A New Type of Double-lobed Radio-emitting Stars ?

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Early history of "Radio Astronomy"

- 1888 Hertz discovers radio waves → O. Lodge can't find the radio Sun
- 1900 Planck discourages research for solar radio emission (if thermal)
- 1901: Nordmann climbs up Mt. Blanc, but fails to detect the (quiet) Sun
- 1933: Jansky detects our Milky Way as diffuse radio emission
- 1944: Reber (ApJ 100, 279) and Hey (during WWII, classified !) independently detect the radio Sun

1949 Bolton, Stanley & Slee find the first optical IDs for 3 discrete radio sources: Tau A (Crab), Cen A (NGC 5128) and Vir A (M87)
but suggest that therefore Cen A & Vir A are likely Galactic !

1956 Burbidge (ApJ) realizes the enormous energy output of RGs in synchrotron emission: ~ 10^{50} – 10^{54} W of total energy for M87.

1959 the 3C catalogue is the first reliable catalogue of ~450 sources
but NONE of these would coincide with a known star . . .

1950MNRAS.110..508R

A PRELIMINARY SURVEY OF THE RADIO STARS IN THE NORTHERN HEMISPHERE

M. Ryle, F. G. Smith and B. Elsmore

(Received 1950 August 25)

Summary

Observations with an interferometer of large resolving power have made it possible to locate 50 discrete sources of radio waves or " radio stars " in the Northern Hemisphere ; their positions and intensities (which cover a range of

1951AuSRA...4..476B

GALACTIC RADIATION AT RADIO FREQUENCIES

IV. THE DISTRIBUTION OF RADIO STARS IN THE GALAXY

By J. G. Bolton* and K. C. Westfold*

1952RSPSA.211..351R

A new radio interferometer and its application to the observation of weak radio stars

By M. Ryle

(*Communicated by Sir Lawrence Bragg, F.R.S.—Received* 19 *June* 1951—*Revised* 10 *October* 1951)

A new type of radio interferometer has been developed which has a number of important advantages over earlier systems. Its use enables the radiation from a weak 'point' source such as a radio star to be recorded independently of the radiation of much greater intensity

A search in the Astrophysics Data System (ADS)
for papers with title words "radio" and "stars" from 1948 - 1960

Selected and retrieved **58** abstracts.

#	Bibcode Authors	Score	Date	List of Links Access Control Help	
1	1960JGR....65.1981B Benson, Robert F.	1.000	07/1960	E Effect of Line-of-Sight Aurora on Radio Star Scintillations	R C
2	1960ITAP....8...50M Manasse, R.	1.000	01/1960	E Maximum angular accuracy of tracking a radio star by lobe comparison	C
3	1960MNRAS.120..581W Whitfield, G. R.	1.000	00/1960	A F G A survey of radio stars at a frequency of 38 Mc/s	R C
4	1960CaJPh..38..883R Ryan, W. D.; Harrower, G. A.	1.000	00/1960	E An apparent solar periodicity in radio star scintillation	

• • •

1963 M. Schmidt: first identification of a quasar (3C 273 at z = 0.16)

1965 A. Sandage: many (bluish) "stars" have high redshifts, but no radio em.

. . . ➔ essentially all discrete radio sources are distant galaxies or QSOs
(and they do not show any concentration towards Galactic plane)

So what about real radio-emitting stars ?

B. Lovell (1969Natur.222.1126L) claims the radio detection with the Jodrell Bank 76-m reflector of an optical flare of YZ CMi (M4 star, V~11 mag, BYDra variable) → later turns out to be interference !

First real detection of radio flare in YZ CMi: 1978Natur.273..644Davis et al. from YZ CMi @408MHz (2-elem. 127-km interferom.: 76m+25m dishes, 1.2")

. . . and after about two decades of effort . . .

Wendker 1987/1995: compilation of radio star observations (1995A&AS..109..177W; updated to 01-Jul-1994)
3021 stars observed, of which: 2192 only have upper limits
821 detected at least once (27 % of observed stars)
variability is very common:
of the stars detected at least once and observed at least twice about 50% are definitely variable (likely a higher fraction)

I found an unpublished version of March 2001 on
ftp://ftp.hs.uni-hamburg.de/pub/outgoing/hjw/kat_neunum
~3700 stars, 1128 of these detected
(file was forwarded to CDS in June 2015, but is not yet released)

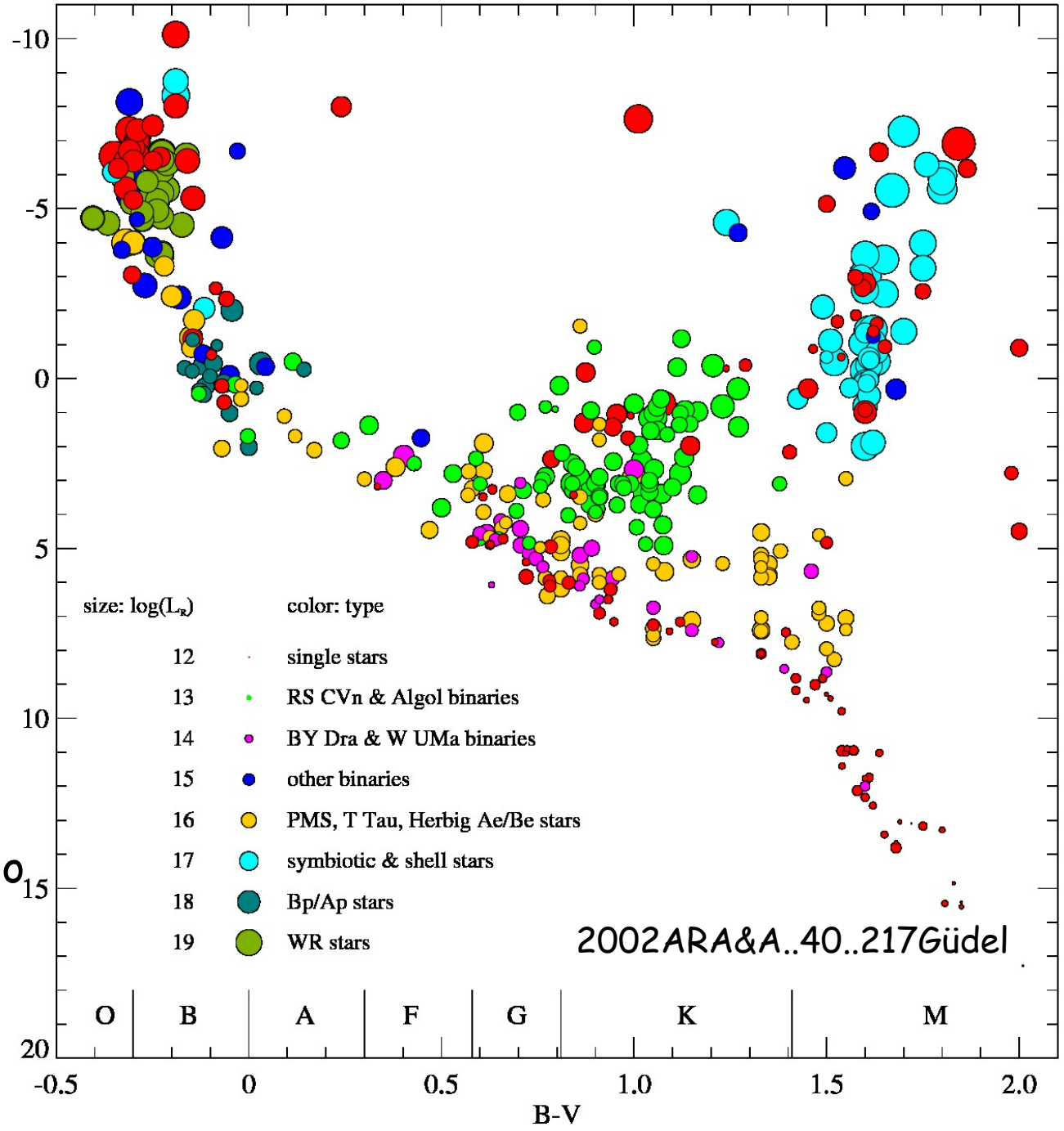
Güdel 2002:
radio HRD of all detected stars in Wendker's 1995 list with symbol size prop. to log L_{radio}

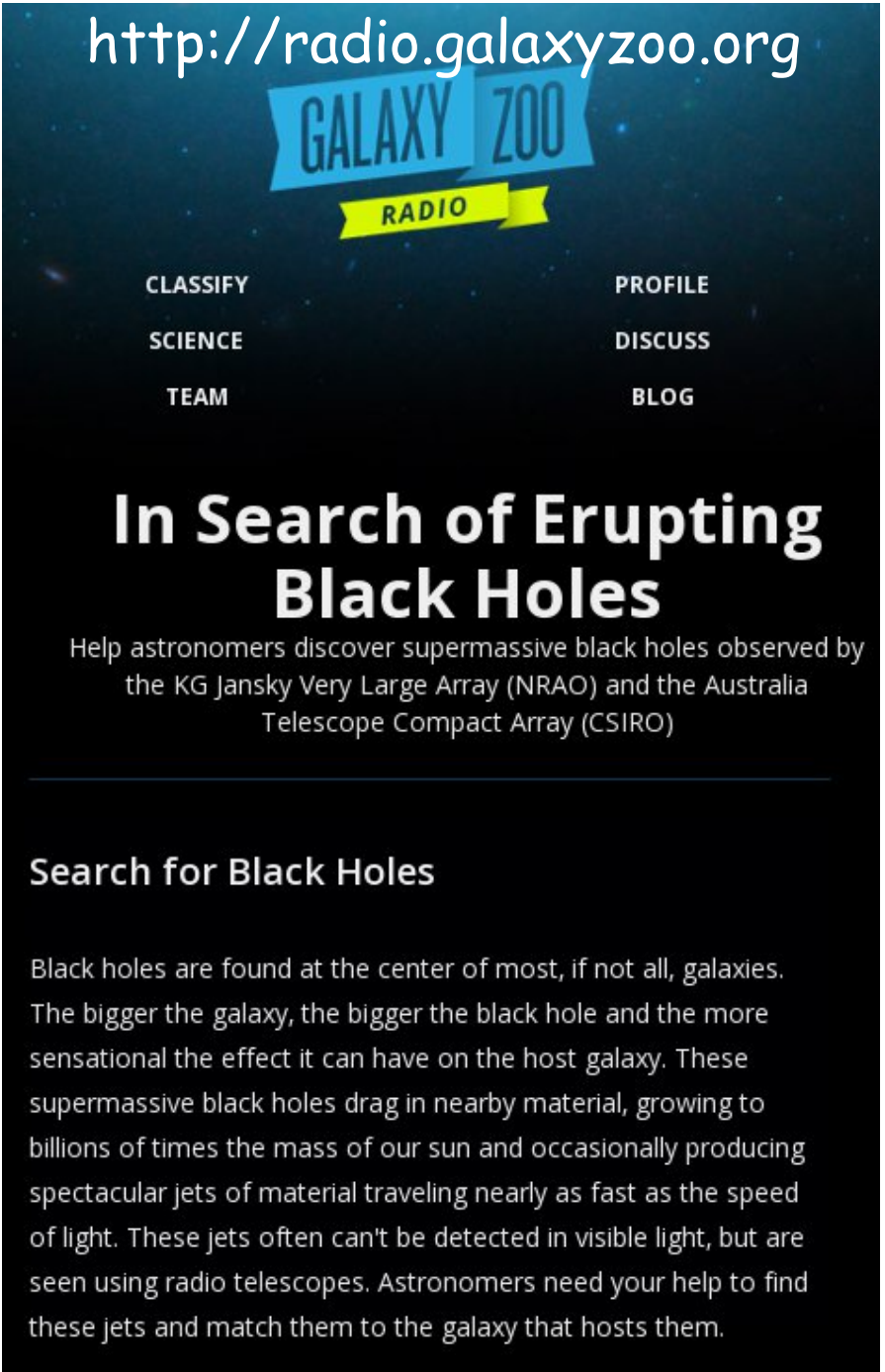
Radio stars fill the entire HRD, and are **mainly binary systems**

Most radio-detected dwarf stars are **strong X-ray sources**

Most cool radio stars show a **nonthermal** radio emission spectrum

So why would I care ... ?





Radio Galaxy Zoo (RGZ), a sequel of Galaxy Zoo, a Citizen Science Project to help classify millions of astronomical objects with volunteers

The homepage of Radio Galaxy Zoo

- launched on Dec. 17, 2013

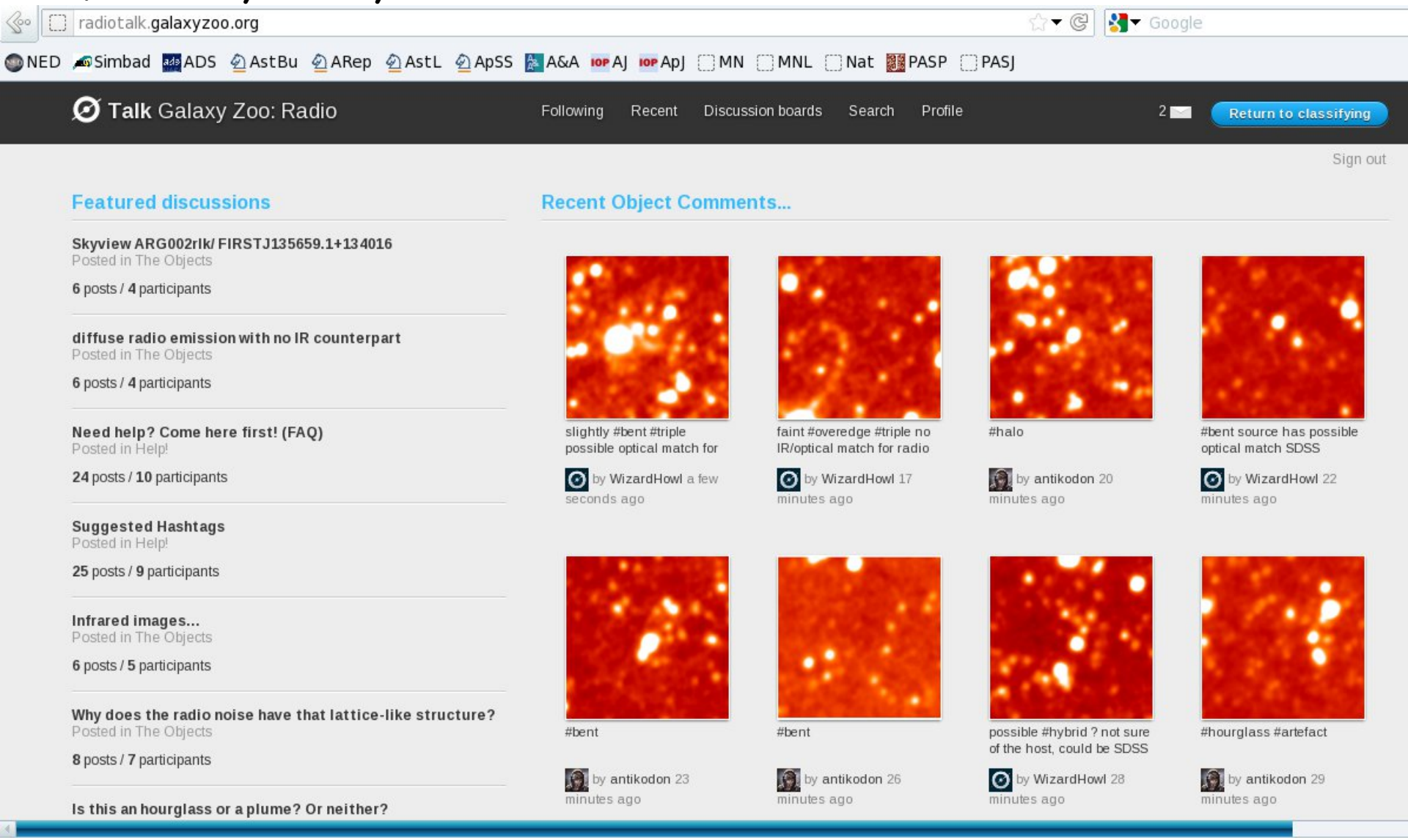
Asks the user to

- select one/more radio sources and then associate these to an IR object in the WISE image
- classify its radio morphology into several classes like

#hourglass (classical double)
#headtail, #wat, #plume, #diffuse, #hybrid, #giant, #overedge, etc.

The user is invited to place doubtful/interesting objects on a discussion page : "radiotalk"

Example of a discussion page: each icon allows to open larger images of FIRST, NVSS, SDSS and WISE



➔ requires follow-up by science team ➔ diverse results

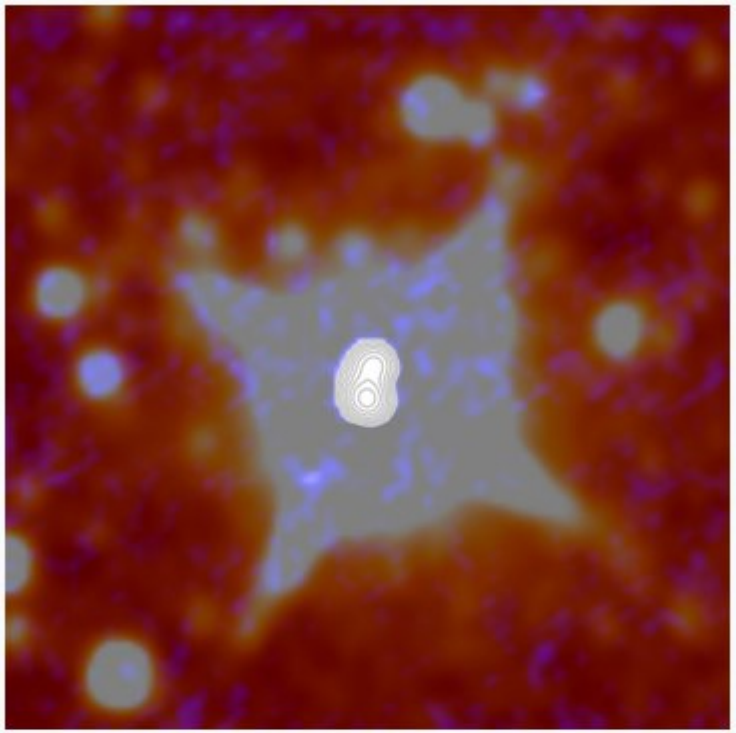
Example:
in 2 years
the ~5000
volunteers
found ~160
new giant
radio galaxies
(> 1 Mpc in
projected size)

but occasionally
. . .

Until recently
my reaction was
"Oh, what
a bad luck ..."

→ no way to
identify the
host galaxy
or quasar

Image ARG000152f



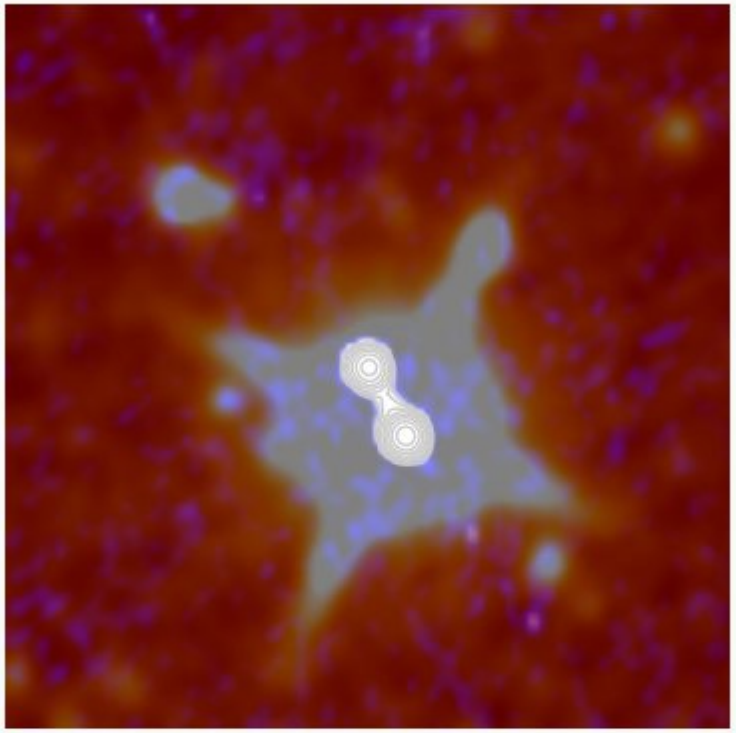
Survey Id:	FIRSTJ082108.4+402059
RA:	125.285
Dec:	40.350
FIRST	
NVSS	
SDSS	
WISE	

BD +40 2030
HIP 40928
V = 9.0 B= 9.8

#star

by bfrink 7 months ago

Image ARG0002wdc



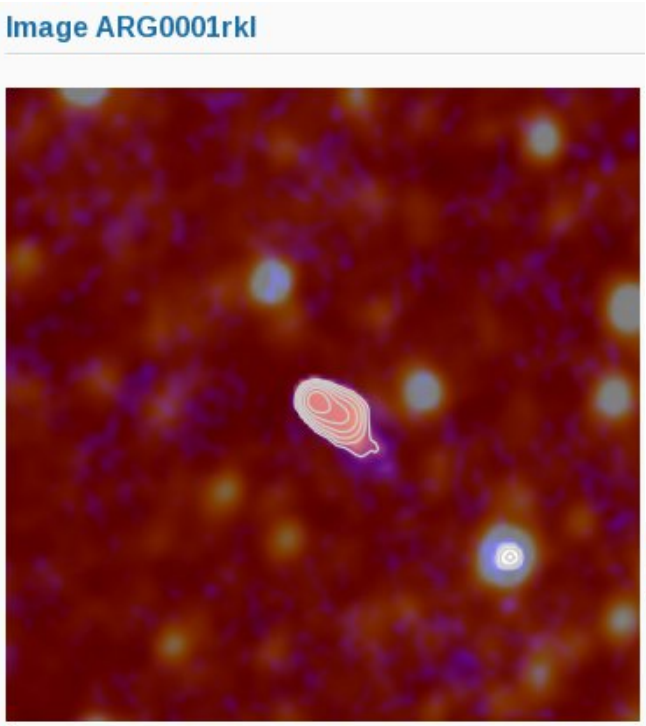
Survey Id:	FIRSTJ095907.8+115901
RA:	149.782
Dec:	11.984
FIRST	
NVSS	
SDSS	
WISE	

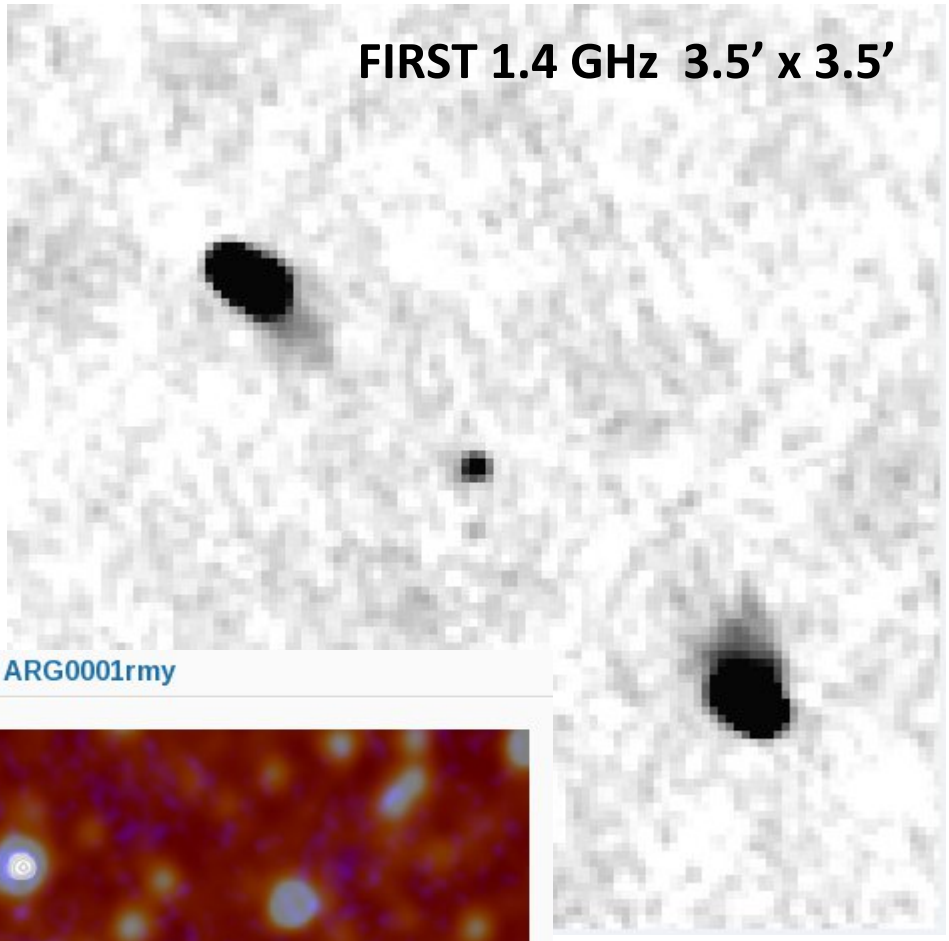
Tyc 832-540-1
V = 10.2 B= 11.3

#hourglass #star preventing basically any more future observations...

by planetaryscience 2 years ago

But then . . .





A triple radio source with
a compact source at center,
coinciding with a starlike
optical object …
→ must be a quasar . . . !?

SDSS J170008.72+291903.7

Look up common name

Type		SDSS Object ID	
STAR		1237661388158664899	
RA, Dec		Galactic Coordinates (*l*, *b*)	
Decimal	Sexagesimal	*l*	*b*
255.03634, 29.31771	17:00:08.72, +29:19:03.77	50.90941	35.83590

r′ = 16.52 mag

FBQS J170008.6+291904
already reported
as a spectroscopic star by
2000ApJS..126..133White

Imaging

Flags	STATIONARY B

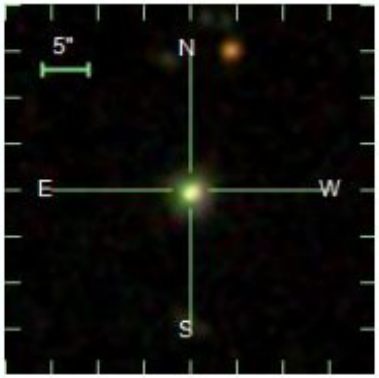
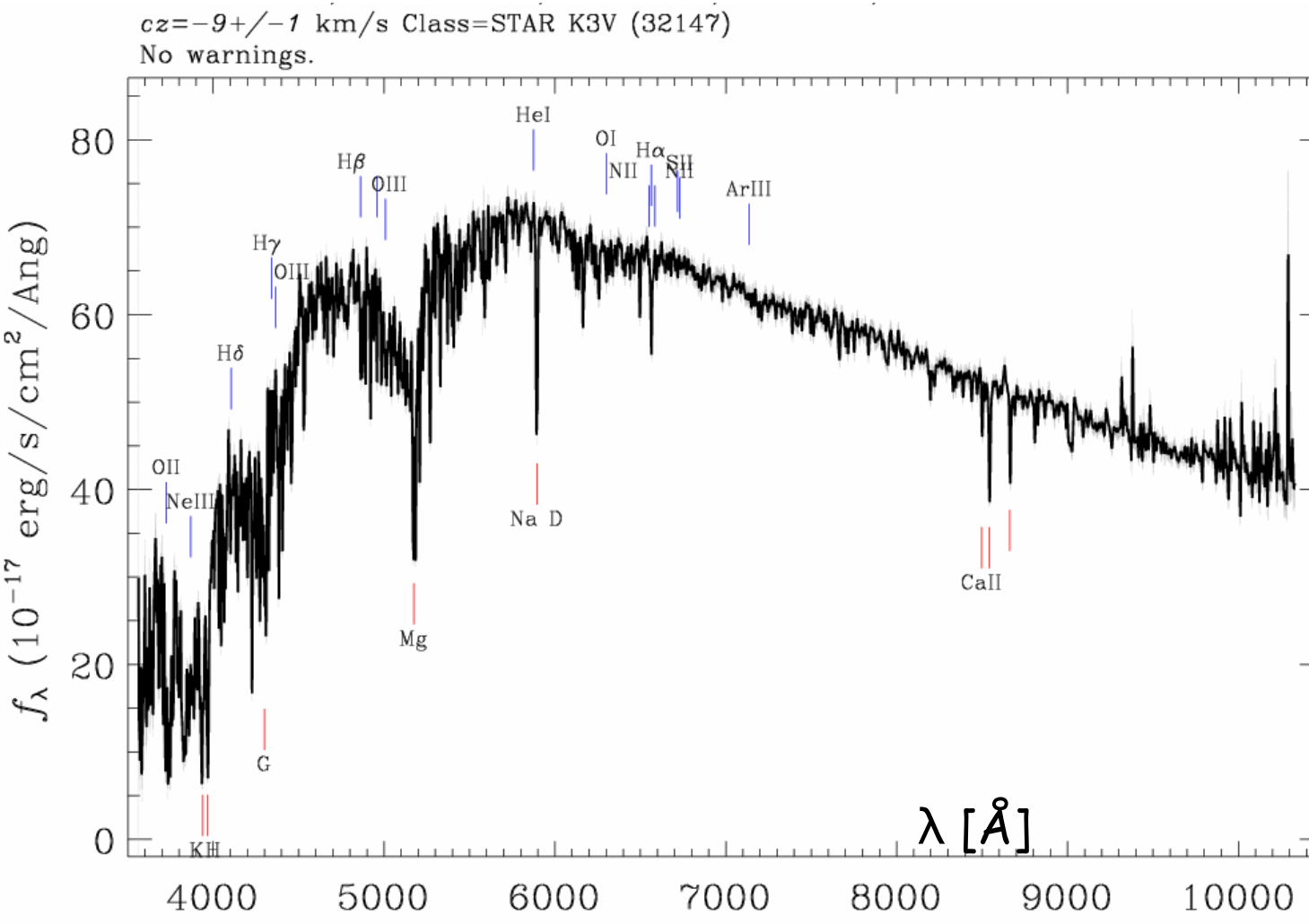


Image MJD	mode	Other observatio
52705	PRIMARY	2

Mjd-Date	photoZ
03/07/2003	



"Unbiased" searches of radio stars in large surveys

VLA FIRST (1.4 GHz, 5.4"beam, now ~950,000 sources in 10,600 deg^2)

1999AJ....117.1568Helfand D.J.+; matched ~440,000 sources in 5000 deg^2 with stars from Hipparcos & Tycho: yields 26 new radio stars (>0.7 mJy)
→ doubled the number of radio stars known in this area

2009ApJ...701..535Kimball A.E.+ Candidate Radio Stars in FIRST & SDSS; they matched 800,000 sources in 9000 deg^2 with 287,000 SDSS stars (stellar spectra) → find 112 candidates within 1" and $S_{1.4GHz}$ > 1.25 mJy
BUT: 108 are expected by chance ➔
only ~1.2 per 10^6 radio sources are stars with 15 < i < 19.1 mag, >1.25 mJy
However, these authors exclude any double radio sources and sources offset by >1 arcsec from the star position

The lower-resolution NVSS radio survey (45", 1.8 million sources) was used to find candidate radio stars... Results were only published in 1997AAS...191.1402Condon, Kaplan & Yin

Title: The Brightest Radio Stars

Authors: Condon, J. J.; Kaplan, D. L.; Yin, Q. F.

Affiliation: AA(NRAO), AB(NRAO), AC(NRAO)

Publication: American Astronomical Society, 191st AAS Meeting, #14.02; Bulletin of the American Astronomical Society, Vol. 29, p.1231

Publication Date: 12/1997

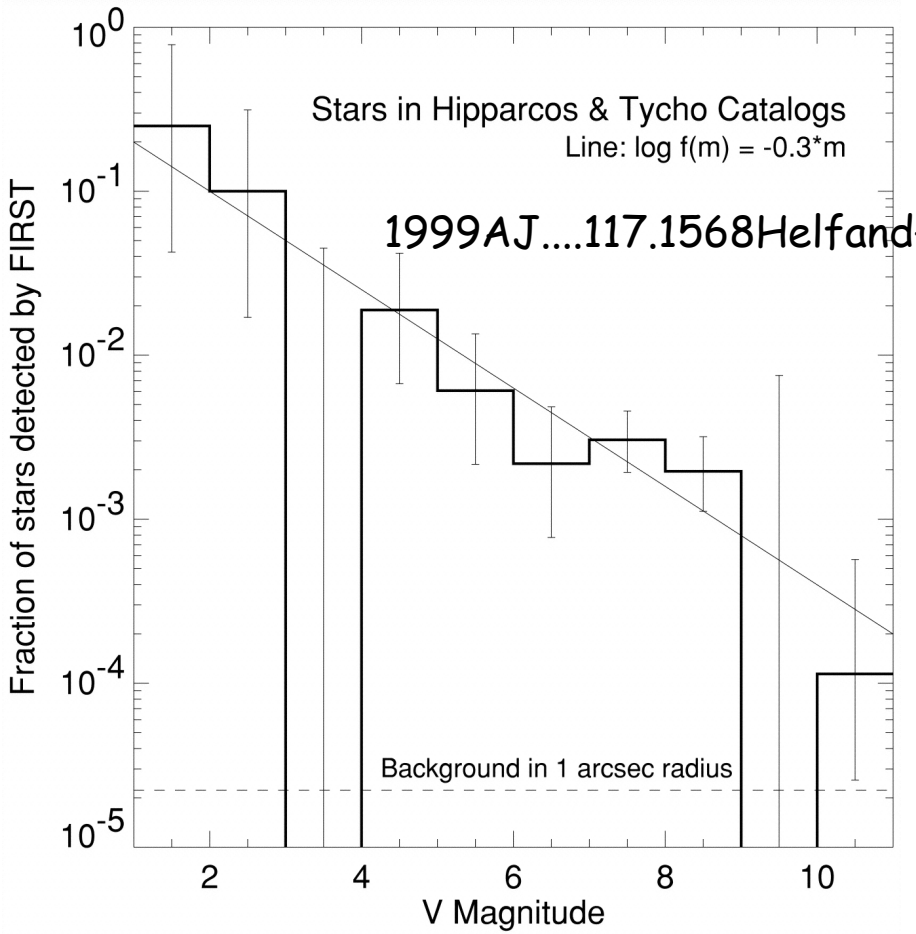
Origin: AAS

Bibliographic Code: 1997AAS...191.1402C

Abstract

Most objects studied by radio astronomers today are the unexpected discoveries of early surveys. Unfortunately, very few stars were found, so nearly all known radio stars have been detected by sensitive observations directed at small samples of stars thought likely to be radio emitters. Such observations are productive but biased against discovering unknown, unexpected, or intrinsically rare objects. We have used the new NRAO VLA Sky Survey (NVSS) to identify unbiased samples of the brightest radio stars in the Omega ~ 10 sr of sky with delta > -40(deg) . Our principal sample consists of all stars brighter than V = 10.5, the completeness limit of the Tycho catalog, and stronger than 5 mJy at 1.4 GHz. Additional samples of X-ray stars from the ROSAT All-Sky Survey, far-infrared stars from the IRAS Faint Source Catalog, and optically selected emission-line stars, chromospherically active binaries, cataclysmic variables, white dwarfs, and stars within 25 pc were associated with NVSS sources stronger than 2.5 mJy. The NVSS identification candidates were reobserved by the VLA on 1997 September 27 in Stokes I, Q, U, and V with 45" resolution at 1.4 GHz and 8" resolution at 8.4 GHz. The 1.4 GHz observations match the NVSS resolution and indicate which sources have varied in total intensity and linear polarization. The nearly simultaneous 1.4 and 8.4 GHz observations determine their radio spectral indices, and the high-resolution 8.4 GHz data were used to confirm or reject uncertain candidates on the basis of position coincidence. At least 50 radio stars were found, most for the first time. They exhibit a range of radio spectra, angular sizes, and polarizations indicating a variety of emission mechanisms. We are following these stars with high-resolution optical spectroscopy.

They observed ~100 candidates at 1.4 and 8.4 GHz with the VLA, confirming 50 new radio stars, but results were never published. We downloaded the archive data and J. M. Masqué (DA-UG) has reduced them; our analysis is in progress ...



Summary of radio star search from the FIRST survey

The fraction of stars detected by FIRST as function of mag

2009ApJ...701..535Kimball

i = 15 i = 19

10^{-6}

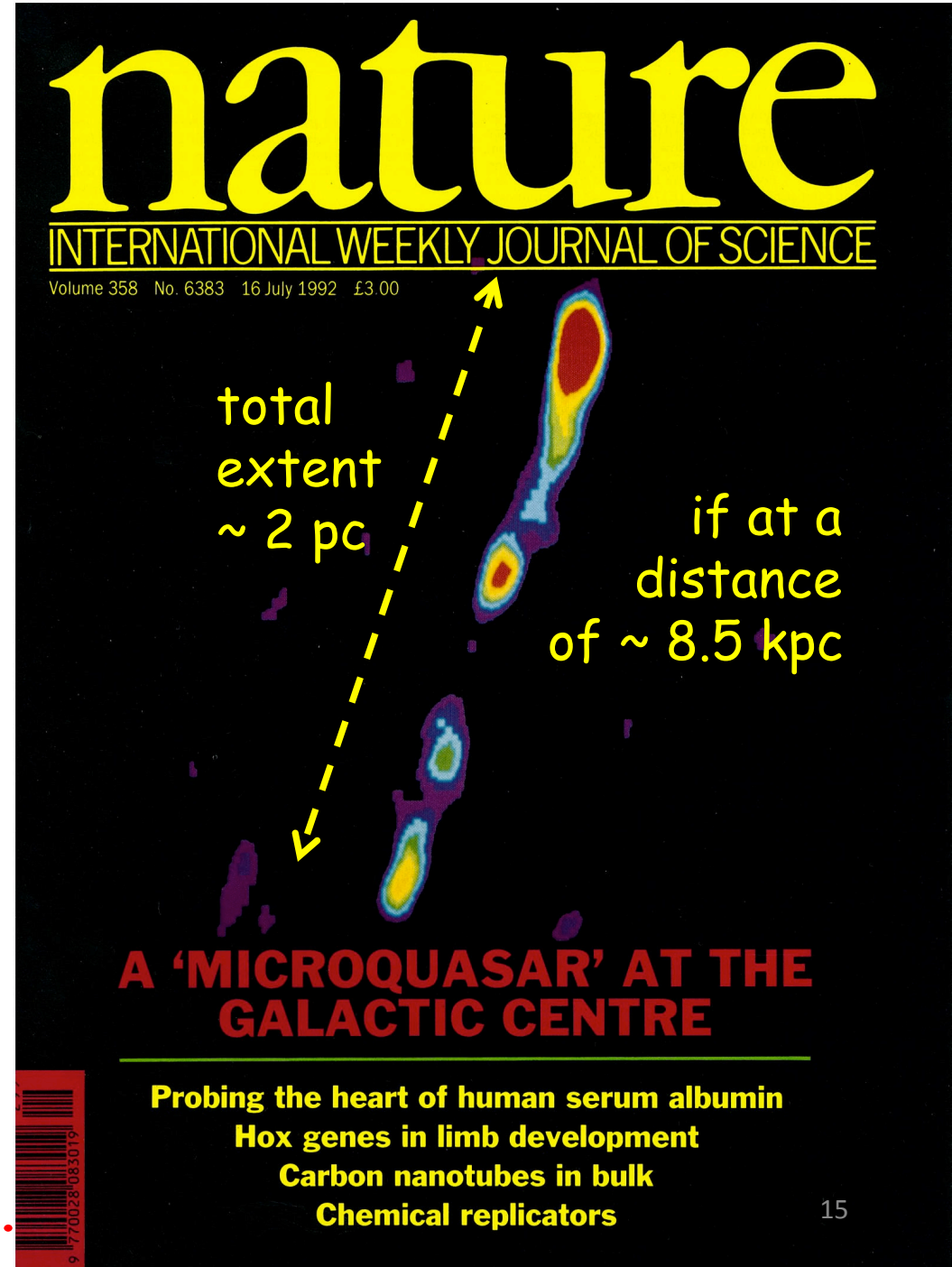
So what about radio stars with double radio lobes ?

Yes! ... **microquasars**!
First proposed by
Mirabel & Rodriguez 1992
1E 1740.7-2942 near G.C.

Examples:	distance
GRS 1915+105	~12 kpc
GRO J1655-40	3.2 kpc
Cyg X-1	
SS 433	. . .

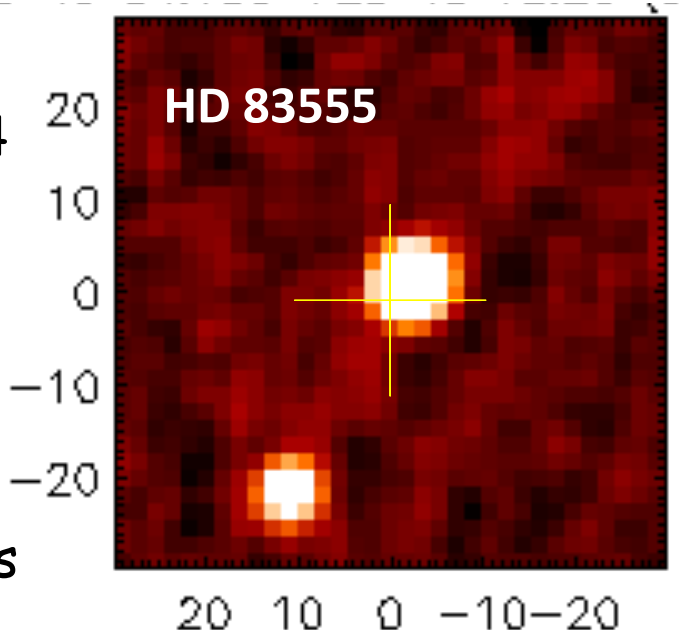
All of them are either low- or high-mass X-ray binaries close to the Galactic plane; one component is a black hole or neutron star of a few $M_\odot$; some show superluminal expansion → v_{bulk} <~ c

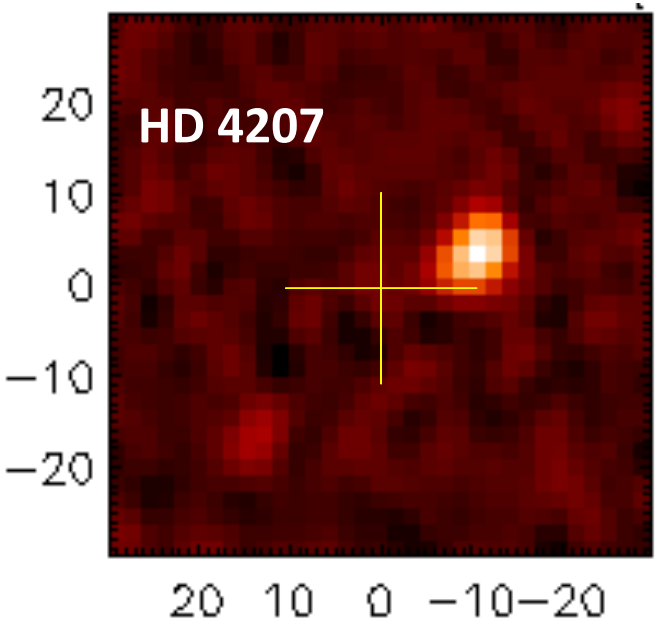
Not similar to "our" stars ...



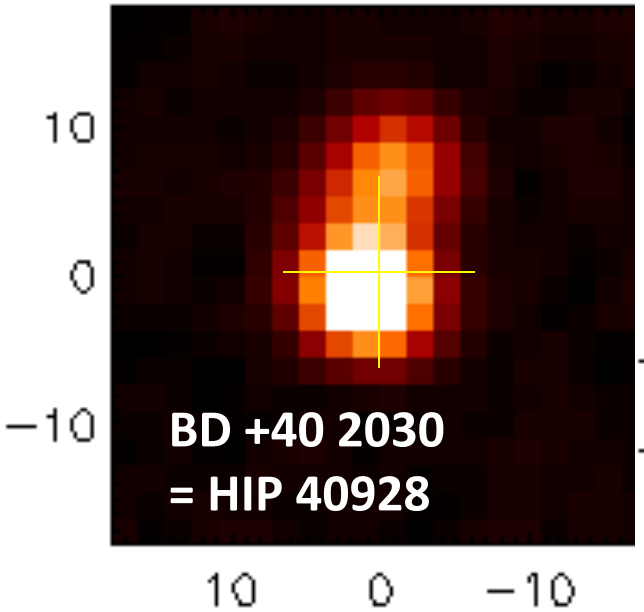
We cross-identified the SAO and UCAC4 star catalogues for V < 12 mag to search for FIRST double sources within ~30"

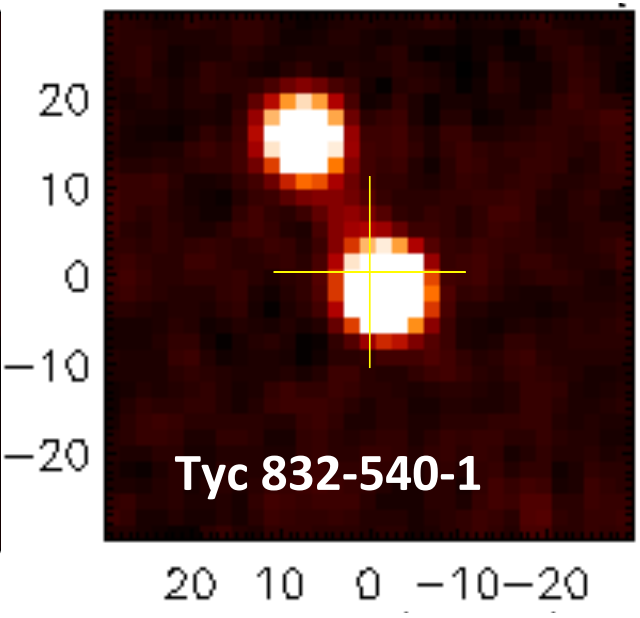
➔ found 5 examples

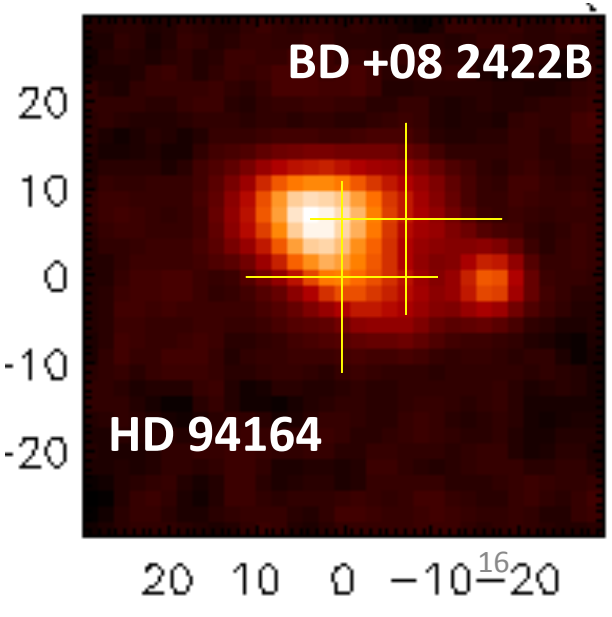




None of them have a publ. spectrum, only 1 has a published RV; V~ 11 mag is just about bright enough for a TIGRE spectrum !







Our sample of TIGRE targets

AO2 proposal 10-June-2015
K.-P. Schröder, D. Jack, C. Rodriguez

Table 1: Stars with V$\lesssim$10 mag coinciding with double radio sources in FIRST

Name	distance pc		radio size(AU)	z pc	B mag	V mag	Spec. Type	PM ″/yr	$S_{1.4}$ mJy	sep. (″)	sp.ind. α	log L_R W/Hz
HIP 40928	63	#	570	34	9.8	9.0	G0	.246	101	9	−0.8	10.6
HD 83555	525		13700	380	10.3	9.1	K1	.017	15	26	−0.9	11.7
HD 4207	400		12800	370	10.6	9.5	G5	.058	13	32	−0.5	11.4
Tyc 832-540-1	275	?	5500?	200?	11.3	10.2	wK1	.006	115	20	−1.9	12.0:
HD 94164 *	263		5260	210	8.9	8.1	G5	.046	(82)	(20)	(−1.1)	(11.8)
BD+08 2422B*	103	#	(5260)	150	9.8	9.3	G5	.040	82	20	−1.1	11.5

*) 12″ binary system # the only stars with a parallax

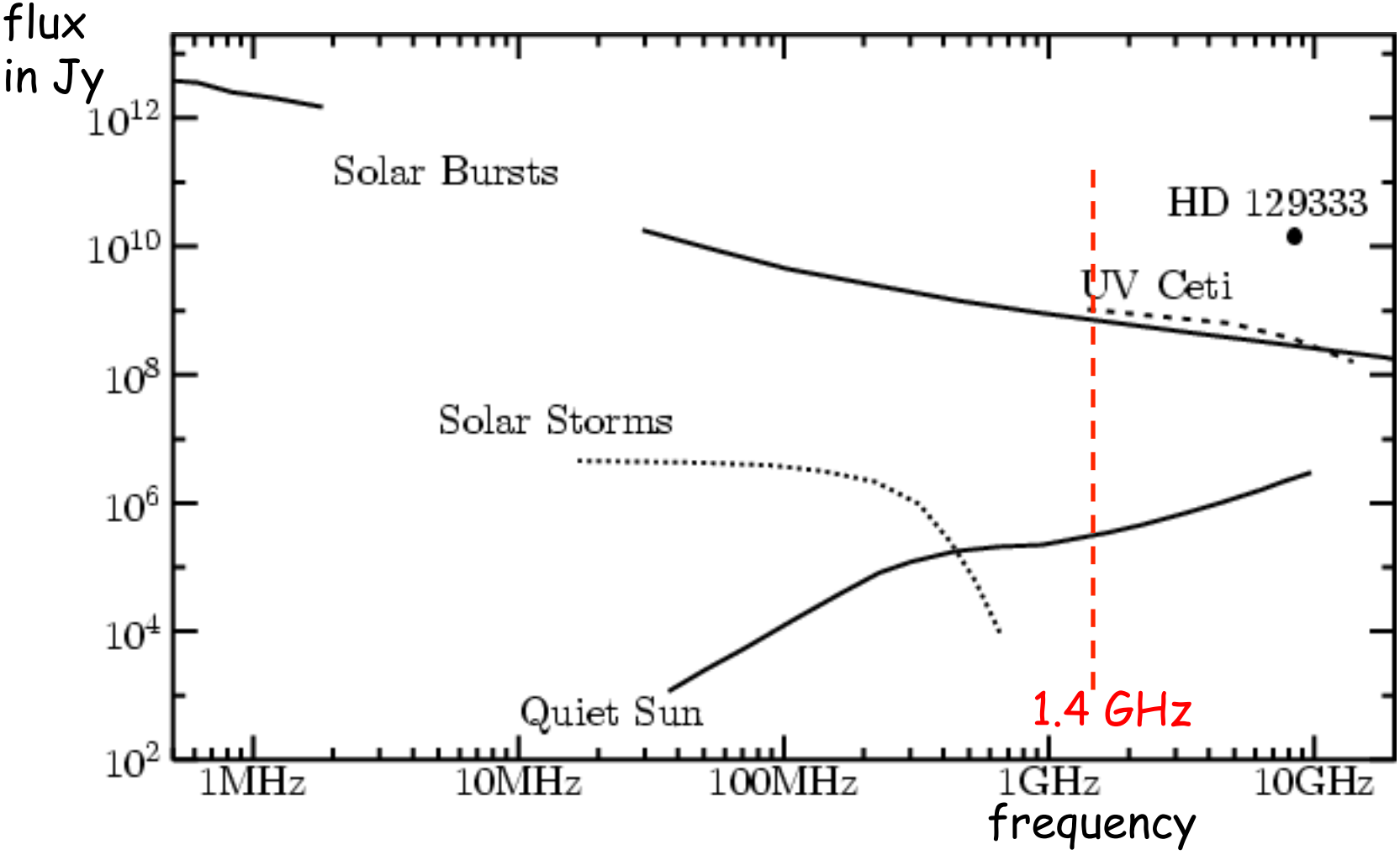
* All of them are late-type (G-K), high Galactic latitude (|b| > 30°)
* None of them is detected in X-rays (according to Simbad + VizieR)
* all have a steep nonthermal radio spectrum (→ magnetic phenomenon ?)
* all have a proper motion low enough not to argue against the optical ID
* radio sizes range from 0.03 to 0.07 pc (MUCH smaller than microQSOs)

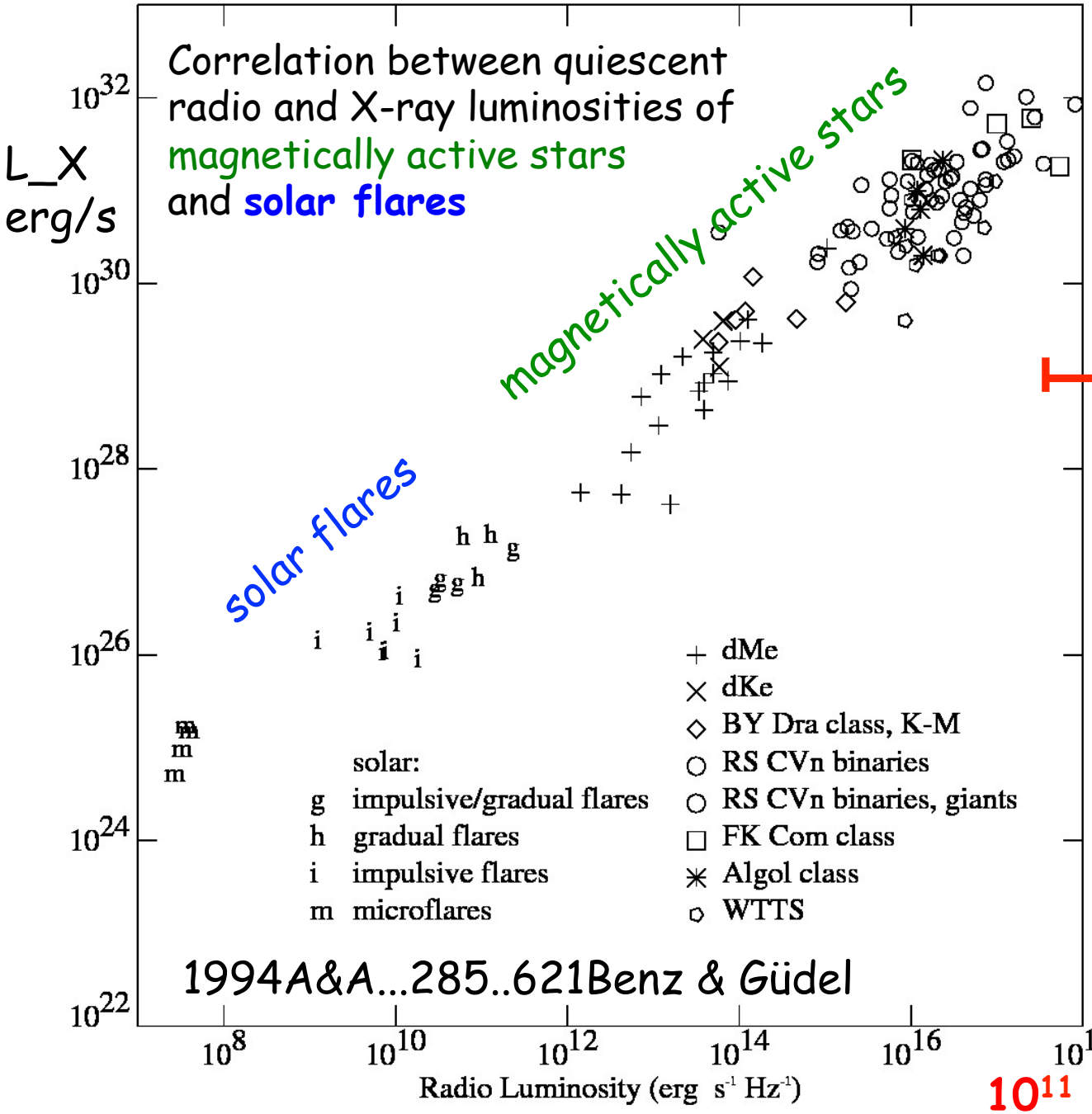
for comparison: radio lobes of UV Cet (dMe flare star at 2.6 pc distance) are separated by only 0.0036 AU !

How does this compare to the radio luminosity of the Sun ?

Solar 1.4-GHz flux: from ~10^5 (quiet) to ~10^9 Jy (burst)

➔ solar radio luminosity is $P_{1.4GHz}$ = 5 x 10^2 ... 3 x 10^6 W/Hz





our new double-lobed radio stars have $L_R \sim 10^{11} - 10^{12}$ W/Hz

but are not X-ray detected

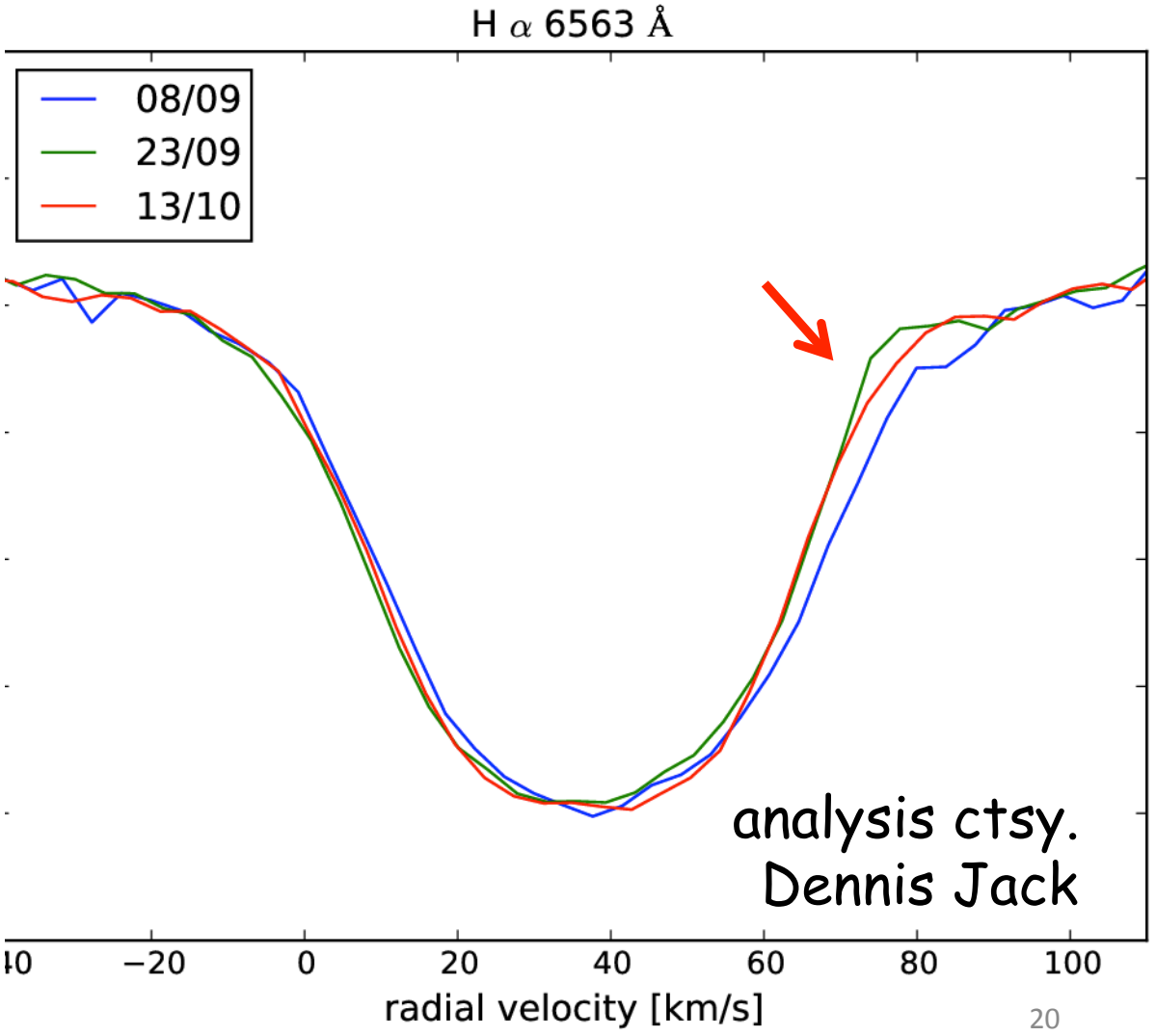
e.g. the microquasar 1E 1740.7-2942 has a radio lumin. of $L_{1.4} \sim 3 \times 10^{13}$ W/Hz

10^{11} W/Hz

Observations with TIGRE so far: only HD 4207 at 3 epochs:
8 Sept, 22/23 Sept, and 13 Oct. 2015

no systematic trend of radial velocity as yet, but the **shape** of the lines may have changed, perhaps indicating variable gas streams (hot gas rising, cold gas falling → superspicules or superturbulences ?)

Surprise: star is rather metal-rich, unexpected for its age and its high Galactic latitude b=−69° (z = 370 pc)



Conclusions

* Double-lobed radio sources with confirmed stars on major axis are frequent (so far ~20 good candidates; systematic searches cross-correlating large surveys are ongoing)

* More often the strongest lobe is closest to the star position

* Chance alignment is rather unlikely, but not excluded; find a faint extragalactic alternative optical ID is hopeless

* Common to all these stars :

- a steep" non-thermal radio spectrum (when available)
- not known to be variable or components of a binary system
- they are not listed in X-ray source catalogues
- tend to be of late type (F, G, K, M) at high Galactic latitude

Further work to be done:

- search for companion with high-resol. TIGRE spectroscopy
- find X-ray flux or upper limit to compare with Benz/Güdel plot
- radio variability ? → future, repeated radio observations
- is there a (faint) radio core ? → get higher-resolution radio images
- look for polarization, but would it allow to distinguish from RGs ?