJy at 5.5 and 9 GHz

- Detection of SS Cyg (Miller-Jones et al. 2013):
  VLBI determined distance SS Cyg vindicated accretion disc theory

Radio observations from novalikes

Question: Is SS Cyg unique?

We observed a sample of 4 novalike CVs with the VLA at 6 GHz to answer this

Name	Radio Flux (uJy)
RW Sex	
V1084 Her	
TT Ari	
V603 Aql	

Radio observations from novalikes

Question: Is SS Cyg unique?

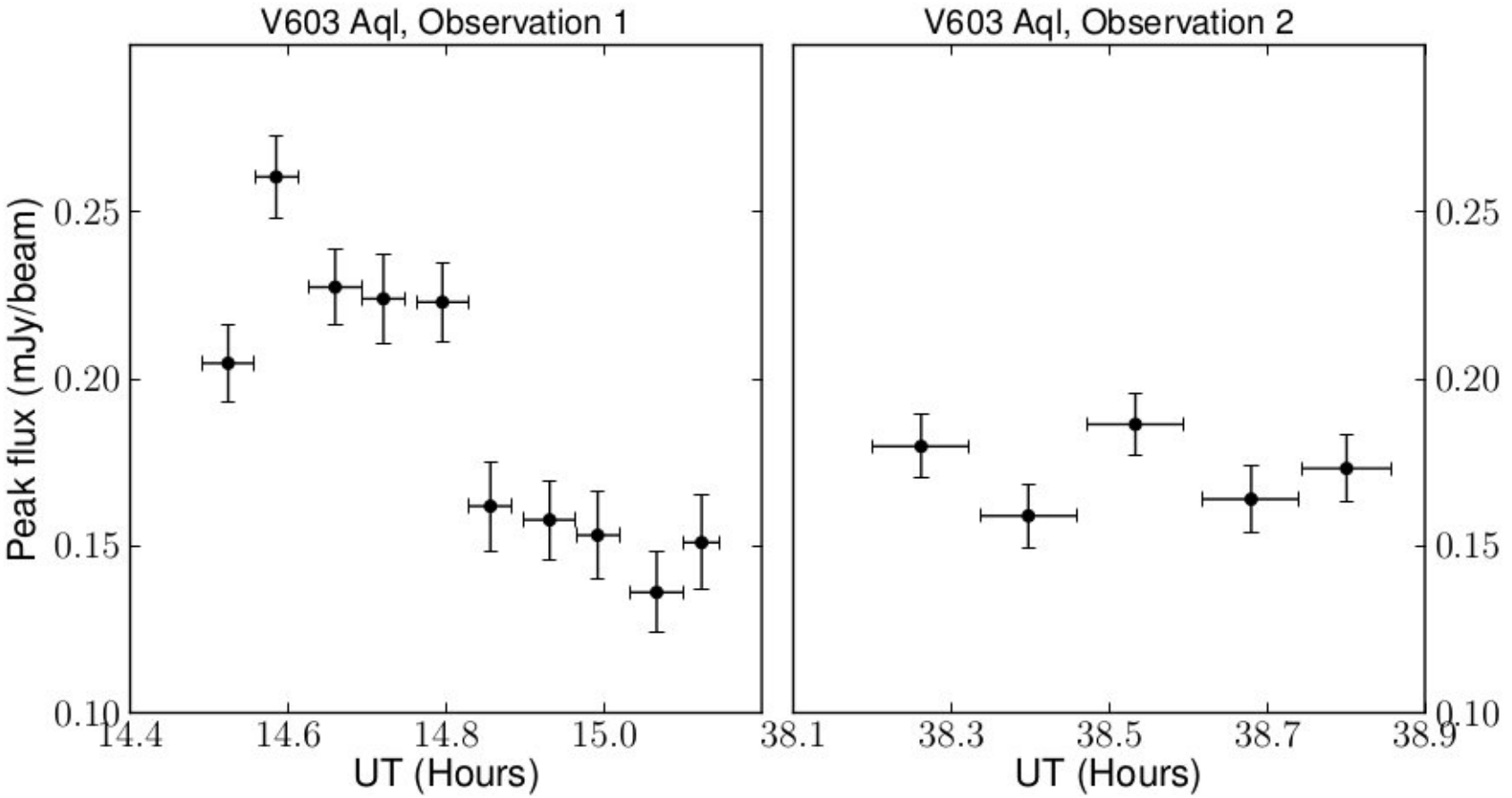
We observed a sample of 4 novalike CVs with the VLA at 6 GHZ to answer this

Non-magnetic CVs are significant radio emitters and we now have the sensitivity to detect them! (Coppejans et al. 2015)

Name	Radio Flux (uJy)	
RW Sex	33.6 ± 3.7	2 days apart
	26.8 ± 3.3	
V1084 Her	<10.2	9 days apart
	<11.4	
TT Ari	39.6 ± 4.2	19 hours apart
	239.1 ± 5.5	
V603 Aql	178.2 ± 4.3	7 days apart
	190.5 ± 3.9	

Radio emission from novalikes: Variability

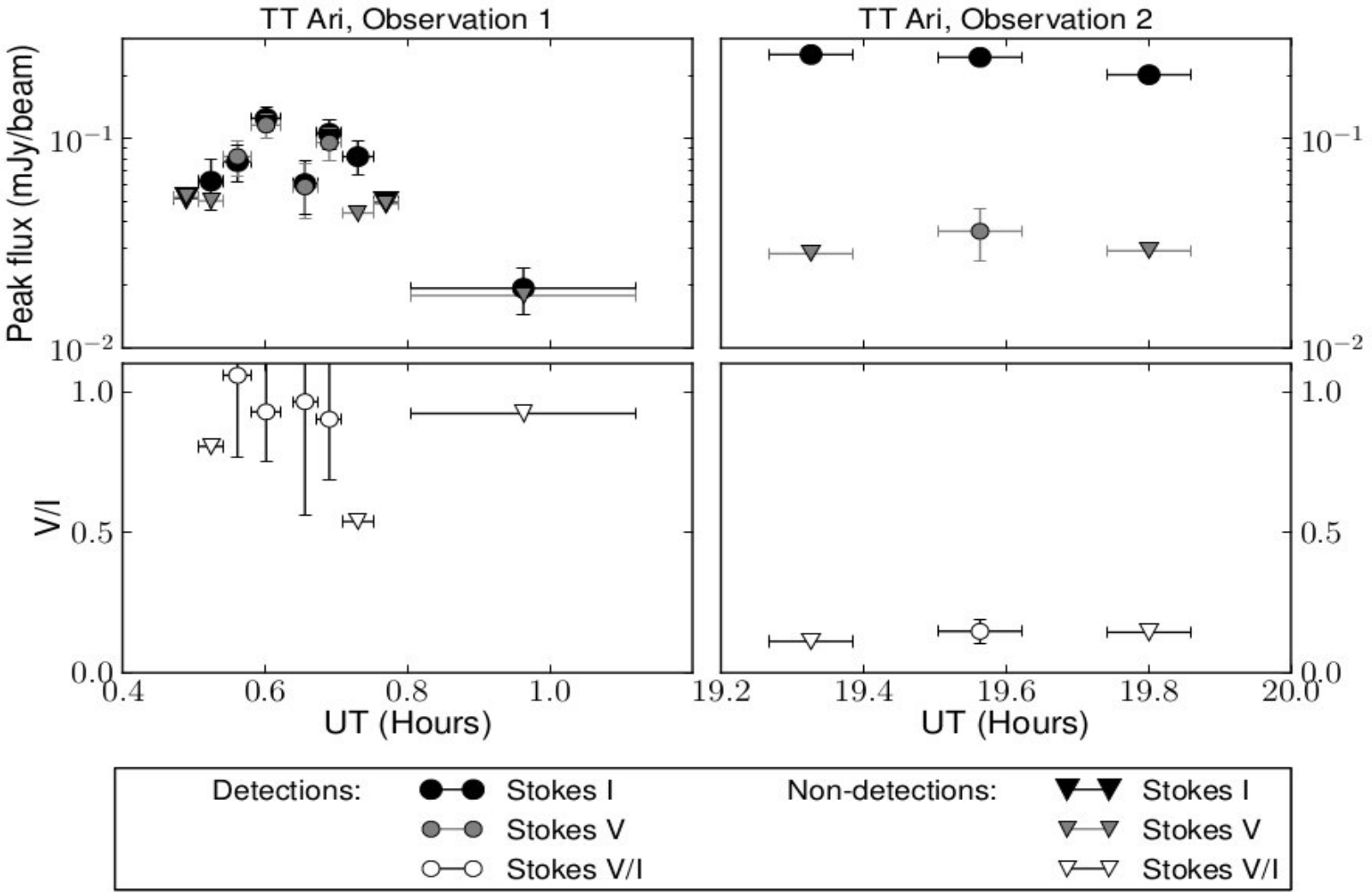
V603 Aql



Coppejans et al. 2015

Radio emission from novalikes: Variability and polarization

TT Ari



Coppejans et al. 2015

Radio emission from novalikes: Spectral Indices

Object	Spectral index ($F=\nu^{\alpha}$)
RW Sex	-0.5 ± 0.7
TT Ari, obs 1	1.6 ± 0.1
TT Ari, obs 2	0.7 ± 0.3
V603 Aql, obs1	0.54 ± 0.05
V603 Aql, obs2	0.16 ± 0.08

Coppejans et al. 2015

Radio emission from novalikes: Mechanisms

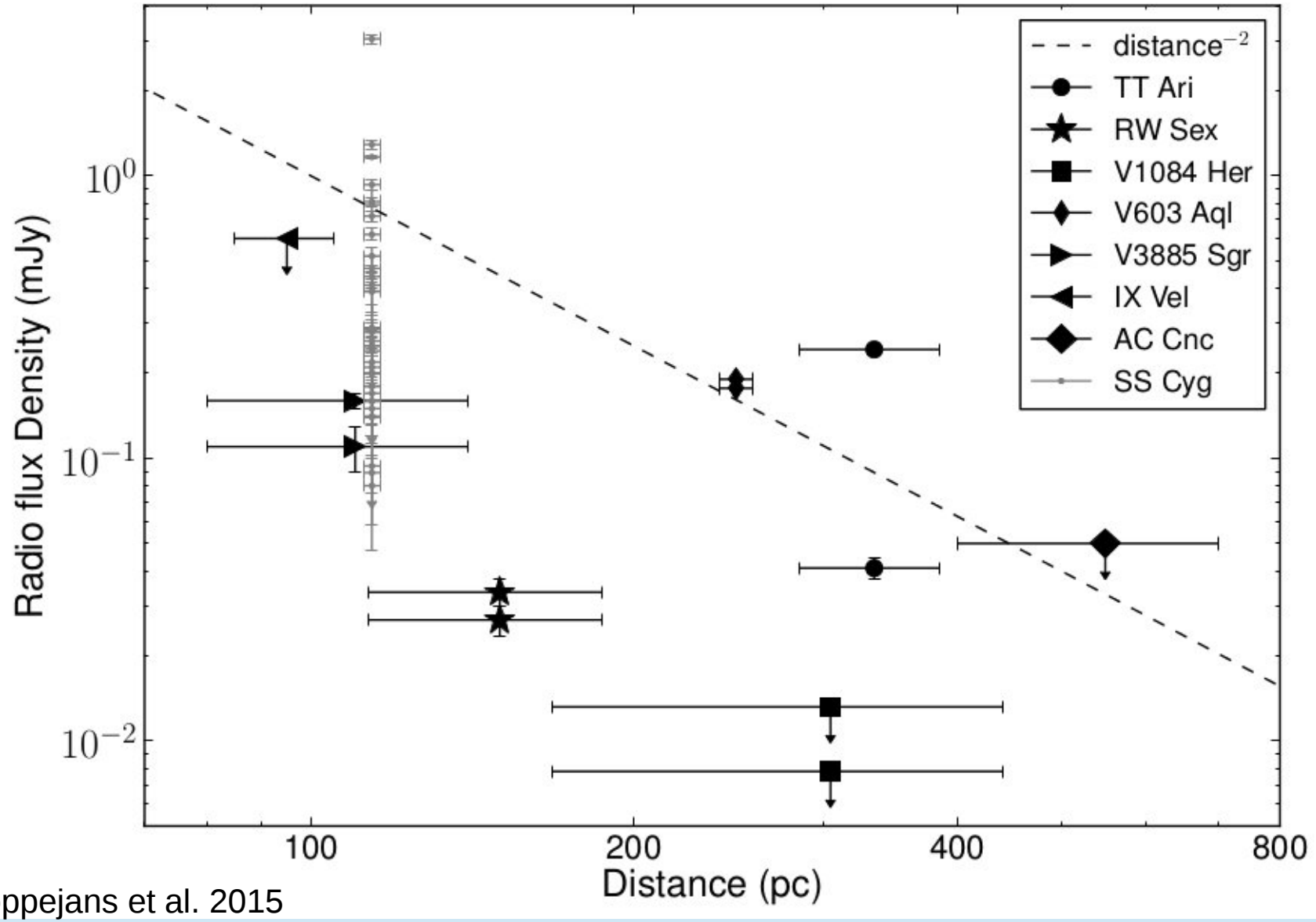
For individual novalikes we found the emission mechanism is consistent with:

- optically thick synchrotron emission
- gyrosynchrotron emission,
- or cyclotron maser emission.

V603 Aql is consistent with optically thick synchrotron emission from a jet, but it is also consistent with gyrosynchrotron or cyclotron maser emission

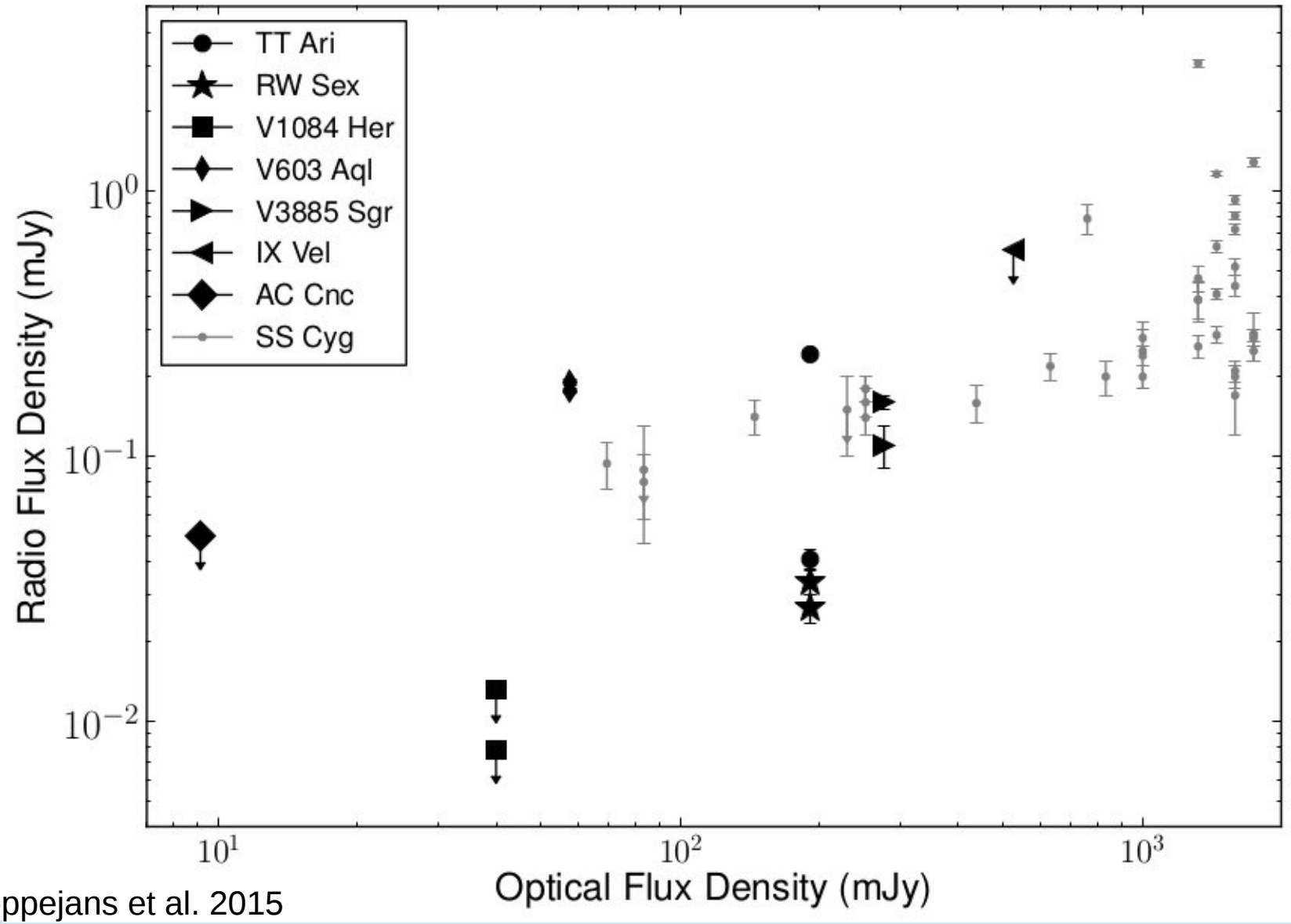
Coppejans et al. 2015

Radio emission from novalikes: Relations?



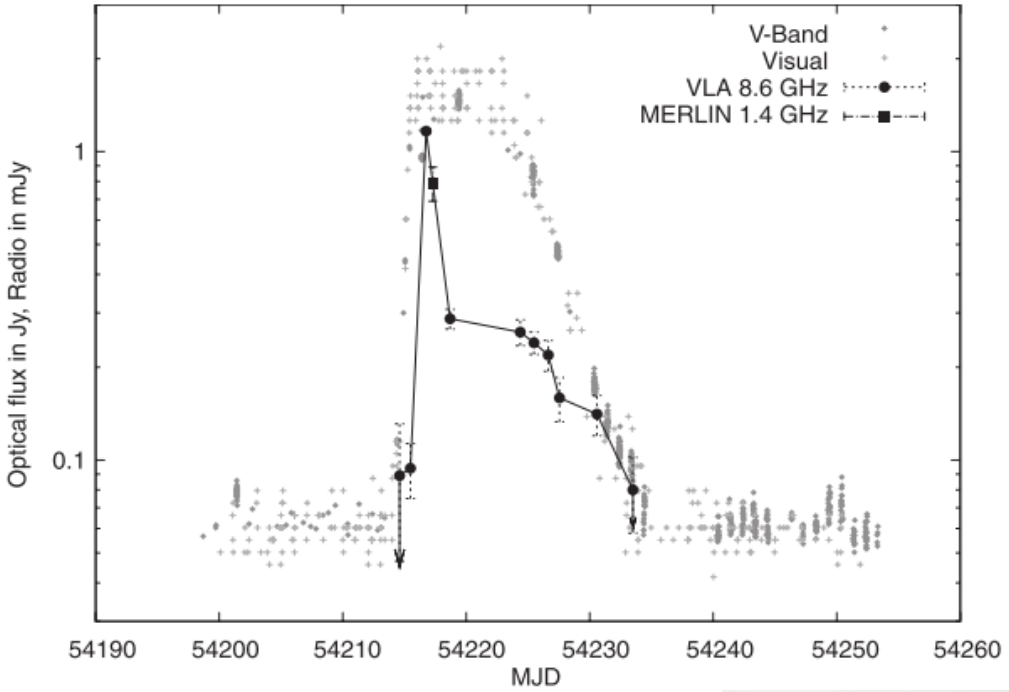
Coppejans et al. 2015

Radio emission from novalikes: Relations?



Coppejans et al. 2015

Radio emission from DN



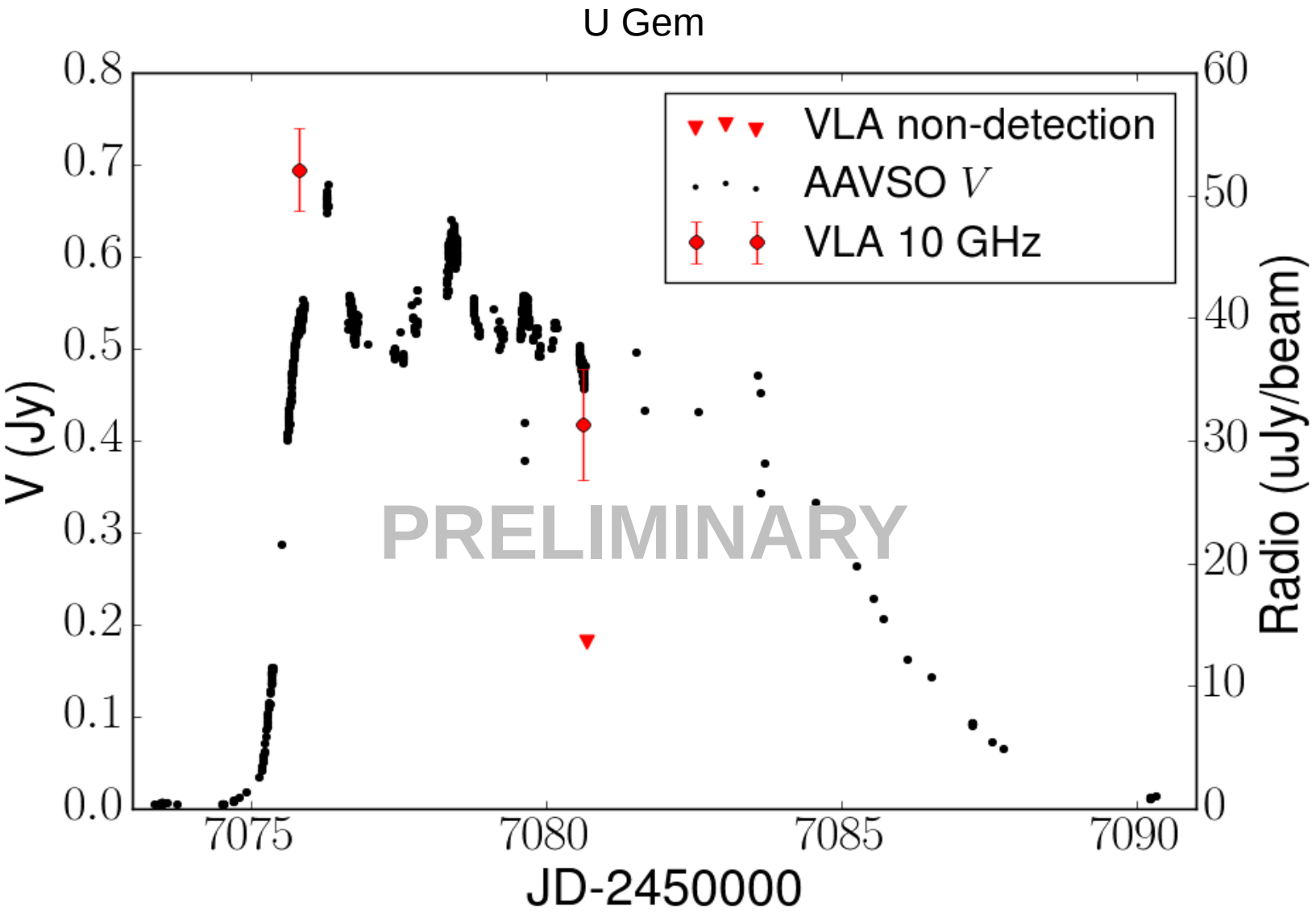
Do other DN behave like SS Cyg?

- Radio emission peaks during the outburst rise (~1 day)
- This makes it difficult to trigger radio observations
- So we organised an AAVSO campaign (alert notice 505)
- Monitor Z Cam, YZ Cnc, U Gem, RX And, SU UMa, SY Cnc, EX Dra, EM Cyg, and AB Dra

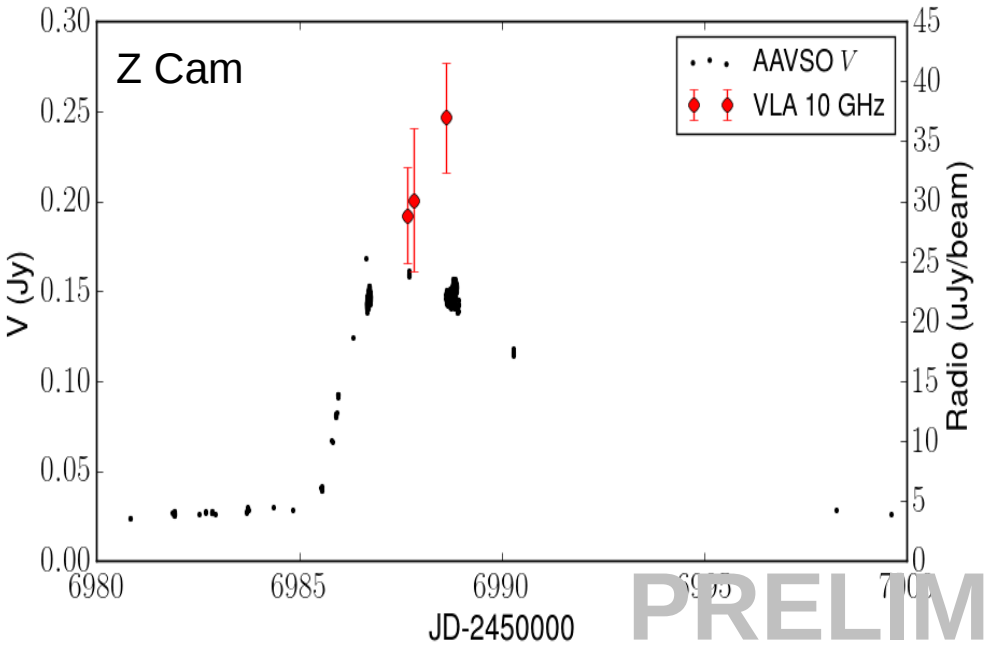
Radio emission from DN

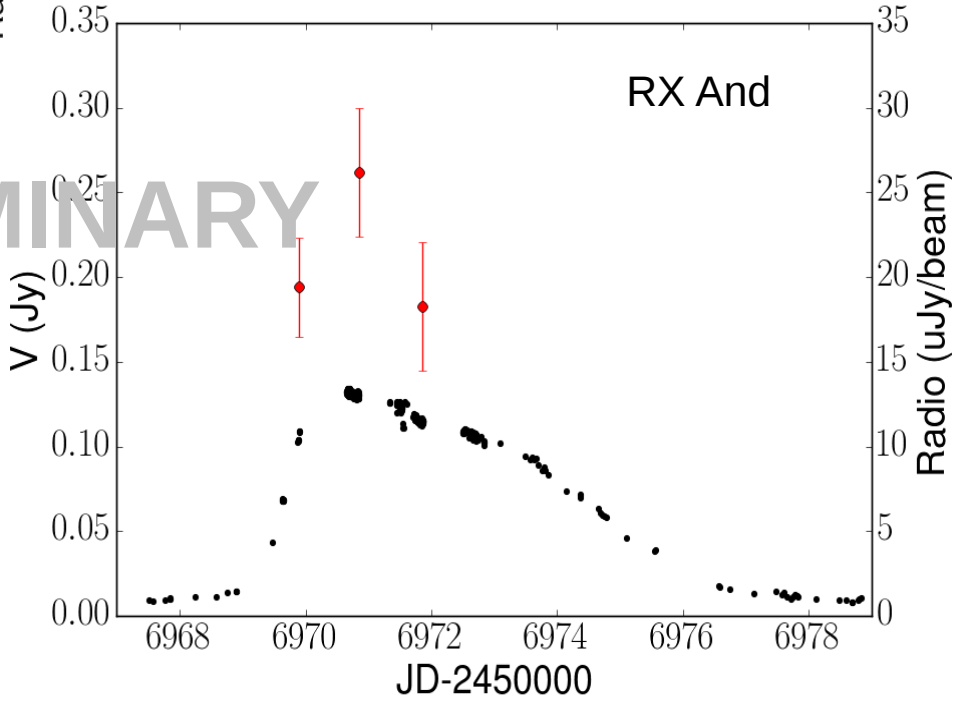
Radio emission was detected from all 5 DN!

Radio emission from DN

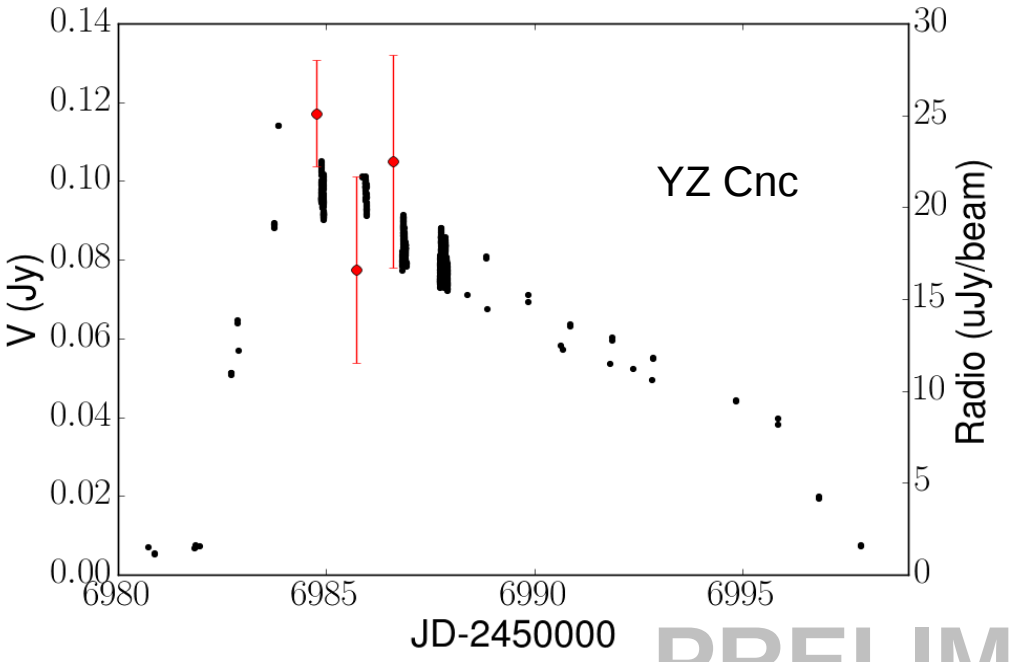


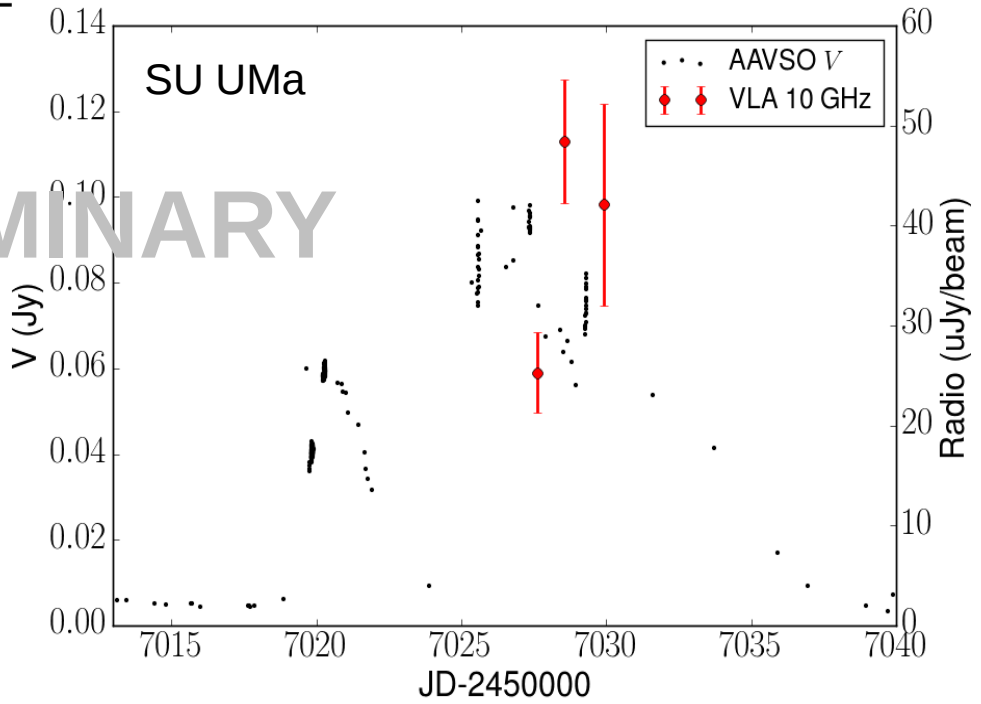
Radio emission from DN





Radio emission from DN





Next steps and future outlook

Next steps:

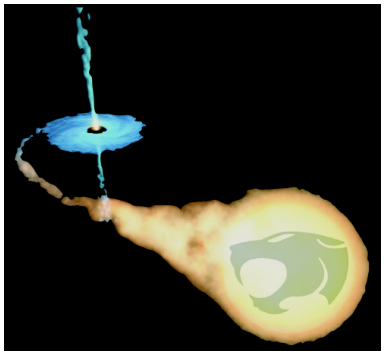
- Is this radio emission only during outburst?
- Does the radio emission of magnetic and non-magnetic CVs differ?
- VLBI observations

Future outlook:

- MeerKAT and SKA will detect these outbursts, and possibly have the resolution to image the jets
- Meerlicht will provide simultaneous optical and radio data, so we can obtain detailed multi-wavelength outburst light curves

SKA SQUARE KILOMETRE ARRAY
www.skatelescope.org

MeerLICHT South Africa



Conclusions

(Non-magnetic) CVs are significant radio emitters

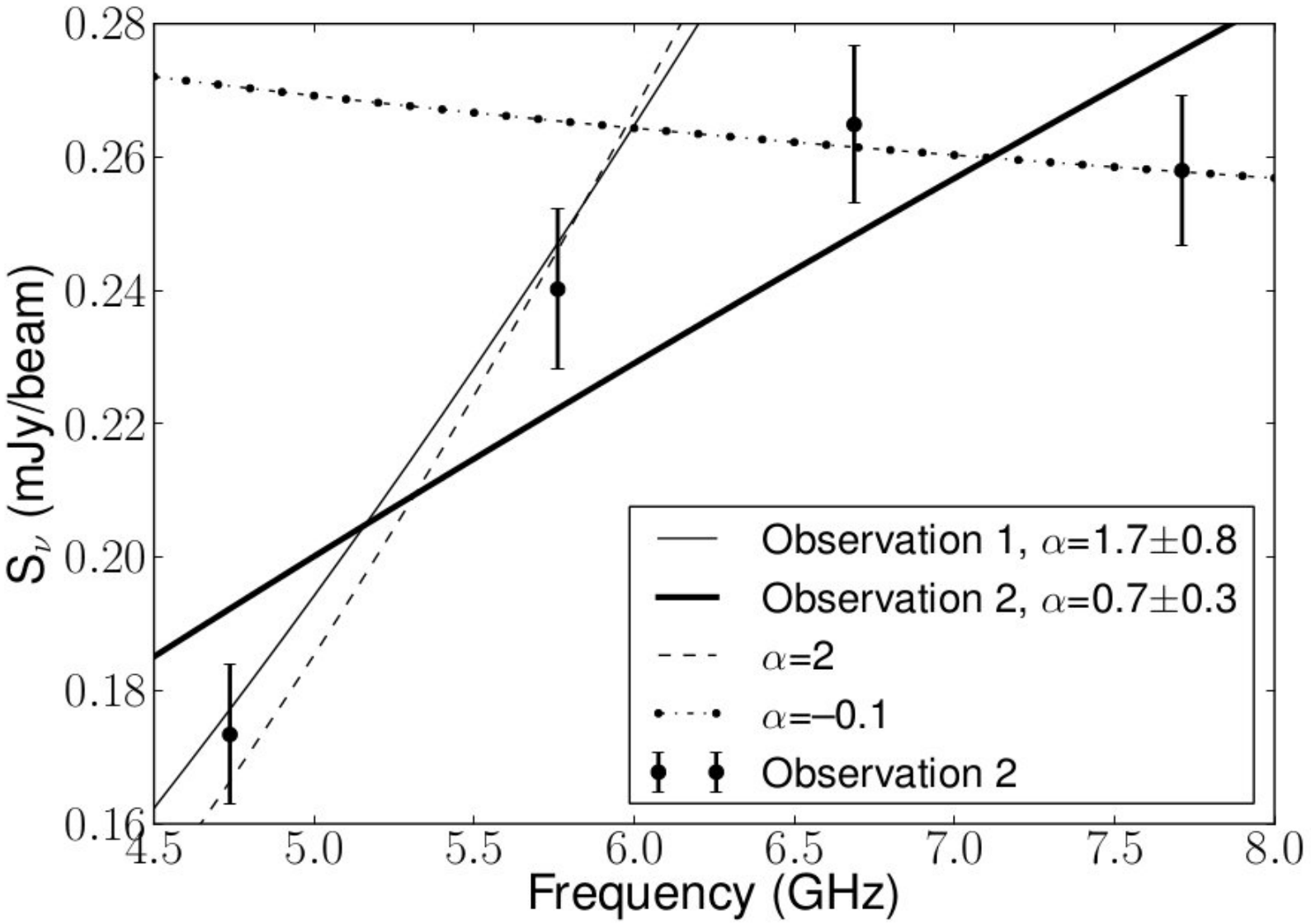
CVs could launch jets

Extra slide: Properties of the novalikes

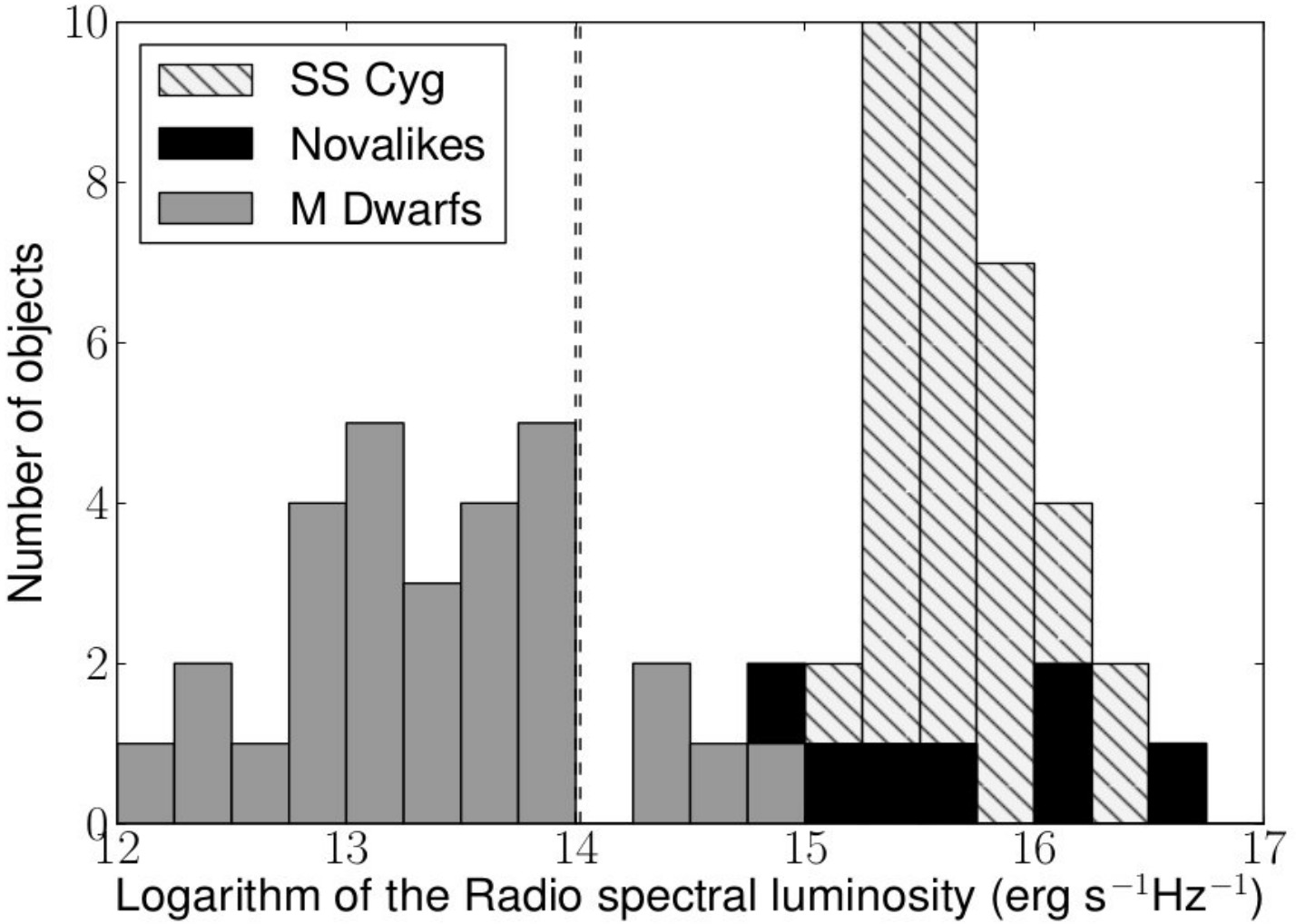
System parameters of the four novalikes

Name	RA (J2000)	DEC (J2000)	V-mag	Distance (pc)
RW Sex	10:19:56	-08:41:56	~10.7	150 (Beuermann 1992) 224 (Ak et al. 2008)
V1084 Her	16:43:46	+34:02:40	~12.4	305 (Ak et al. 2008)
TT Ari	02:06:53	+15:17:42	~10.7	206 (Ak. et al. 2008) 335 (Gaensicke et al. 1999)
V603 Aql	18:48:55	+00:35:03	~12	232 (Ak. et al. 2008) 249 (Harrison et al. 2008)

Extra slide: TT Ari's spectral index



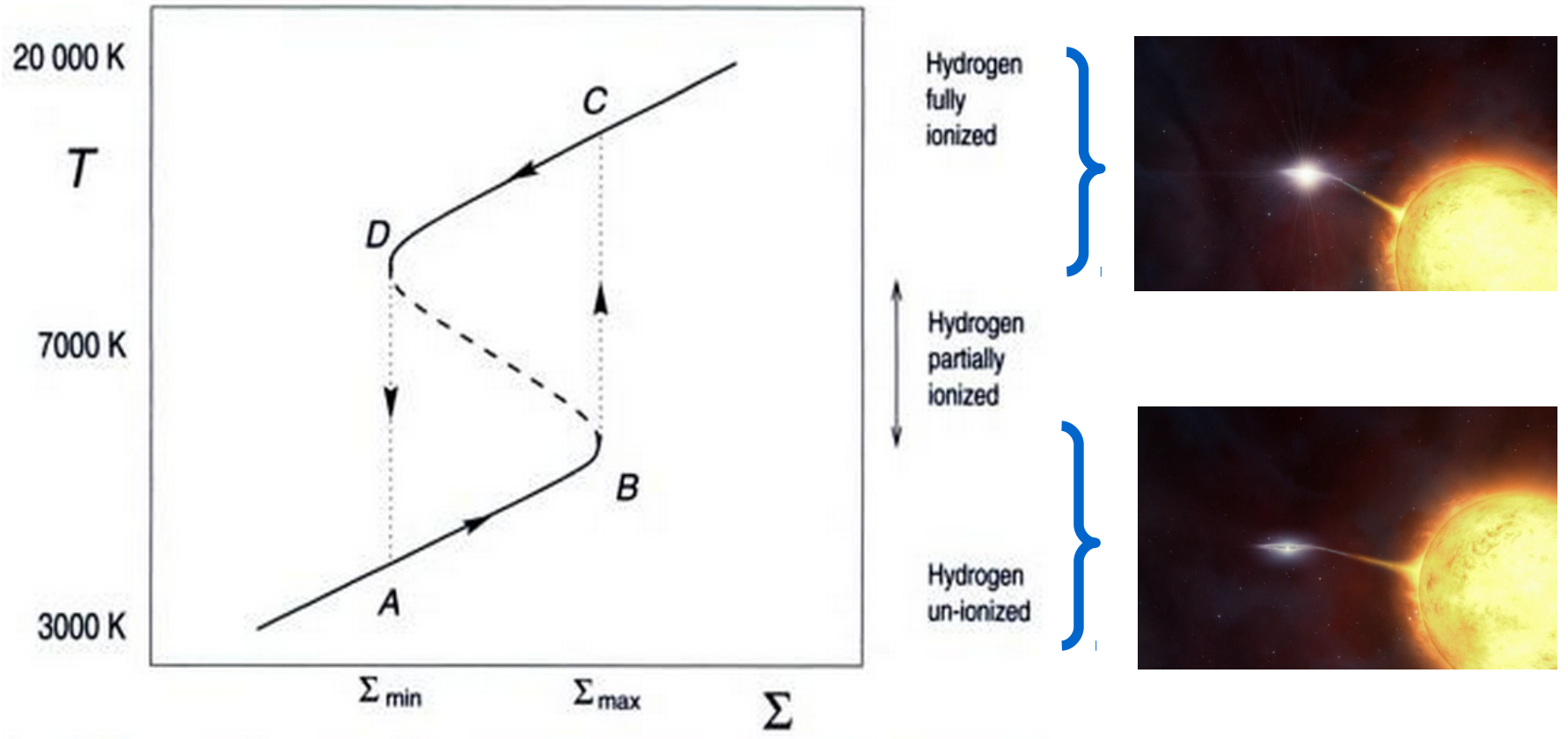
Extra slide: Radio emission from novalikes from the secondary stars?



Coppejans et al. 2015, Luminosities from McLean et al. 2012, upper-edge of quiescence from Guedel et al. 1993

Extra slide: The DIM model for DN outbursts

Disc Instability Model



Credit: Hellier figure 5.7 illustrating the Disc Instability Model (Osaki 1974 & Meyer & Meyer-Hofmeister 1981)

Extra slide: Prediction for a jet - The disc-fraction luminosity diagram

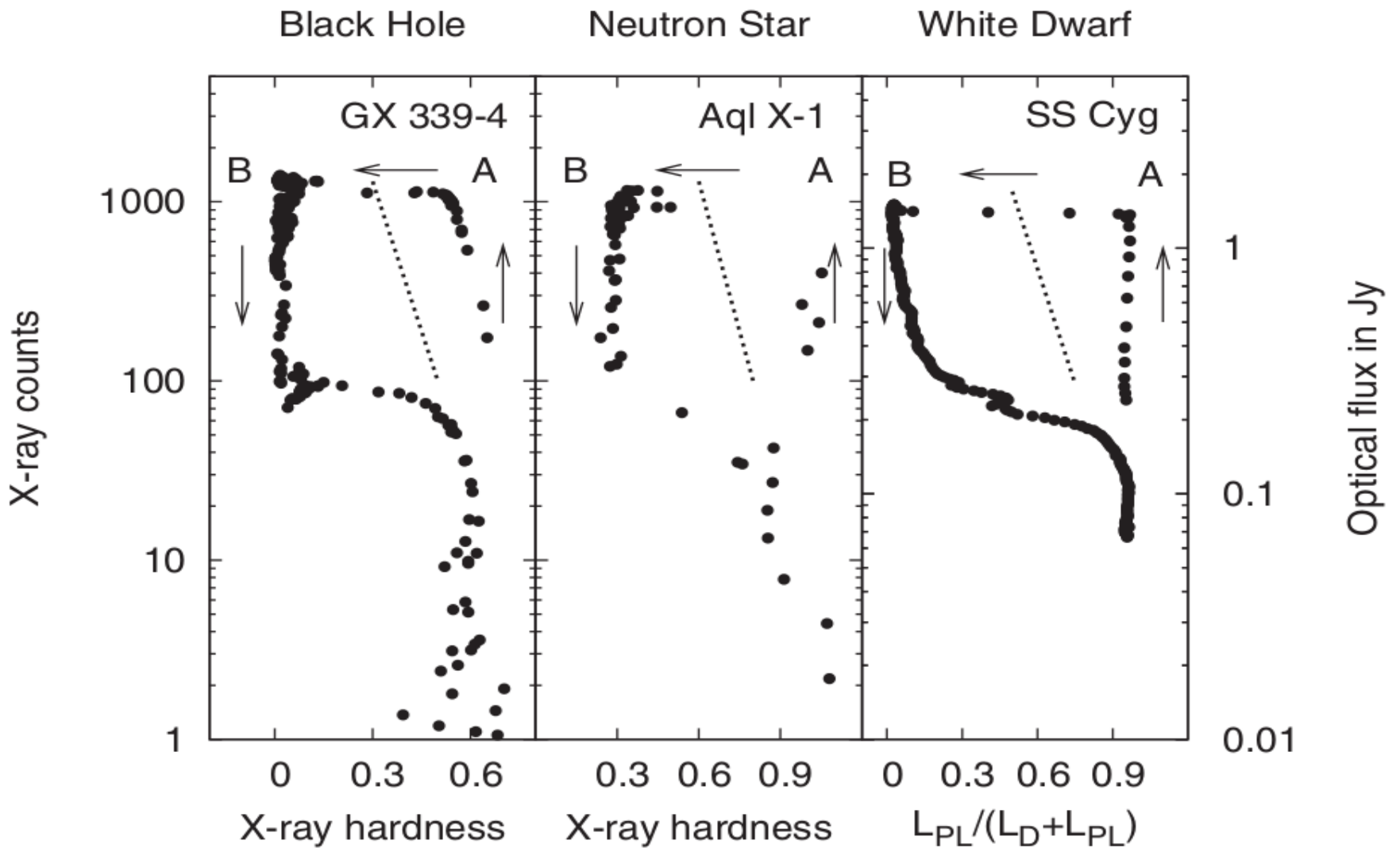


Figure 1 from Körding et al. 2008