

Discovery of **P**eculiar Radio Morphologies in **ASKAP** using **Un-supervised Machine Learning**

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CSIRO Space & Astronomy**

Collaborators:

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Courtesy : ASKAP

Australian Square Kilometre Array Pathfinder (ASKAP)

CSIRO's ASKAP radio telescope, is situated at the Murchison region of Western Australia.

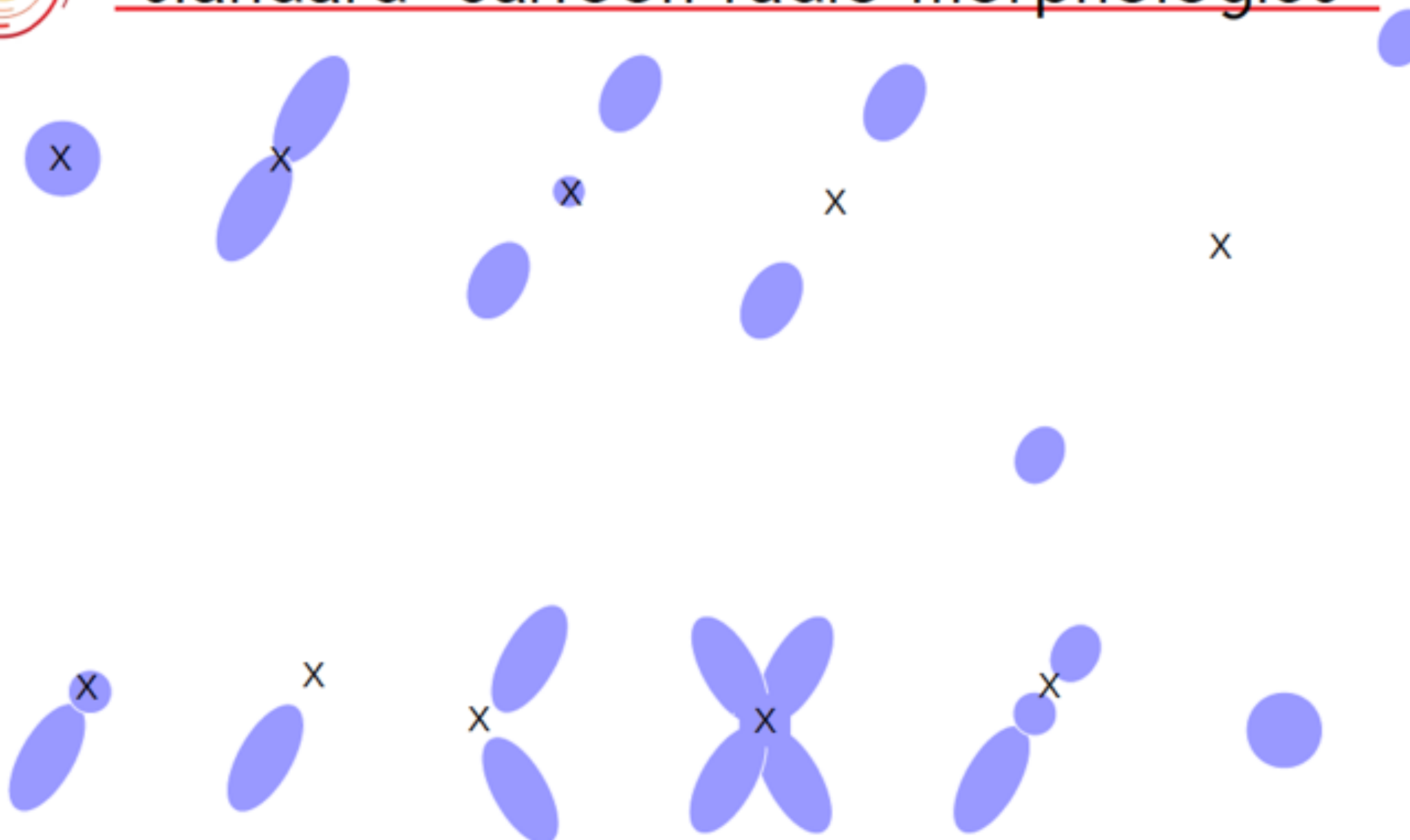
Equipped with Phased Array Feeds, ASKAP has 36 dish antennas, each 12m in diameter, and spread out with baselines up to 6km.



What are **P**eculiar Radio Morphologies?



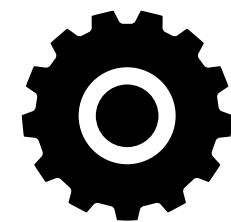
'standard' cartoon radio morphologies



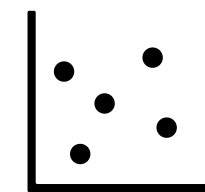
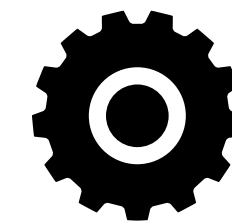
Outline



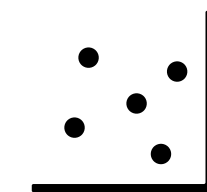
ASKAP
Observations



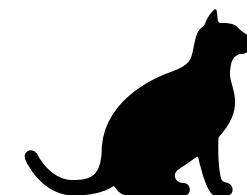
Machine Learning
Method



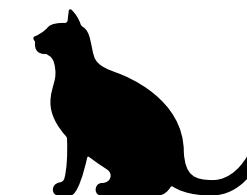
Selection of rare/peculiar sources



Circular Sources (Odd Radio Circle Candidates)



Other Peculiar radio emissions



Observations

Australian Square Kilometre Array Pathfinder (ASKAP)

1. Evolutionary Map of the Universe (EMU; Norris 2021) - Pilot Survey

- Covers 270 deg^2 of sky with declination
- RMS sensitivity of $25 - 35 \mu\text{Jy}/\text{beam}$
- Beamwidth of $13'' \times 11''$ FWHM
- $\sim 41,000$ complex radio components ($\sim 220\text{K}$ total)



2. Deep Investigation of Neutral Gas Origins (DINGO) - PS

- RMS sensitivity of $\sim 20 - 40 \mu\text{Jy}/\text{beam}$ for GAMA15
- Beamwidth of $10'' \times 6''$ FWHM
- $\sim 3,800$ complex radio components



3. Survey With ASKAP of GAMA-09 + X-ray (SWAG-X) - PS

- RMS sensitivity of $\sim 30 - 35 \mu\text{Jy}/\text{beam}$
- Beamwidth of $14'' \times 12''$ FWHM
- $\sim 21,000$ complex radio components



Observations

Australian Square Kilometre Array Pathfinder (ASKAP)

EMU full survey may detect >40 million radio galaxies!

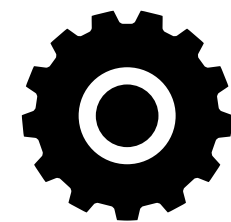
1. Evolutionary Map of the Universe
 - Covers 270 deg² of sky
 - RMS sensitivity of 25 mJy
 - Beamwidth of 13" x 13"
 - ~1,000 complex radio components
2. Deep Investigation of Neutral Hydrogen
 - RMS sensitivity of ~10 mJy
 - Beamwidth of 10" x 10"
 - ~4,500 complex radio components
3. Survey With ASKAP of GAMMA CORPUS ULTRA-DEEP FIELD
 - RMS sensitivity of ~10 mJy
 - Beamwidth of 14" x 12" FWHM
 - ~5,000 complex radio components



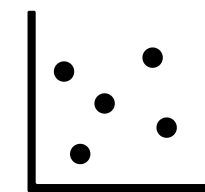
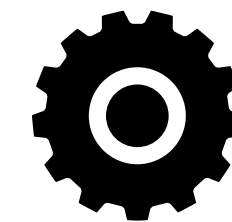
Outline



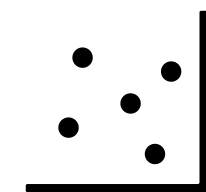
Observations
Radio, Infrared, Optical



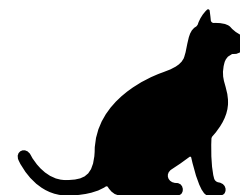
Method
Machine-learning method



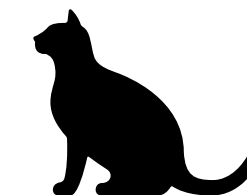
Selection of rare/peculiar sources



Circular Sources (Odd Radio Circle Candidates)



Other Peculiar radio emissions



Method

Machine Learning: Self Organising Maps

- Self-organizing map (SOM; Kohonen 1982) is a neural network that provides an efficient way to understand high dimensional data.

Method

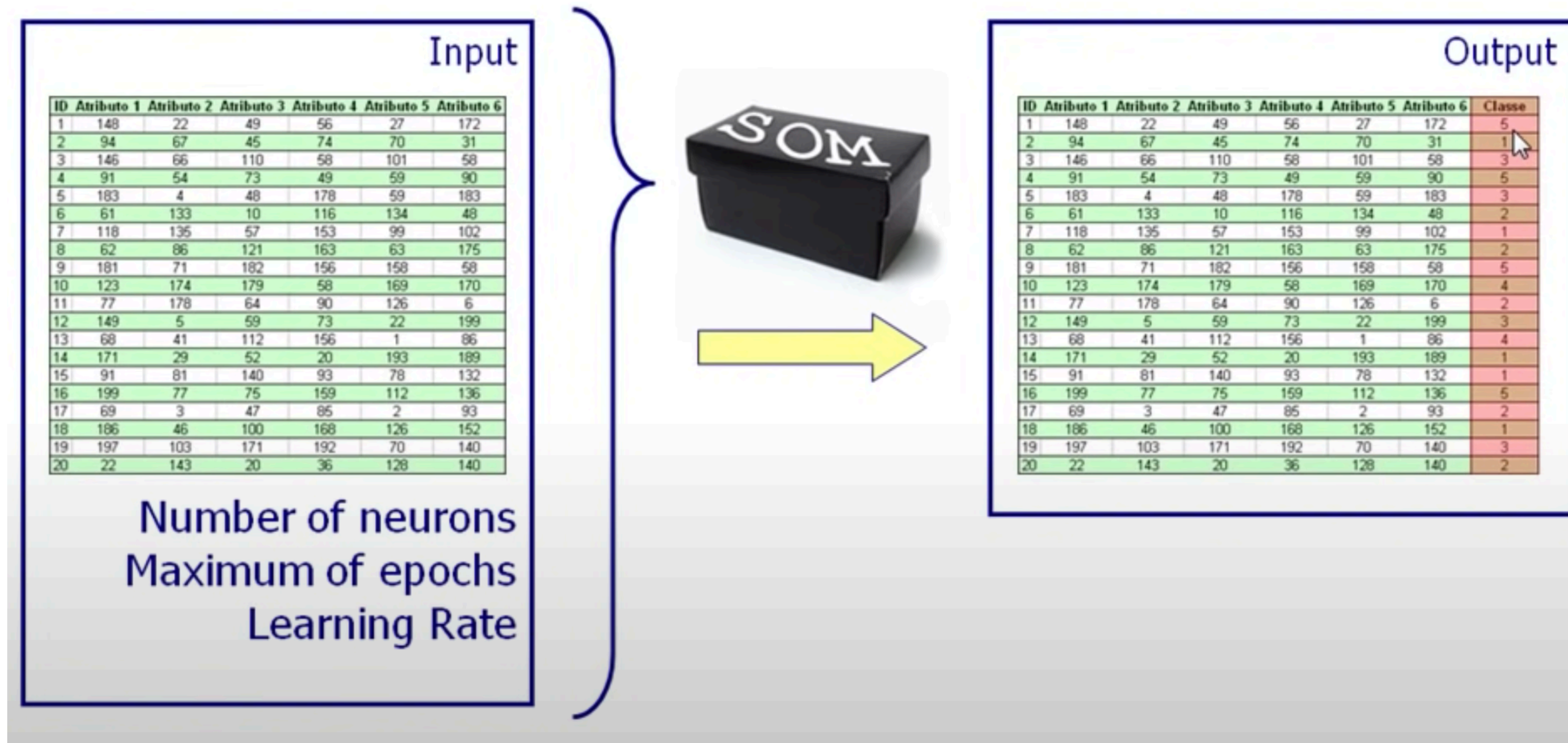
Machine Learning: Self Organising Maps

- Self-organizing map (SOM; Kohonen 1982) is a neural network that provides an efficient way to understand high dimensional data.
- SOM learns in an un-supervised manner and does not require a target vector for dataset.



Method

Machine Learning: Self Organising Maps



Method

Machine Learning: Self Organising Maps

- Self-organizing map (SOM; Kohonen 1982) is a neural network that provides an efficient way to understand high dimensional data.
- SOM learns in an un-supervised manner and does not require a target vector for dataset.
- The neural network constructs a representative feature map of the training dataset by measuring the similarities between neurons and images.

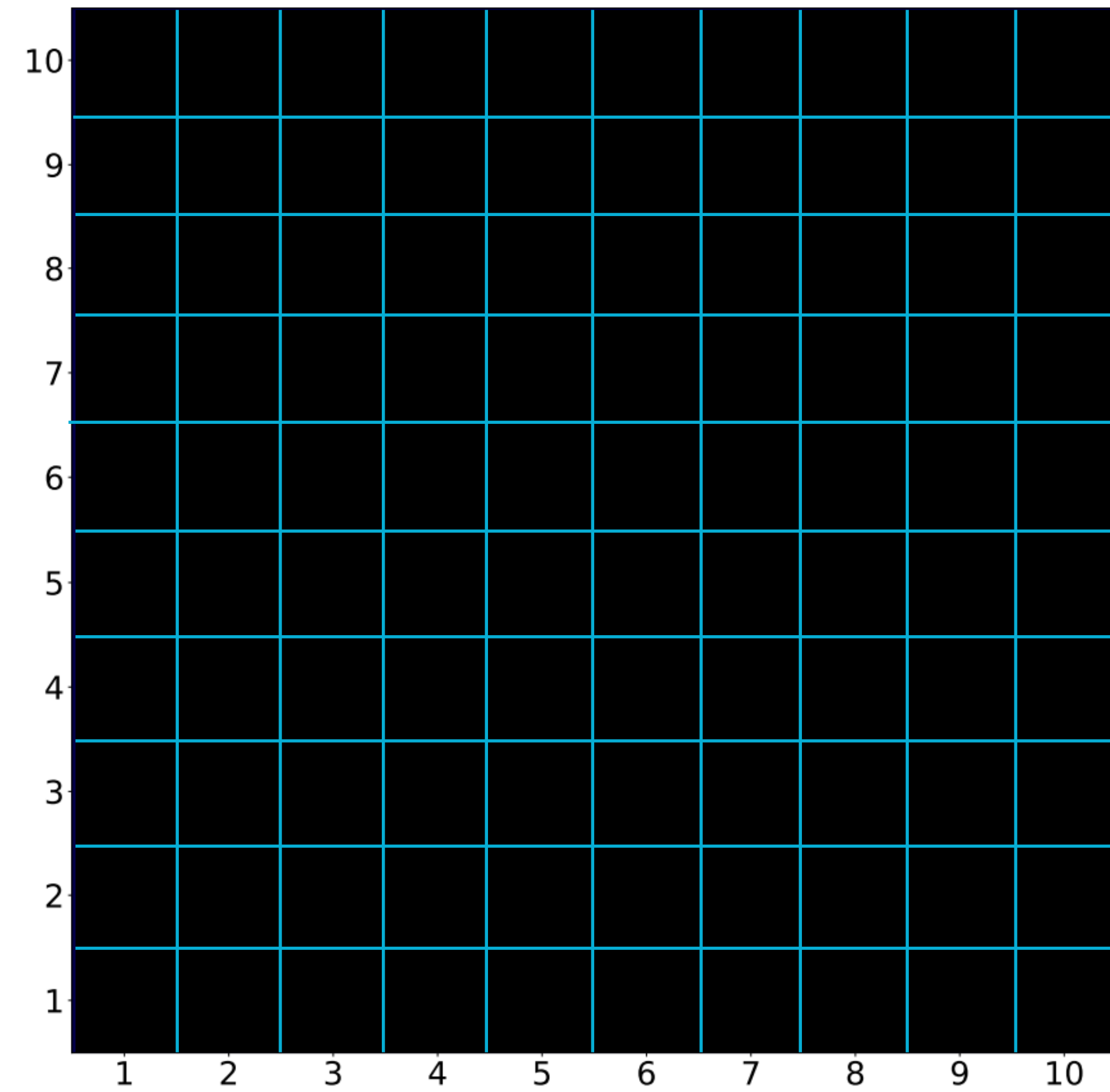


Method

Machine Learning: Self Organising Maps



Radio Images



SOM Lattice (10x10)



Outline



Observations
Radio, Infrared, Optical



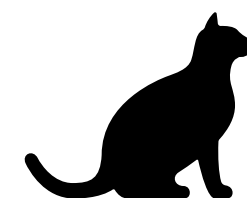
Method
Machine-learning method



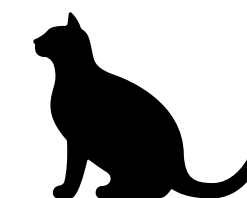
 Selection of rare/peculiar sources 



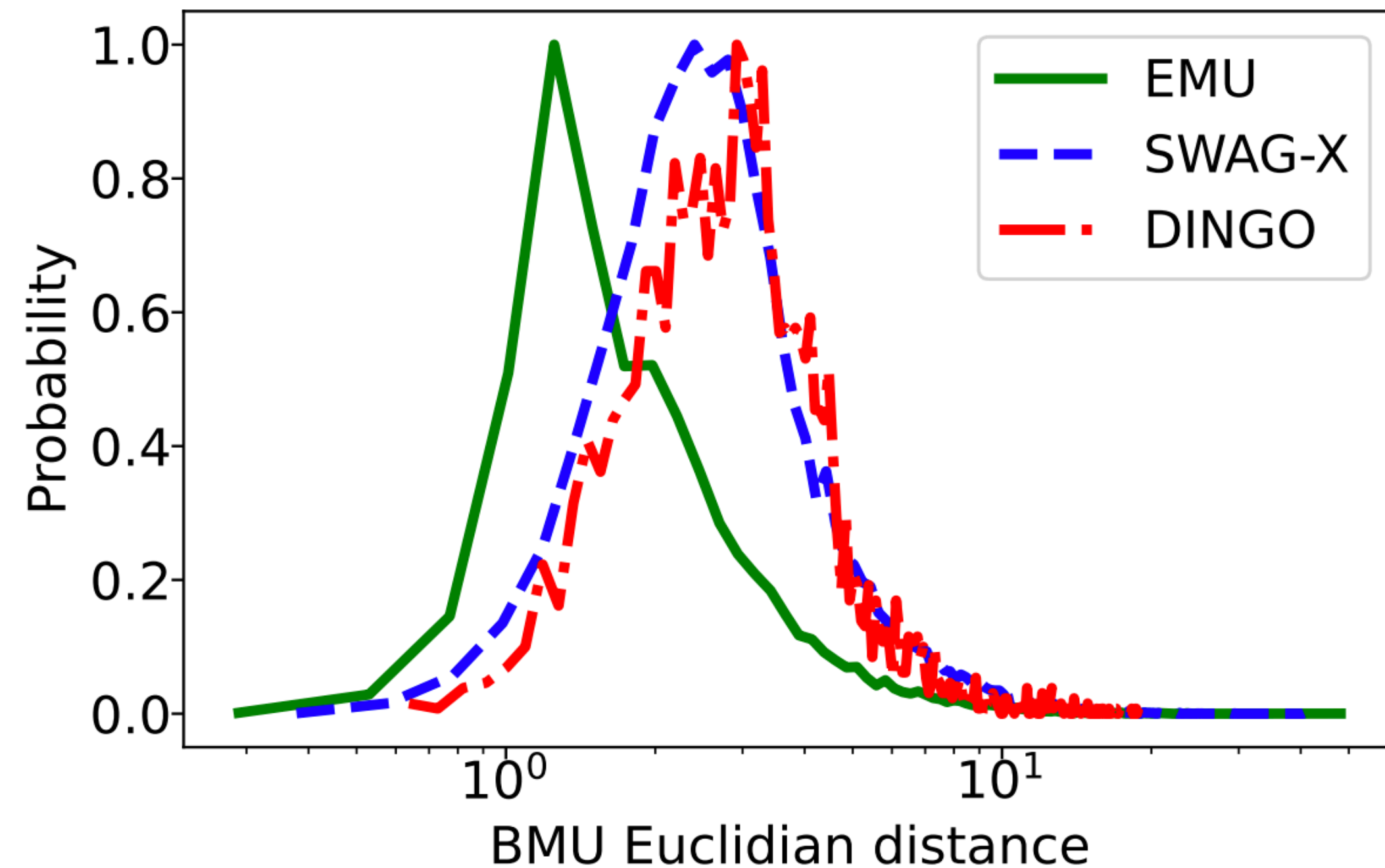
Circular Sources (Odd Radio Circle Candidates)



Other Peculiar radio emissions



Selection of interesting sources



- For an adequately trained SOM, the predominant sources in the dataset should have a BMU.
- The rare and unusual sources are not expected to be clustered in a single neuron.
- We use the modified euclidean distance metric to to identify these objects.

**For each ASKAP survey we examine 0.5% sources above a certain the euclidean distance.
Visually inspect 200, 100 and 20 sources in the EMU-PS, SWAG-X and DINGO surveys.**

Outline



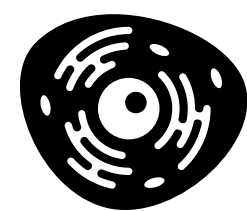
Observations
Radio, Infrared, Optical



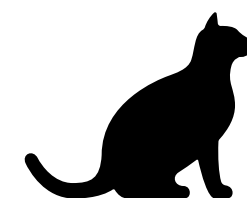
Method
Machine-learning method



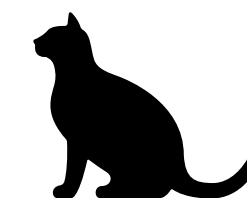
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Circular Sources (Odd Radio Circle Candidates)

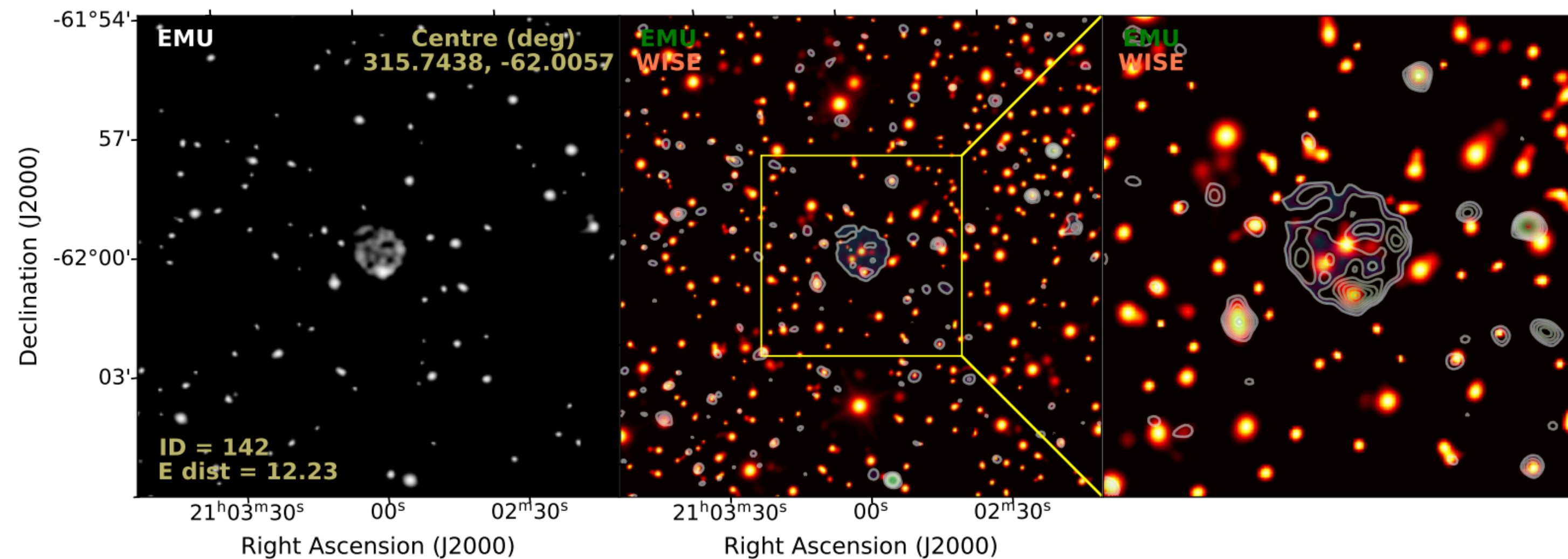
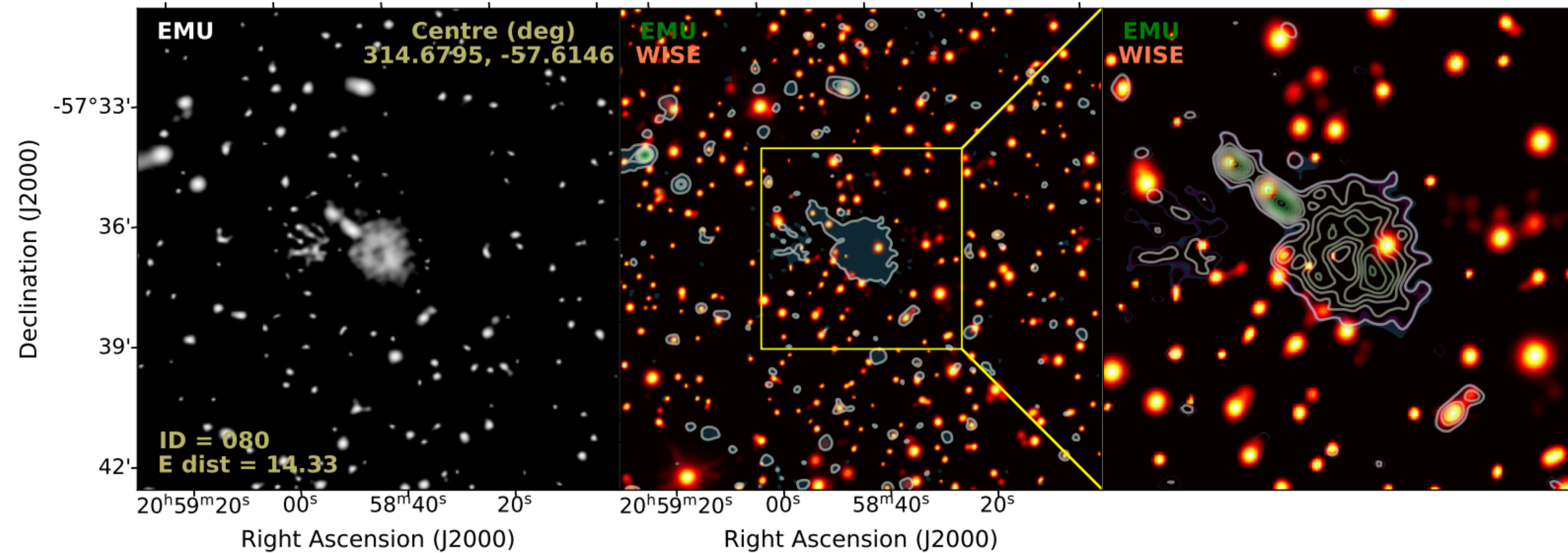


Other Peculiar radio emissions



Results

Circular shaped sources: Odd Radio Circles (ORCs) from Norris et al. 2020
ORC J2102-6200 and ORC J2058-5736





Share: **Space**

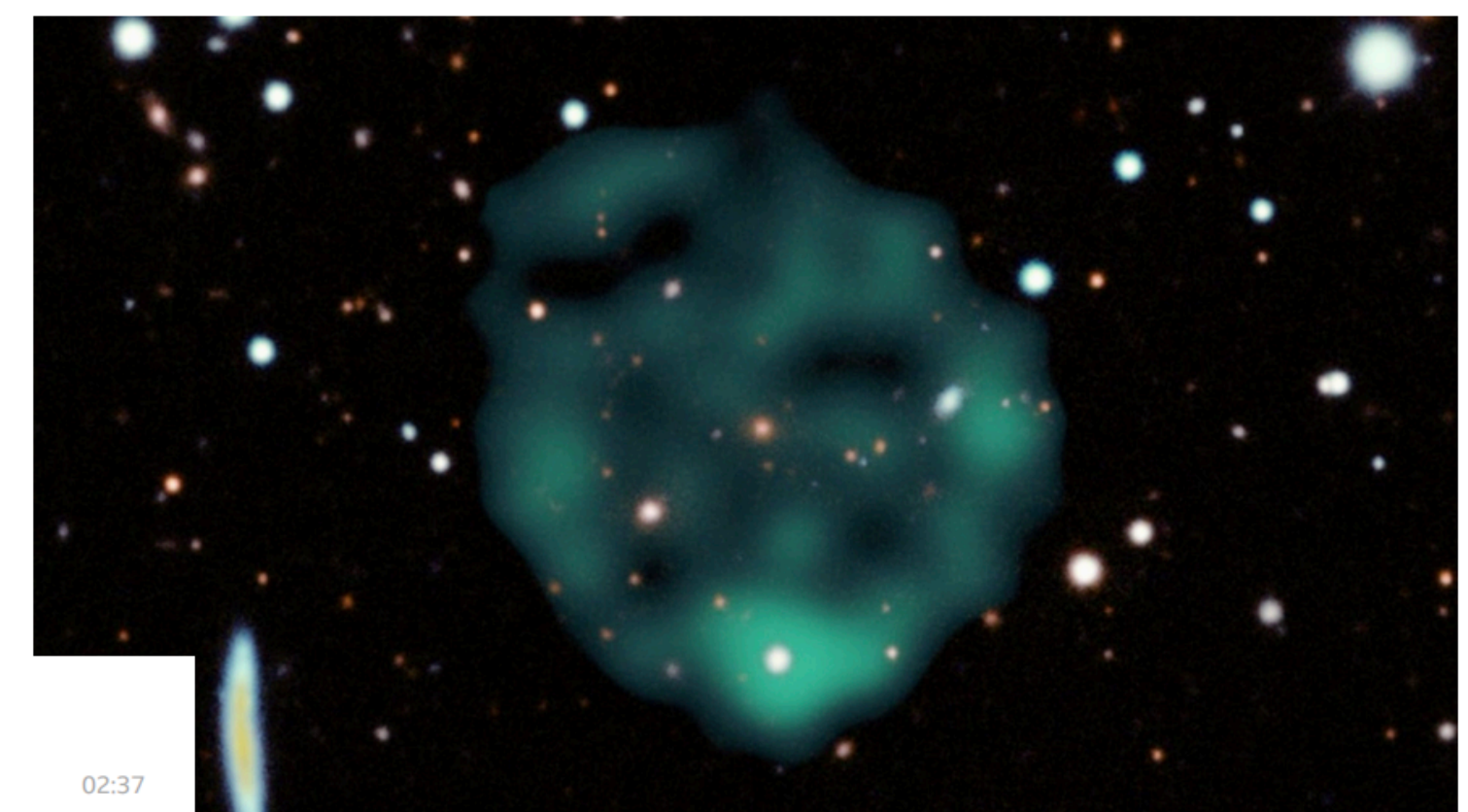
Astronomers ponder Odd Radio Circles in space

Posted by [Paul Scott Anderson](#) | July 24, 2020



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Astronomers Detect Another Mysterious Ghostly Circle in Extragalactic Space

MICHELLE STARR 29 APRIL 2021

The discovery of a giant, ghostly circle in extragalactic space is bringing us closer to understanding what these mysterious structures actually are.

ORC J0102-2450, as seen with ASKAP and overlaid onto other surveys. (Koribalski et al., arXiv, 2021)

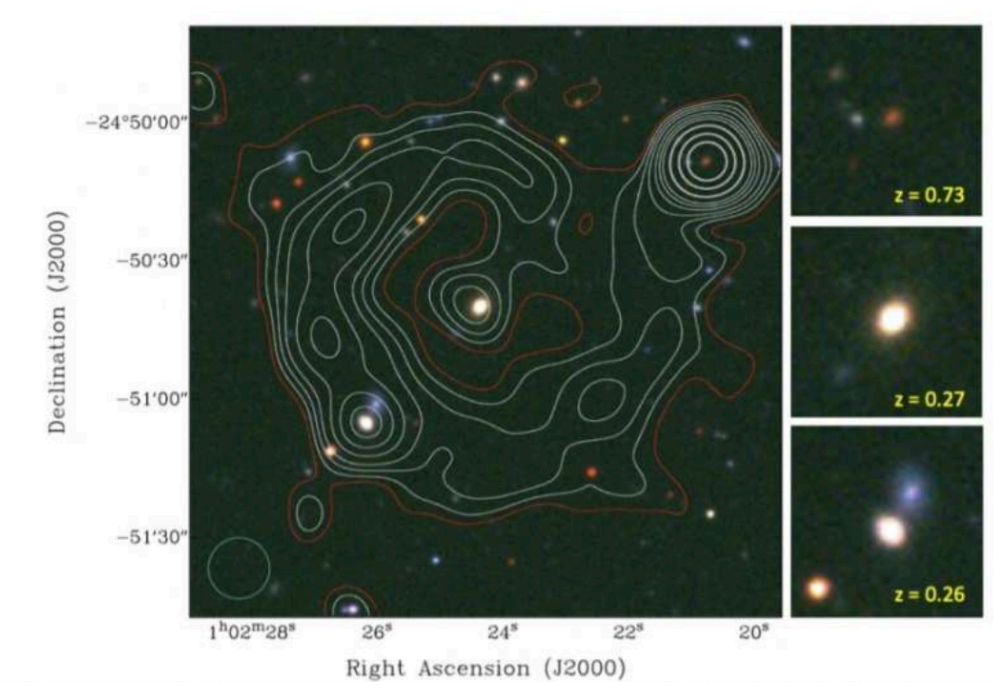
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MAY 4, 2021 **REPORT**

Astronomers discover a new extragalactic circular radio source

by Tomasz Nowakowski, Phys.org



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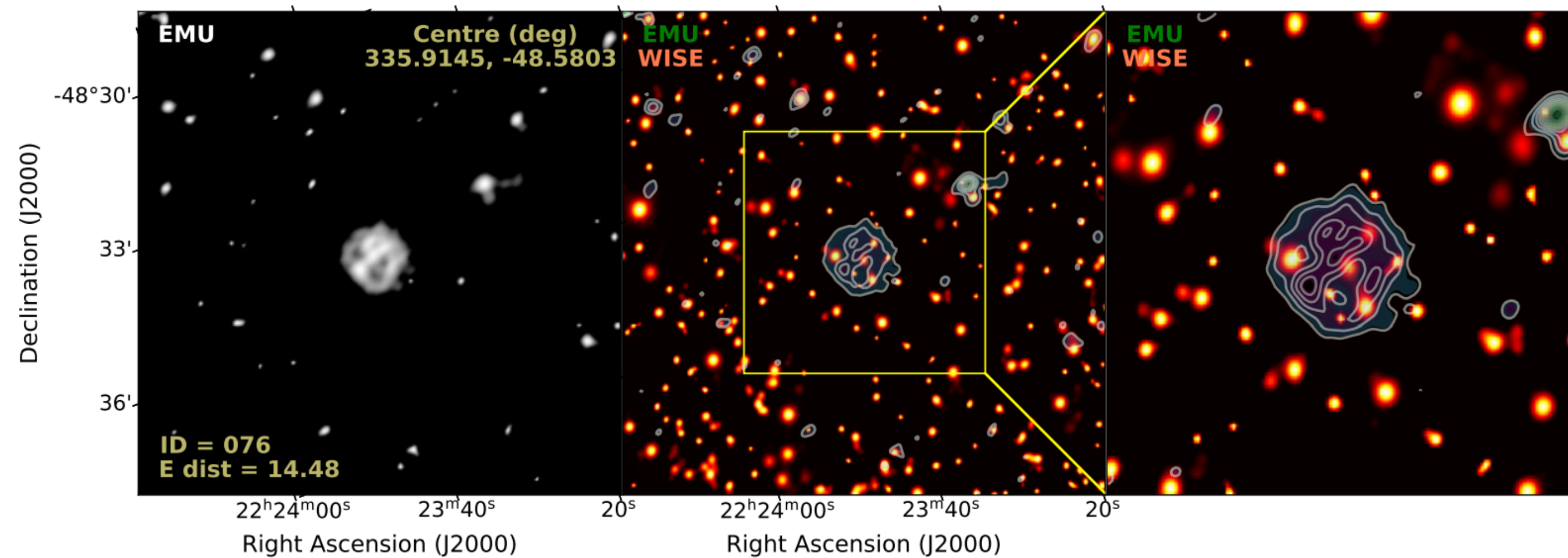
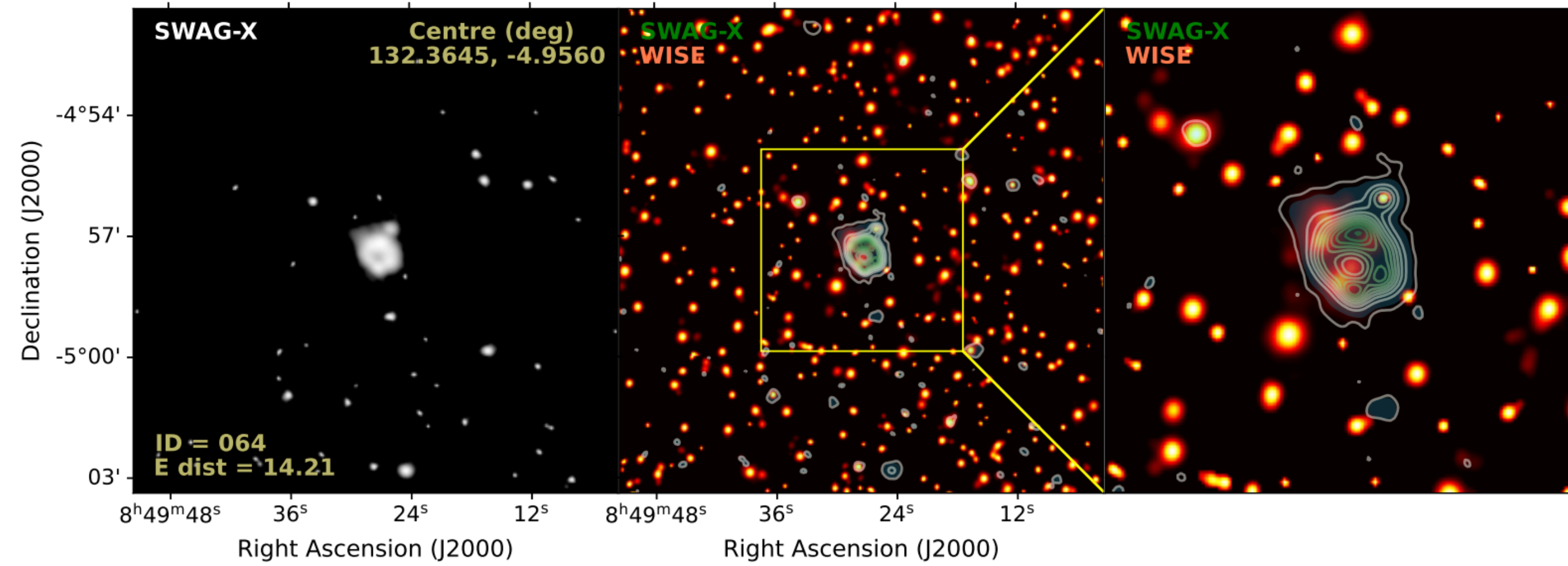
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JAN 28, 2022



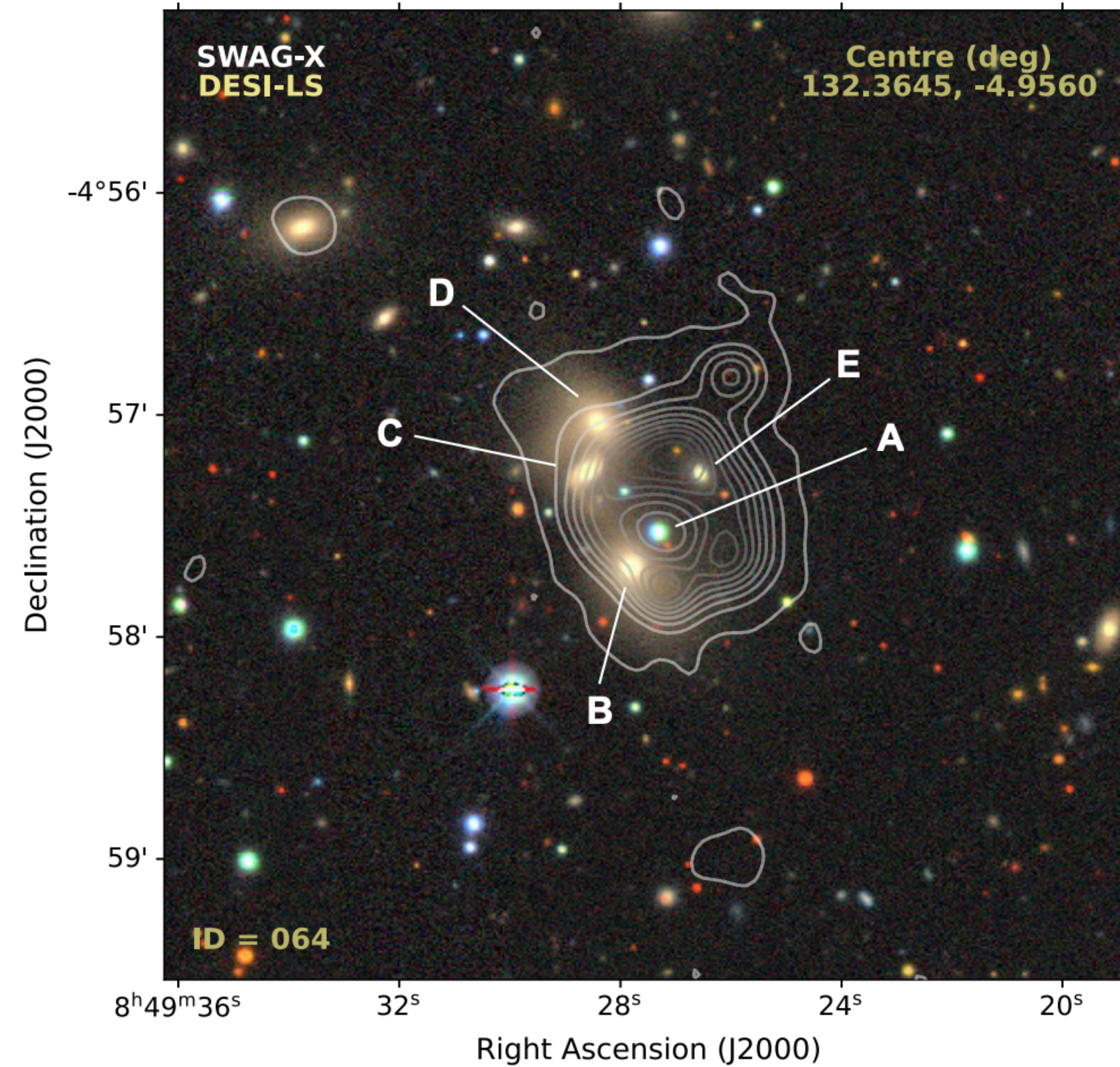
Results

Circular shaped sources: New ORC Candidates



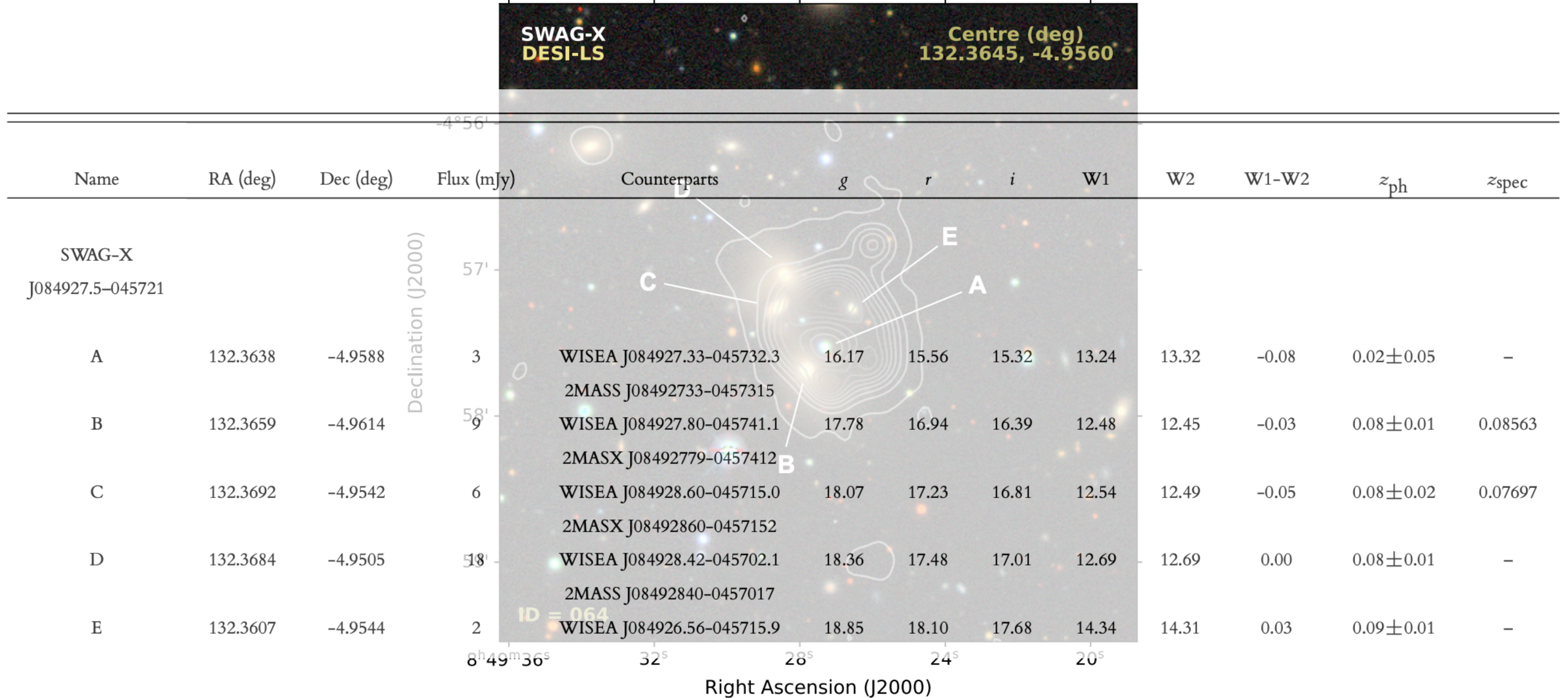
Results

Circular shaped sources: New ORC Candidate 1 SWAG-X J084927.5-045721



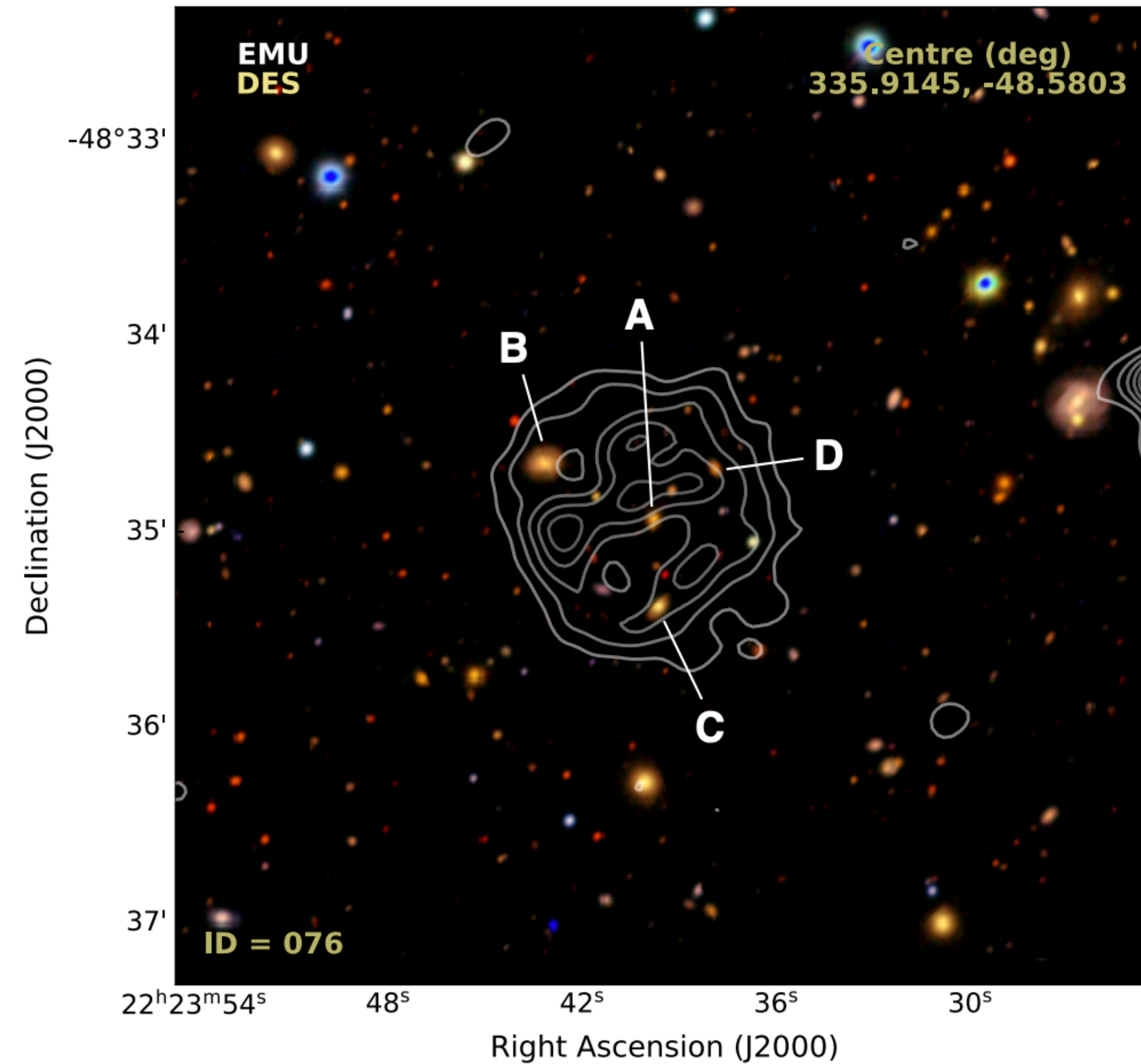
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Circular shaped sources: New ORC Candidate 1 SWAG-X J084927.5-045721



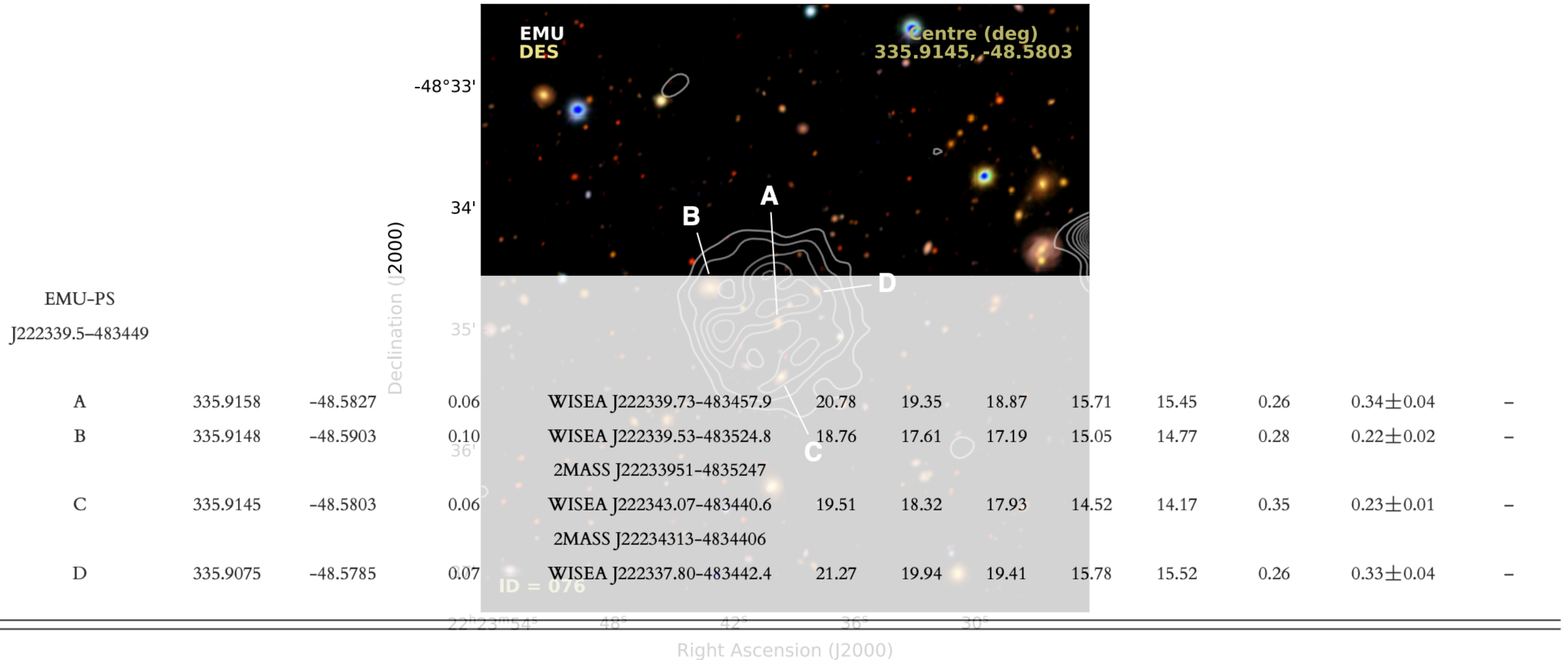
Results

Circular shaped sources: New ORC Candidate 2 EMU-PS J2223-4834



Results

Circular shaped sources: New ORC Candidate 2 EMU-PS J2223-4834



Outline



Observations
Radio, Infrared, Optical



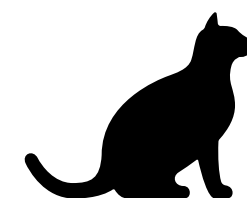
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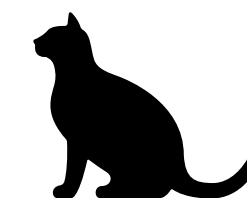
Selection of rare/peculiar sources



Circular Sources (Odd Radio Circle Candidates)

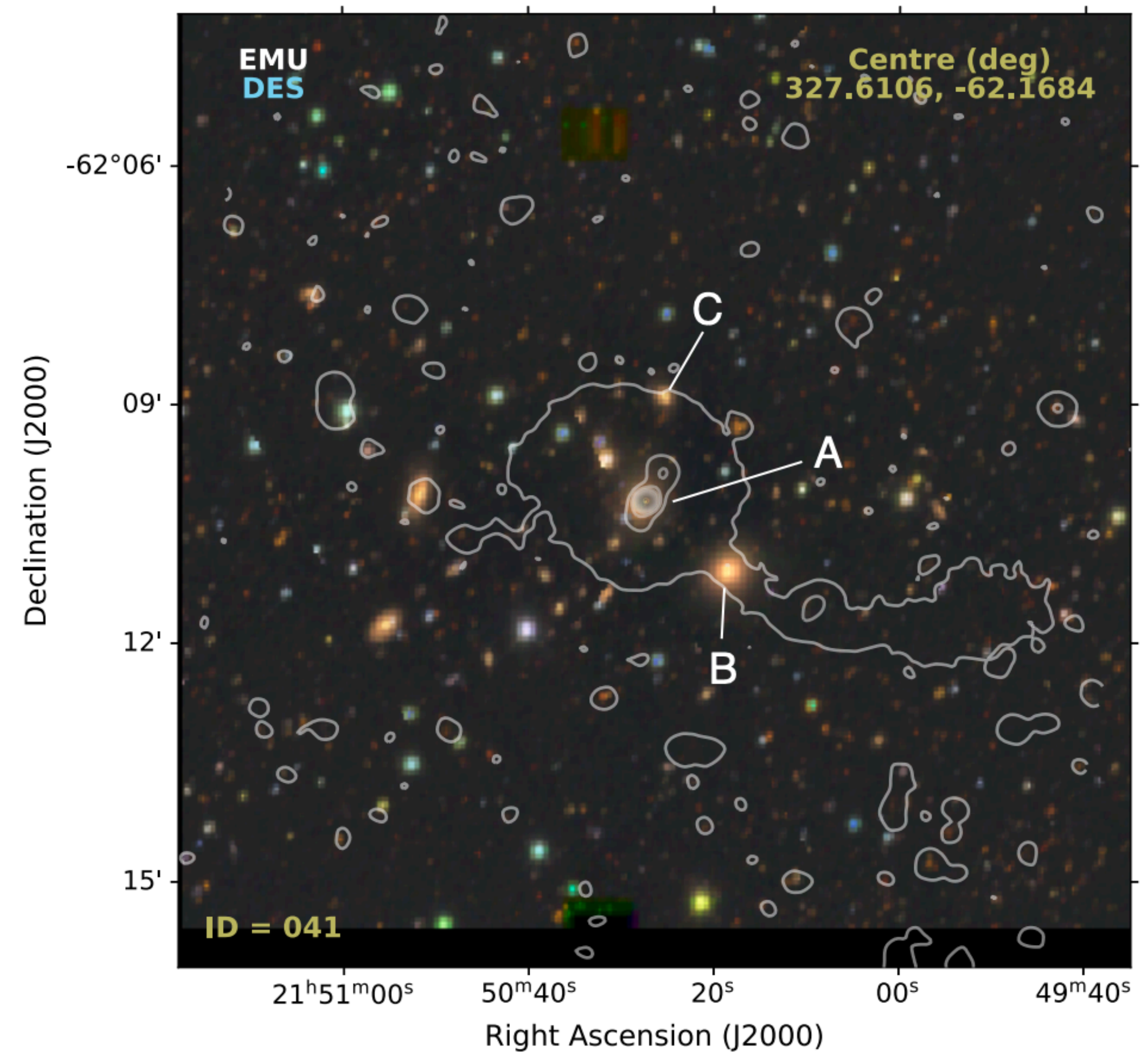
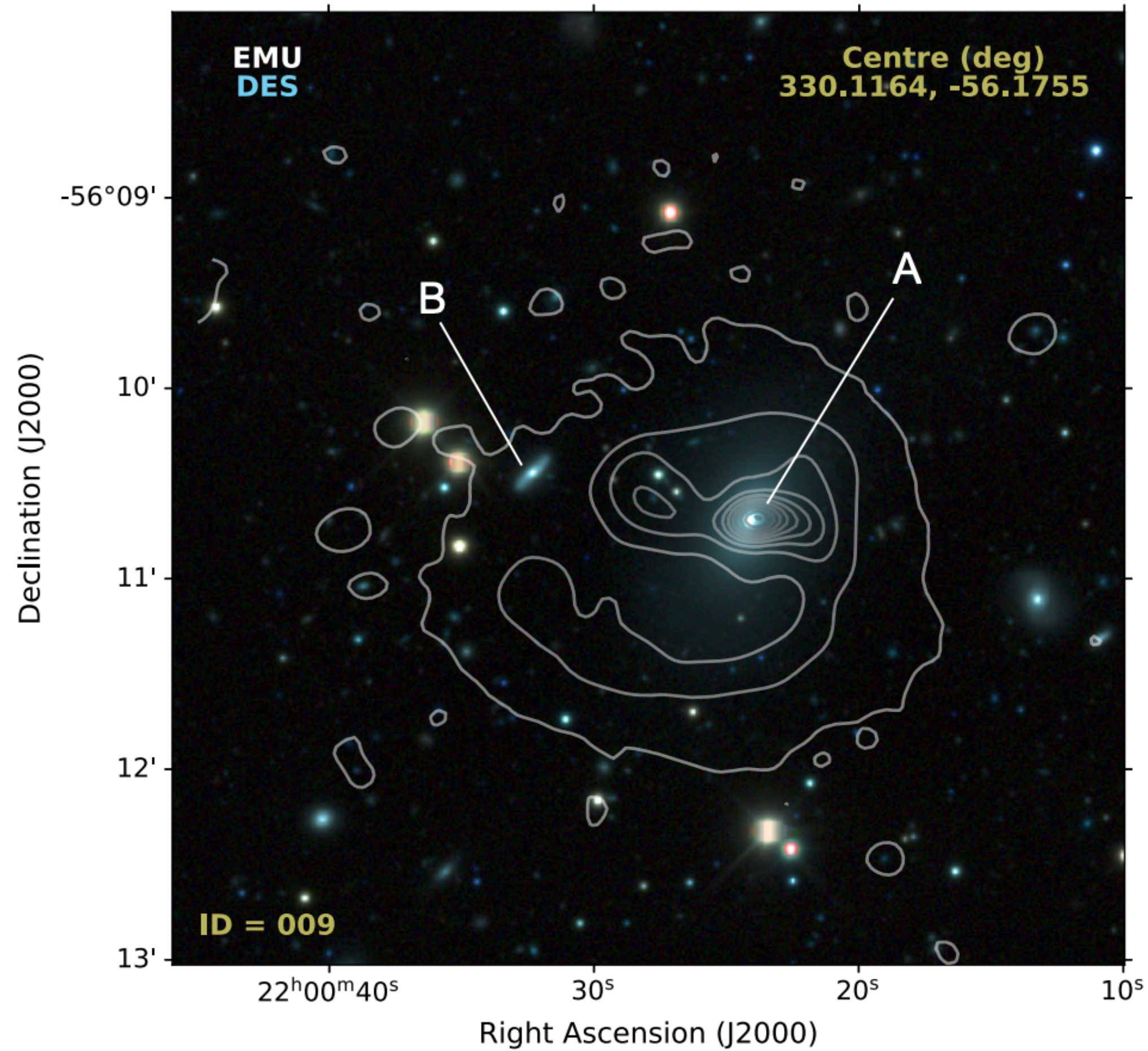


Other Peculiar radio emissions



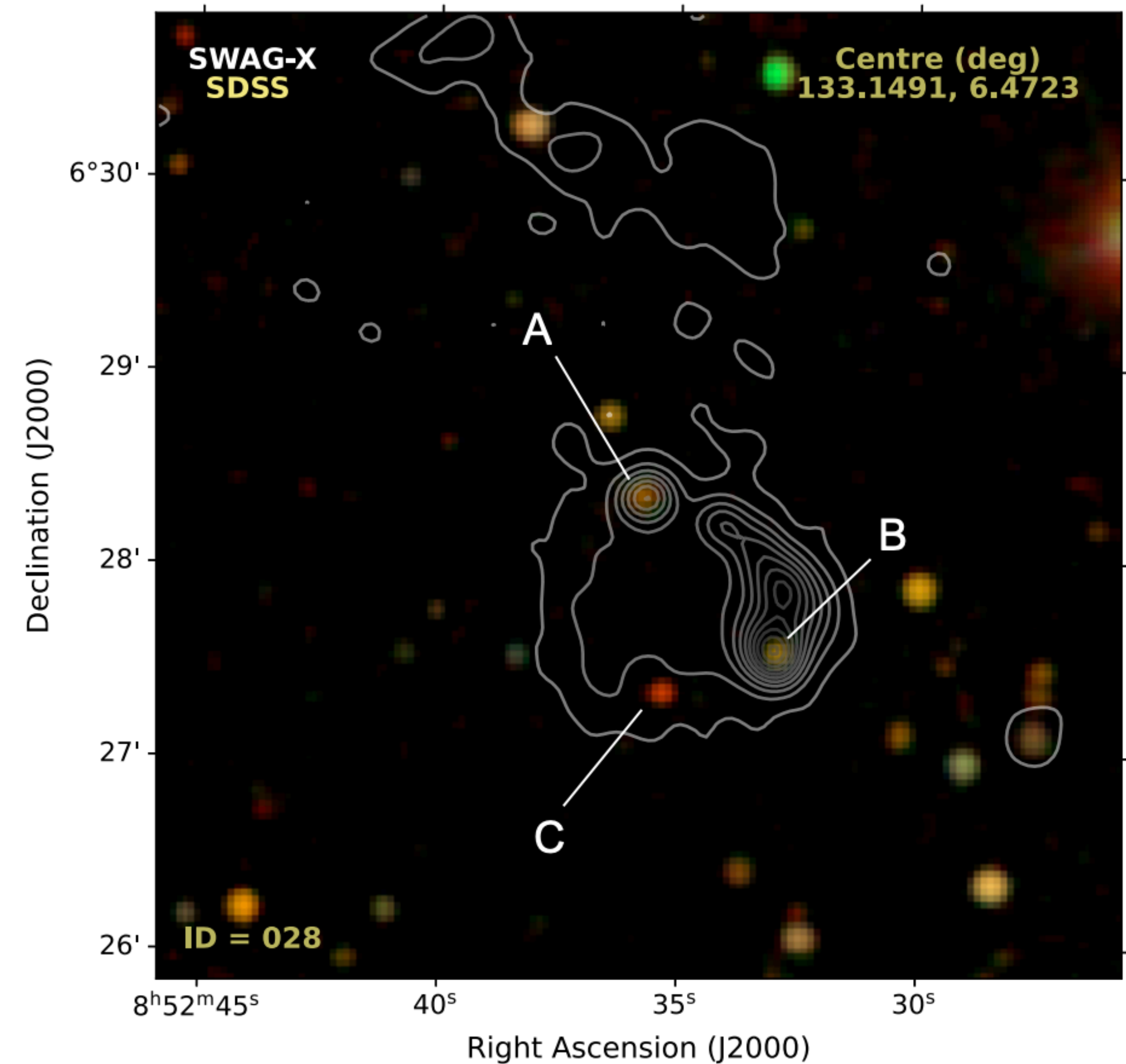
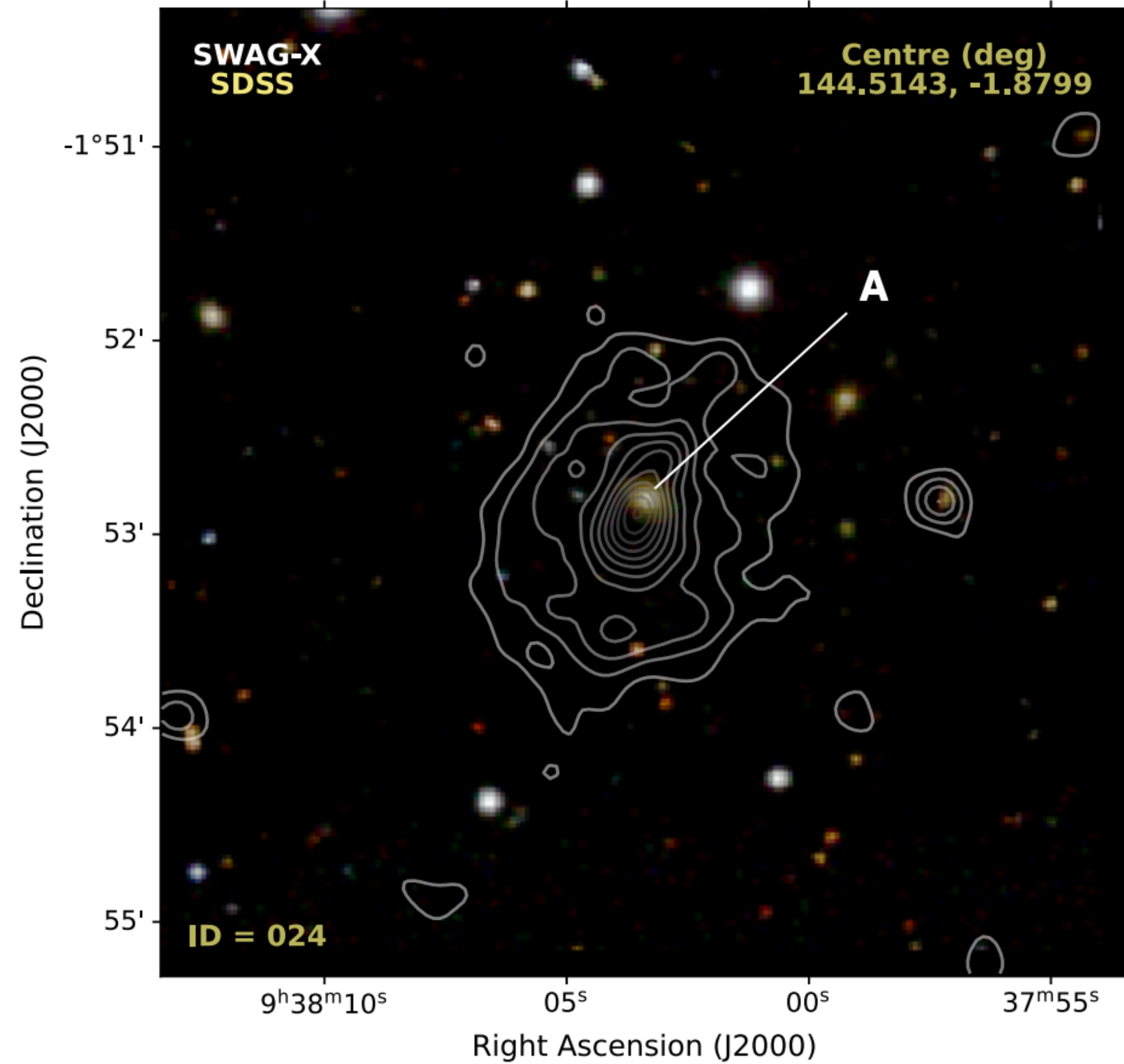
Results

Peculiar shaped sources among top 0.5% (EMU-PS)



Results

Peculiar shaped sources among top 0.5% (SWAG-X)



Summary

- Machine learning method to search for the rarest and most interesting sources in ASKAP continuum radio surveys.
- Selected a small fraction (0.5%) of radio sources with highest euclidean distances for visual inspections.
- Among these sources at high euclidean distances found 2 new Odd Radio Circle (ORC) candidates, other peculiar radio morphologies and odd conventional morphologies like galaxy clusters, resolved star forming galaxies, bent-tailed galaxies, and FR-I & FR-II sources (Gupta et al. 2022, submitted).

