An update on potential double-lobed radio stars

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TIGRE VII, Guanajuato, Mexico
08 November 2019

An update ...?   ... of two previous talks:

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

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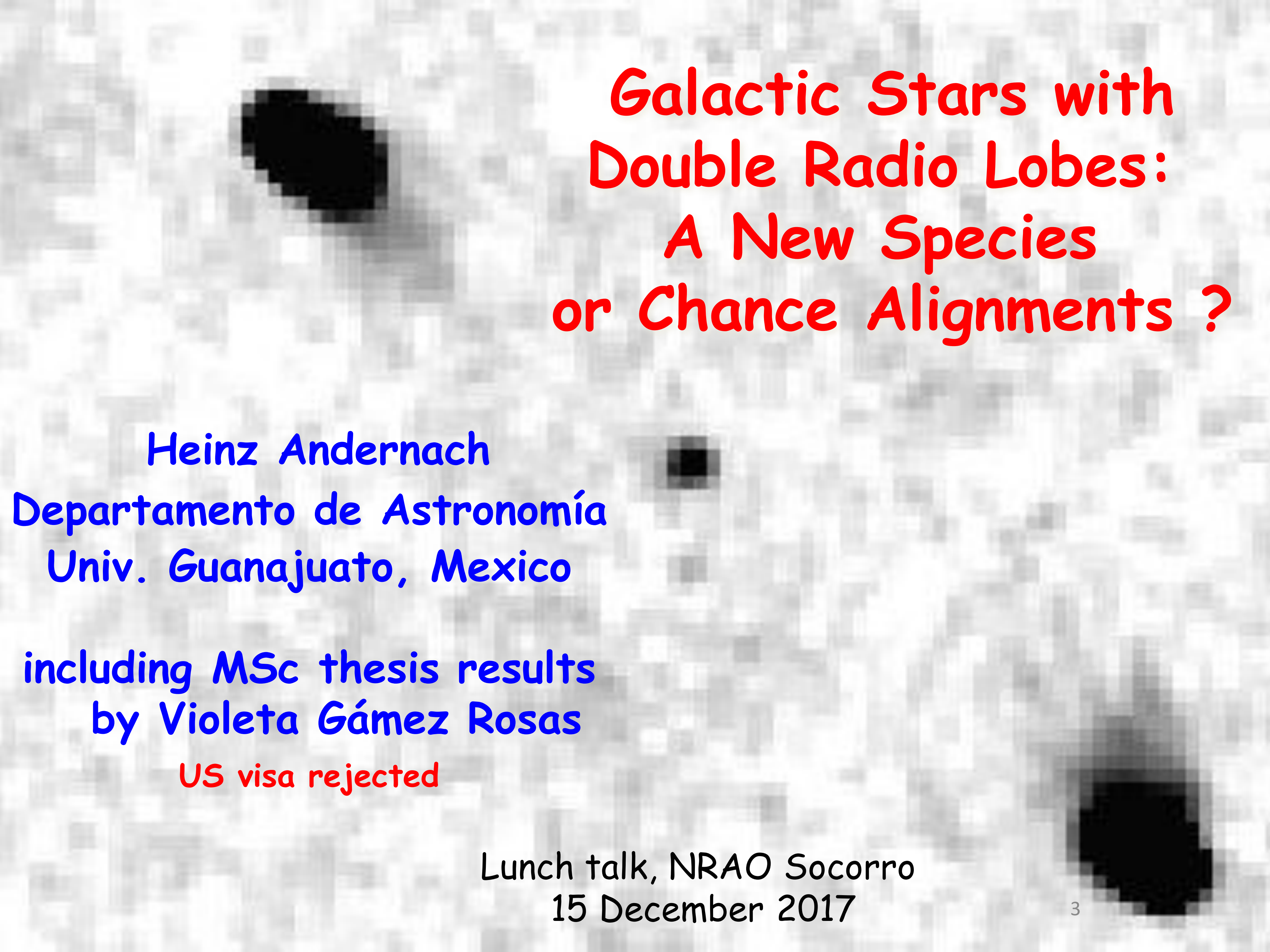
Departamento de Astronomía
Universidad de Guanajuato

4th TIGRE Workshop, Guanajuato, Mexico   31 November 2015



Galactic Stars with Double Radio Lobes: A New Species or Chance Alignments ?

Heinz Andernach
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including MSc thesis results
by Violeta Gámez Rosas

US visa rejected

Lunch talk, NRAO Socorro
15 December 2017

Til ~1960 "radio stars" = extragalactic sources !
First real radio-emitting star found only in 1978:

A radio flare in YZ CMi: 1978Natur.273..644Davis et al.
detected at 408 MHz (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I found an unpublished version of **March 2001** on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_neu num
~3700 stars, 1128 of these detected
(file was forwarded to CDS in June 2015, released late 2015,
sometimes cited as "Wendker 2015" , who died in 2008)

http://radio.galaxyzoo.org


GALAXY ZOO
RADIO

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In Search of Erupting Black Holes

Help astronomers discover supermassive black holes observed by the KG Jansky Very Large Array (NRAO) and the Australia Telescope Compact Array (CSIRO)

Search for Black Holes

Black holes are found at the center of most, if not all, galaxies. The bigger the galaxy, the bigger the black hole and the more sensational the effect it can have on the host galaxy. These supermassive black holes drag in nearby material, growing to billions of times the mass of our sun and occasionally producing spectacular jets of material traveling nearly as fast as the speed of light. These jets often can't be detected in visible light, but are seen using radio telescopes. Astronomers need your help to find these jets and match them to the galaxy that hosts them.

The motivation for this topic derived from a project totally unrelated:

Radio Galaxy Zoo (RGZ)
Citizen scientist project to help optically identify ~200,000 extended radio sources in the VLA FIRST survey
(1.4 GHz, resol. 5.4″, ~14,000 deg^2

- launched on Dec. 17, 2013
- **shut down on May 1, 2019**

achieved ~80% of its goal

The users are invited to place doubtful/interesting objects on a discussion page : "radiotalk"

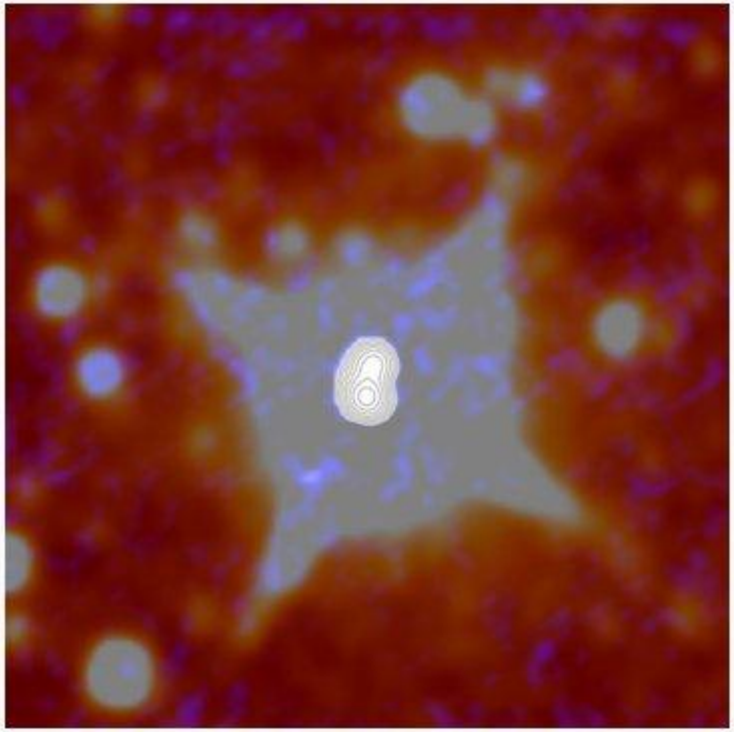
Example:
in 2 years
the ~5000
volunteers
found ~160
new giant
radio galaxies
(> 1 Mpc in
projected size)

but occasionally
. . .

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

→ no way to
identify the
host galaxy
or quasar

Image ARG000152f



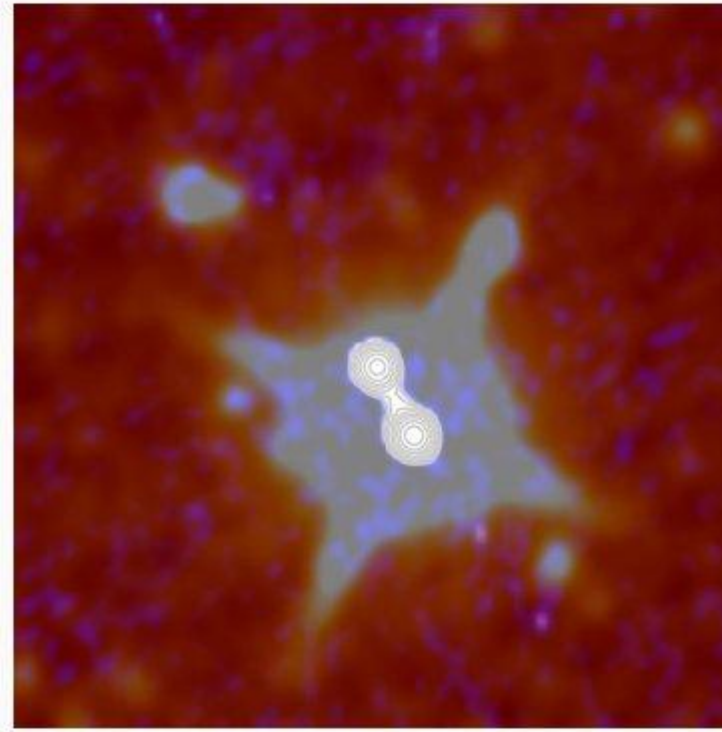
Survey Id:	FIRSTJ082108.4+402059
RA:	125.285
Dec:	40.350
FIRST	
NVSS	
SDSS	
WISE	

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

#star

by bfrink 7 months ago

Image ARG0002wdc



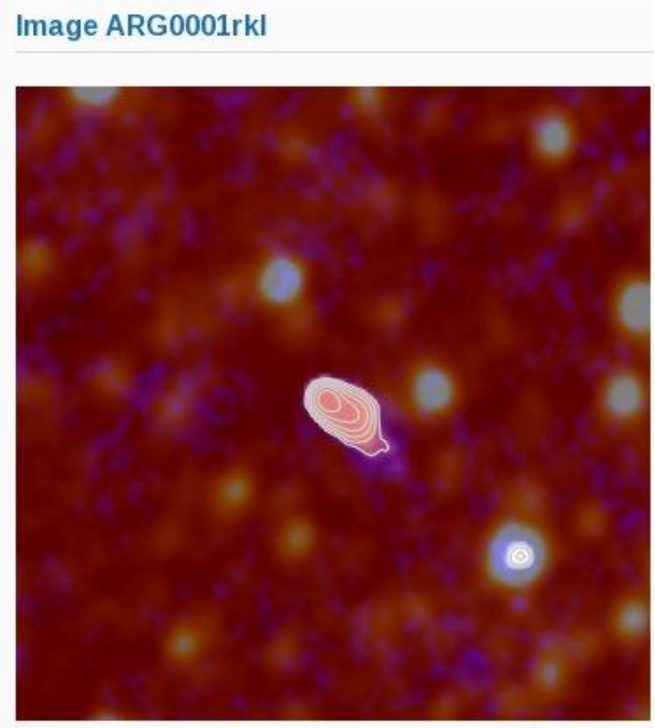
Survey Id:	FIRSTJ095907.8+115901
RA:	149.782
Dec:	11.984
FIRST	
NVSS	
SDSS	
WISE	

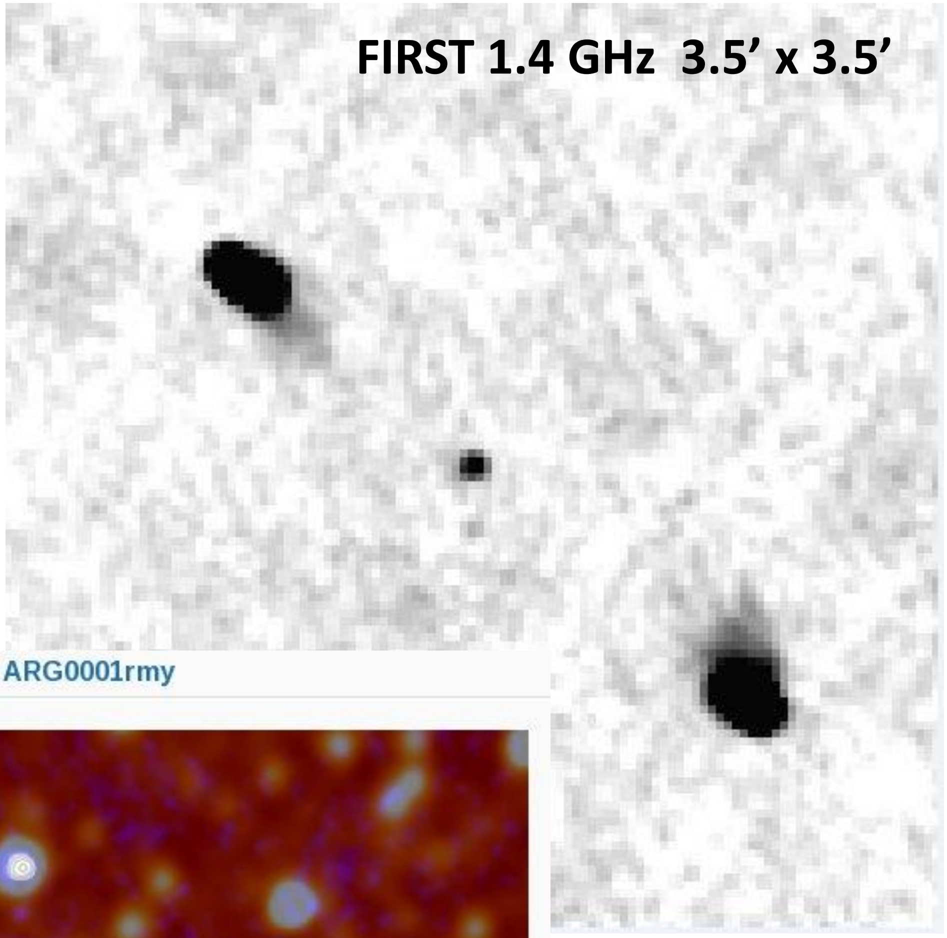
Tyc 832-540-1
V = 10.2 B= 11.3

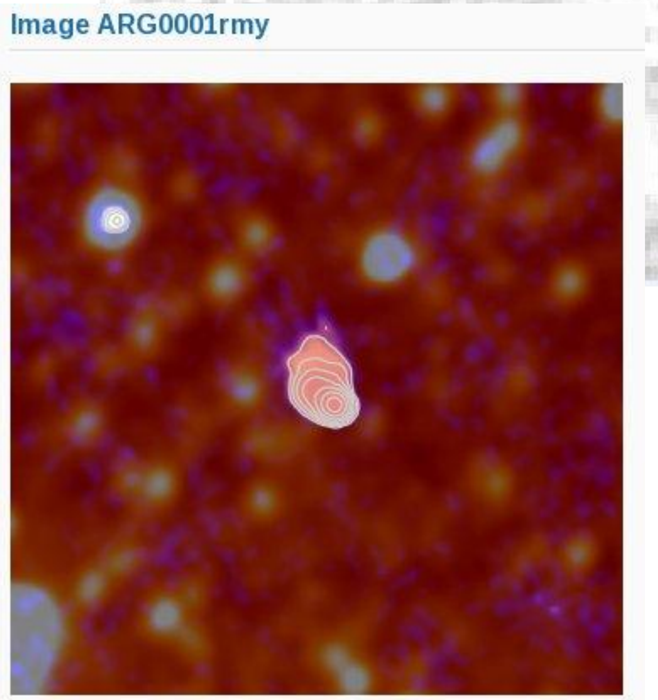
#hourglass #star preventing basically any more future observations...

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

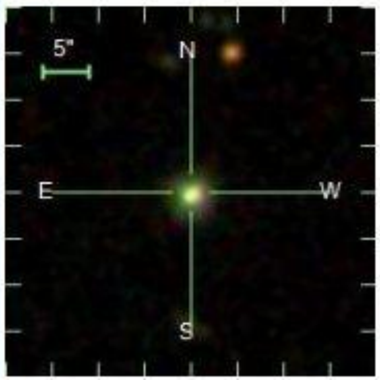
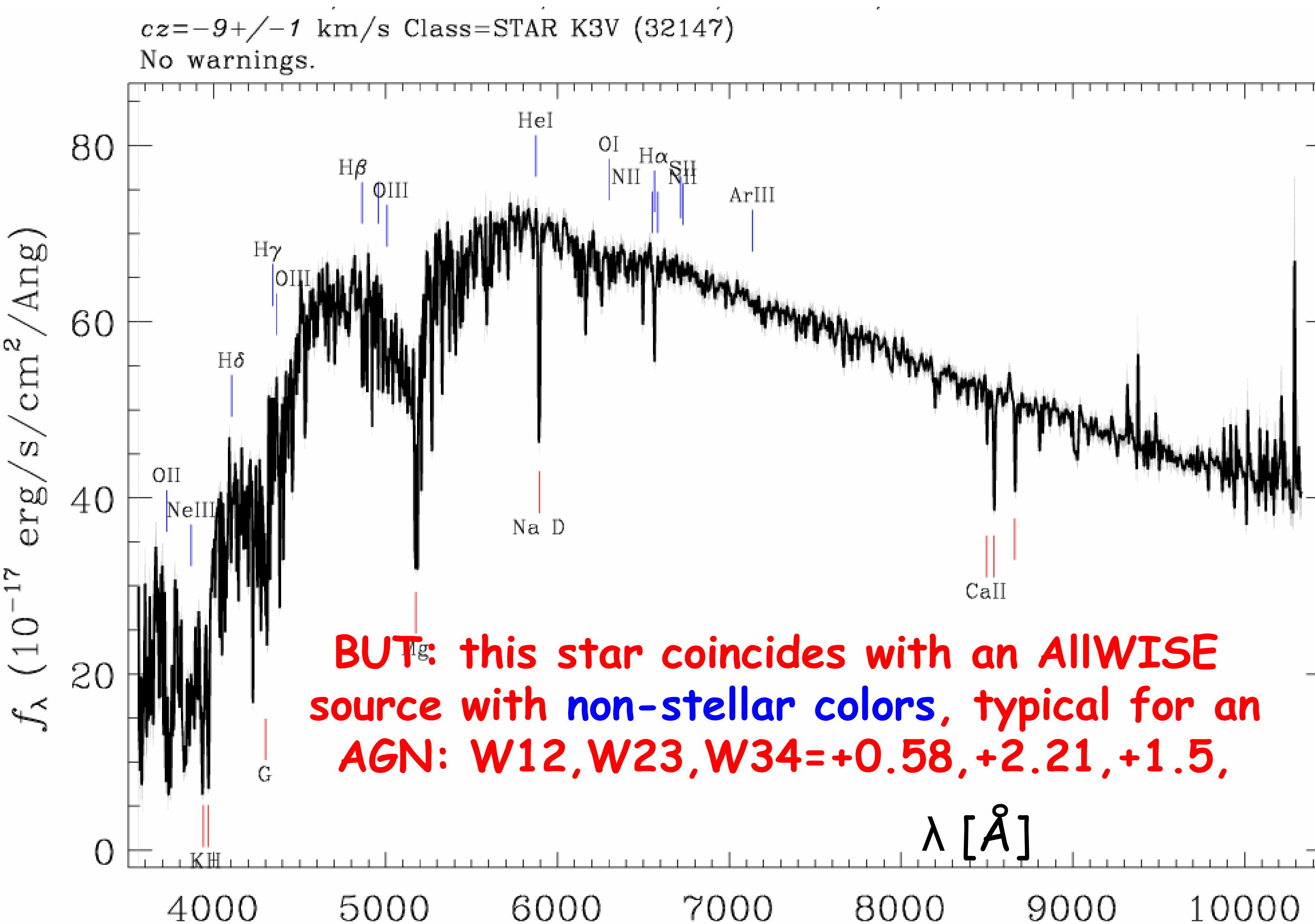


Image MJD	mode	Other observatio
52705	PRIMARY	2

Mjd-Date	photoZ
03/07/2003	



BUT: this star coincides with an AllWISE source with non-stellar colors, typical for an AGN: W12,W23,W34=+0.58,+2.21,+1.5,

Previous "unbiased" searches of radio stars in large surveys

VLA FIRST (1.4 GHz, 5.4"beam, ~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

2019RNAAS...3...37Callingham+ cross-match ~267,000 radio sources from LOFAR with Gaia DR2 → ~11,700 matches, but **none is likely real**

However, these authors exclude any double radio sources and sources offset by >1 arcsec from the star position

➔ are there known stars with double-"lobed" (jetted) radio emission ?

Yes (but not for "normal" stars like those found in RGZ) :

A) microquasars!

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

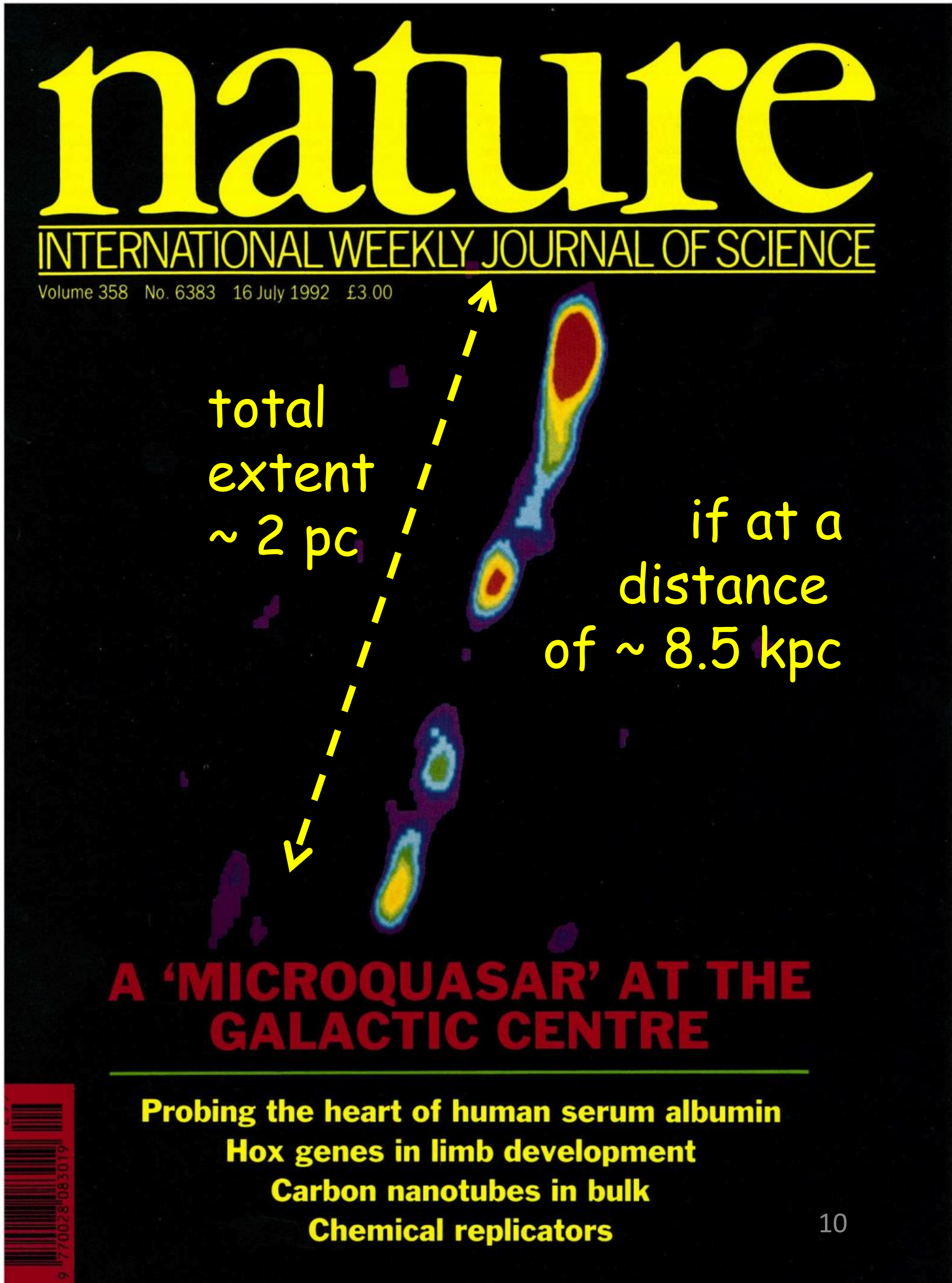
Examples:	distance
GRS 1915+105	~12 kpc
GRO J1655-40	3.2 kpc
Cyg X-1, SS 433 . . .	

All are either low-/high-mass X-ray binaries close to the Galactic plane; one component is a black hole or neutron star

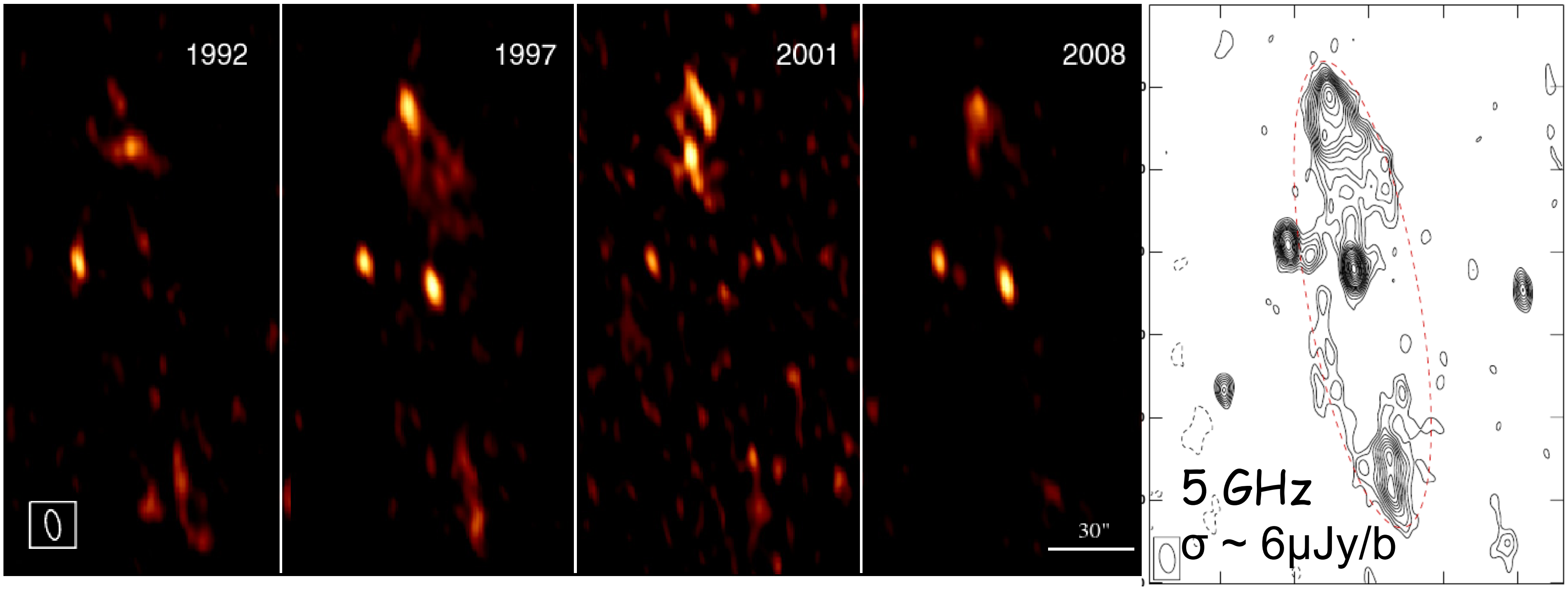
some show superluminal expansion → v_{bulk} <~ c

B) Herbig-Haro / YSO's

➔ **neither A) nor B) are similar to "our" stars ...**



Time evolution of jets and lobes of microquasar GRS 1758-258
no optical ID, dist ~ 8.5 kpc assumed (2015A&A...578L..11Marti et al.)



Time evolution of the GRS 1758−258 extended radio jets as observed with the VLA interferometer at the 6 cm wavelength (4.8 GHz) over years (1992–2008) with nearly identical angular resolution. North is up and east to the left. The horizontal bar at the bottom right corner he angular scale. The interferometric synthesized beam is 10.″50 × 4.″75, with position angle of 10° (bottom left ellipse). The vertical bar provides a linear brightness scale in units of μJy beam^{-1}. The rms background noise is 10, 10, 19 and 8 μJy beam^{-1} for the 1992 to ames, respectively. The two variable point sources are the GRS 1758−258 central core and an unrelated object about 25″ to the east of it.

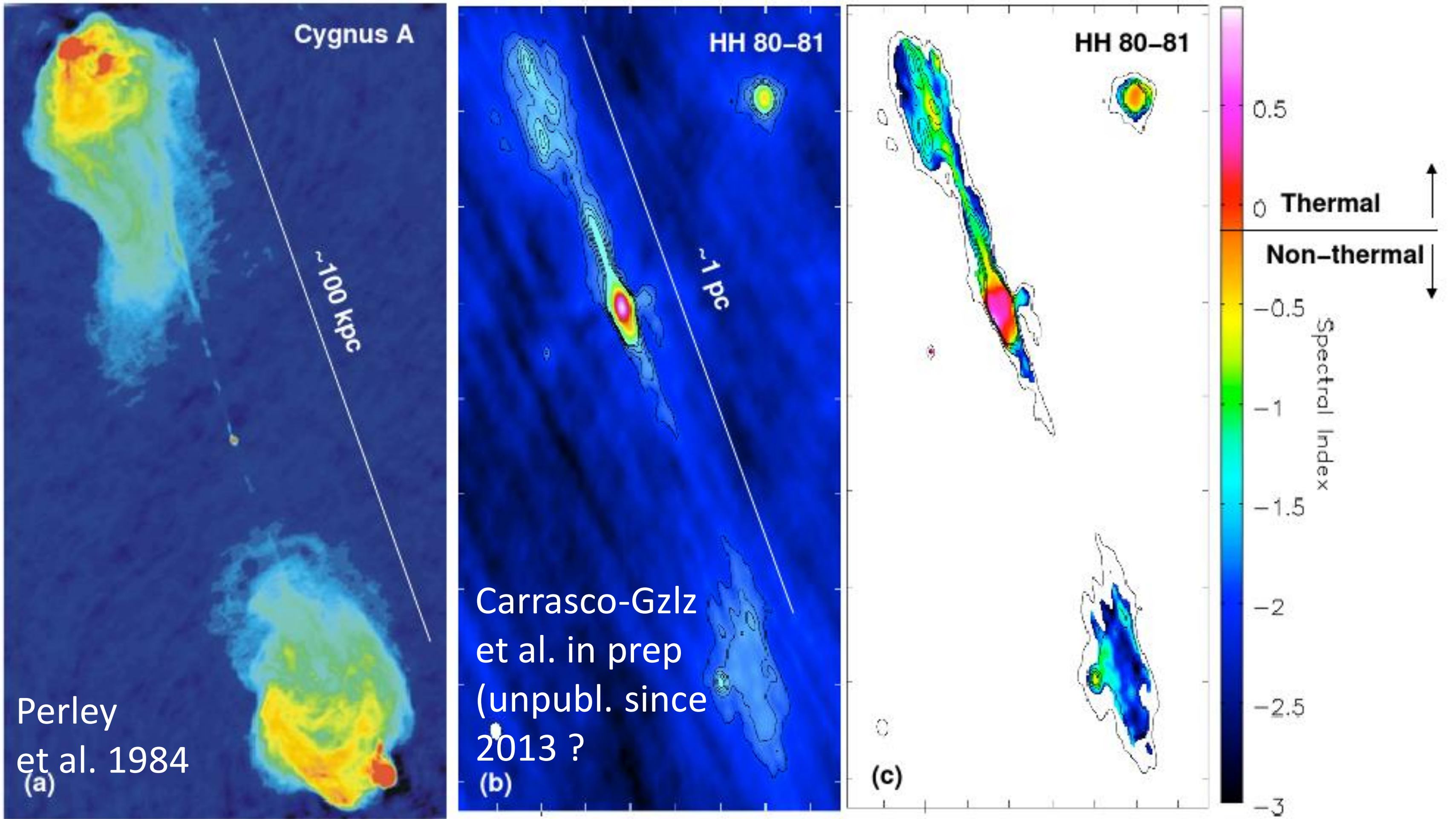
total on-source time ~19 hours with VLA 5 GHz

Discovery of synchrotron emission from a YSO jet

EPJ Web of Conferences **61**, 03003 (2013)

Carlos Carrasco-González[1,2,a], Luis F. Rodríguez[2], Guillem Anglada[3], Josep Martí[4], Jose M. Torrelles[5], and Mayra Osorio[3]

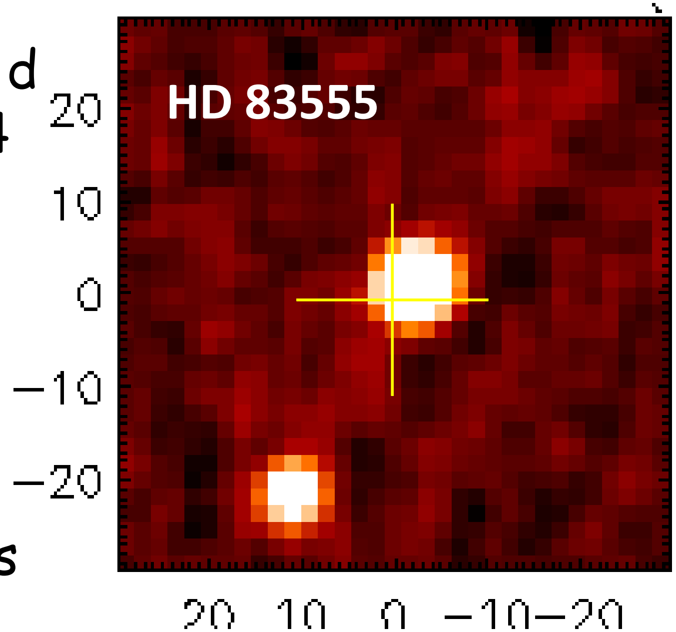
First proof of B field + relativistic particles in slow YSO jets

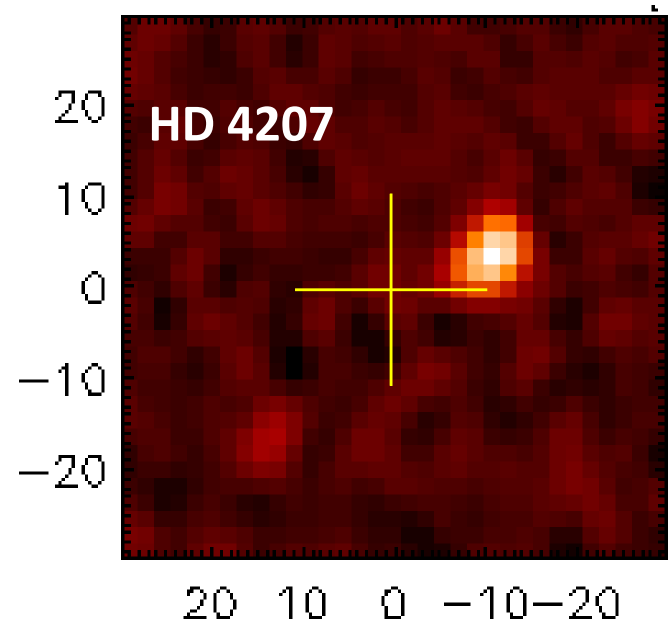


Comparison between Cygnus A and HH80-81

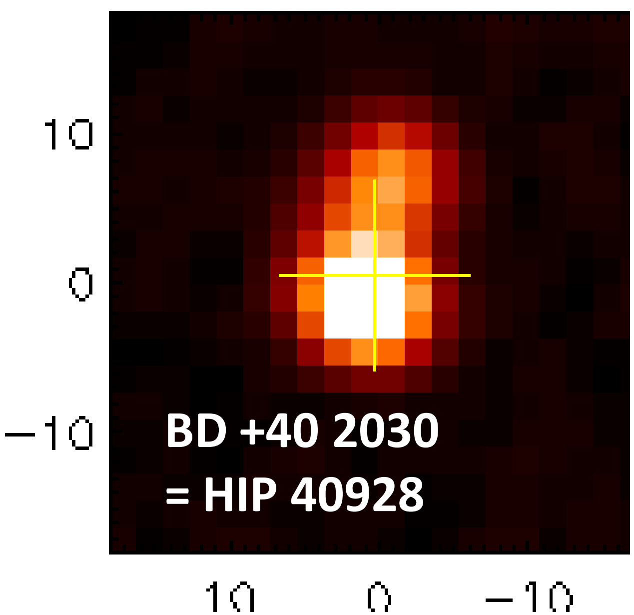
In 2015 I cross-id'd the SAO and UCAC4 star catalogues for V < 12 mag to search for FIRST double sources within ~30″

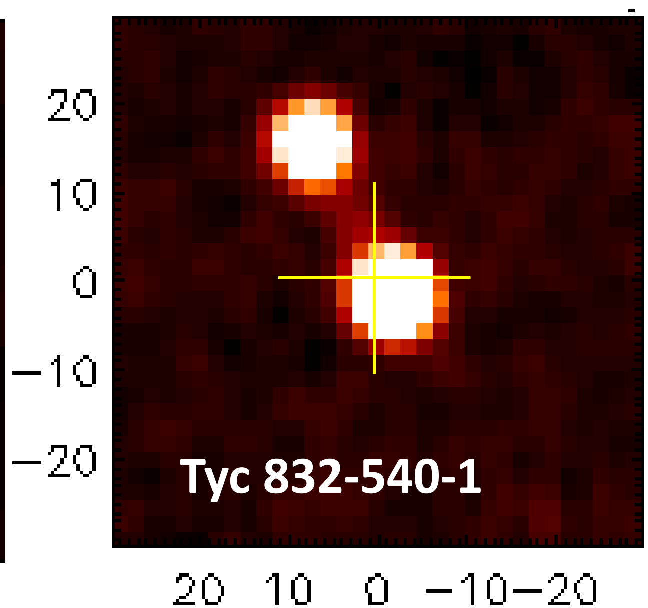
➔ found 5 examples

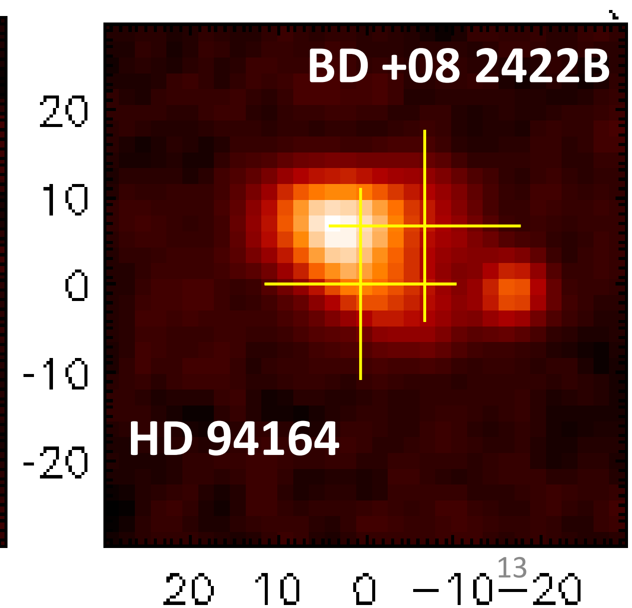




None of them had a published spectrum, only 1 had a published RV; V~ 11 mag is just about bright enough for a TIGRE spectrum !







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 Al ... ch ... ources st ... Q, U, ar ... nd in ... ot ...

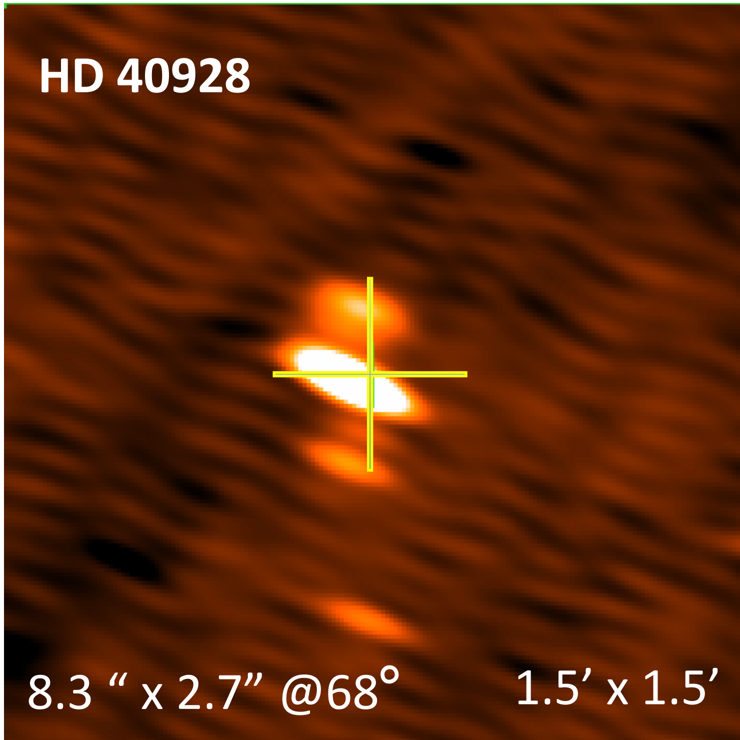
Low-resolution NVSS radio survey (45", 1.8 million sources) was used to find candidate radio stars... Results only appeared as an abstract : 1997AAS...191.1402Condon, Kaplan & Yin

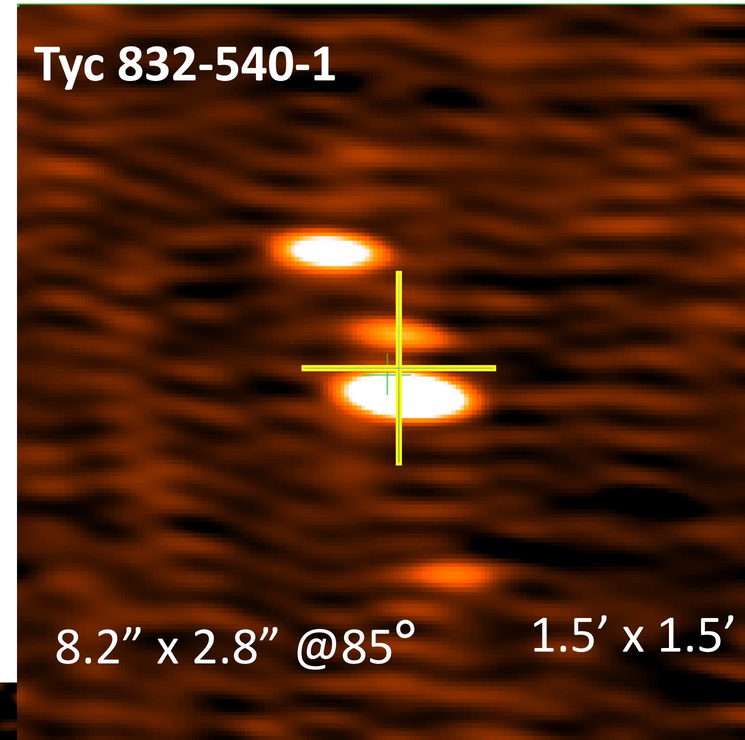
uncertain candidates on the basis of position coincidence. At least 50 radio stars were found, most for the first time. They exhibit a range of radio spectra, angular sizes, and polarizations indicating a variety of emission mechanisms. We are following these stars with high-resolution optical spectroscopy.

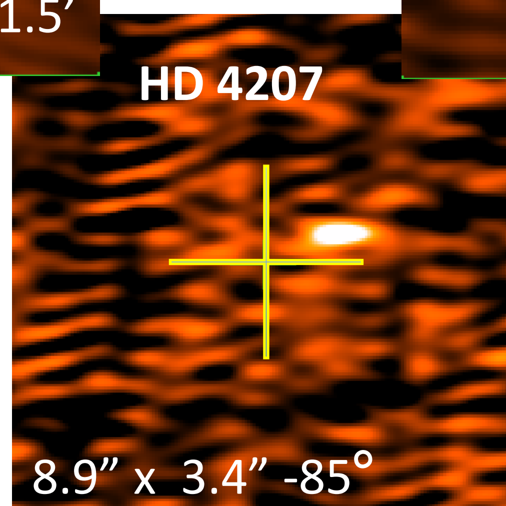
They observed ~100 candidates at 1.4 and 8.4 GHz with the VLA, confirming 50 new radio stars, but results were never published. We downloaded the archive data and J. M. Masqué (DA-UG) has reduced them; our analysis is in progress ... **see later in this talk**

But what about radio stars with double radio lobes ?

8.4-GHz radio images from VLA archive (AC0496, Condon+ 1997)
D configuration snapshots very elliptical beams







Images do NOT suggest a physical association with the stars; radio spectra steepen to $\alpha < -1.1$ beyond 5 GHz

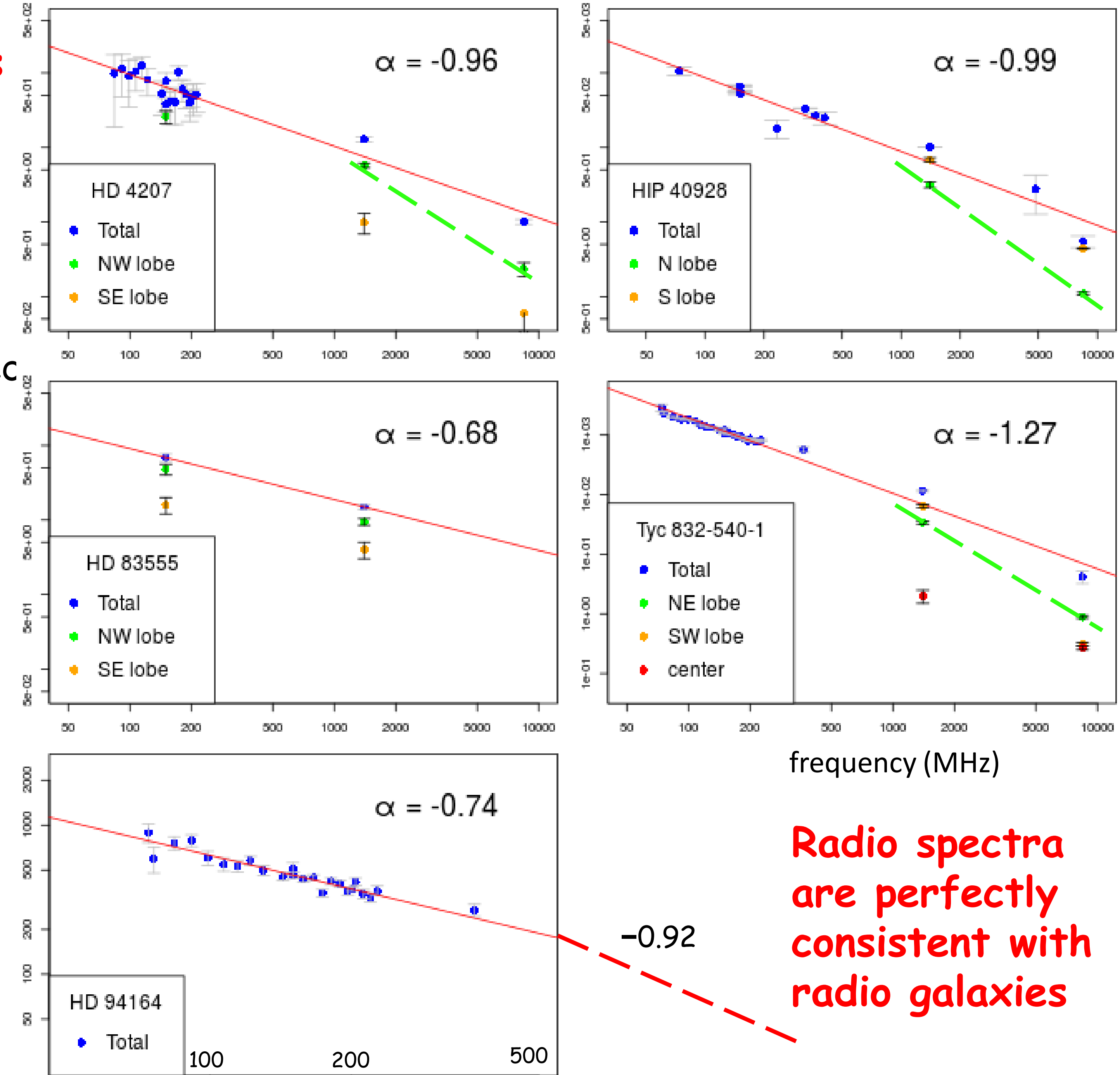
NOTE: crosses are not from Gaia, nor corrected for observing epoch !

from MSc thesis Violeta Gámez Rosas

Radio spectra based on fluxes from the CATS service at cats.sao.ru

3 “stars” detected in GLEAM survey
→ dense low-freq. coverage

those observed at 8.4 GHz show a strong steepening above ν ~ 1.4 GHz



Radio spectra are perfectly consistent with radio galaxies

What is the probability of these being chance alignments ?

How many stars per deg^2 out to V~11 mag at |b| > 30° ?
→ made star counts in UCAC4 in VizieR (CDS) → ~10 stars deg^{-2}

How many double radio sources are there in FIRST ?

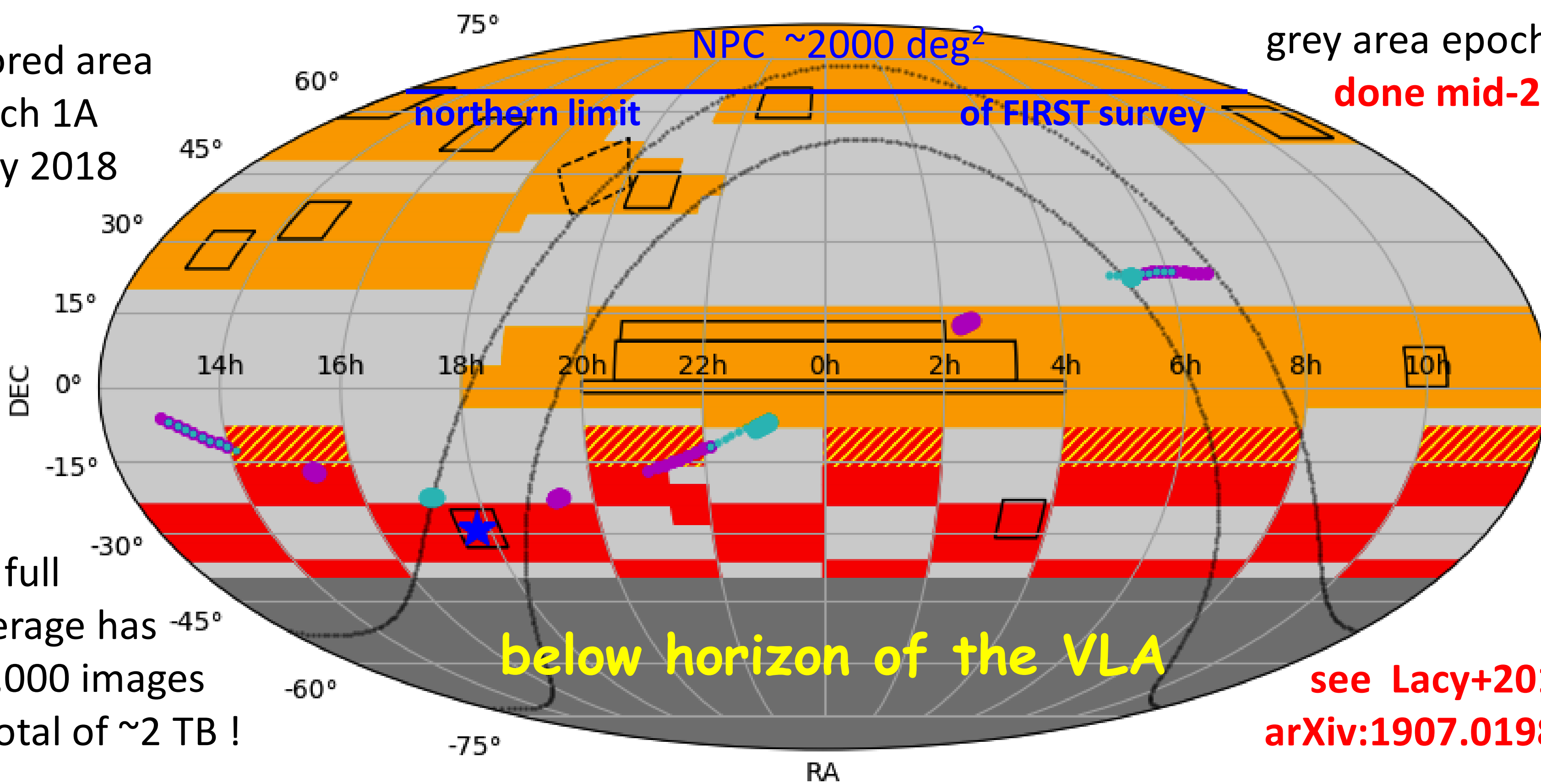
2015MNRAS.446.2985VanVelzen+ 50,000 doubles (10"–50") in 10575 deg^2
2011ApJS..194...31Proctor : 74,788 doubles (<60" sep.)
applying same criteria as found for the 5 TIGRE stars
(sep <25", flux ratio < 8, S_{total} 5–500 mJy, P(S)<0.5) → ~40,000 doubles
within a rectangle of 5" x 30", we have a total area of
40,000 x 5" x 25" = 0.5 deg^2 within which 0.5 x 10 ~ 5 stars
would be expected at random ➔ **coincidences consistent with random**
(One can tweak the above numbers but there's no way to get far below a few per cent to confirm real associations)

TIGRE spectra were obtained from Sept 2015 to April 2017
➔ no detectable variation of radial velocity ➔ not close binaries
➔ all 5 stars are evolved (F,G,K) and have left the main sequence
➔ this is **NOT a random selection** of high-latitude stars
(expect ~90% main sequence stars at random)

Sept. 2017: VLA Sky Survey (VLASS) started . . .

Survey of entire sky with DEC > –40° ➔ 82% of sky (~34,000 deg^2)
using the VLA at S-band (2–4 GHz) in its B configuration,
first time VLA is used with new technique: "on-the-fly" (OTF)
six observing epochs 1.1, 1.2, 2.1, 2.2, 3.1, 3.2 (2017–2024)
angular resolution 2.5" ; σ per epoch ~0.12 mJy/b, σ_{final} ~ 0.07 mJy/b
release Quicklook (QL) images (1 deg^2) within weeks of observations

colored area epoch 1A early 2018

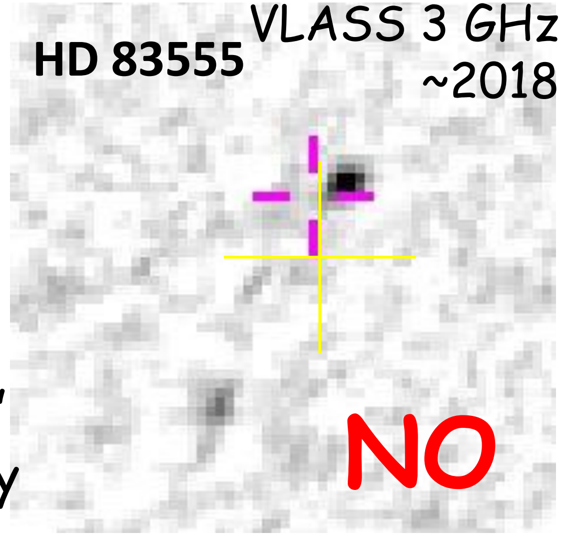


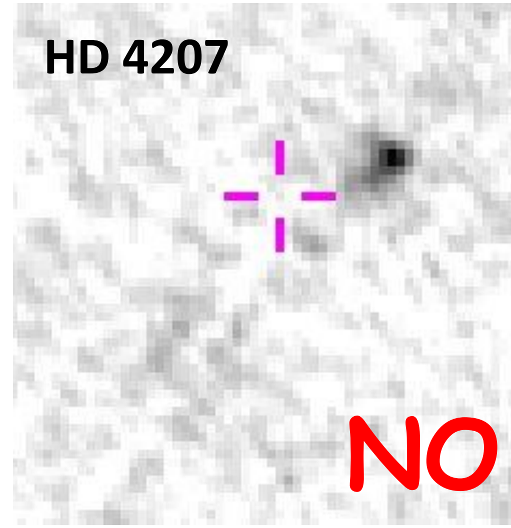
grey area epoch 1B **done mid-2019**

one full coverage has ~35,000 images → total of ~2 TB !

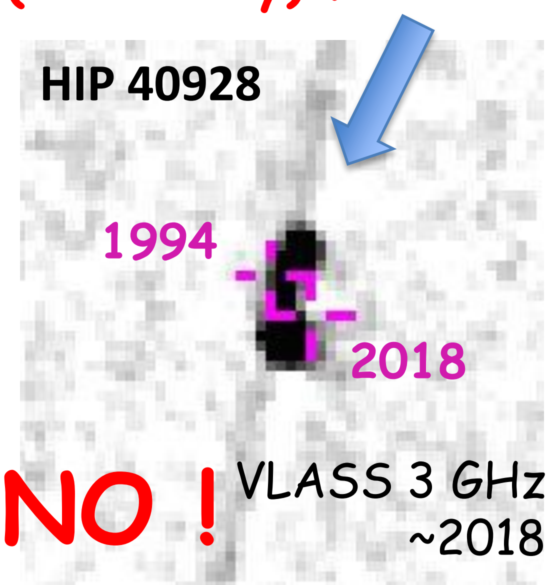
see Lacy+2019 arXiv:1907.01981

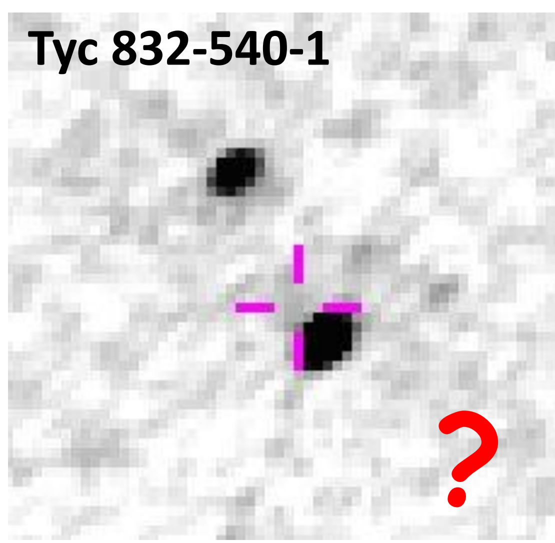
Our 5 TIGRE stars at 2x better angular resolution (2.5”) → red crosses mark the Gaia DR2 positions on a VLASS 3-GHz image
NOTE: QL still has ~1” astrometric uncertainty

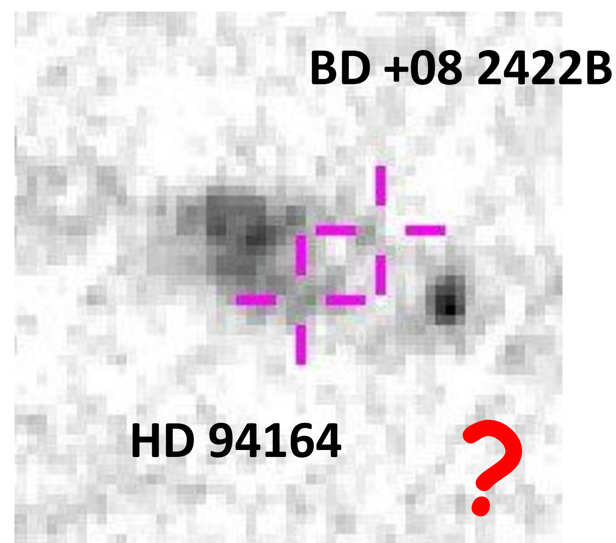




Only HIP 40928 has PM high enough (~5” in 20 yrs) to pass over the (stationary) FIRST & VLASS sources (24 yrs time difference)







Inspection of radio star samples from literature

Wendker 2001 Of all 3699 stars in his radio star compilation, only 58 have a FIRST source within 60" but inspecting these, we found no single double source straddling the star position

Kimball et al. 2009 inspection of some of the 76 resolved radio sources shows that up to 50% may be identified with background objects, (VLASS images not yet inspected)

Flesch 2016 (MORX) lists 67 starlike objects with double radio lobes within 2' from the "stars"; the majority can be identified with known types of sources (e.g. PNs, background AGN) except very few that remain genuine candidates

An independent way to assess the presence of non-stellar hosts :
WISE colors: W12= W1−W2 and W23 = W2−W3
→ background AGN may outshine a foreground star if the star is "not too bright" (perhaps V > 15 mag)

Further searches for radio doubles in large spectroscopic samples

During 3 summer internships (2015 – 2017)
a few additional candidates were found

2015: Marco A. Jimenez wrote a code to find radio doubles symmetrically placed around stars: applied to 2MASS vs. FIRST

2016:

arXiv.org > astro-ph > arXiv:1610.02572

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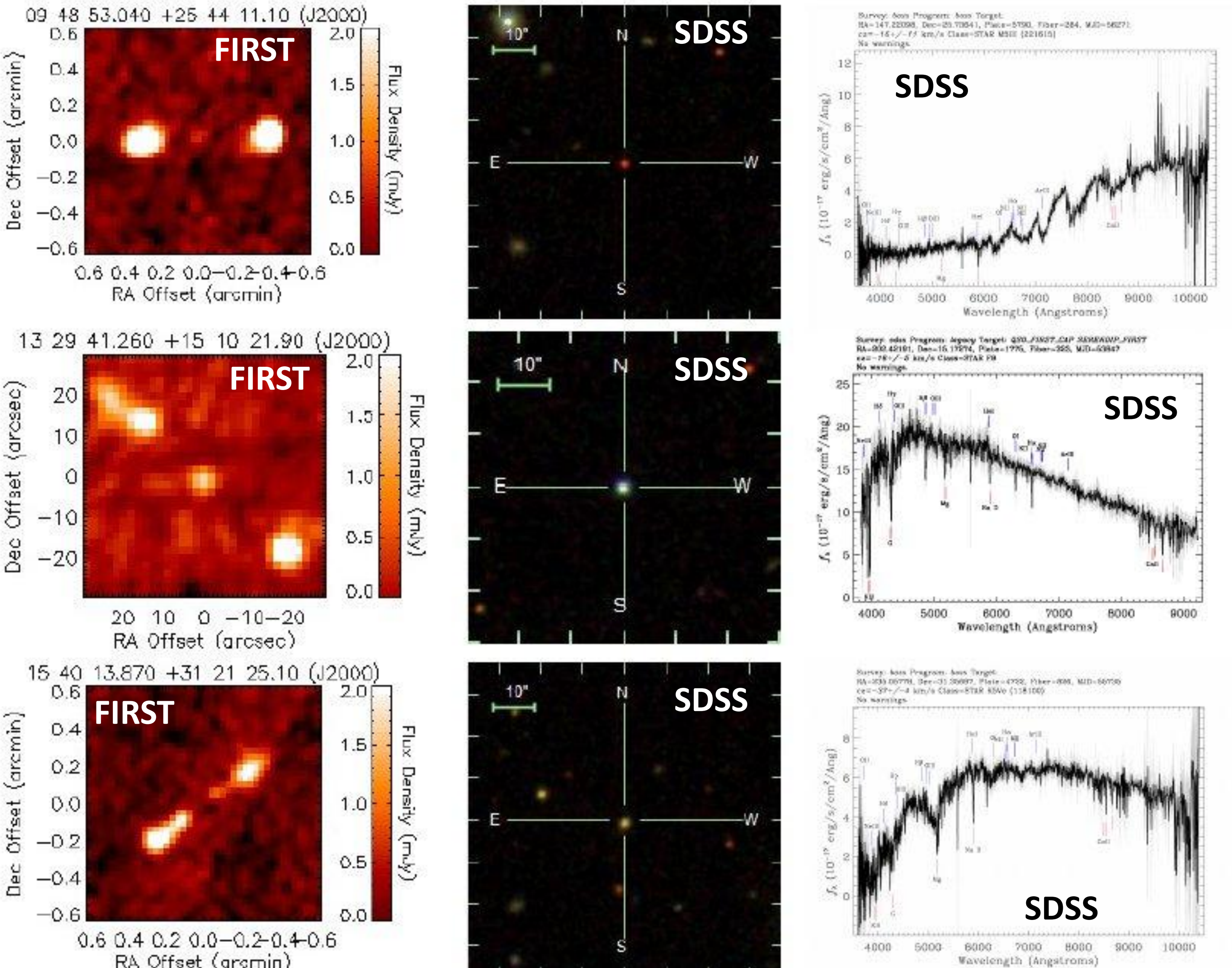
Astrophysics > Astrophysics of Galaxies

A Search for double-lobed radio emission from Galactic Stars and Spiral Galaxies

Abiel Felipe Ortiz Martínez, Heinz Andernach

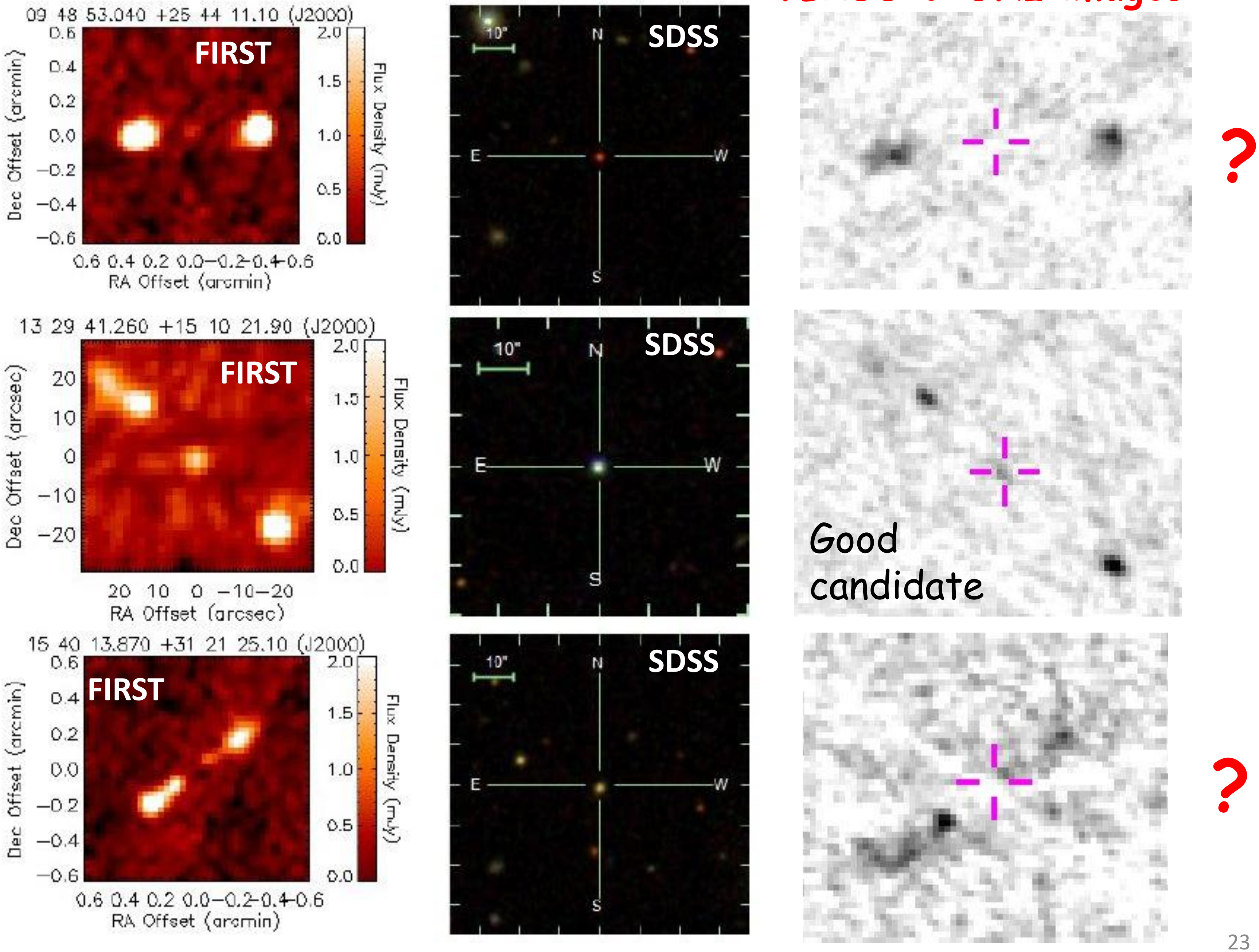
(Submitted on 8 Oct 2016)

Checked 878,000 spectroscopic stars from SDSS for presence of radio sources placed on opposite sides of the star.
Found only 3 potential candidates



09 48 53.040 +25 44 11.10 (J2000)
FIRST
Dec Offset (arcmin)
RA Offset (arcmin)
Flux Density (mJy)
SDSS
10"
N
E
W
S
SDSS
Wavelength (Angstroms)
13 29 41.260 +15 10 21.90 (J2000)
FIRST
Dec Offset (arcsec)
RA Offset (arcsec)
Flux Density (mJy)
SDSS
SDSS
15 40 13.870 +31 21 25.10 (J2000)
FIRST
Dec Offset (arcmin)
RA Offset (arcmin)
Flux Density (mJy)
SDSS
SDSS

VLASS 3-GHz images



2017: checked 2.5 million from Chinese LAMOST survey
→ found four promising candidates

arXiv.org > astro-ph > arXiv:1712.02920

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Astrophysics > Astrophysics of Galaxies

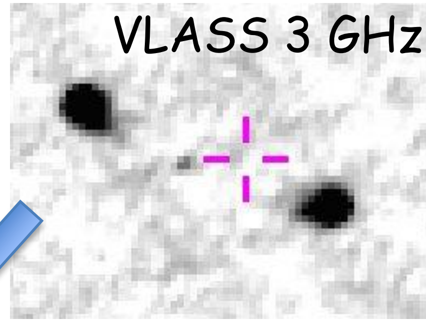
A Further Search for Galactic Stars with Double Radio Lobes

Braulio Arredondo Padilla, Heinz Andernach

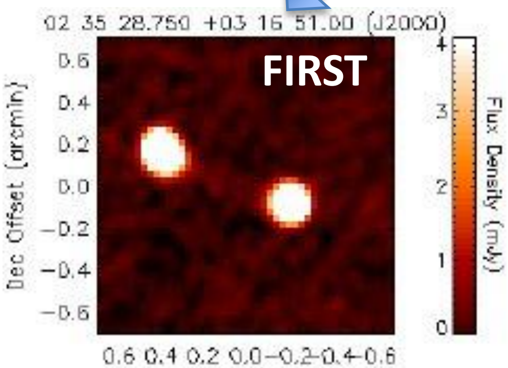
(Submitted on 8 Dec 2017)

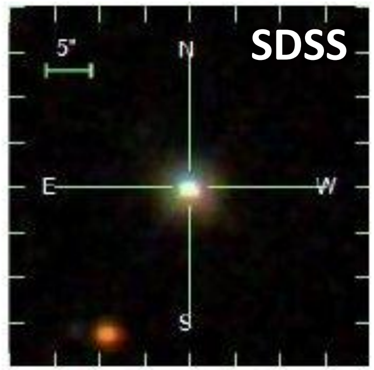
Over a thousand stars in our Galaxy have been detected as radio emitters, but no normal stars are known to possess radio-emitting lobes similar to radio galaxies. Several recent attempts by us and other authors to find such objects remained inconclusive. Here we present a further search for double-lobed radio stars in two large samples of spectroscopic stars: over 20,000 white dwarves from the Sloan Digital Sky Survey (SDSS) DR12, and 2.5 million stars from the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST). These

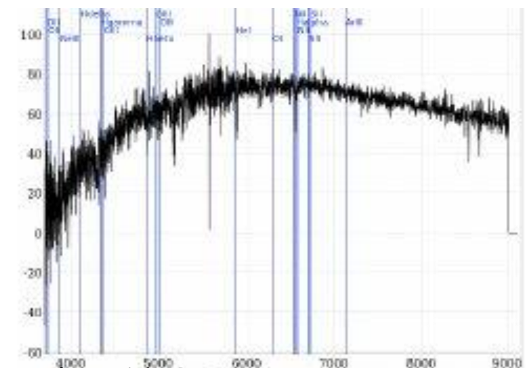
Thanks to VLASS
→ two discarded candidates



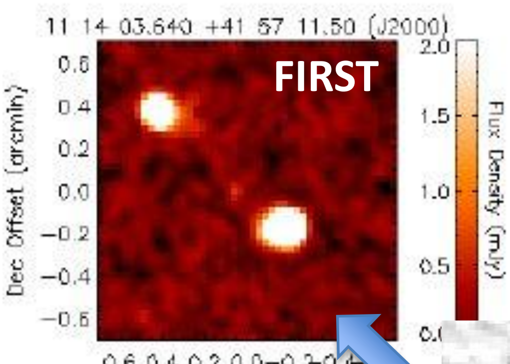
Star is displaced ~9″ W of the apparent radio nucleus

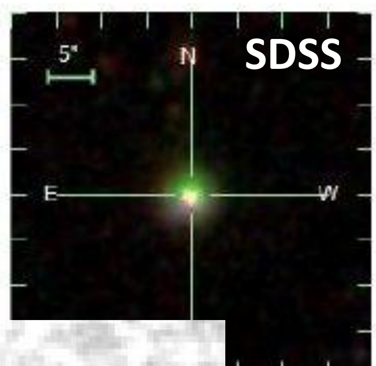


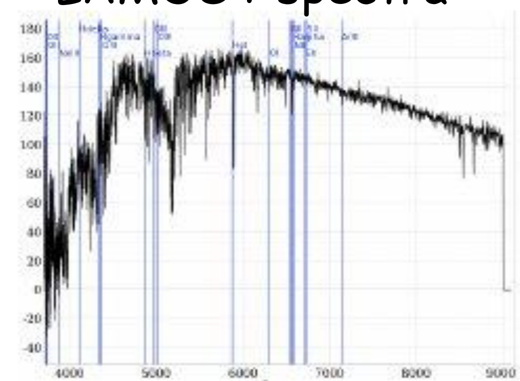


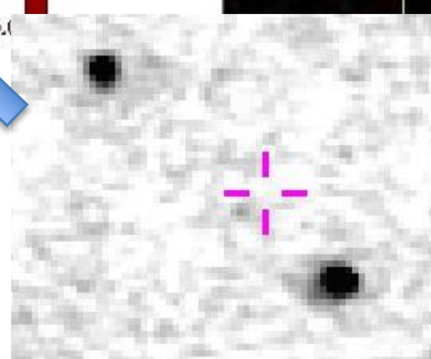


LAMOST spectra



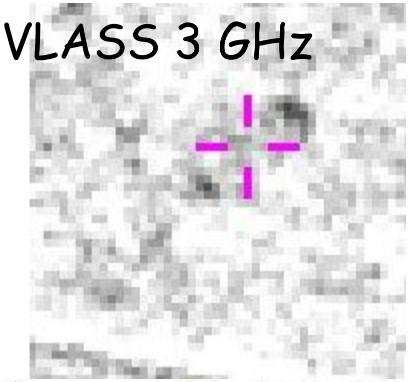




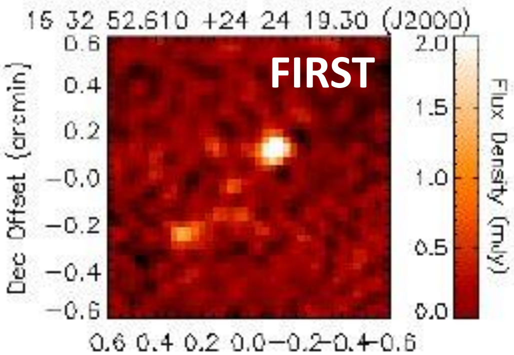


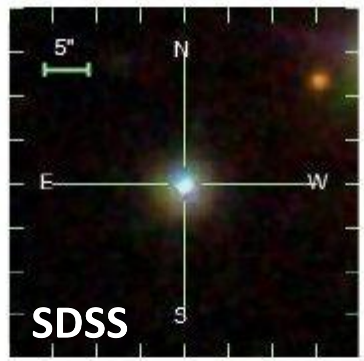
Star is displaced ~3″ NW of the apparent radio nucleus

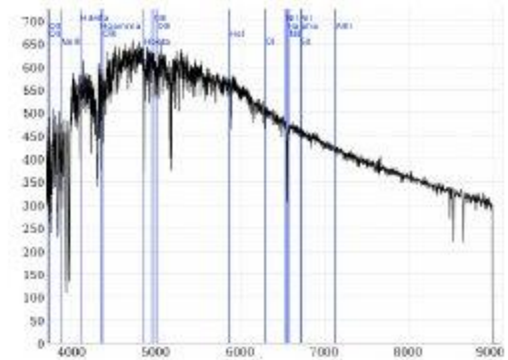
Another two discarded candidates



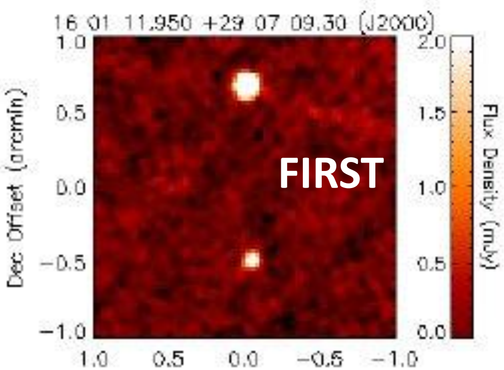
The star is accidentally superposed between the core and the NW lobe

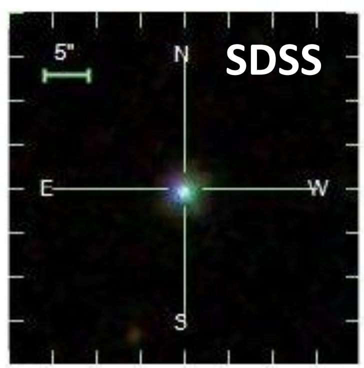


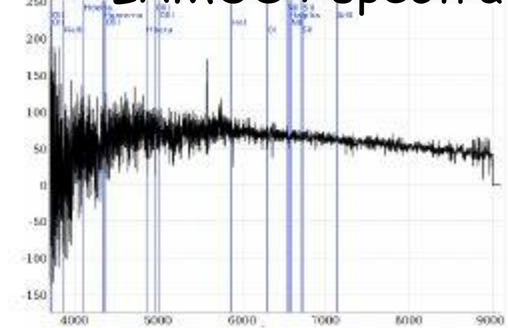




LAMOST spectra







No radio core detected... neither in VLASS,
→ star very likely superposed on the radio axis,
the real host must be very faint

The **most secure results** from the latter 3 searches:

2016: Radio emission coincident with an object classified in SDSS with a spectroscopic star is an efficient method to find **misclassified optical spectra in SDSS**

2017: LAMOST DR3 (with 4.8 million spectra) may have ~17 % (> 800,000) **wrongly classified spectra**, based on 46,627 cross-matches with 5.8 million SDSS objects: 7875 (~17%) are correctly classified as galaxies or QSOs in SDSS

2019: LAMOST DR5 (9 million spectra)
cross-match with my own radio galaxy compilation (~10^4 RGs)
→ 28 (~7%) of 416 matches misclassfied as stars!

I confirmed this problem in the last few days with another list of "radio stars" with LAMOST spectra . . .

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http://www.raa-journal.org *http://iopscience.iop.org/raa*

Research in Astronomy and Astrophysics

2017RAA....17..105Zhang L.-Y.+

Radio stars observed in the LAMOST spectral survey

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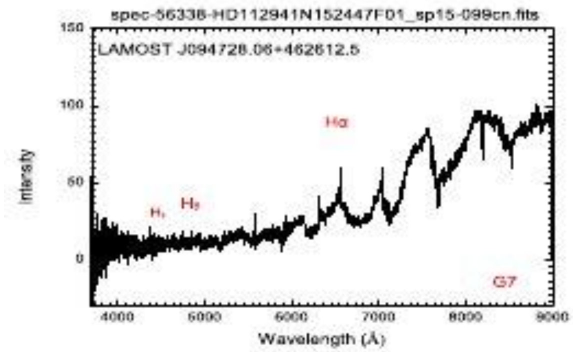
* claims LAMOST spectra for 659 “radio stars”, but lists ~1600 stars
* listed positions differ by up to ~30″ from the stars
* does not explain how the stars were cross-matched with radio sources
* I looked at **43 objects** with at least 2 more FIRST sources in approx. opposite directions of the stars

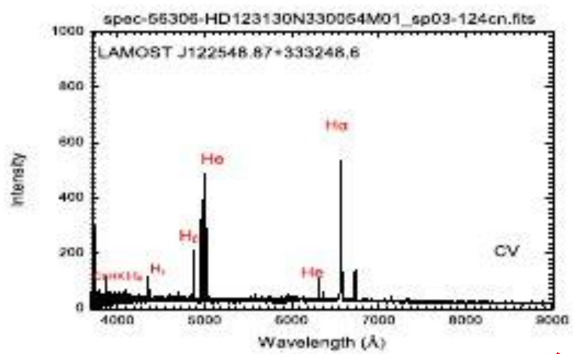
→ found **21 galaxies, 5 QSOs**, but LAMOST claims z~0 for them . . .
17 are stars (3 with large pos. offsets)

A blatant example: the starburst galaxy NGC 4395 claimed to be a radio star

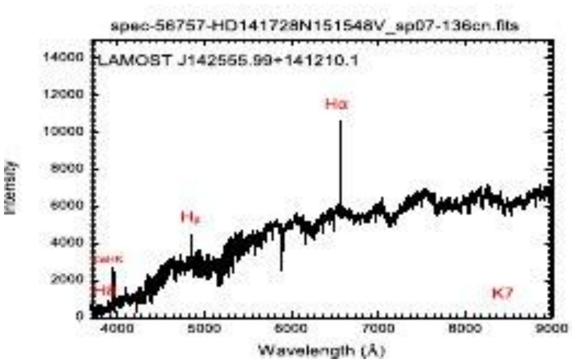


(h) LAMC

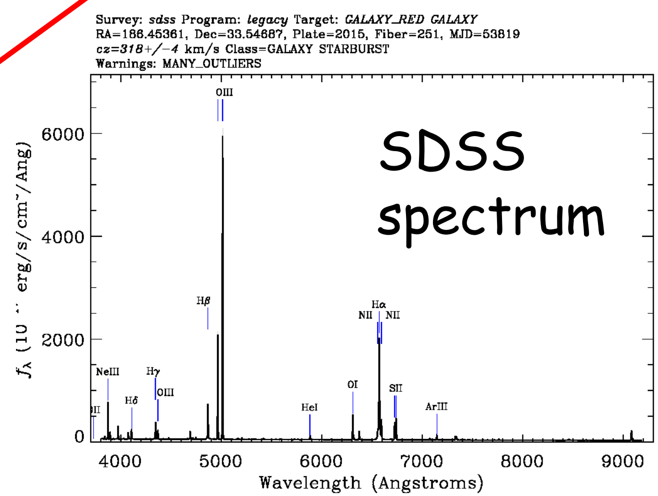
correct
stellar
spectrum



(i) LAMC

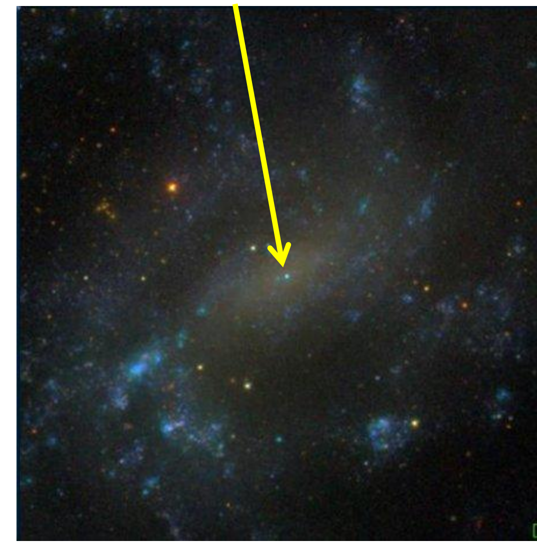


correct
stellar
spectrum



SDSS
spectrum

This is the starburst
nucleus of NGC 4395



NGC 4395

From Wikipedia, the free encyclopedia

even wikipedia has a page on it . . .

Galaxy nucleus has one of the few known intermediate mass black holes $\sim 10^5\ M_{sun}$

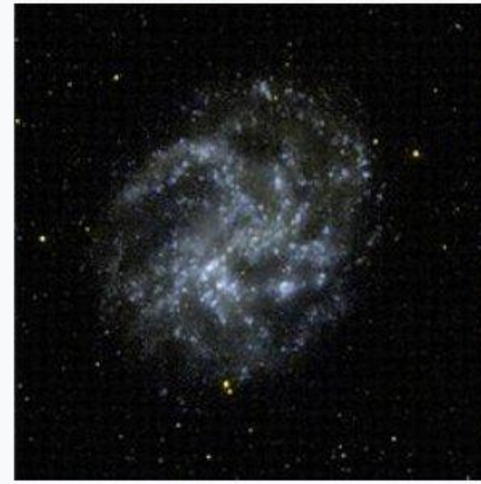
NGC 4395 by HST

NGC 4395 by the 32 inch Schulman Telescope at the Mount Lemmon Observatory

NGC 4395 is a low surface brightness spiral galaxy with a halo that is about 8′ in diameter. It has several wide areas of greater brightness running northwest to southeast. The one furthest southeast is the brightest. Three of the patches have their own NGC numbers: 4401, 4400, and 4399 running east to west.[3]

The nucleus of NGC 4395 is active and the galaxy is classified as a Seyfert. It is notable for containing one of the smallest supermassive black hole with an accurately-determined mass.[4] The central black hole has a mass of "only" 300,000 Sun masses,[5] which would make it a so-called "intermediate-mass black hole".

NGC 4395



An ultraviolet image of NGC 4395 taken with GALEX.
Credit: GALEX/NASA

Observation data (J2000 epoch)	
Constellation	Canes Venatici[1]
Right ascension	$12^h\ 25^m\ 48.9^s$[2]
Declination	+33° 32′ 48″[2]
Redshift	319 ± 1 km/s[2]
Distance	~14 million light-years
Apparent magnitude (V)	10.6[2]

Characteristics	
Type	SA(s)m[2]
Size	50,000 ly (diameter)
Apparent size (V)	13′.2 × 11′.0[2]

References [edit]

1. ^ Celestia version 1.4.1. Laurel, Chris, 2006.
2. ^ a b c d e f g h "NASA/IPAC Extragalactic Database". *Results for.* Retrieved 2006-11-04.

A very recent idea: if double radio lobes are caused by binary stars → cross-match Dennis Jack's recent catalog of **~35,000 spectroscopic binaries** with the FIRST source catalog

➔Not one double source close to any of these stars

➔The only point source match is very faint and undetected in VLASS

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ORIGINAL ARTICLE

Astronomische Nachrichten

A catalog of spectroscopic binary candidate stars derived from a comparison of Gaia DR2 with other radial velocity catalogs

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Funding information

Consejo Nacional de Ciencia y Tecnología; Universidad de Guanajuato (UG), CIIC 021/2018

Abstract

Using the recently published Gaia second data release that includes measurements of the mean radial velocity of about 7.2 million stars, we performed a systematic comparison with other existing radial velocity catalogs to search for variations in the radial velocity measurements, with the goal that detected differences may indicate that these stars are possibly spectroscopic binary stars with only one visible component (SB1). We present a catalog of spectroscopic binary candidate stars containing 35,246 stars, compiled to encourage follow-up observations obtaining spectra at different epochs of orbits of these stars to verify their binarity and to study these systems using radial velocity curves. Comparing the Gaia DR2 database with the K-M dwarf catalog, we found 16 stars that show radial velocity variations. In a comparison with the Pulkovo radial velocity catalog of Hipparcos stars, we identified a total of 539 SB1 candidate stars. In the largest radial velocity catalog available, the radial velocity experiment (RAVE) catalog, we found a total of 34,691 stars that show radial velocity variations when compared to the Gaia DR2 data.

Conclusions & Future Work

* Double-lobed radio sources with confirmed stars on major axis are frequent, but number of good candidates decreases with higher angular resolution data

* Chance alignment is likely, but a few real associations are possible

* finding a faint extragalactic alternative optical ID is possible only for V > 15 mag, via SDSS images or AllWISE colors

* obtain better X-ray fluxes or upper limits (e.g. from eROSITA)

* inspect and classify the many possible radio associations for fainter stars (~80 to be inspected from Radio Galaxy Zoo)

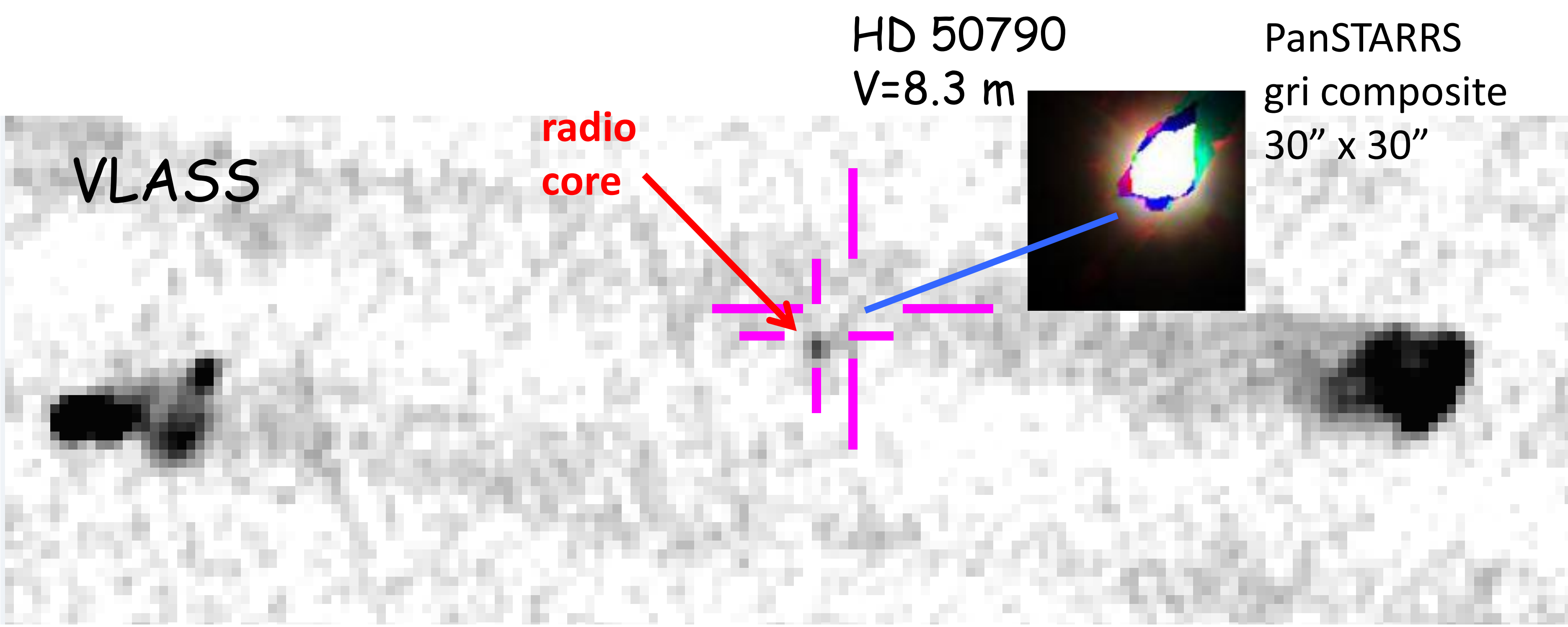
* only for most promising stars: VLBA → astrometry at mas level and detect a radio core

* radio variability ?

-* determine radio PMs and compare with optical ones from GAIA

Hoping they aren't all like this one:

J0658+5843: found accidentally while inspecting a recent VLASS image: bright star HD 50790 blends the ID of the radio core of a 2.6' – wide background radio galaxy



Thank you !