Search for AGN counterparts of unidentified Fermi-LAT sources with optical polarimetry

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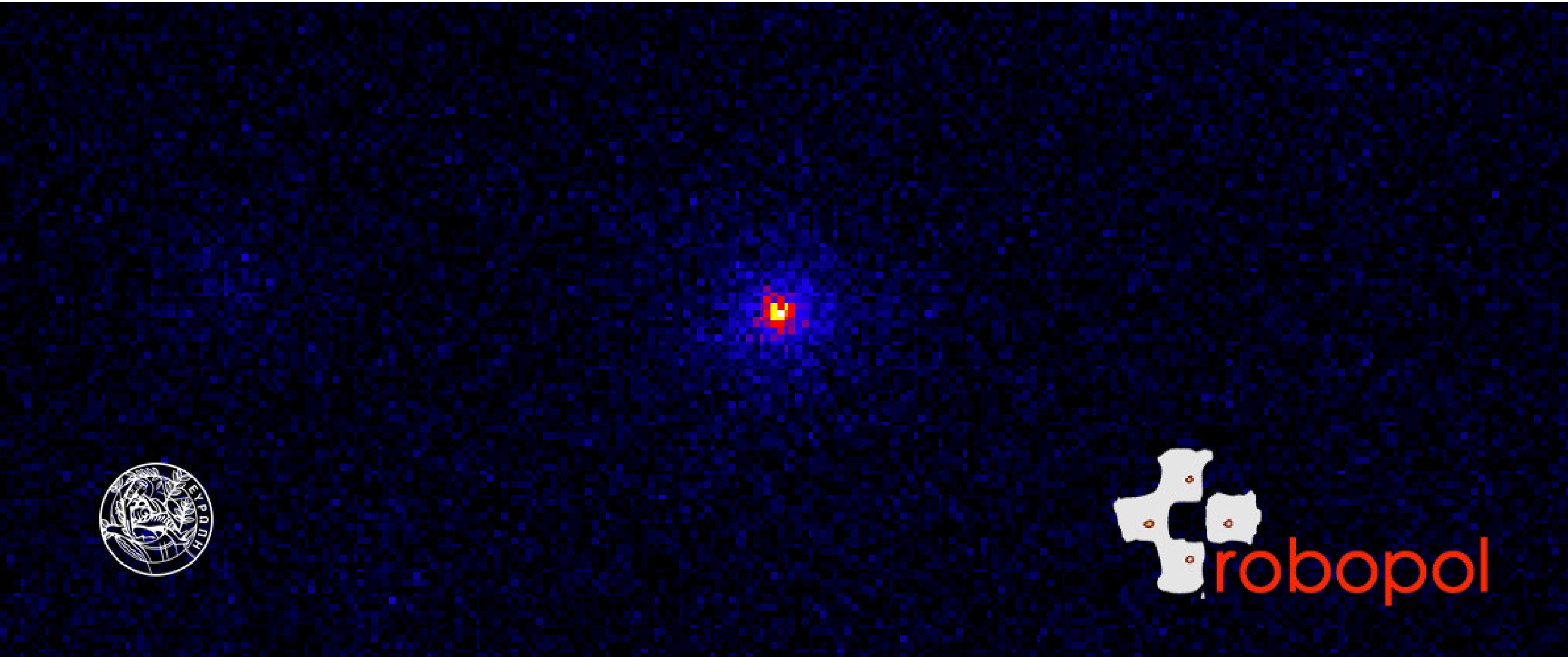
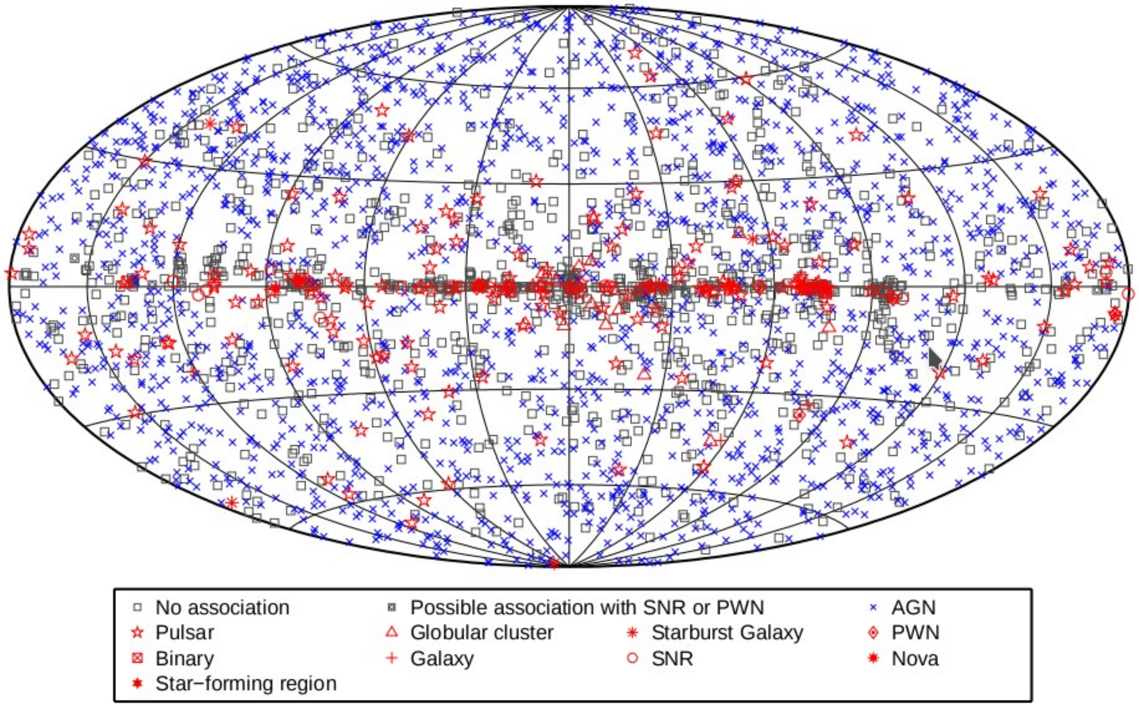


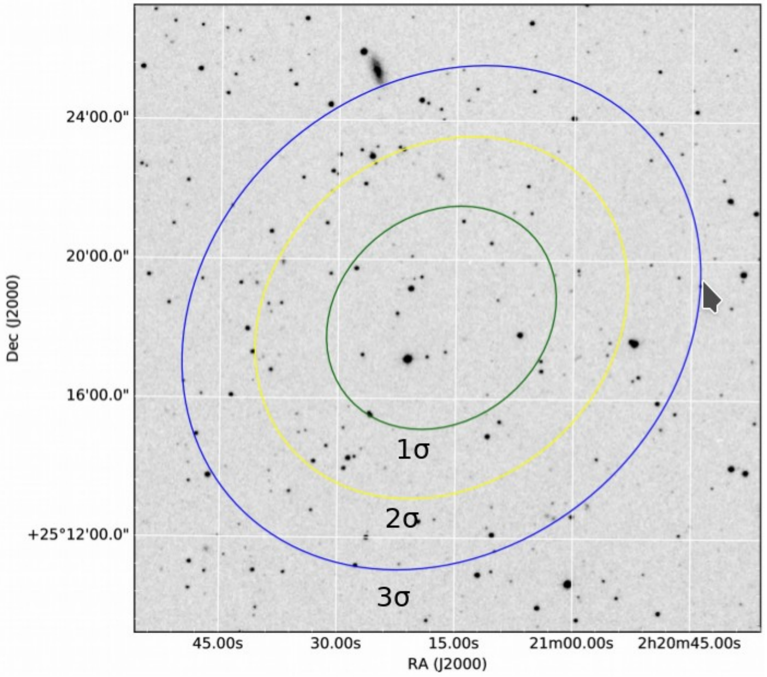
4 year Fermi LAT (3FGL) catalog

- 3034 sources
- 1010 unidentified
- 85% are blazars
- 220 arcmin^2 - typical location 95% CL area

UFO - unidentified Fermi object



Acero et al. 2015, ApJS, 218, 23



Existing association techniques

- VLBI observations
  Kovalev 2009, ApJL 707,56
- Association with pulsars using steep radio spectra
  Frail et al. 2016, MNRAS, 461, 1062
- Cross-matching of multifrequency catalogs
  Acero et al. 2013, ApJ, 779, 133
- Radio surveys of UFO fields
  Barr et al. 2013, MNRAS, 429, 1633; Schinzel et al. 2017, ApJ, 838, 139
- Peculiar IR colors + spectroscopy
  Massaro et al. 2016, Ap&SS, 361, 337

Total flux ✓

Spectra ✓

SED ✓

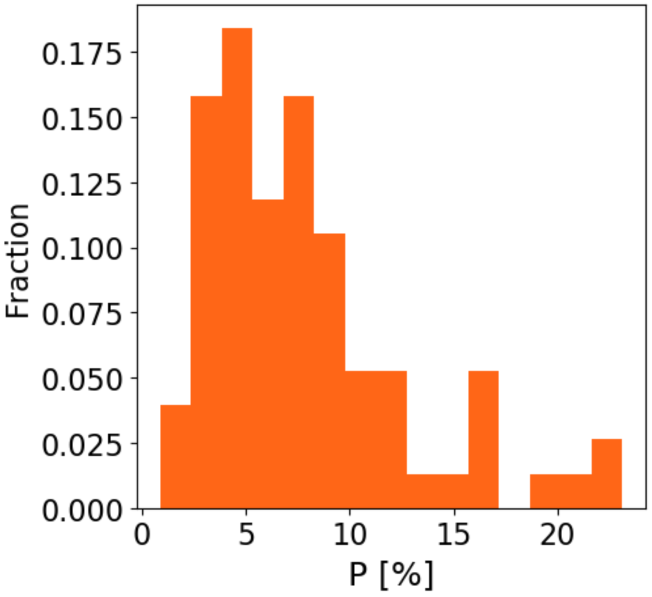
Polarization ?

Optical polarization for blazars detection

3FGL identified/associated:

86% are AGN

85% are blazars



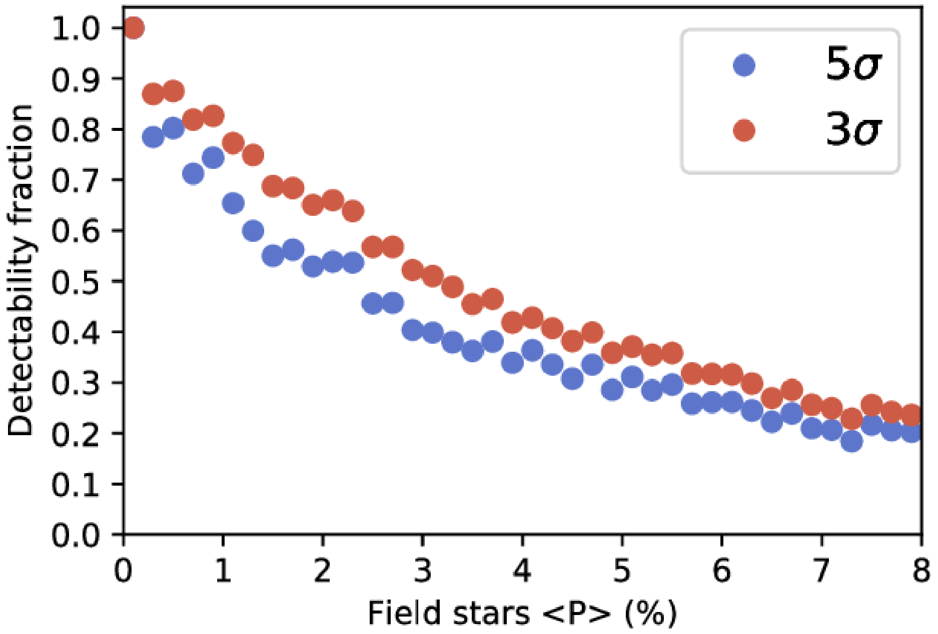
Angelakis et al. 2016, MNRAS, 463, 3365

Detection efficiency

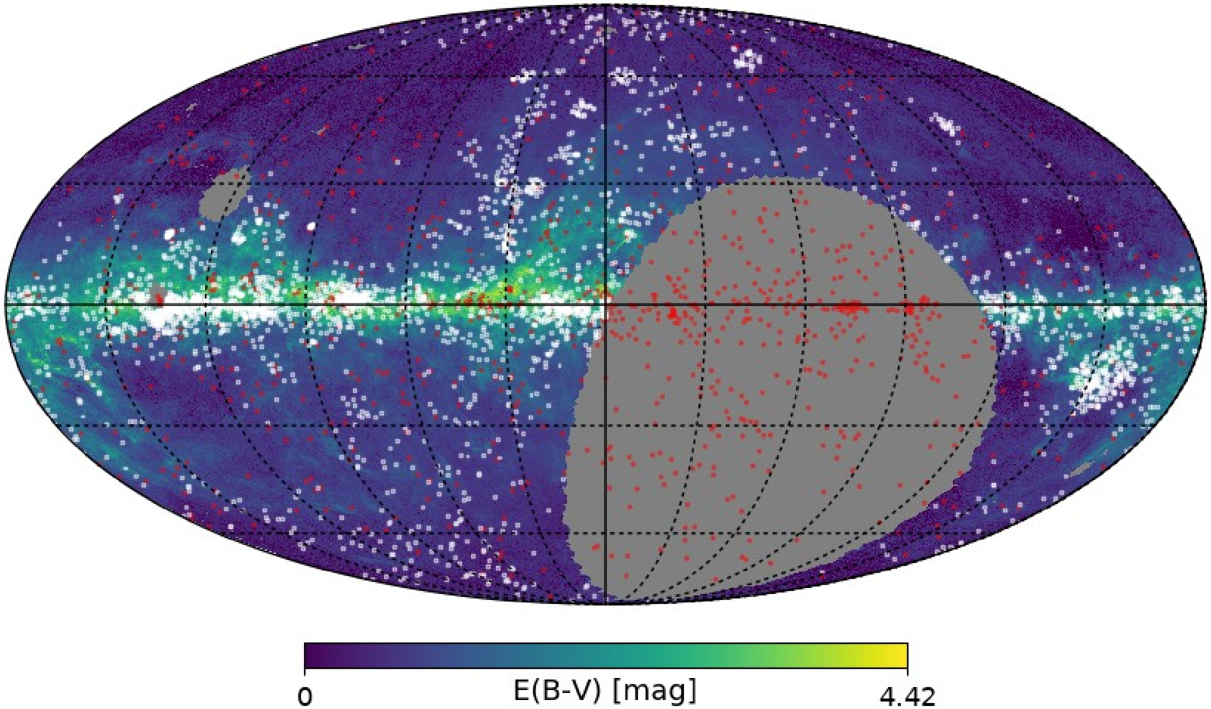
Can we distinguish blazars from polarization caused by ISM?

1) Assign <P> for a field of 50 stars
2) Generate P_i for these stars using some realistic distribution
3) Choose random blazar from Angelakis et al. 2016, MNRAS, 463, 3365
4) Assign random P_{blaz} according to its polarization and variability parameters
5) Consider the blazar detectable if:

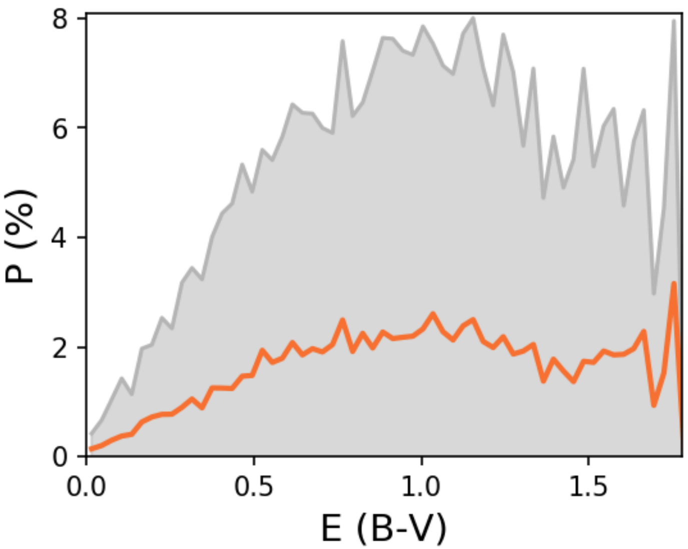
$$P_{blaz} \geq \langle P \rangle + SL \times std\_dev(P_i)$$



Expected number of detections



Schlafly et al. 2014, ApJ, 500, 525



5600 stars from Heiles 2000, AJ, 119, 923

1) Choose random blazar from Angelakis et al. 2016, MNRAS, 463, 3365
2) Assign random P_{blaz} according to its polarization and variability parameters
3) Consider the blazar detectable if:

$$P_{blaz} \geq P(E(B\text{-}V)) + 3 \times \sigma P(E(B\text{-}V))$$

If 85% of UFOs are blazars

366 ± 6

New detections

(36% of UFOs in 3FGL)

Observations

robopol

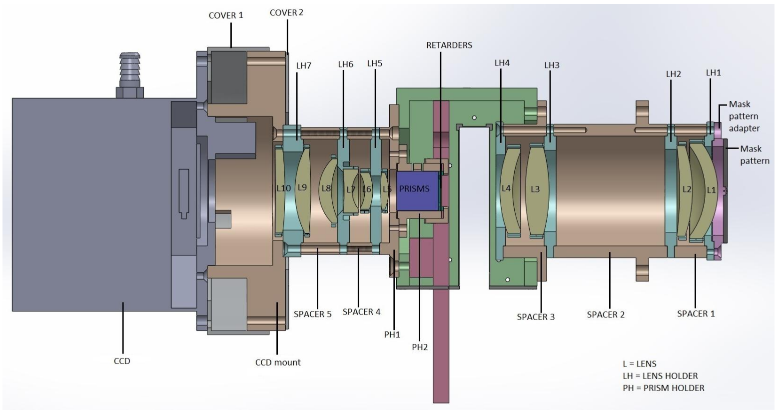
Four channel polarimeter

Automated operation

Optimized for single source observations

13’x13’ FoV

1.3 m telescope (Skinakas observatory)



4 random UFO fields:

J1848.6+3232

J0419.1+6636

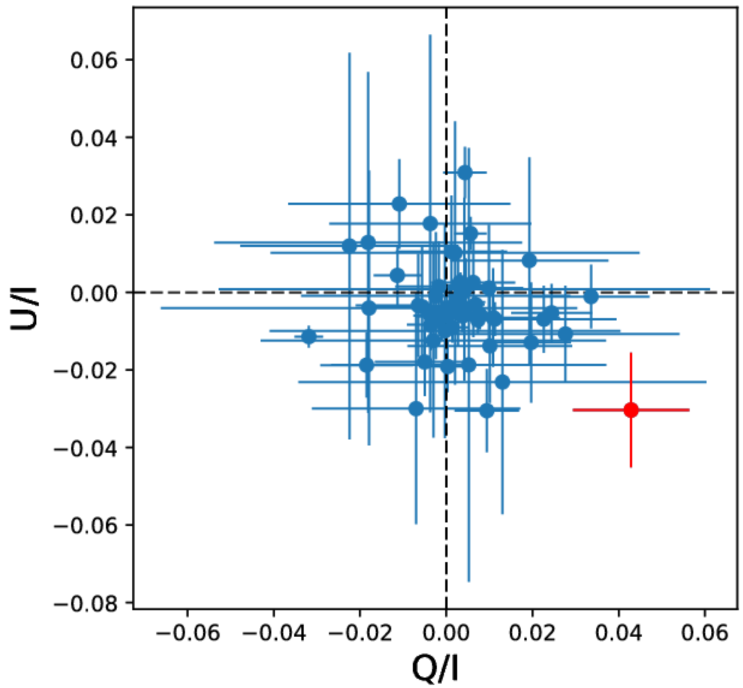
J0336.1+7500

J0221.2+2518

R-band 3x190sec at 5 positions separated by ~1’

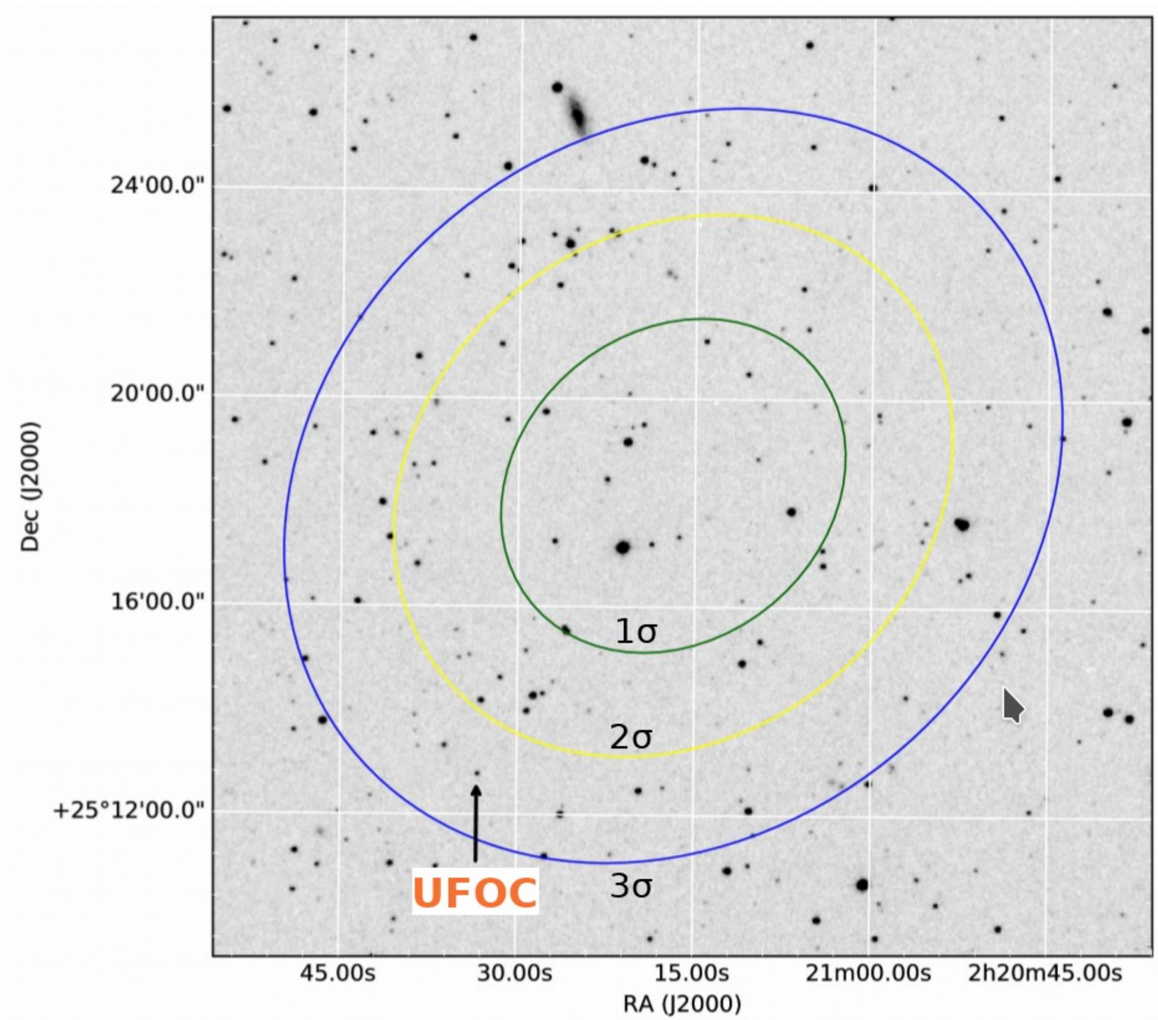
(48 min of total exposure)

3FGL J0221.2+2518



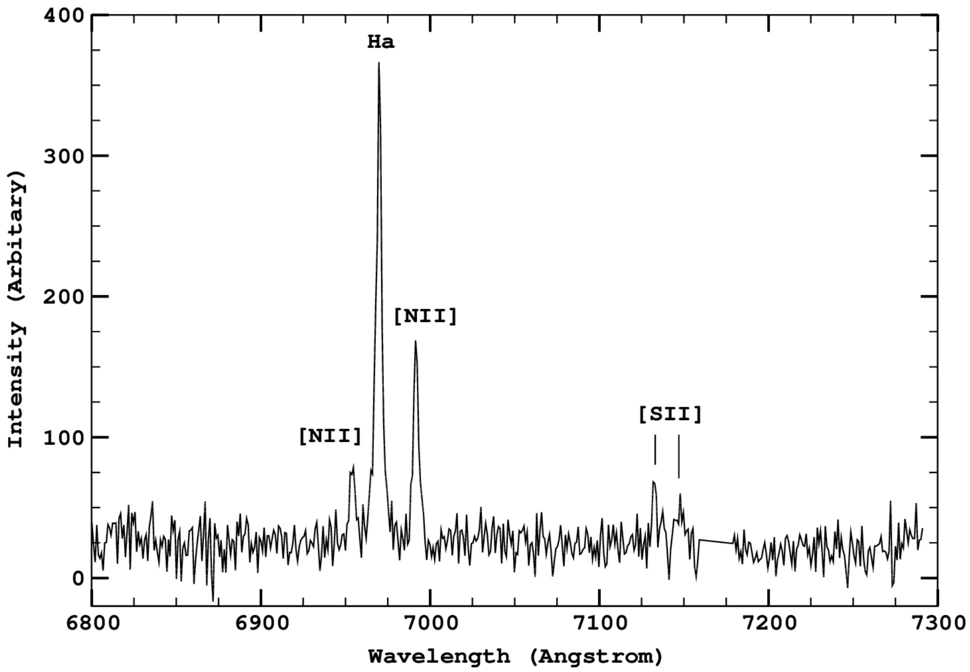
Field <P> = 0.91±0.07%

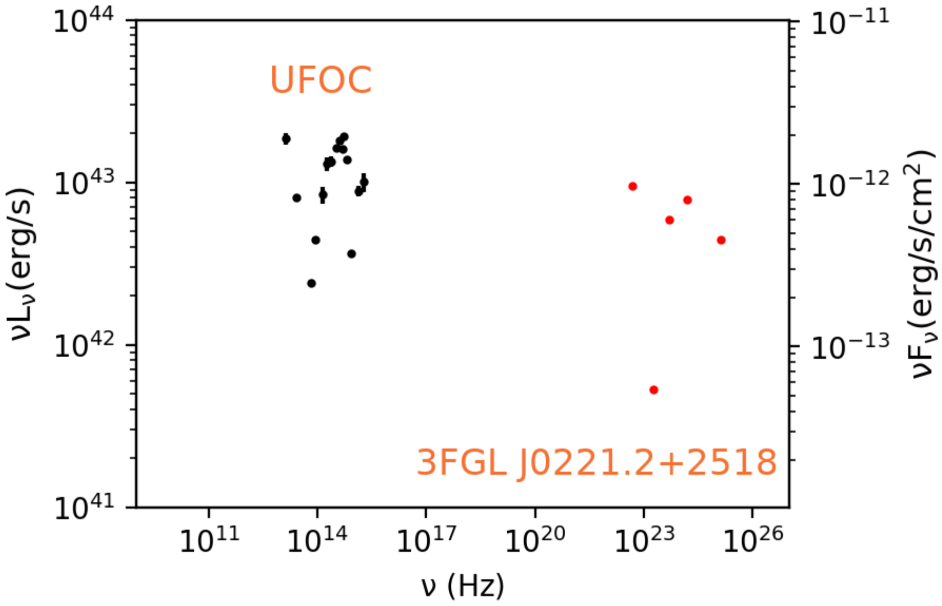
UFOC P = 5.3±1.4%



SDSS r = 17.59^m

UFOC is extragalactic!





z=0.06169 ± 0.00004

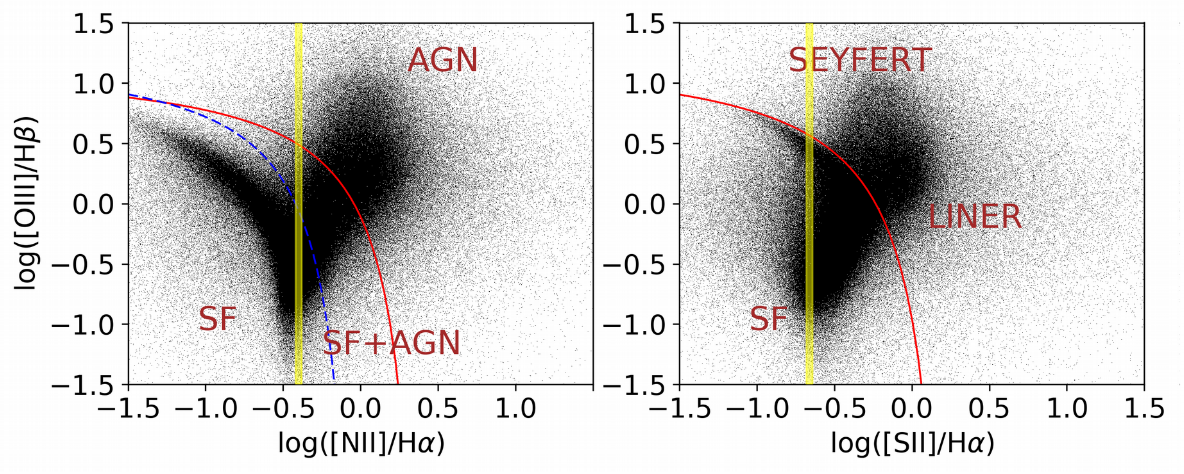
FWHM = 4.37 → u = 188 km/s

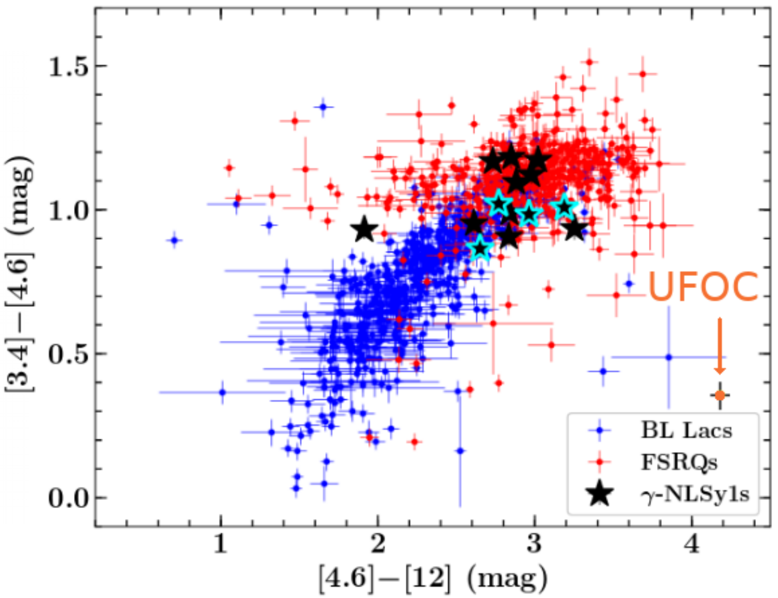
Radio – detected by the Effelsberg RT!

What is UFOC?

BPT diagnostic diagram

Baldwin et al. 1981, PASP, 93, 5





Paliya et al. 2018, ApJL, 853, L2

Star-forming galaxy

AGN

SF + AGN

Polarization of SF galaxies ~1%

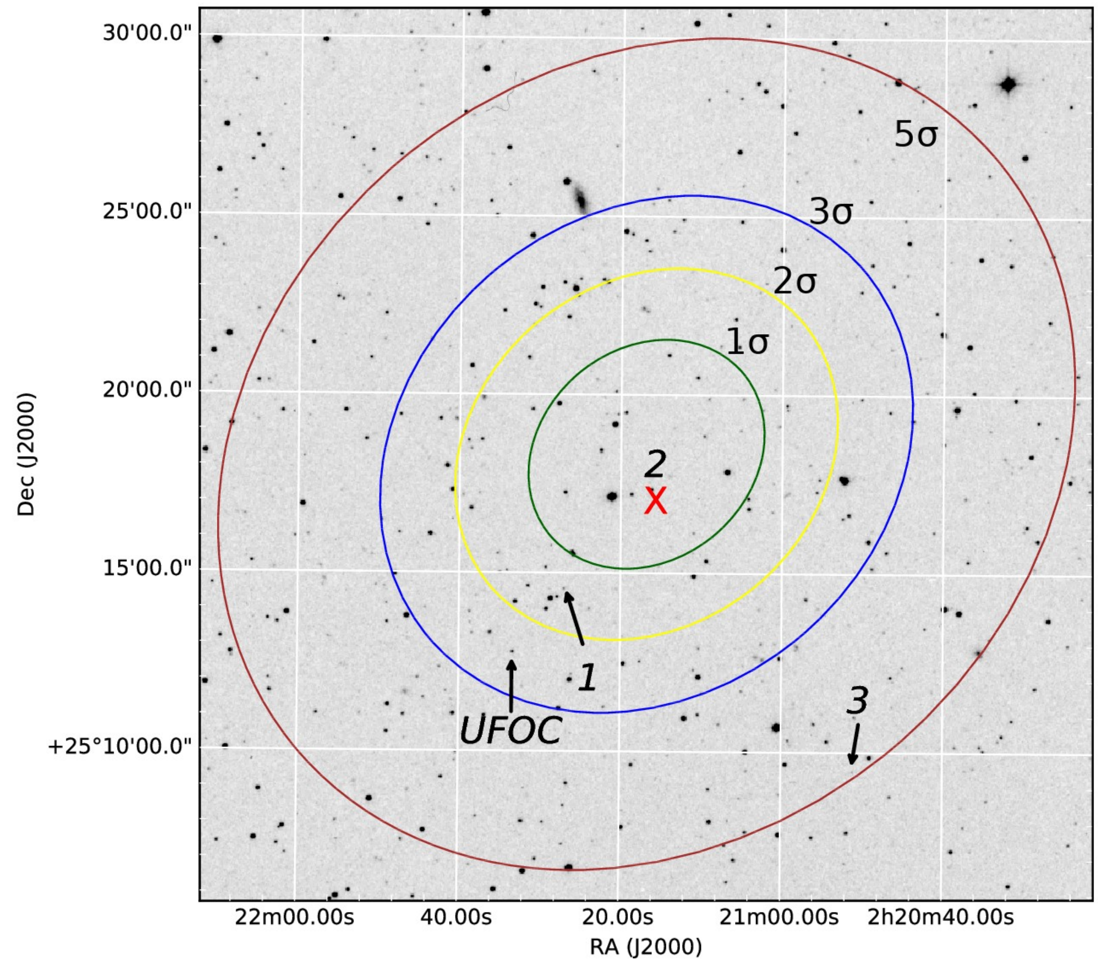
Scarrott et al. 1993, MNRAS, 264, L7

Alternative counterparts for 3FGLJ0221.2+2518

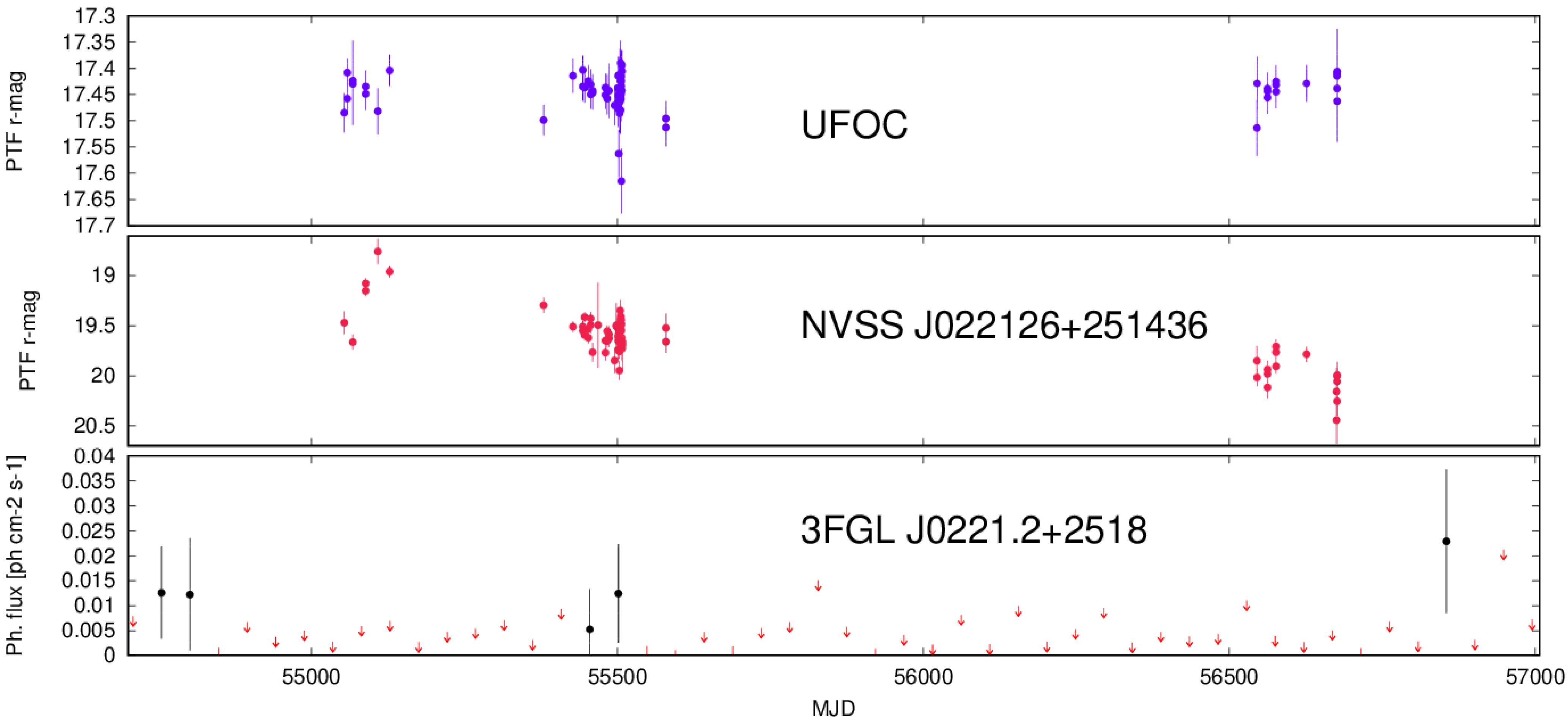
1. NVSS J022126+251436
   Schinzel et al. 2017, ApJ, 838, 139

2. RA=02h21m15.67s
   DEC=25°16’58.5’’
   Schinzel et al. 2017, ApJ, 838, 139

3. WISEJ022051.24+250927.5
   Paggi et al. 2014, AJ, 147, 112
   Massaro et al. 2016, ApJ, 838, 139



NVSS J022126+251436 vs 3FGL J0221.2+2518



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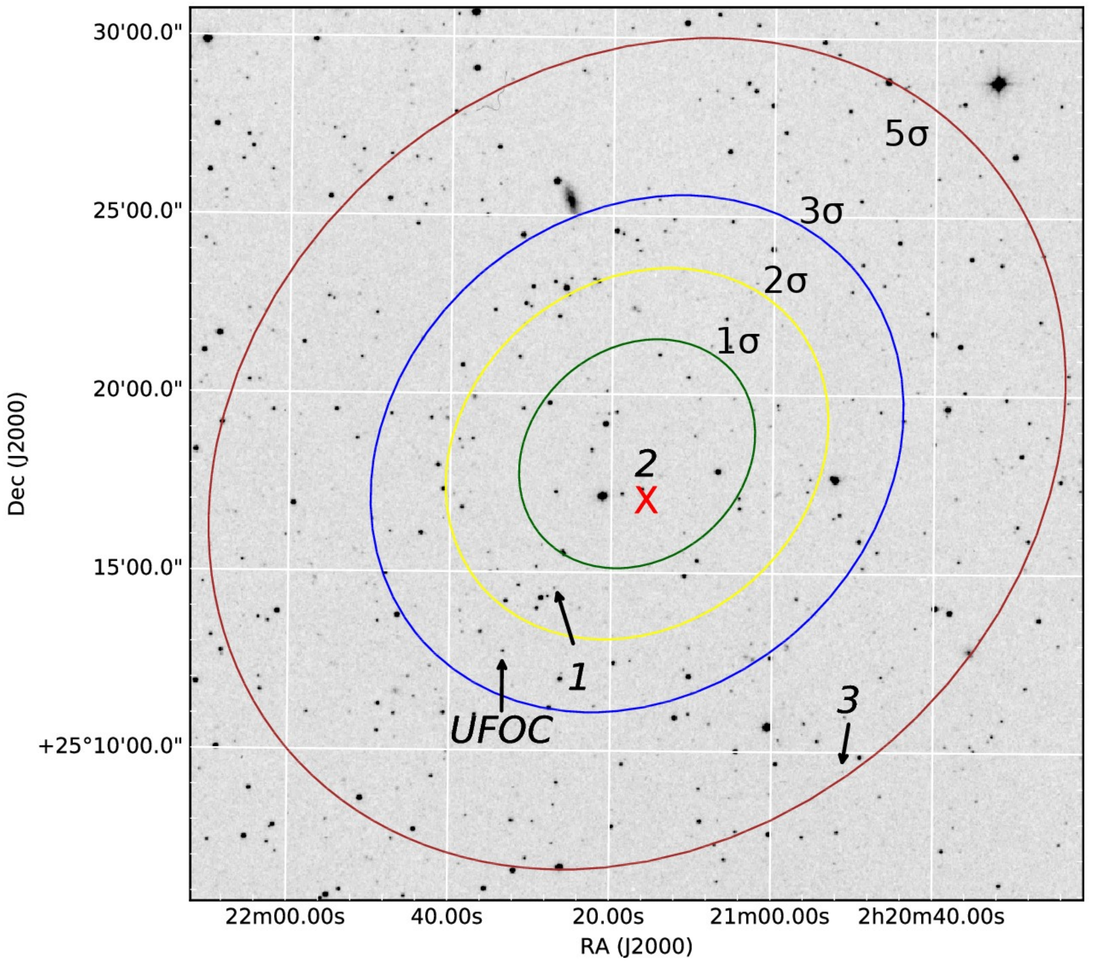


Conclusions

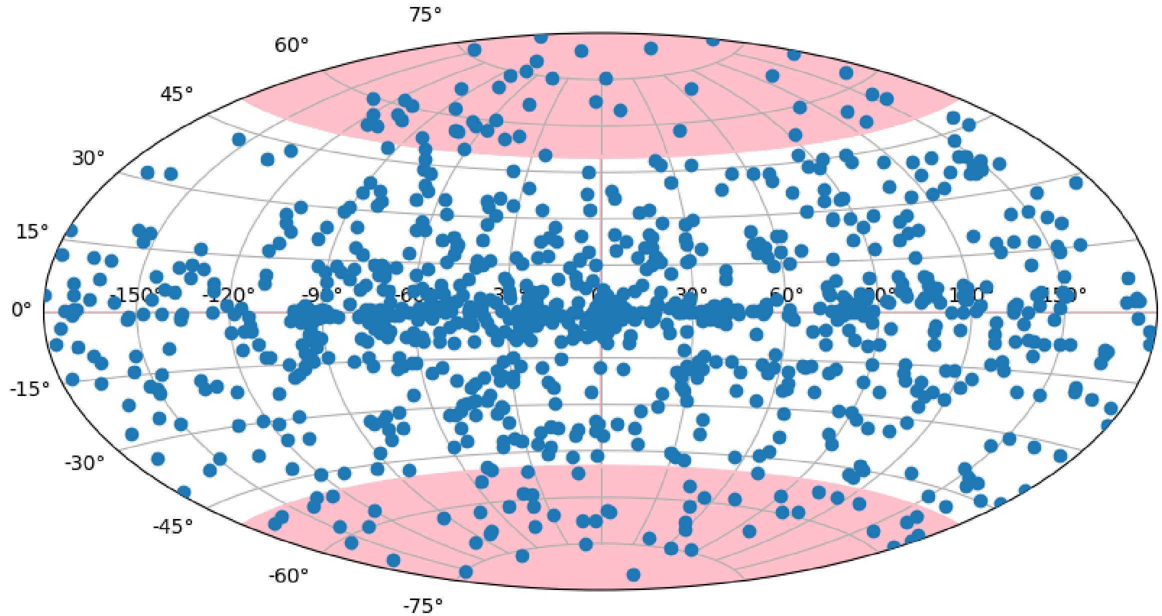
1) Optical polarimetry is a fast and efficient tool for association of γ-ray sources

2) Rough theoretical estimate suggests that 1/3 of UFOs can be detected in polarization

3) We found new AGN in 1 out 4 UFO fields

Future

Accuracy in P~0.1%
for stars R≤16^{m}
and |b| > 50° FoV ~ 30’



- Gaia distances and proper motions
- IR – colors
- Polarization
- Machine learning techniques

http://pasiphae.science