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Radio Survey Cross Identification for Data Mining

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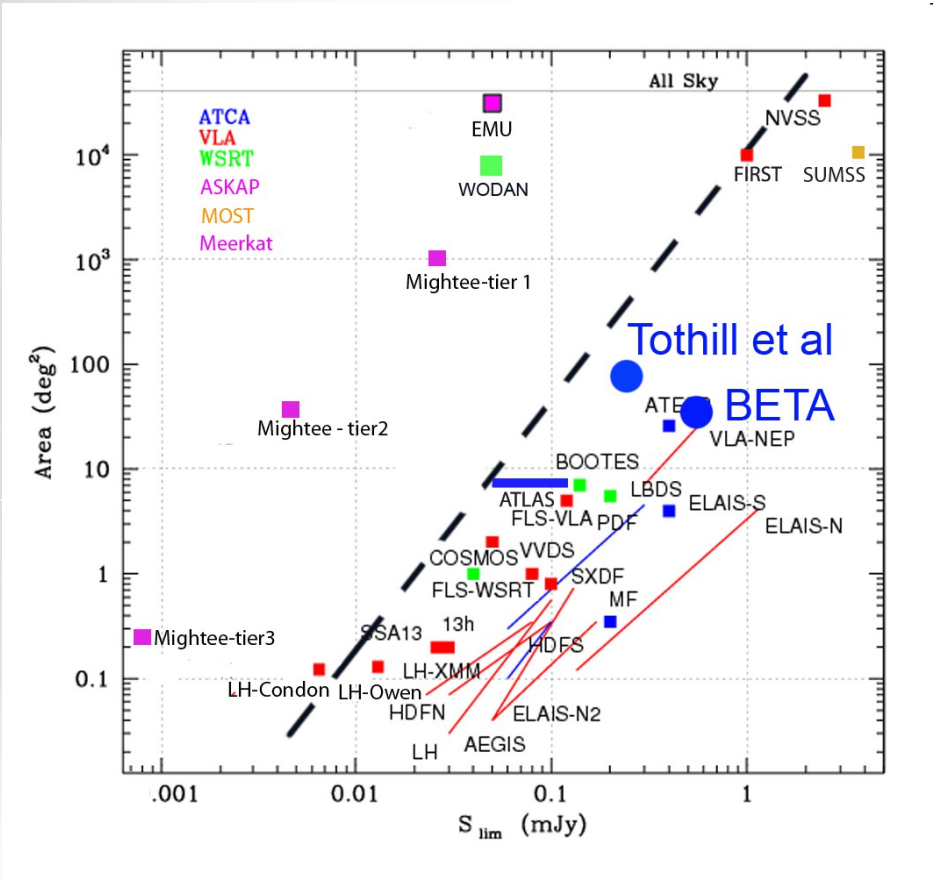
ASTROINFORMATICS 2013

The Chandra Deep Field South, observed in the U-, B-, and R-bands with ESO"s VIMOS and WFI instruments. Credit: ESO/ Mario Nonino, Piero Rosati and the ESO GOODS Team

Deep Astronomical Surveys

Plot showing the survey areas (deg^2) against the radio limit S_{lim} (mJy) of the respective surveys Credit: Ray Norris 2013

About the banner above: The banner is a representation of the "emu in the sky", which is an important dreaming-spirit of the Aboriginal traditional owners of the land on which ASKAP will be built. For more information on this image, see http://www.atnf.csiro.au/research/AboriginalAstronomy/Examples/emu.htm



Credit: Ray Norris

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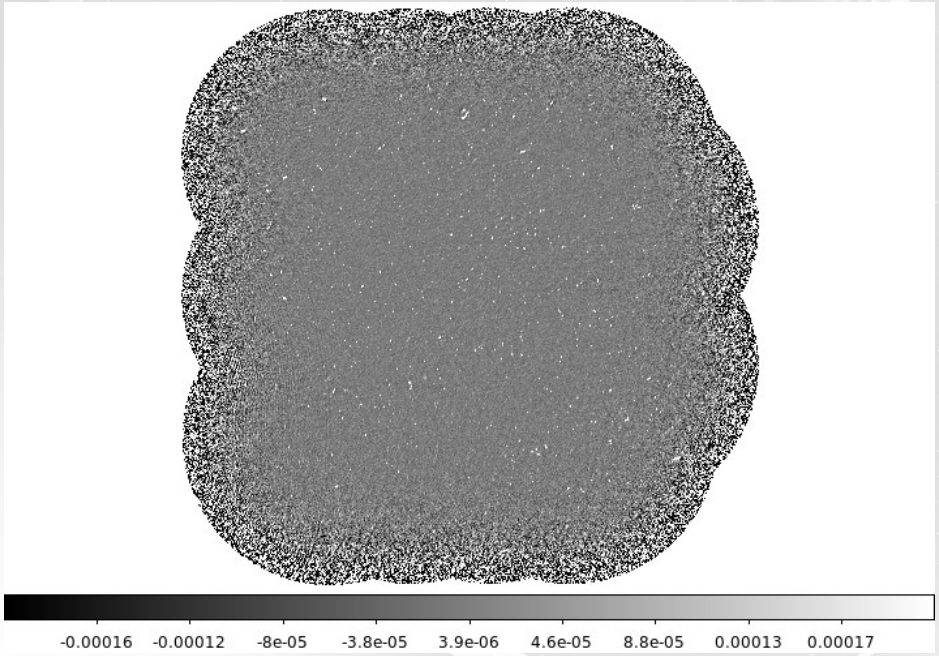
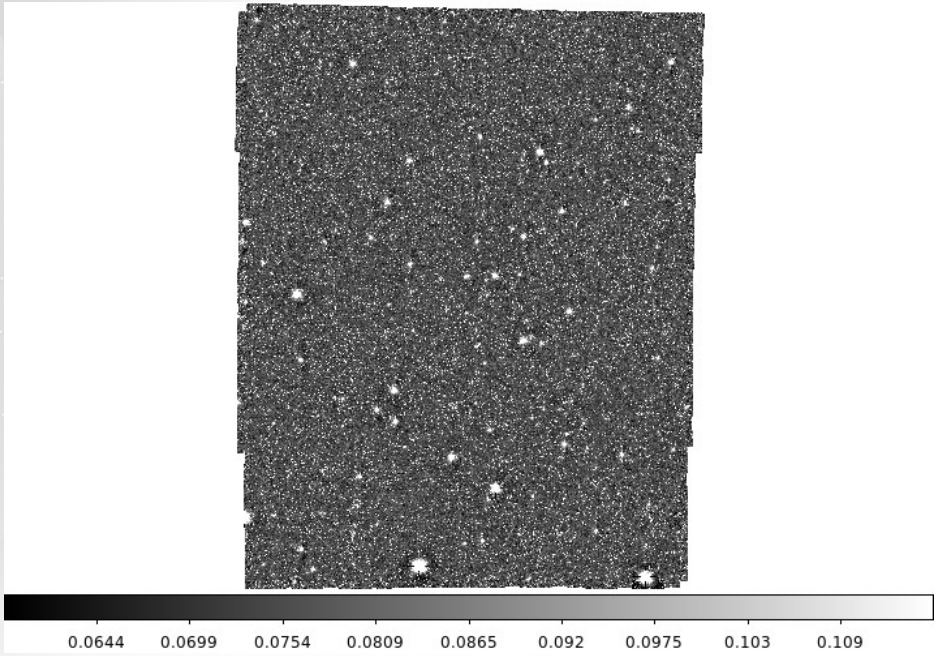
Survey Cross Identification

ATLAS ELAIS_S1



SPITZER ELAIS_S1



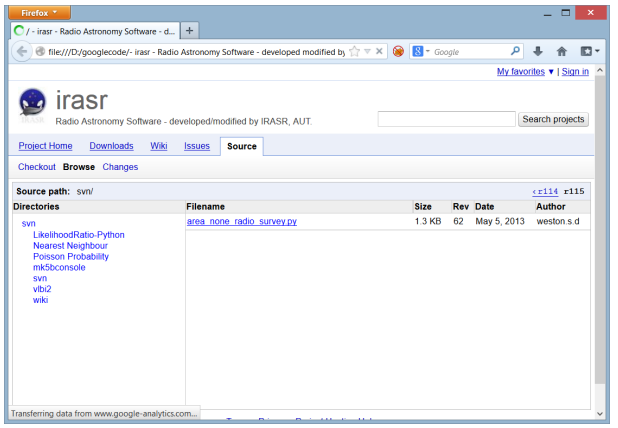
Survey Cross Identification

?

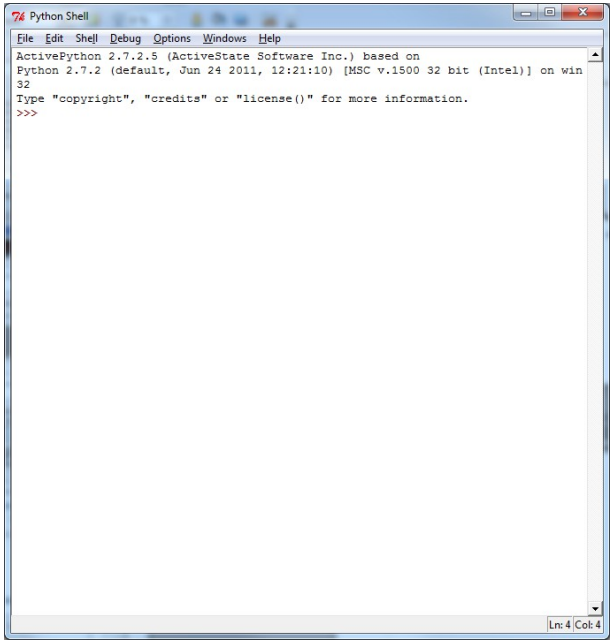
- Currently ATLAS DR1 by the MK1 eye of an experienced radio astronomer
- Several 100 radio objects

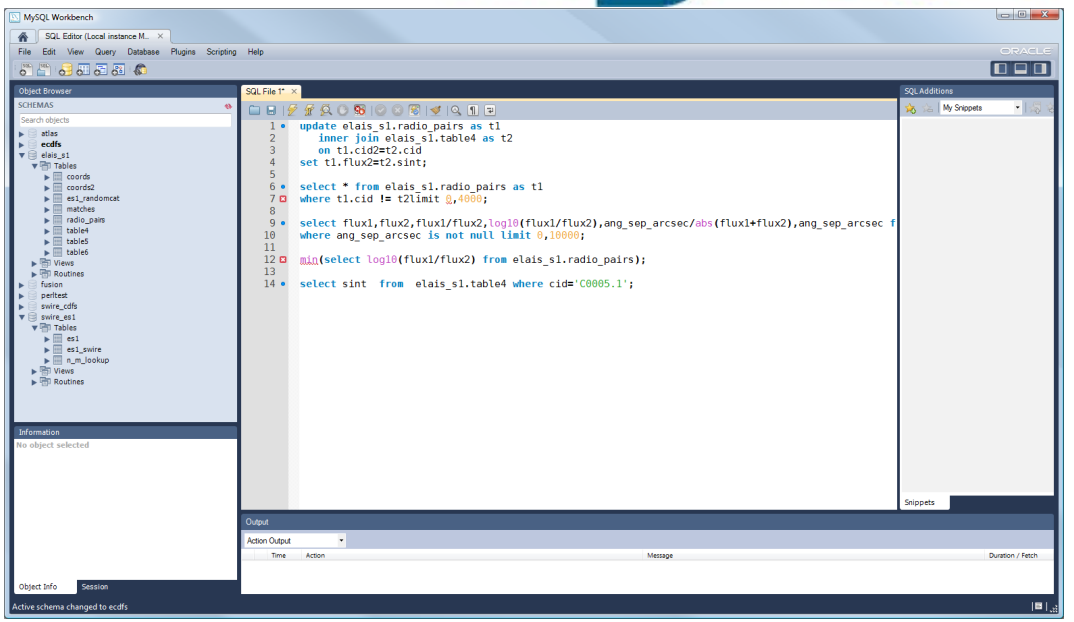
- ATLAS DR3 > 5000 radio sources
- EMU ~ 70 million radio sources

Tools of the Trade



GoogleCode
https://code.google.com/p/irasr/



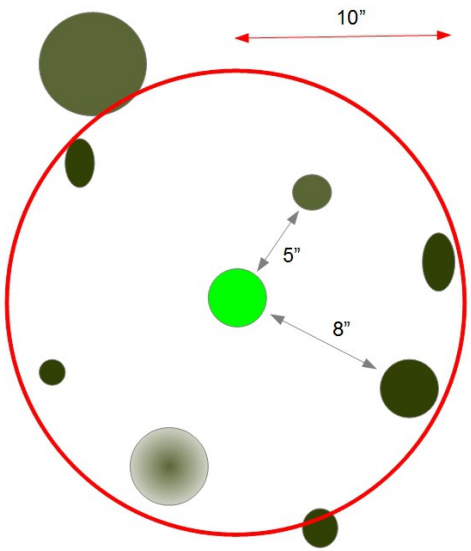


Techniques for XID

- Simple Nearest Neighbour
- Likelihood Ratio
- Poisson Probability

Simple Nearest Neighbour

- Nearest neighbour is a well-known method in astronomy
- Only uses one piece of information – angular separation



Prior Information

- Angular Separation
- Radio Flux
- IR Flux
- Source/Object Density

Likelihood Ratio Technique

The ratio of the probability that two sources are associated to the probability that the same two sources are unrelated.

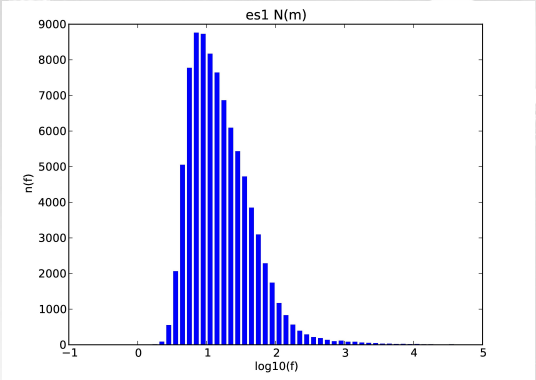
(Sutherland and Saunders, 1992)

Likelihood Ratio

$$L = \frac{q(m)\, f(r)}{n(m)}$$

$$f(r) = \frac{1}{2\pi\,\sigma_{pos}^{2}} \exp\left(\frac{-r^{2}}{2\sigma_{pos}^{2}}\right)$$

f(r) - The probability distribution of positional errors



$$q(m) = \frac{real(m)}{\sum_{i}(real(m)_{i})} \times Q$$

n(m) – Surface density of unrelated background/foreground objects per unit magnitude/flux

$$real(m) = \left[total(m) - (n(m) \times N_{radiosources} \times r^{2})\right]$$

q(m) – Probability distribution of true counterparts with magnitude *m*

Reliability

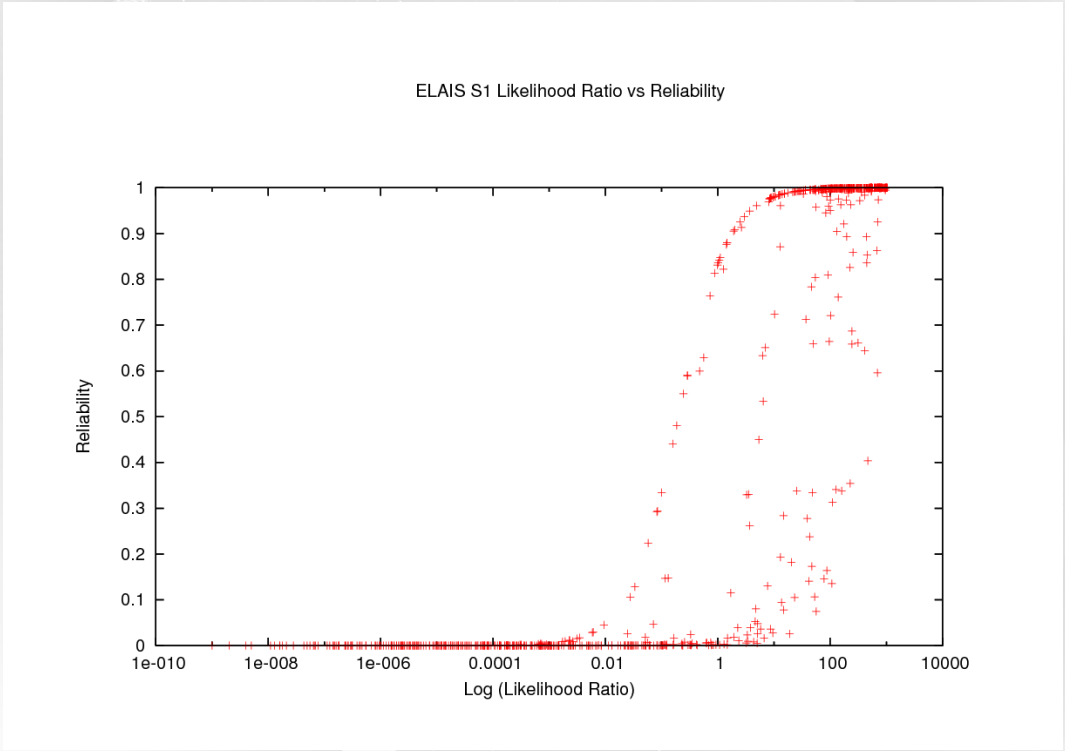
$$R_j = \frac{L_j}{\sum_i (L_i) + (1 - Q)}$$

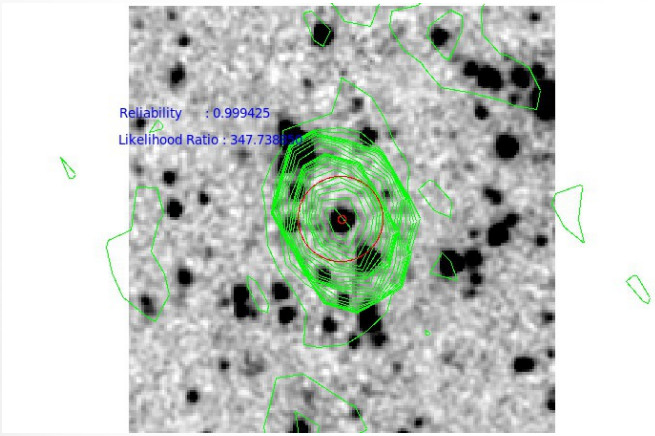
R_j is the probability that the candidate object *j* is associated to the radio source

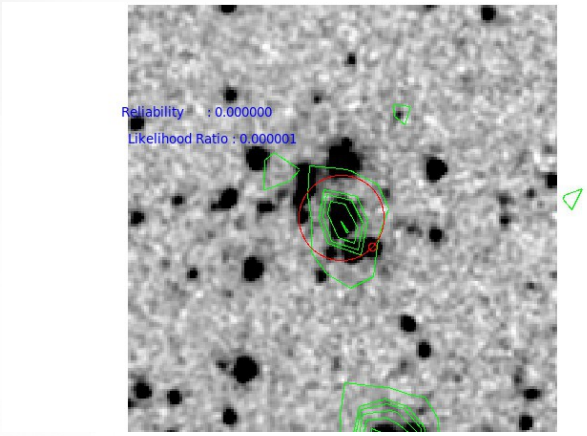
L_i is the likelihood ratio for candidate *i*

Q is the probability that a radio source is above the detection limit in the matching survey

Likelihood Ratio







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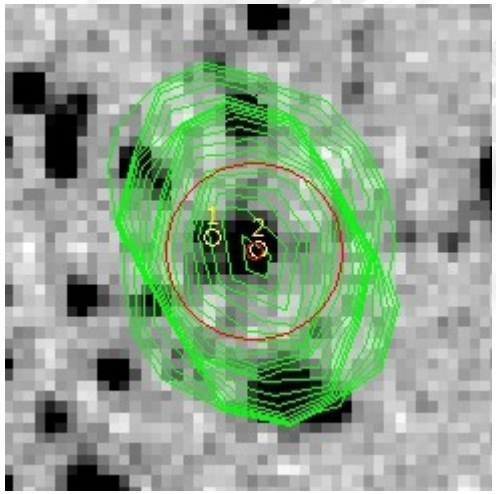
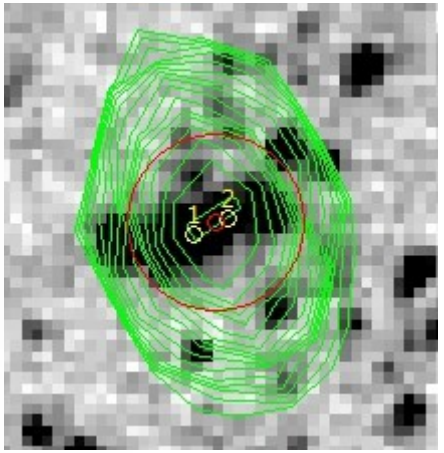
LR Results in detail

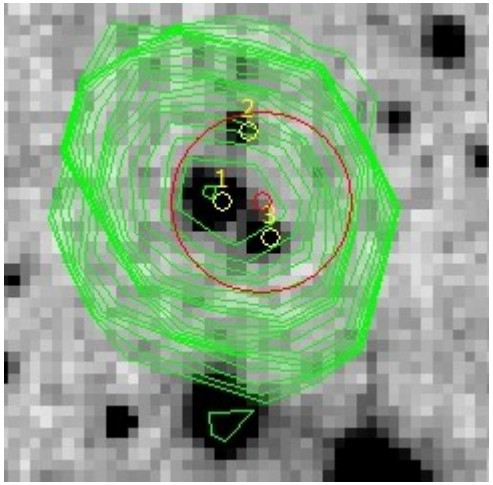
CID	SWIRE_ID	r_arcsec	LR	Reliability
EI0003	220870	0.6828	521.836	0.99942
EI0003	220796	5.7643	0.10152	0.00019



CID	SWIRE_ID	r_arcsec	LR	Reliability
EI0017	112359	2.15206	241.4844	0.5822
EI0017	112417	1.08245	172.3513	0.4155



CID	SWIRE_ID	r_arcsec	LR	Reliability
EI0009C2	162771	5.0414	4.30099	0.52005
EI0009C2	162835	4.10418	3.769	0.45574
EI0009C2	162803	8.312	0.00016	0.00002



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Poisson probability

$$\mu_c = \pi r_s^2 \int_{-\infty}^{\infty} n(f)\,df$$

$$P_c = 1 - e^{\mu_c}$$

$$\mu_f = \pi r^2 \int_{f}^{\infty} n(f)\,df$$

$$P_f = 1 - e^{\mu_f}$$

$$E = P_c \quad for\ P_f \geq P_c$$

$$E = P_f\{1 + \ln(P_c / P_f)\} \quad for\ P_f < p_c$$

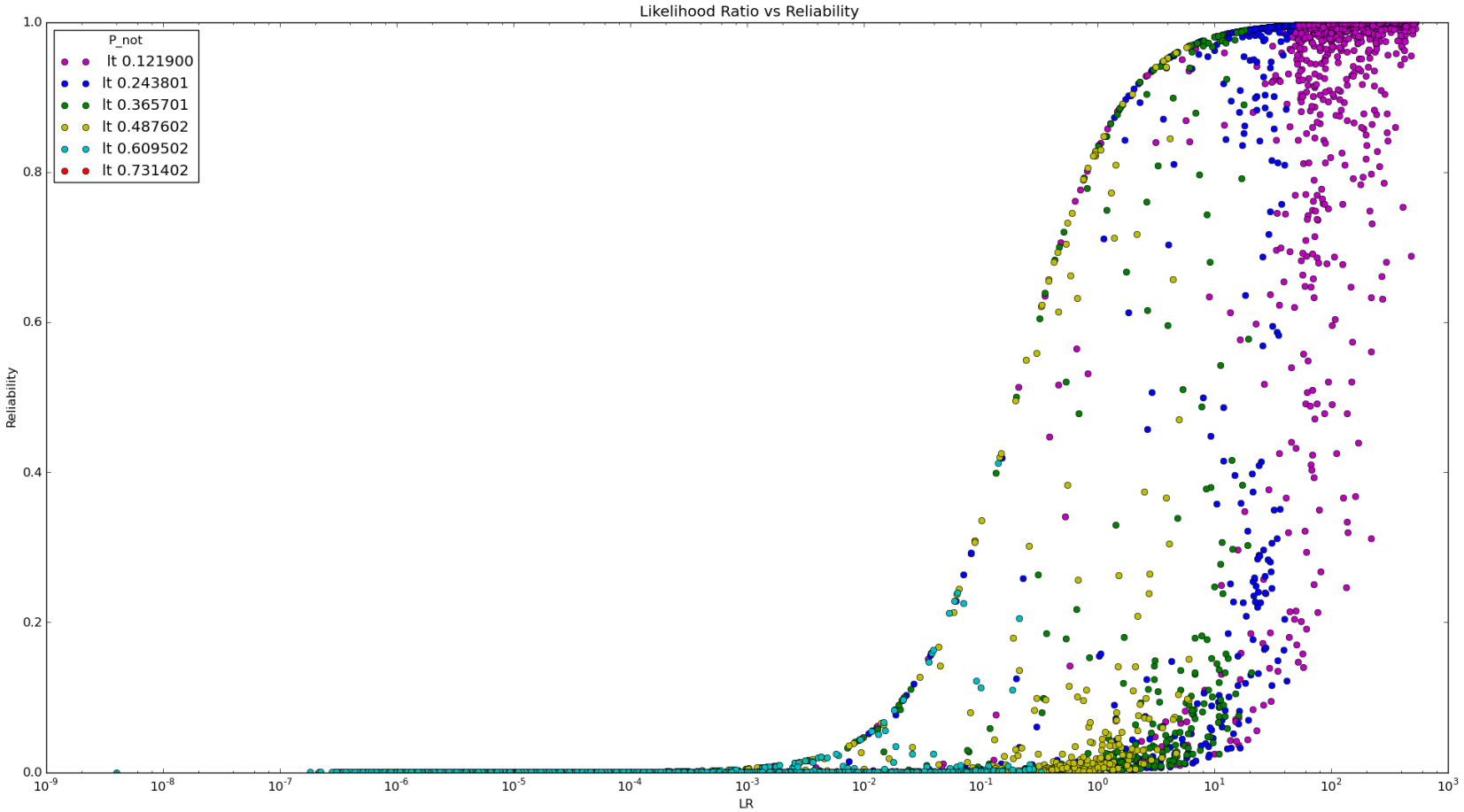
$$P_{not} = 1 - e^{-E}$$

Poisson probability approaches the problem:

- Given a candidate with flux *f* at a distance *r* from the radio position, calculate the probability of such an event occuring
- Given the surface density, *N*, of objects brighter then *f*, find the expected number of events within *r*
- For a candidate we can derive the probability that it is a chance coincidence P_{not}
- If there are several candidates to a radio source in the search radius, calculate P_{not} for each and take the one least likely to be there by chance as the best candidate

Downes et al 1986

Poisson probability

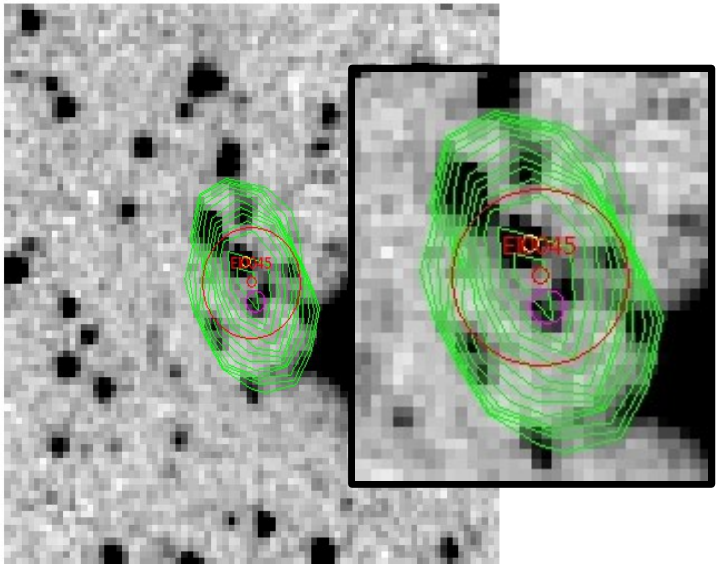


Comparison of NN with LR candidates

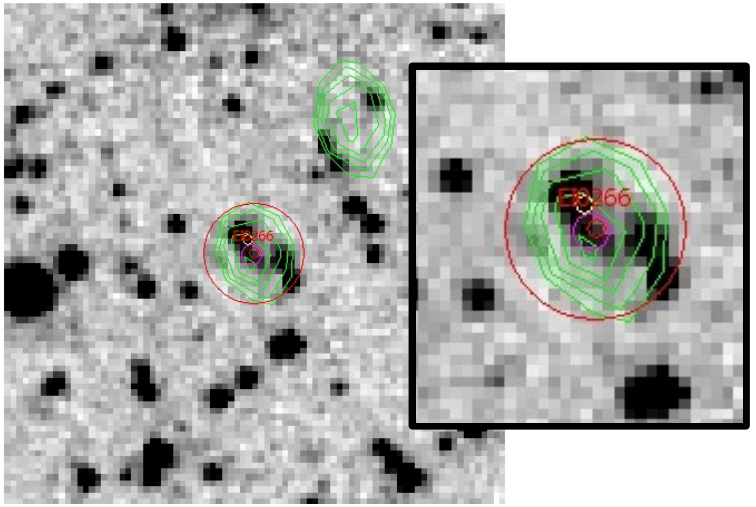
Field	DR3	NN	LR (Rel > 0.8)	# Diff NN vs LR
ELAIS_S1	2067	2013	1738	12
ECDFS	3079	2892	1736	20

Comparison of NN with LR candidates

ELAIS_S1

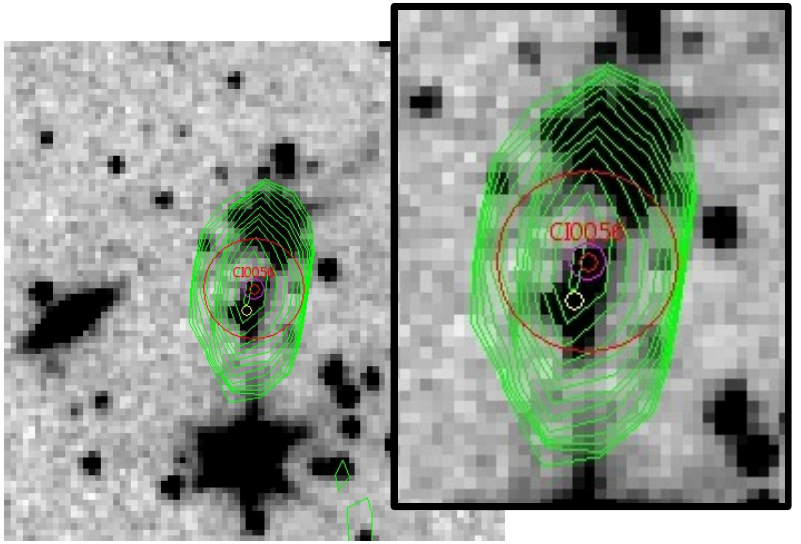


EI0045

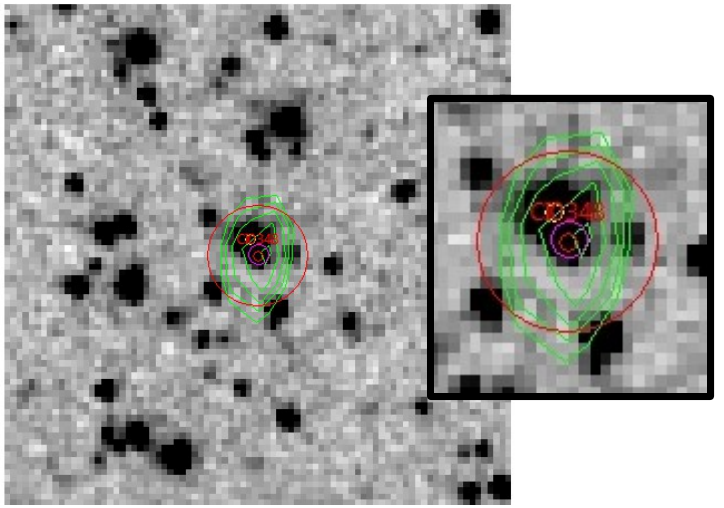


EI0266

ECDFS



CI0056



CI0348

Refinement of LR Technique

Can we identify radio doubles and possibly triples ?

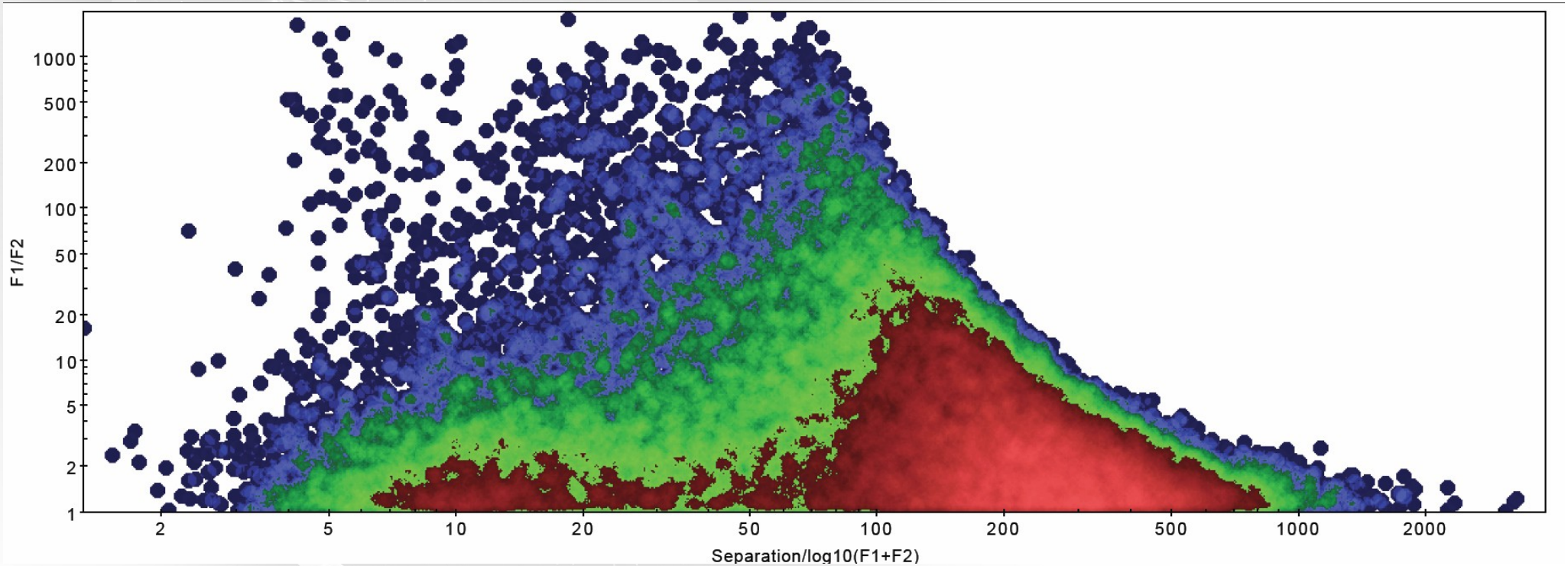
Doubles : possible method via Flux Ratio/R1-R2
Triples : do we have doubles with a common radio source

If we can identify these objects

Treat double as one radio source, identify possible non-radio candidates to double centre

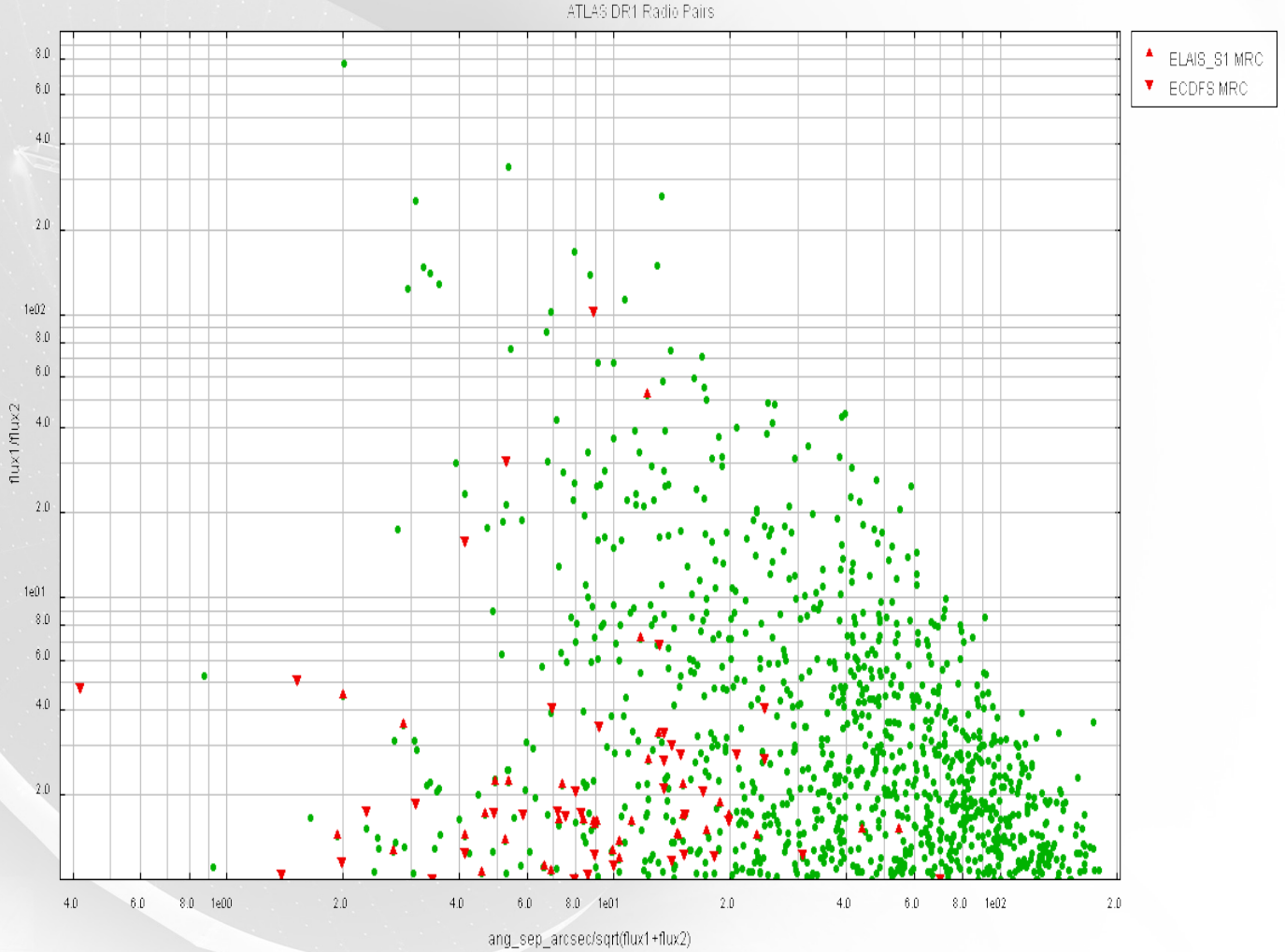
Feedback into LR

Multiple Radio Component Sources



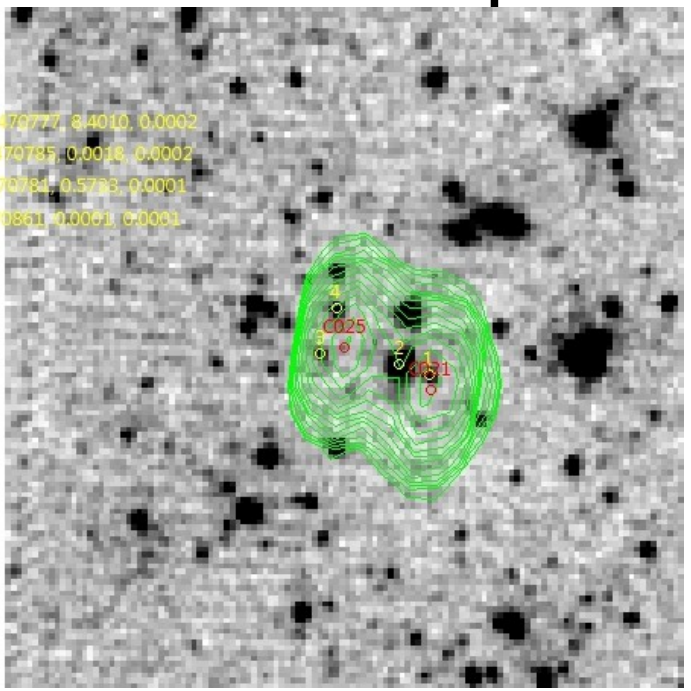
Density Plot based on FIRST normalised separation vs flux ratio
Credit: N. Seymour

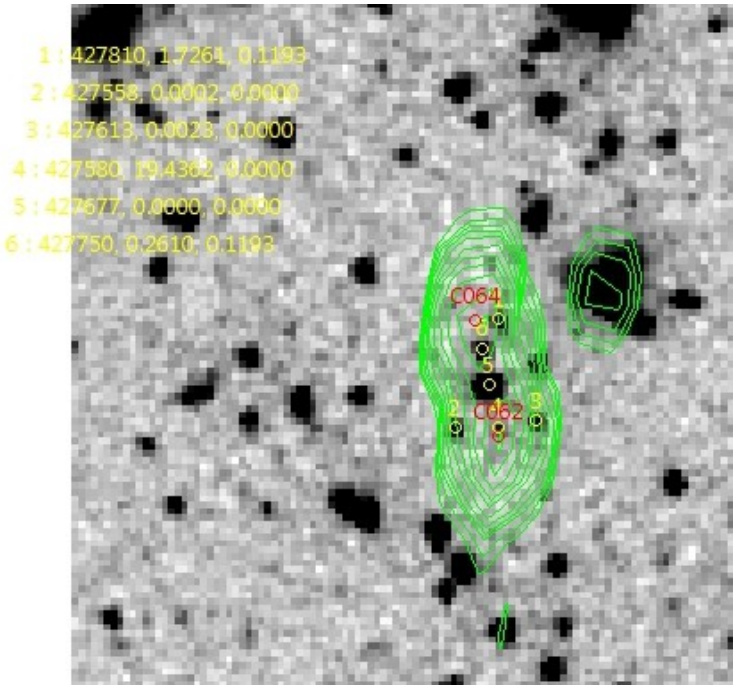
Multiple Radio Component Sources

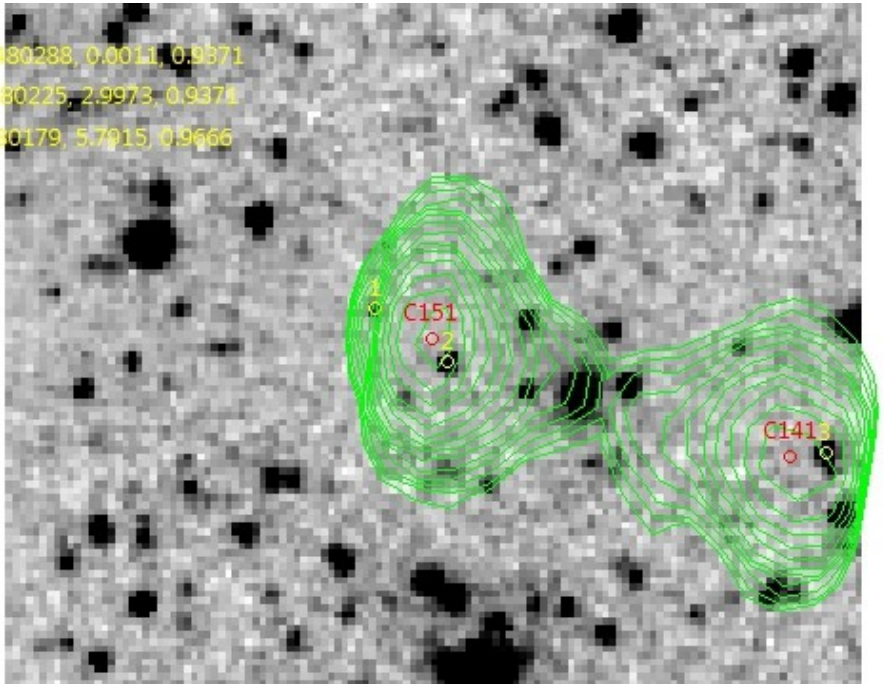


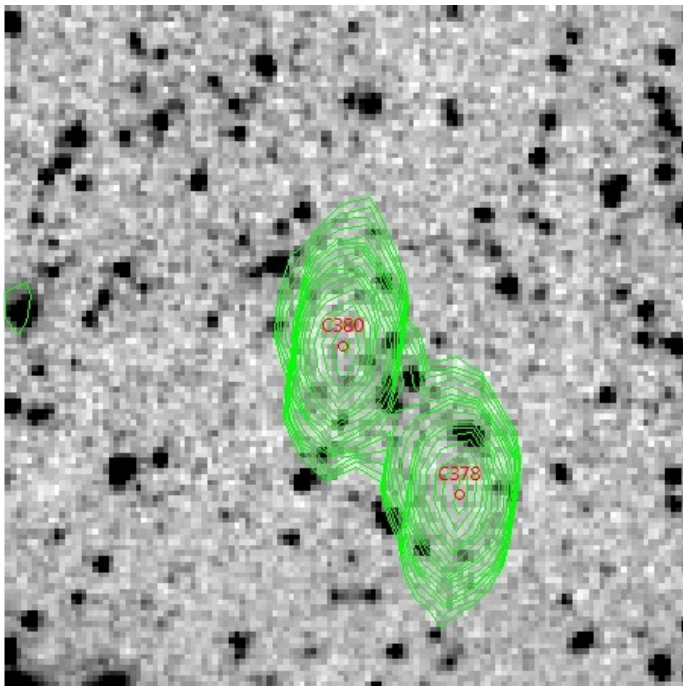
ATLAS Nearest Neighbour search on itself, r_{search} 100 arcsec.

Multiple Radio Component Sources









The way forward

- Run against the full final ATLAS DR3 catalogue
- Test against other radio surveys FIRST/WISE
- Possible candidate pipeline for ASKAP to SKA

Conclusions

- The difference in candidate selection between NN and LR is only ~ 1%

  But for EMU that could be 700k sources missed or poorly cross identified.

- LR uses more information about the radio source and candidates and we feel is more robust in its XID

- Can we use LR and PP together to provide a better algorithm for XID ?

- These methods we feel can be extended to more complex radio sources

Thank you

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