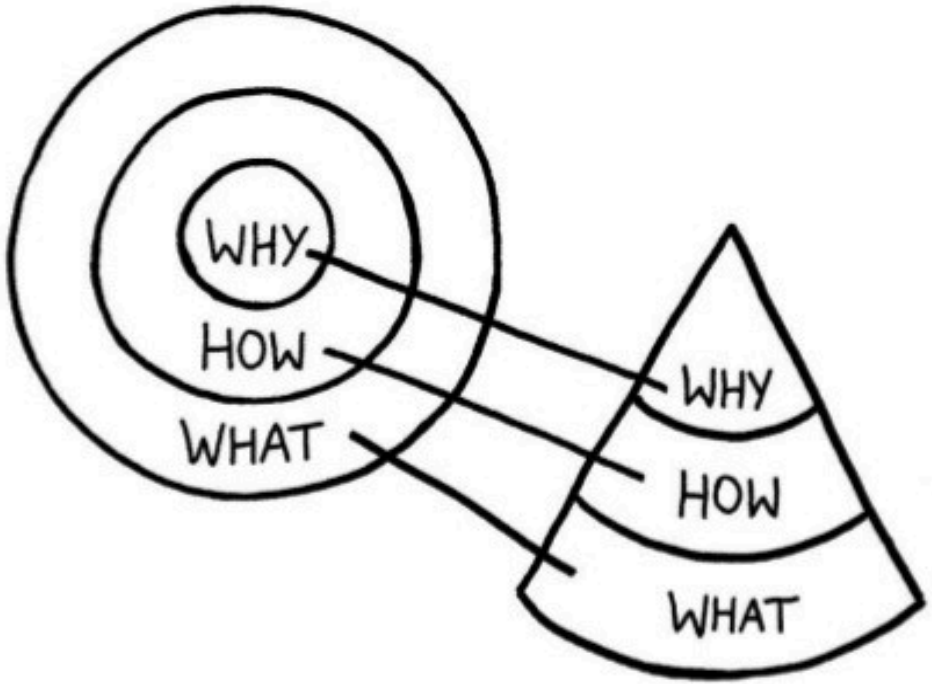
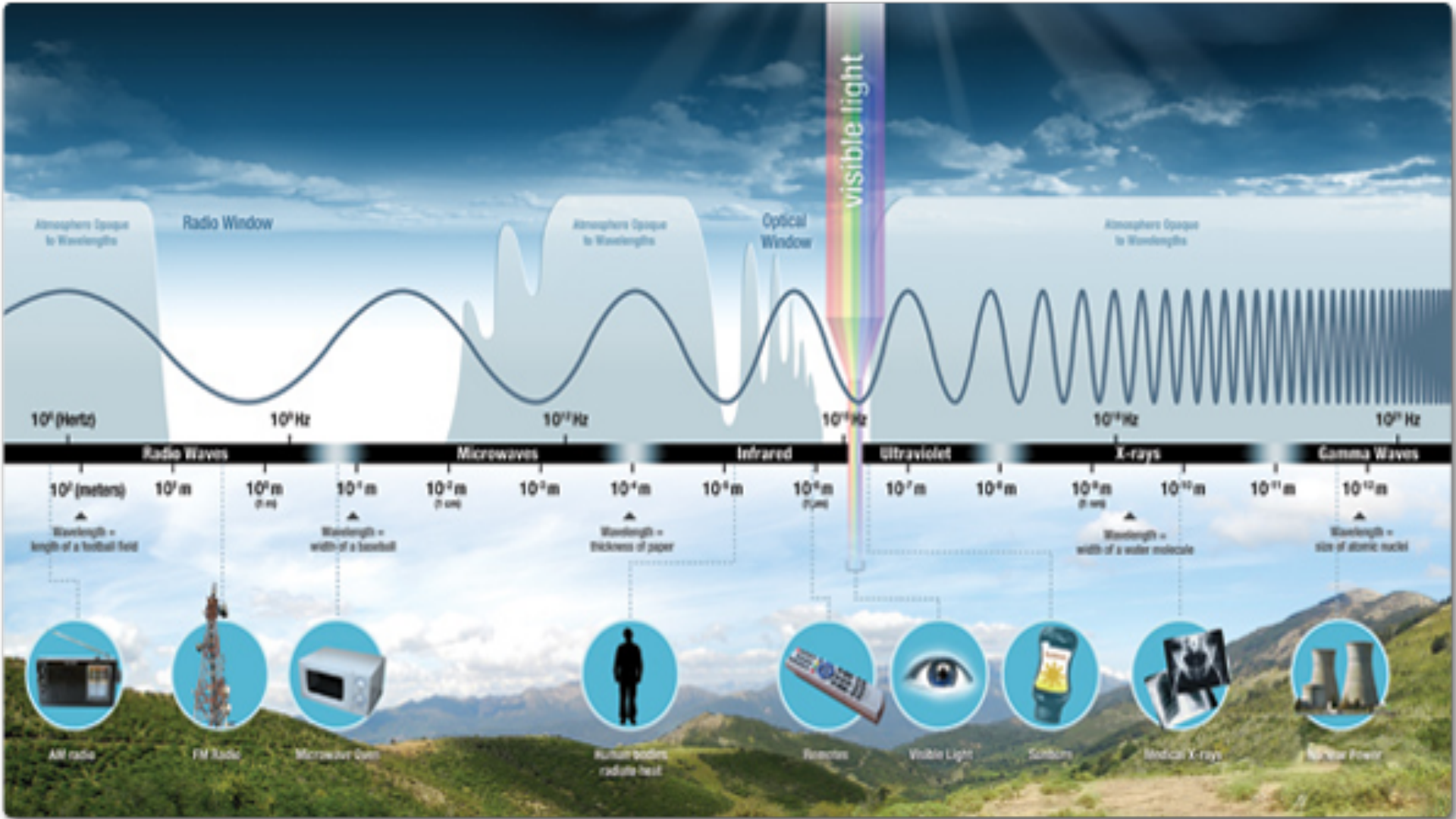
Radio Surveys
&
Era of AI

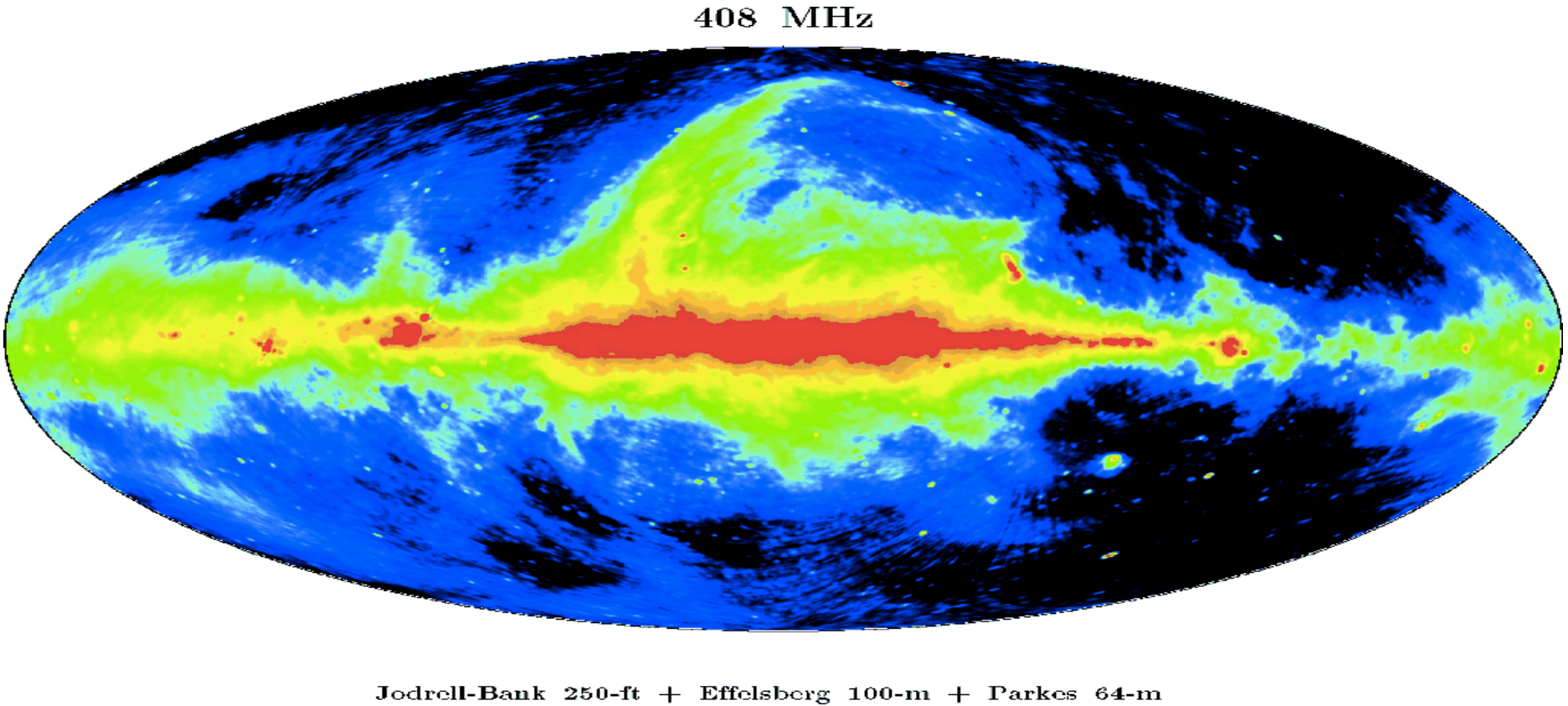
Nadeem Oozeer, PhD.
Data Scientist
SARAO

The Golden Circle + Cone



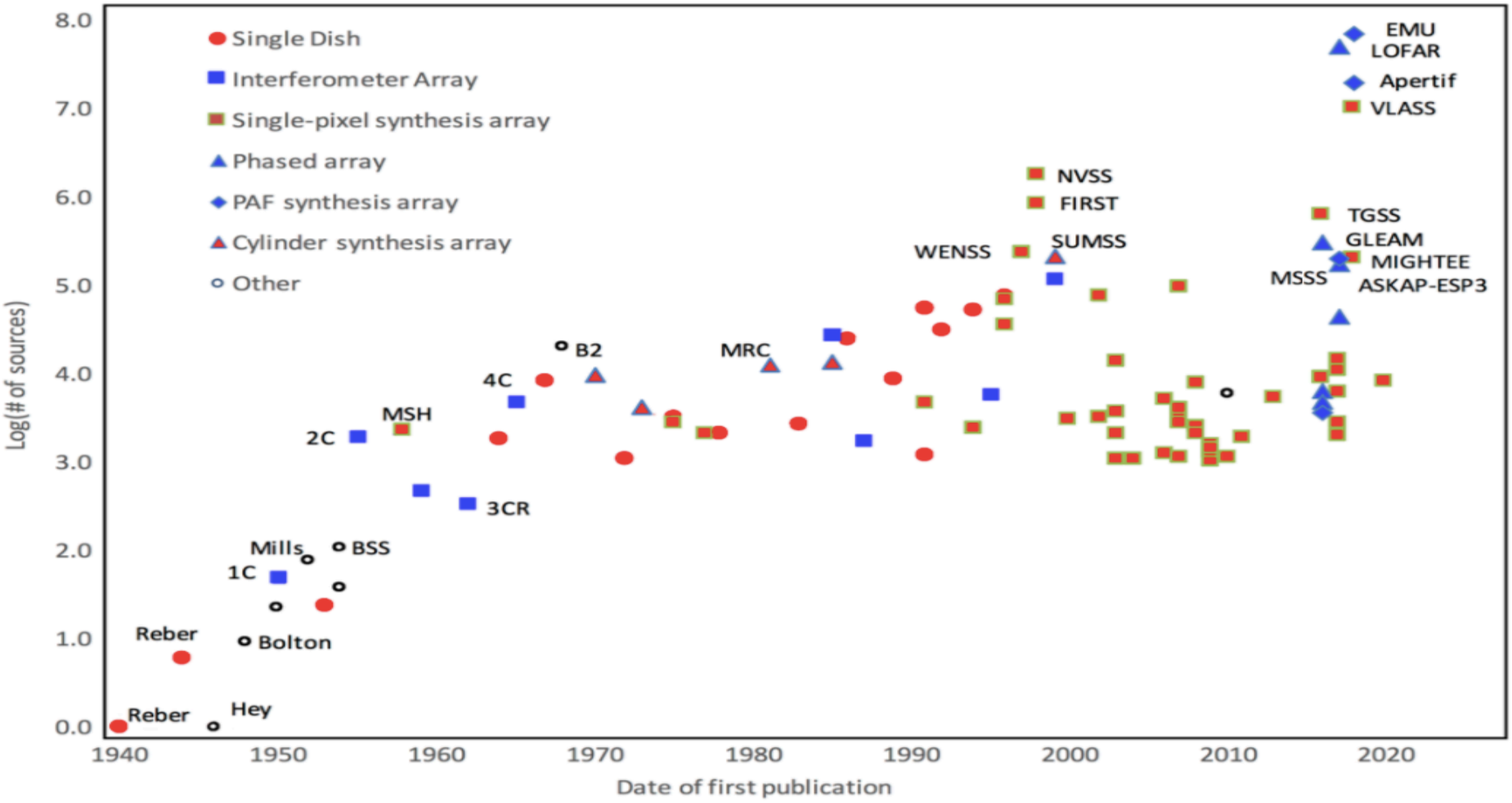
© 2012 Simon Sinek, Inc.


visible light
Atmosphere Opaque to Wavelengths
Radio Window
Atmosphere Opaque to Wavelengths
Optical Window
Atmosphere Opaque to Wavelengths
10^{0} (Hertz)
10^{3} Hz
10^{12} Hz
10^{15} Hz
10^{18} Hz
10^{21} Hz
Radio Waves
Microwaves
Infrared
Ultraviolet
X-rays
Gamma Waves
10^{2} (meters)
10^{1} m
10^{0} m
10^{-1} m
10^{-2} m
10^{-3} m
10^{-4} m
10^{-5} m
10^{-6} m
10^{-7} m
10^{-8} m
10^{-9} m
10^{-10} m
10^{-11} m
10^{-12} m
Wavelength = length of a football field
Wavelength = width of a baseball
Wavelength = thickness of paper
Wavelength = width of a water molecule
Wavelength = size of atomic nuclei
AM radio
FM Radio
Microwave Oven
Human bodies radiate heat
Remotes
Visible Light
Sunburn
Medical X-rays
Nuclear Power

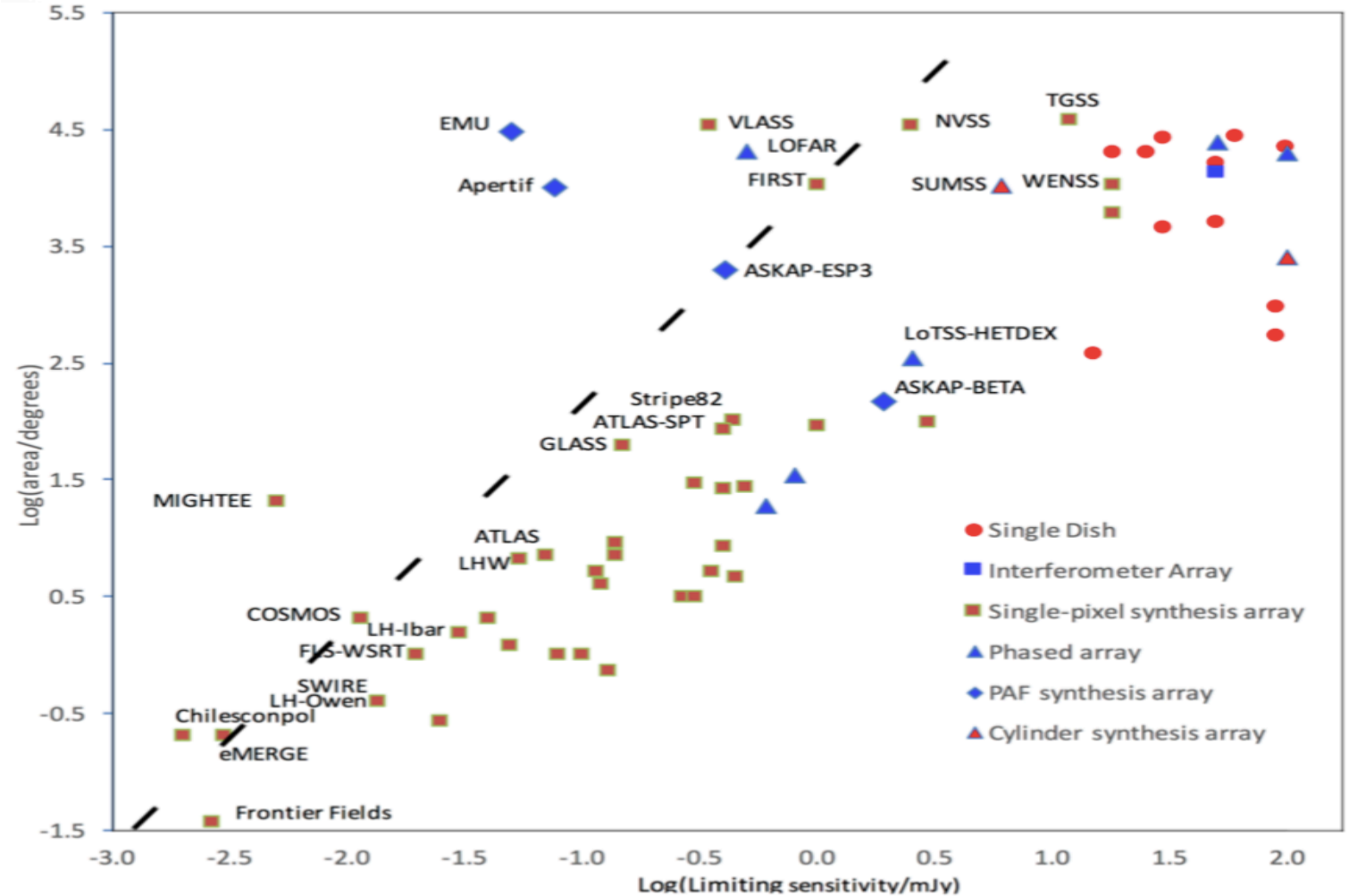


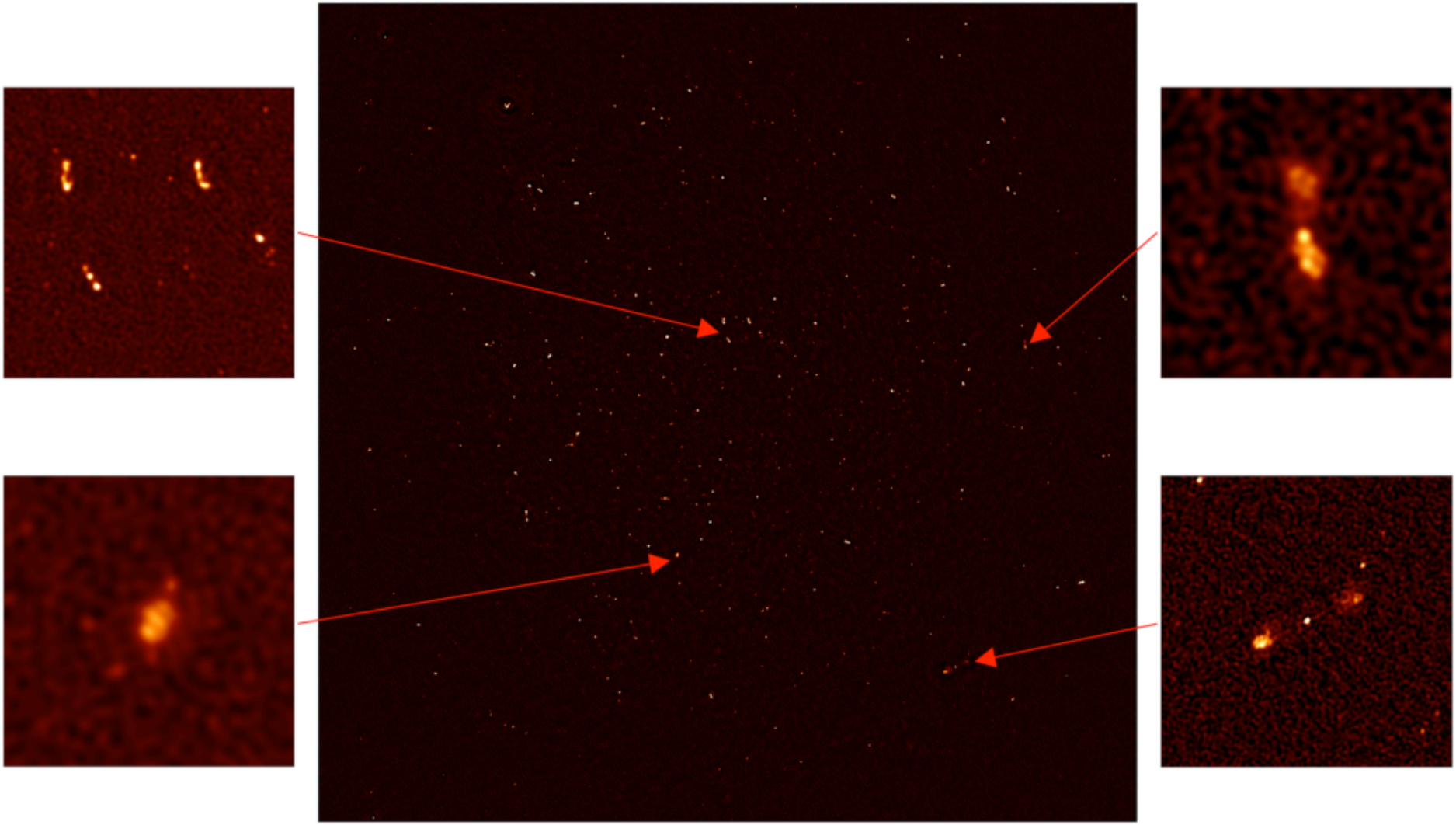
A&A 500, 245–246 (2009)

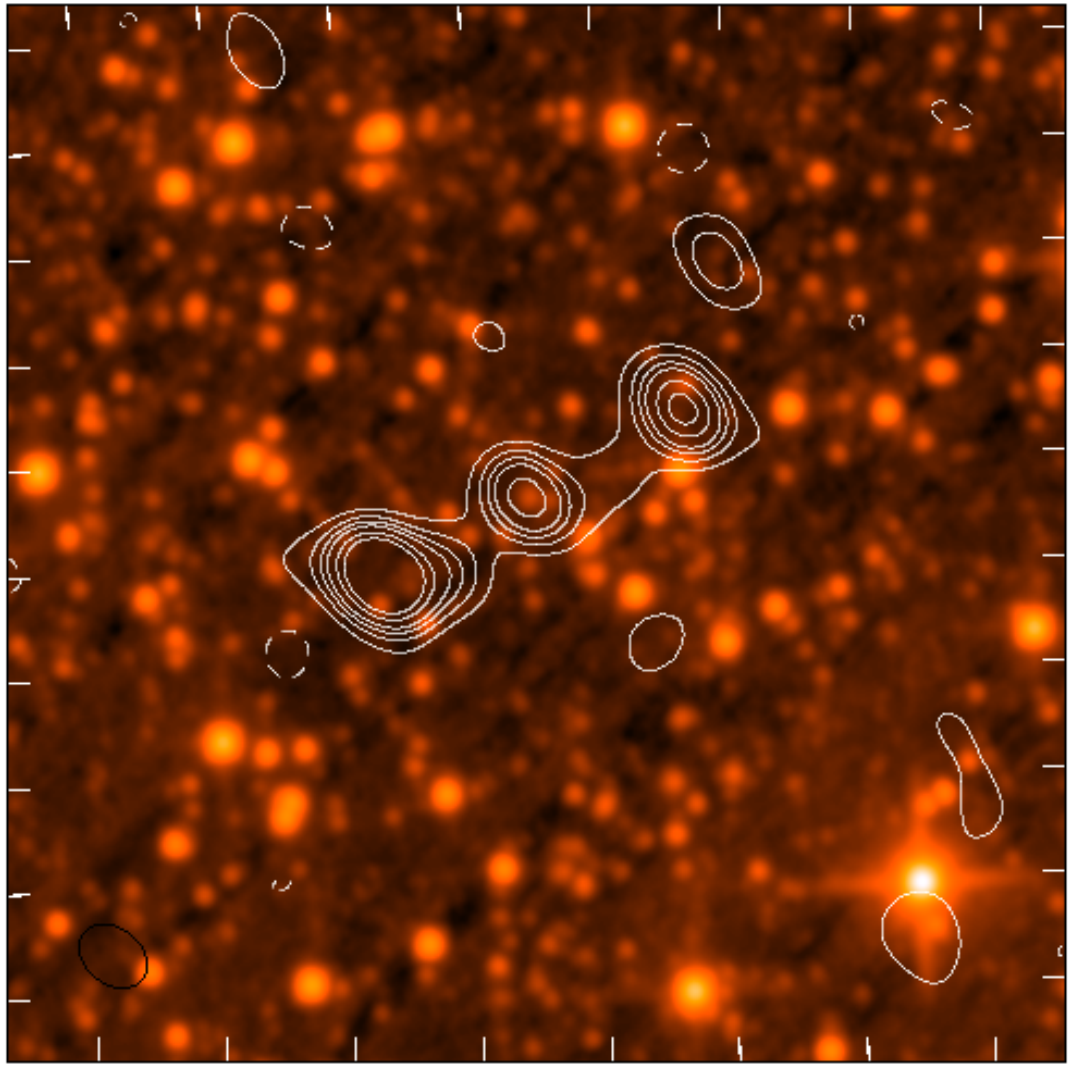
- Resolution
- Sensitivity

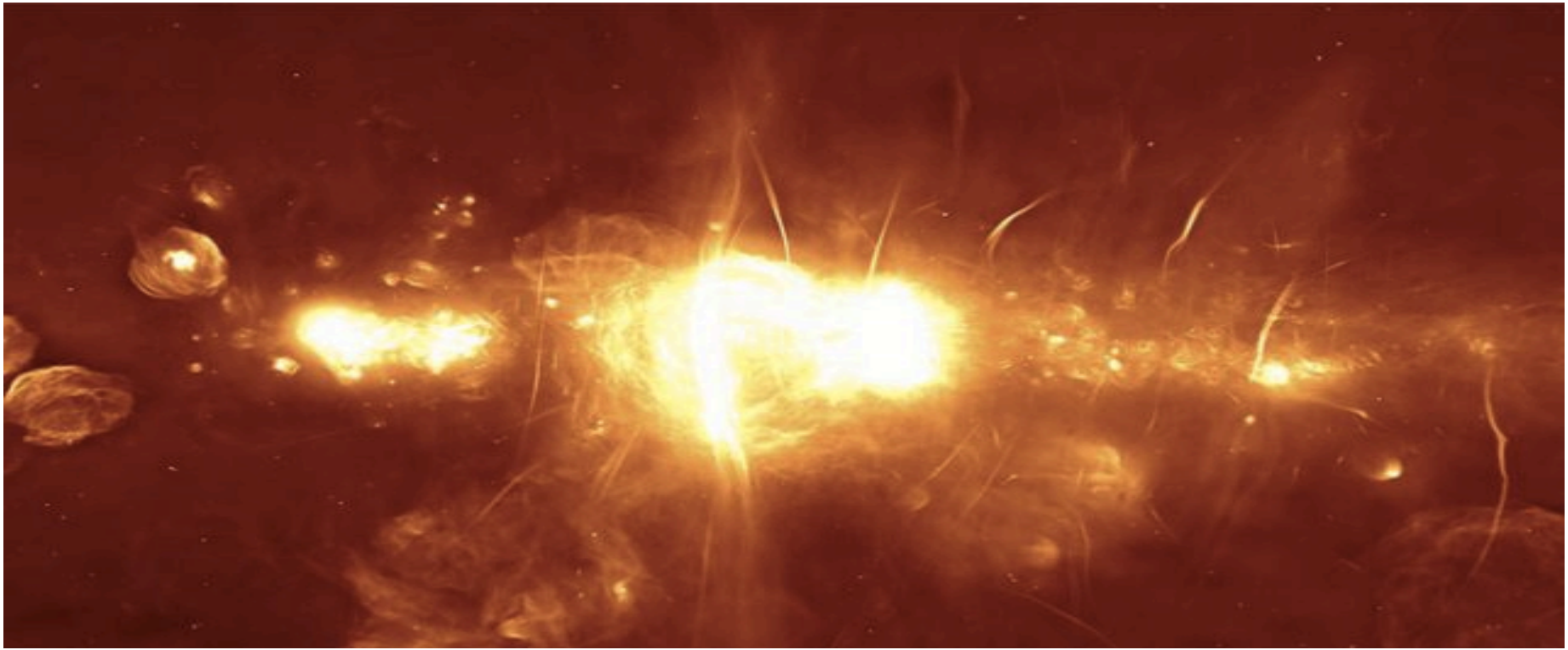


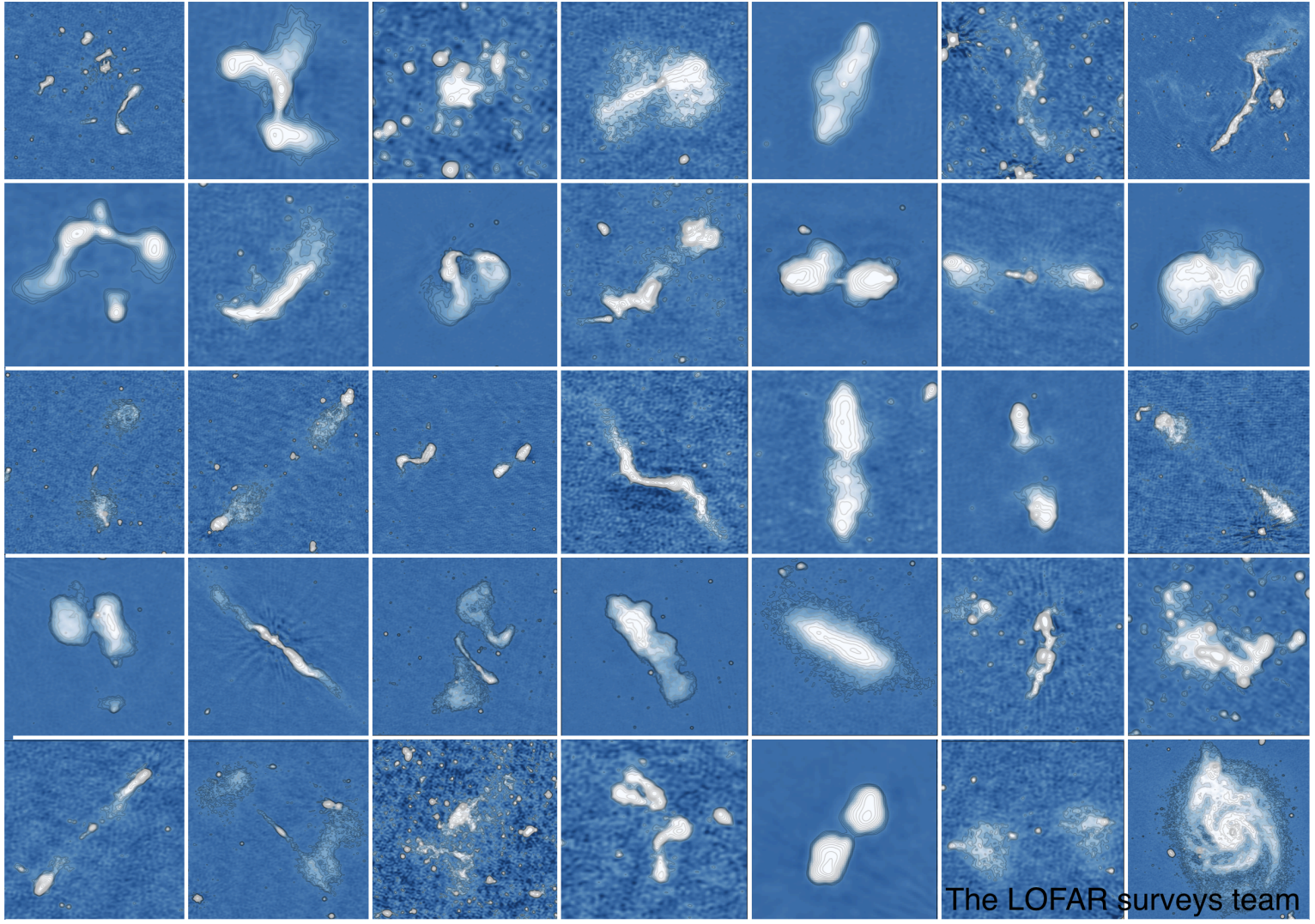
Norris, 2017 - 1709.05064


5.5
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
Log(area/degrees)
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Log(Limiting sensitivity/mJy)
EMU
Apertif
VLASS
LOFAR
FIRST
NVSS
TGSS
SUMSS
WENSS
ASKAP-ESP3
LoTSS-HETDEX
ASKAP-BETA
Stripe82
ATLAS-SPT
GLASS
MIGHTEE
ATLAS
LHW
COSMOS
LH-Ibar
FIS-WSRT
SWIRE
LH-Owen
Chilesconpol
eMERGE
Frontier Fields
Single Dish
Interferometer Array
Single-pixel synthesis array
Phased array
PAF synthesis array
Cylinder synthesis array

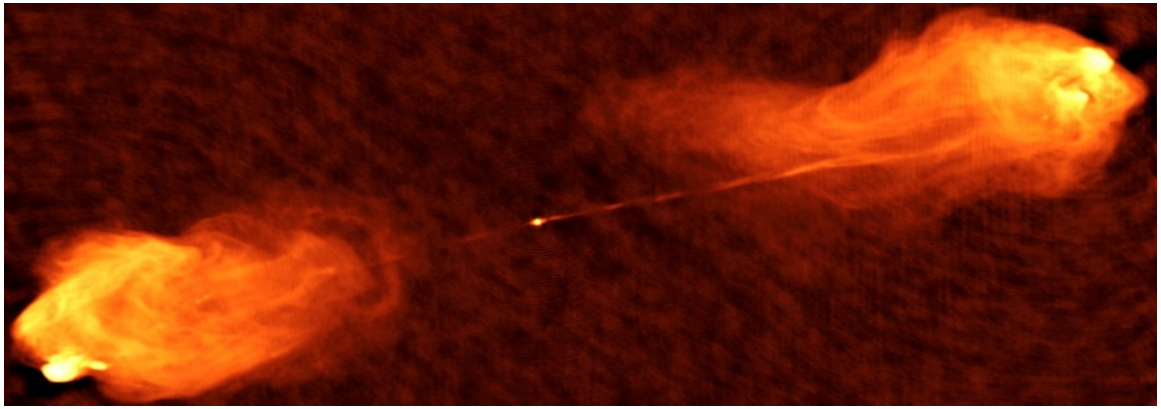


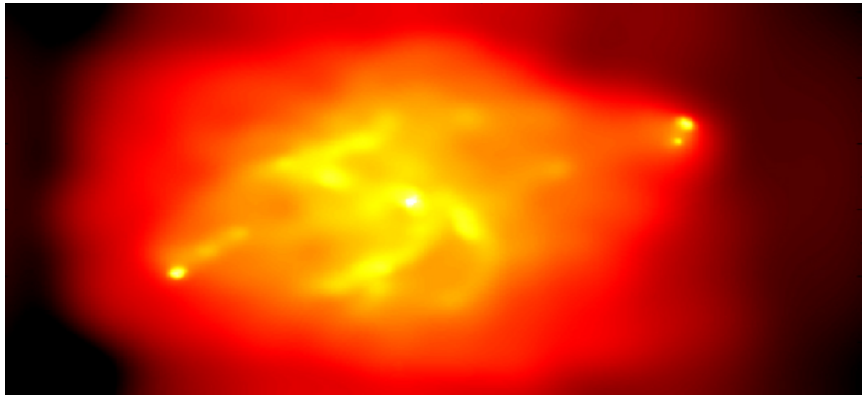


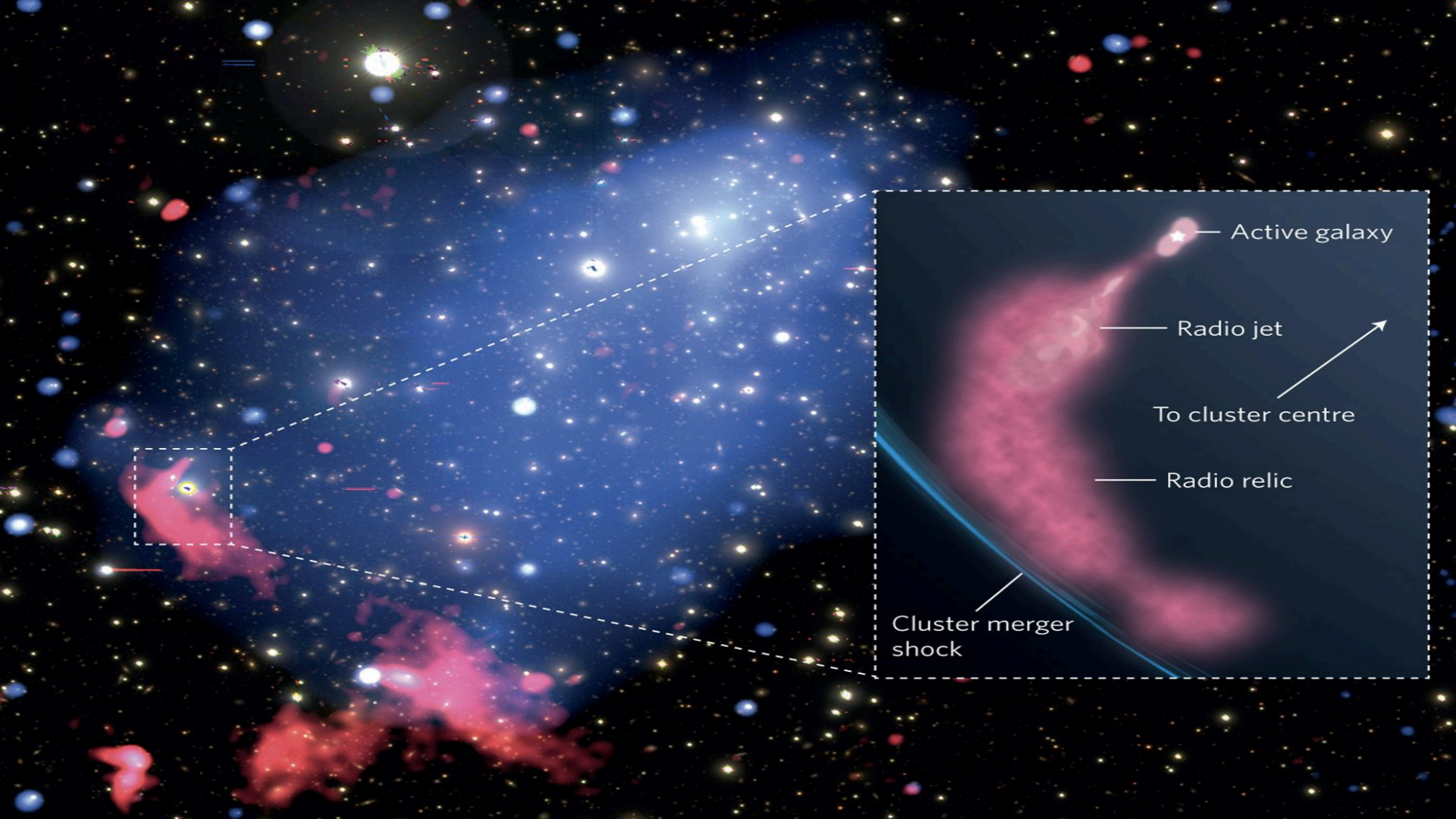


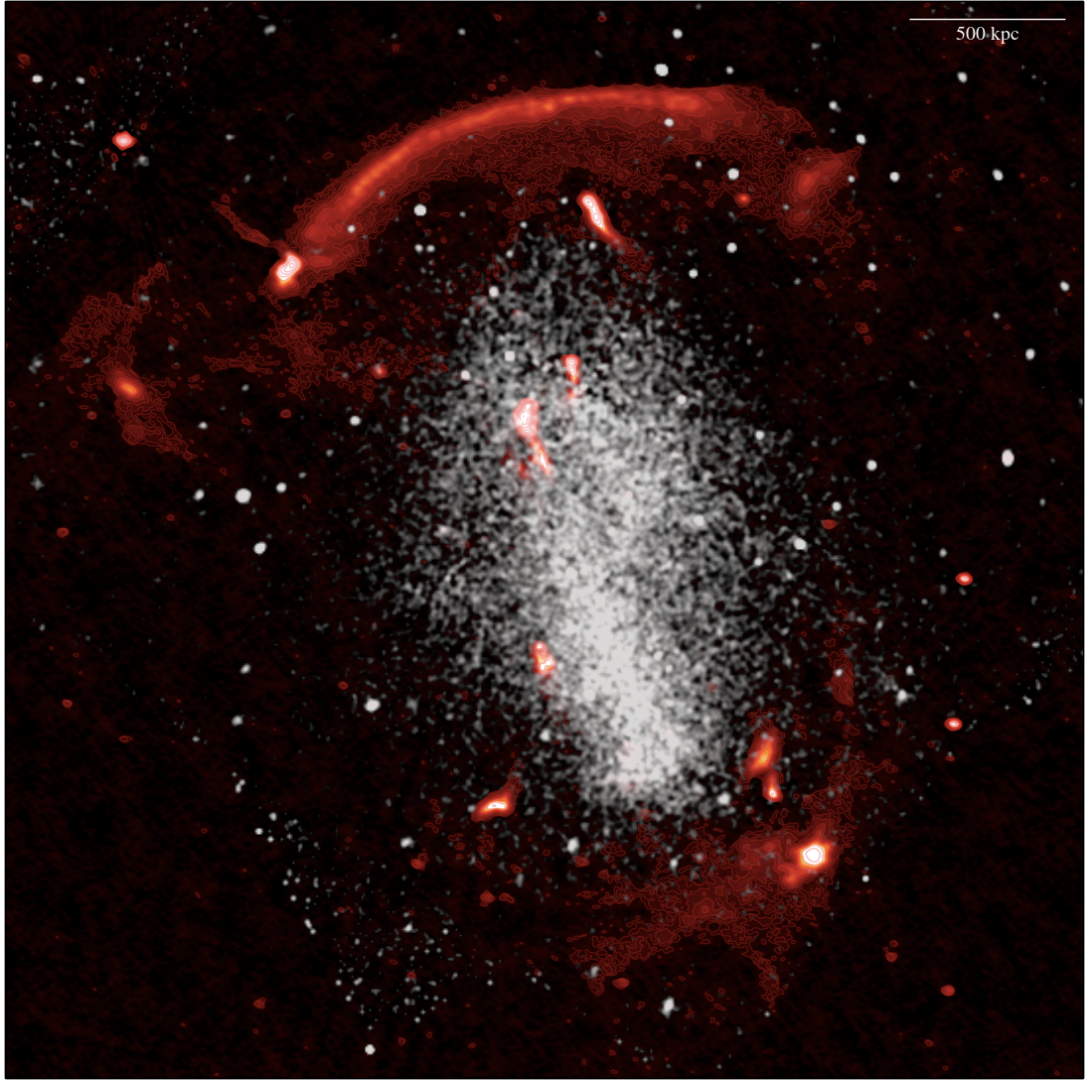

The LOFAR surveys team

RADIO GALAXY:

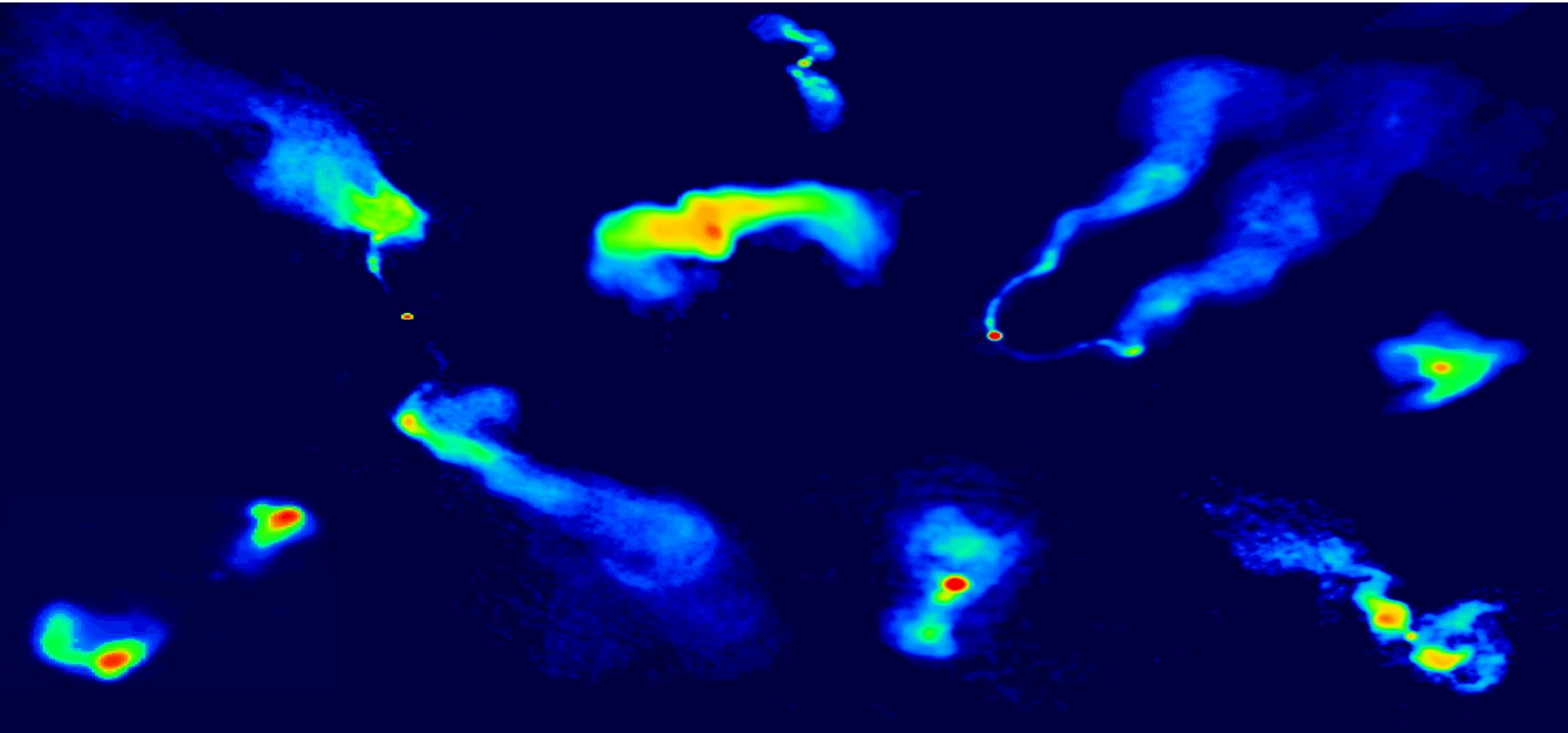


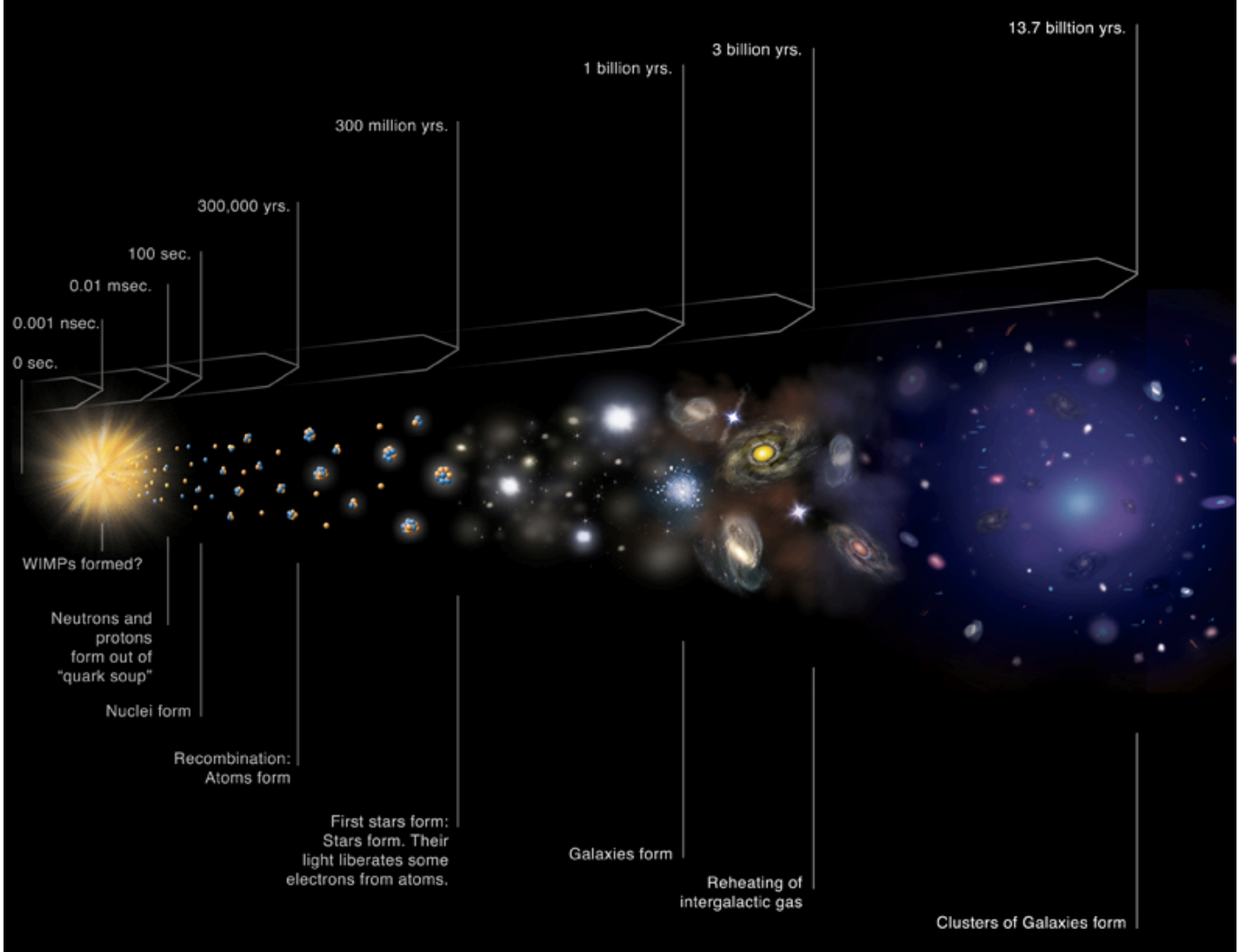


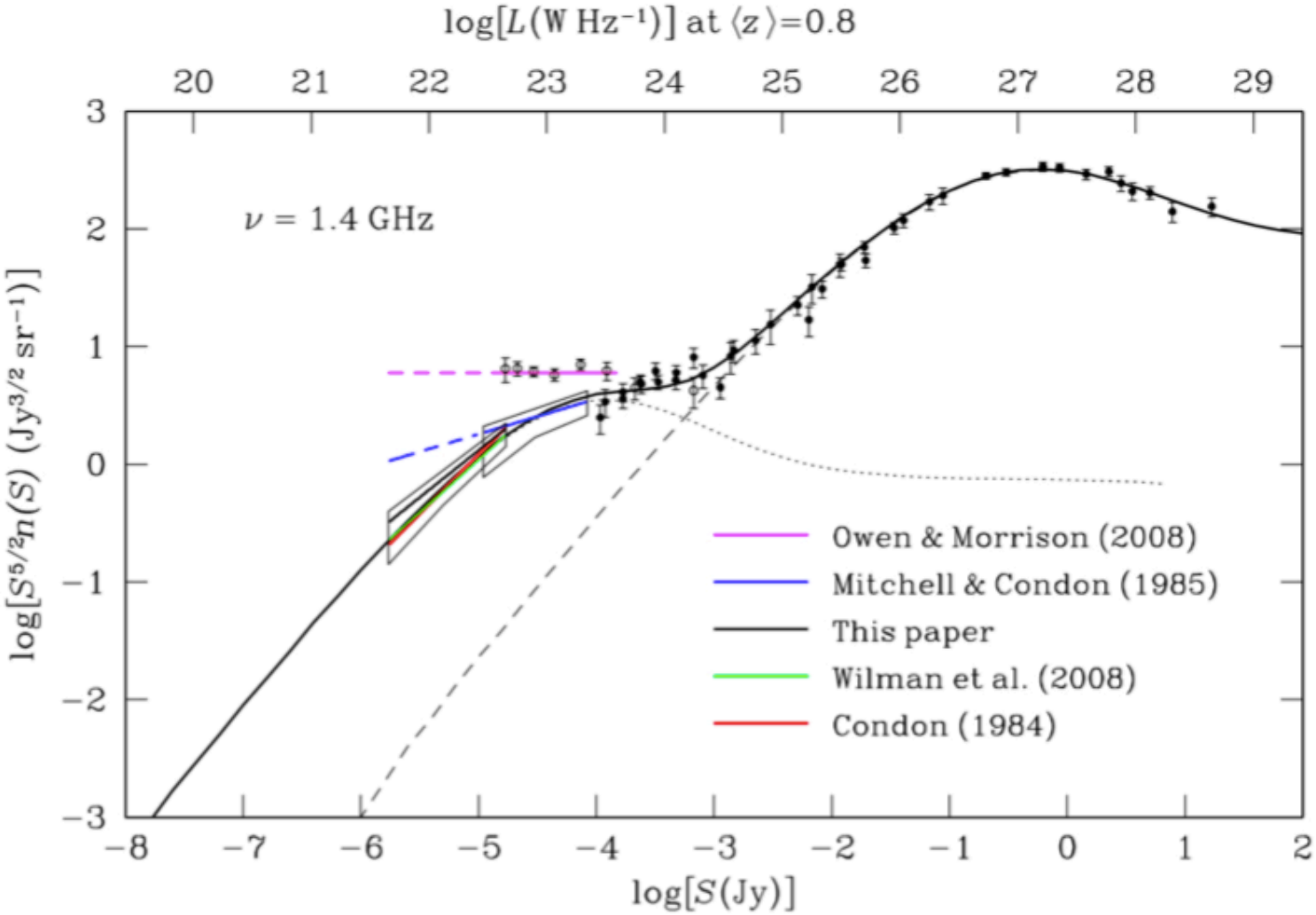

Active galaxy
Radio jet
To cluster centre
Radio relic
Cluster merger shock


500 kpc

Intergalactic Weather Station




13.7 billtion yrs.
3 billion yrs.
1 billion yrs.
300 million yrs.
300,000 yrs.
100 sec.
0.01 msec.
0.001 nsec.
0 sec.
WIMPs formed?
Neutrons and protons form out of "quark soup"
Nuclei form
Recombination: Atoms form
First stars form: Stars form. Their light liberates some electrons from atoms.
Galaxies form
Reheating of intergalactic gas
Clusters of Galaxies form

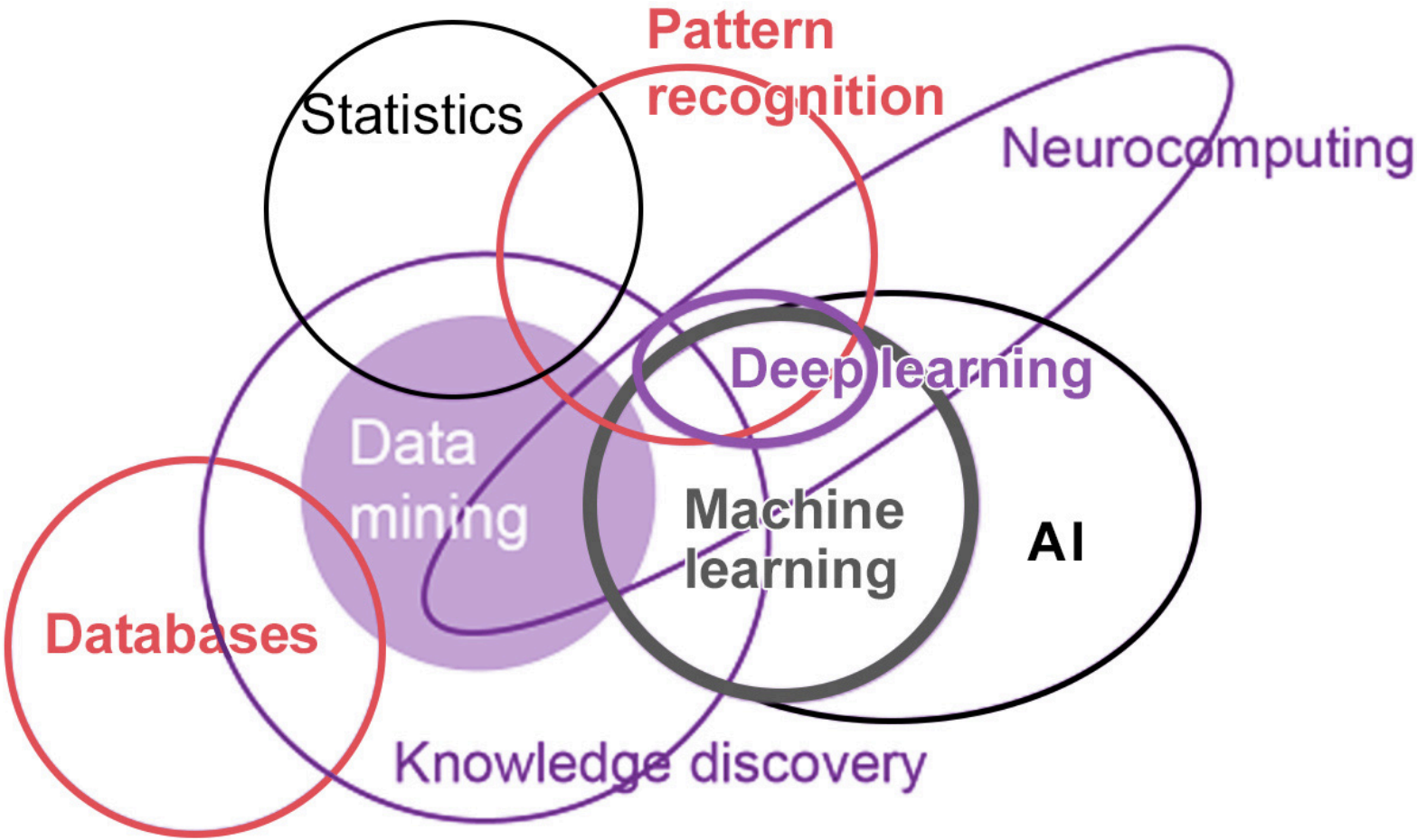

log[L(W Hz⁻¹)] at ⟨z⟩=0.8
20
21
22
23
24
25
26
27
28
29
3
2
1
0
−1
−2
−3
ν = 1.4 GHz
log[S^5/2 n(S) (Jy^3/2 sr^−1)]
Owen & Morrison (2008)
Mitchell & Condon (1985)
This paper
Wilman et al. (2008)
Condon (1984)
−8
−7
−6
−5
−4
−3
−2
−1
0
1
2
log[S(Jy)]

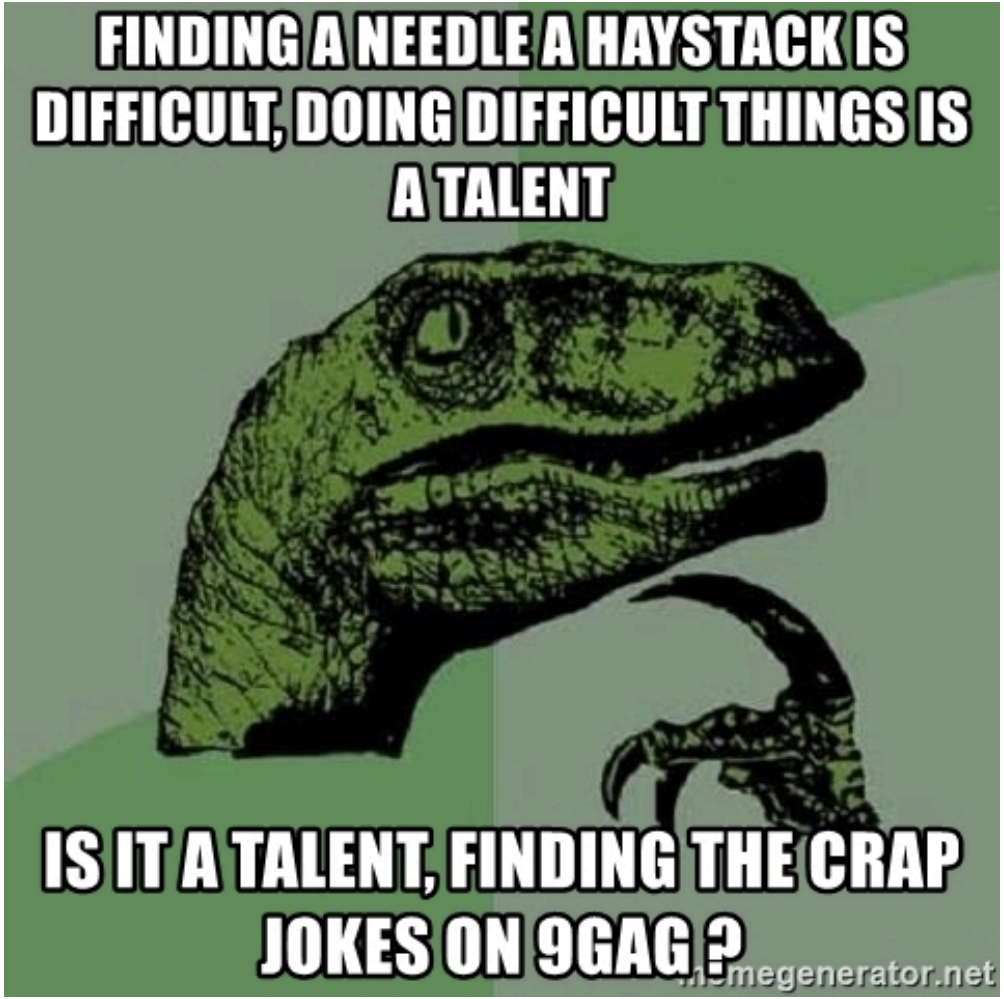
CHALLENGES TO RADIO SURVEYS

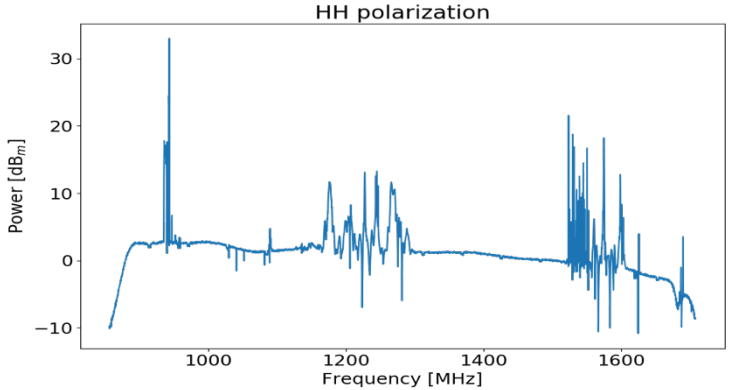
Professor Urquat makes his final contribution to the world of science.

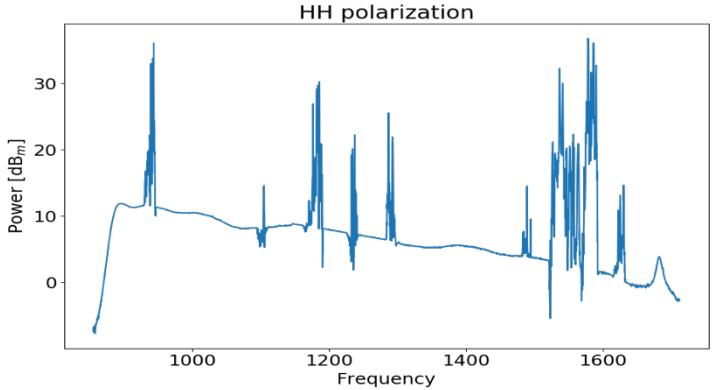
MeerKAT – The Future Is Here!

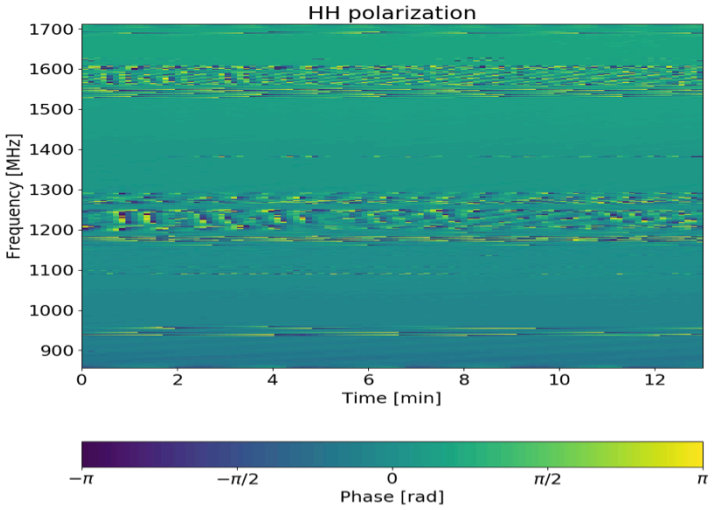
Thinking Humanly	**Thinking Rationally**
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

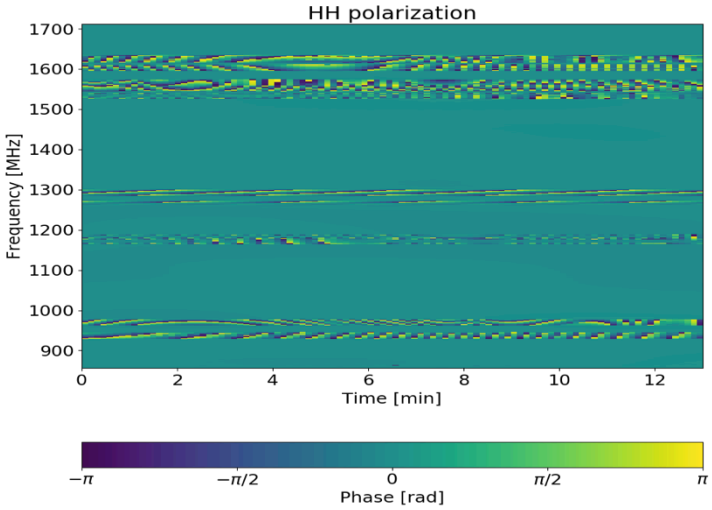

Statistics
Pattern recognition
Neurocomputing
Deep learning
Data mining
Machine learning
AI
Databases
Knowledge discovery


FINDING A NEEDLE A HAYSTACK IS DIFFICULT, DOING DIFFICULT THINGS IS A TALENT
IS IT A TALENT, FINDING THE CRAP JOKES ON 9GAG ?
memegenerator.net

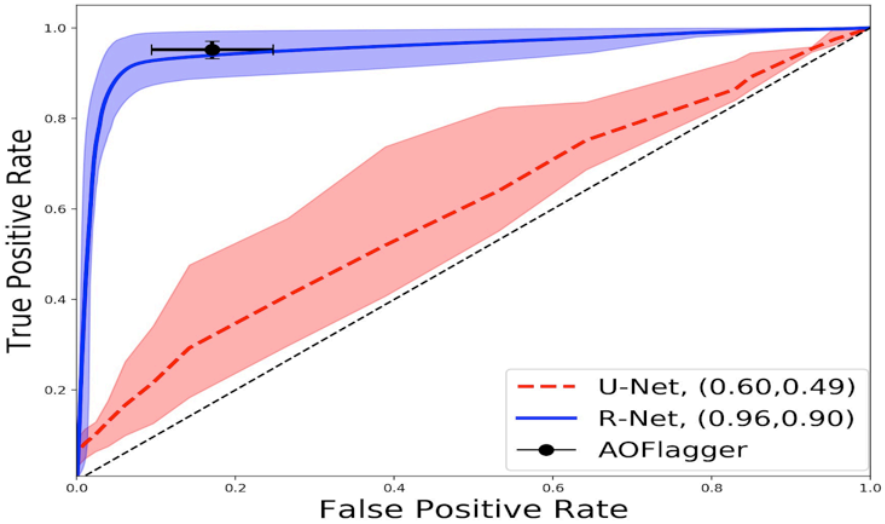

HH polarization
Power [dBm]
30
20
10
0
−10
1000
1200
1400
1600
Frequency [MHz]

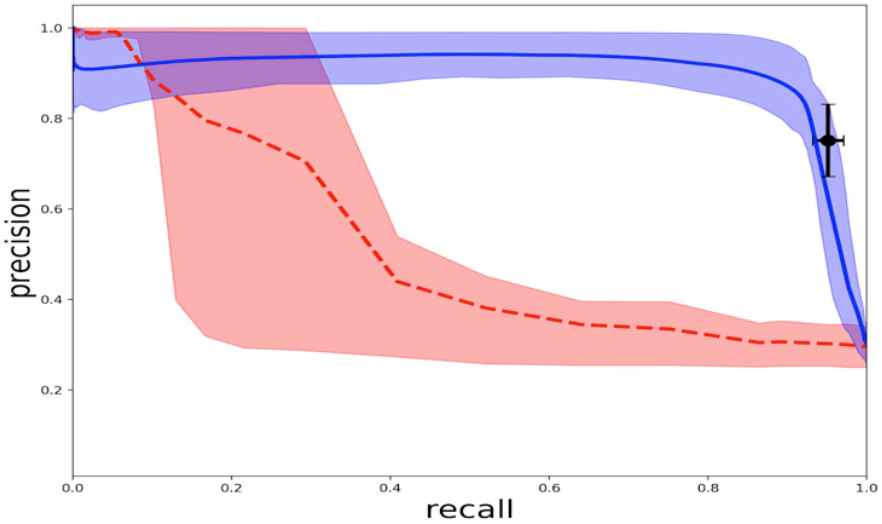

HH polarization
Power [dBm]
30
20
10
0
1000
1200
1400
1600
Frequency


HH polarization
Frequency [MHz]
1700
1600
1500
1400
1300
1200
1100
1000
900
0
2
4
6
8
10
12
Time [min]
−π
−π/2
0
π/2
π
Phase [rad]


HH polarization
Frequency [MHz]
1700
1600
1500
1400
1300
1200
1100
1000
900
0
2
4
6
8
10
12
Time [min]
−π
−π/2
0
π/2
π
Phase [rad]

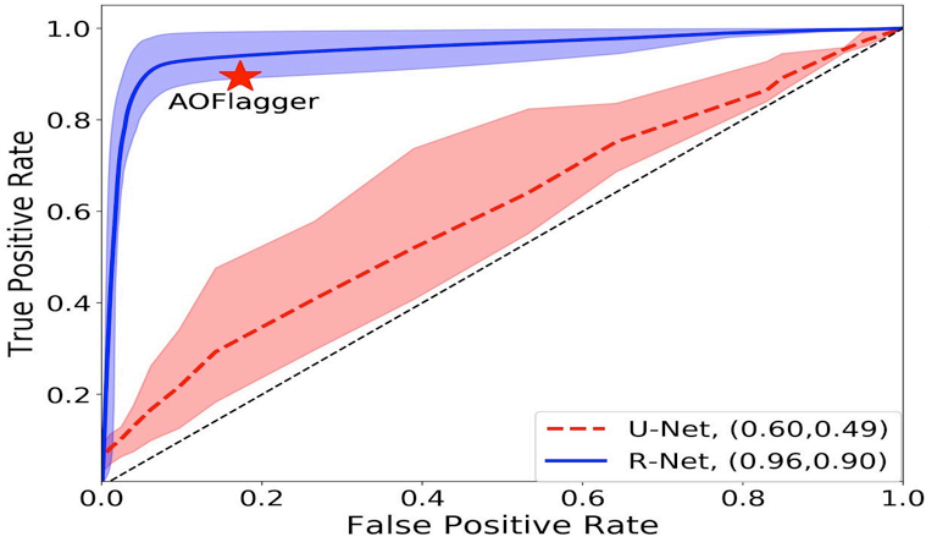
Comparison with Optimised AOflagger

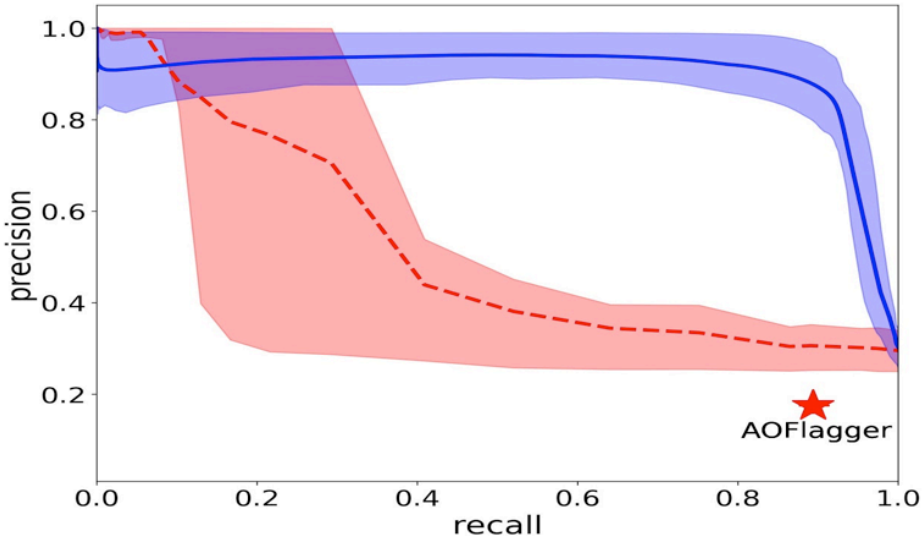




Alireza et al., SARAO DS team

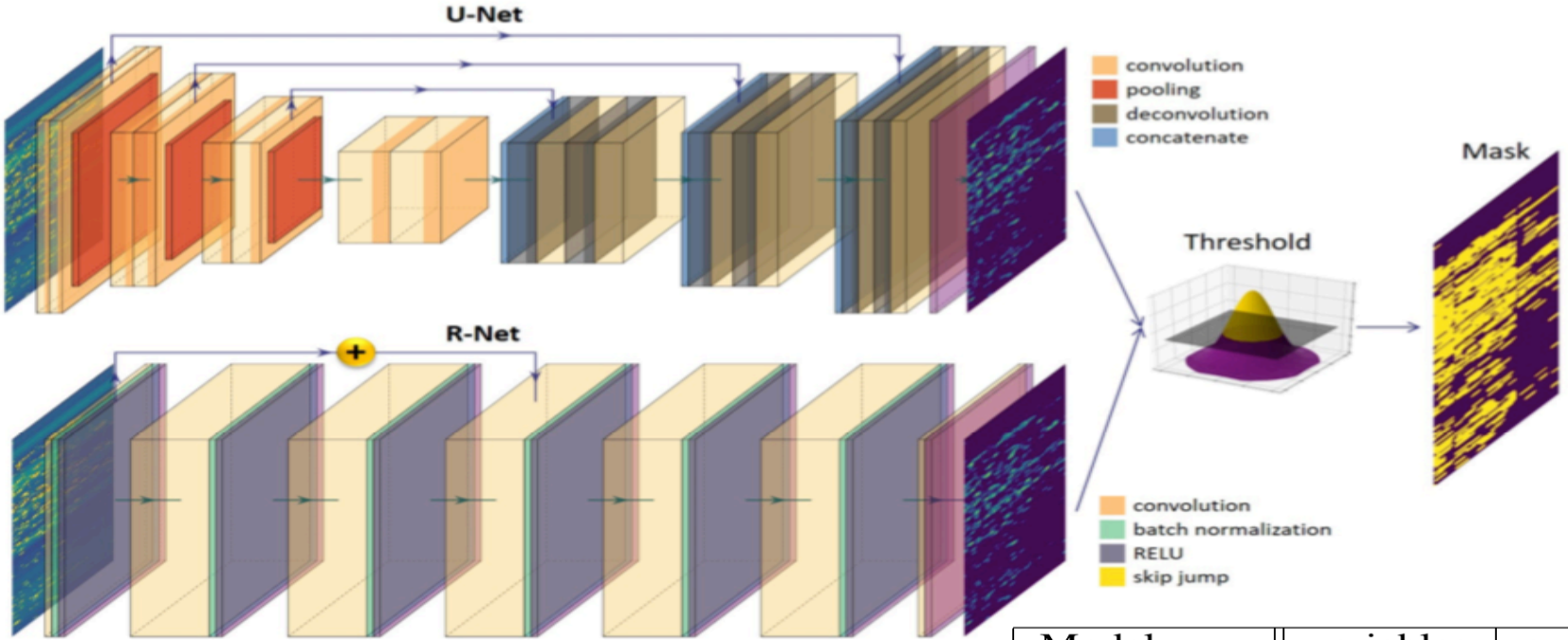
Comparison with Default AOflagger



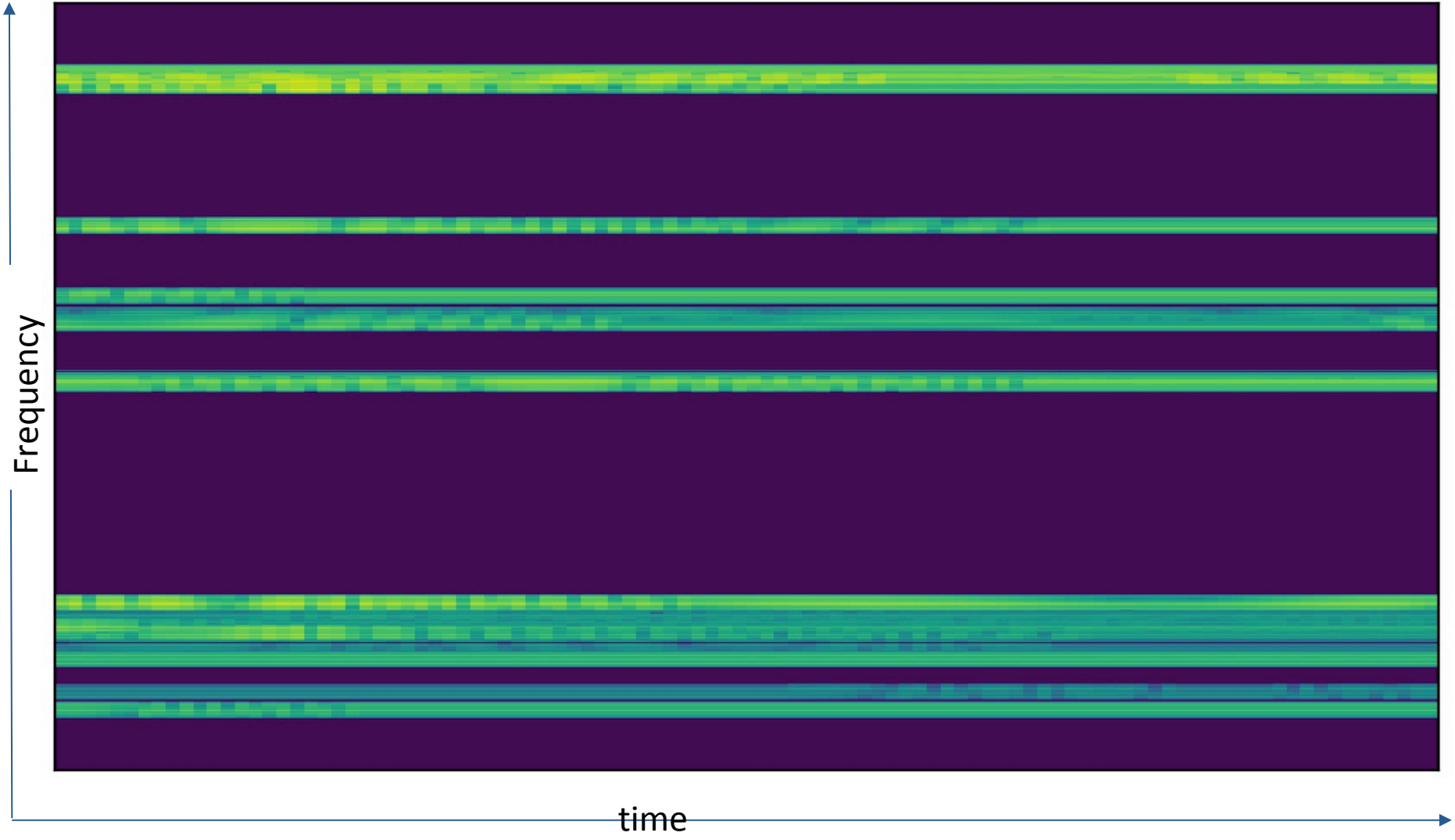


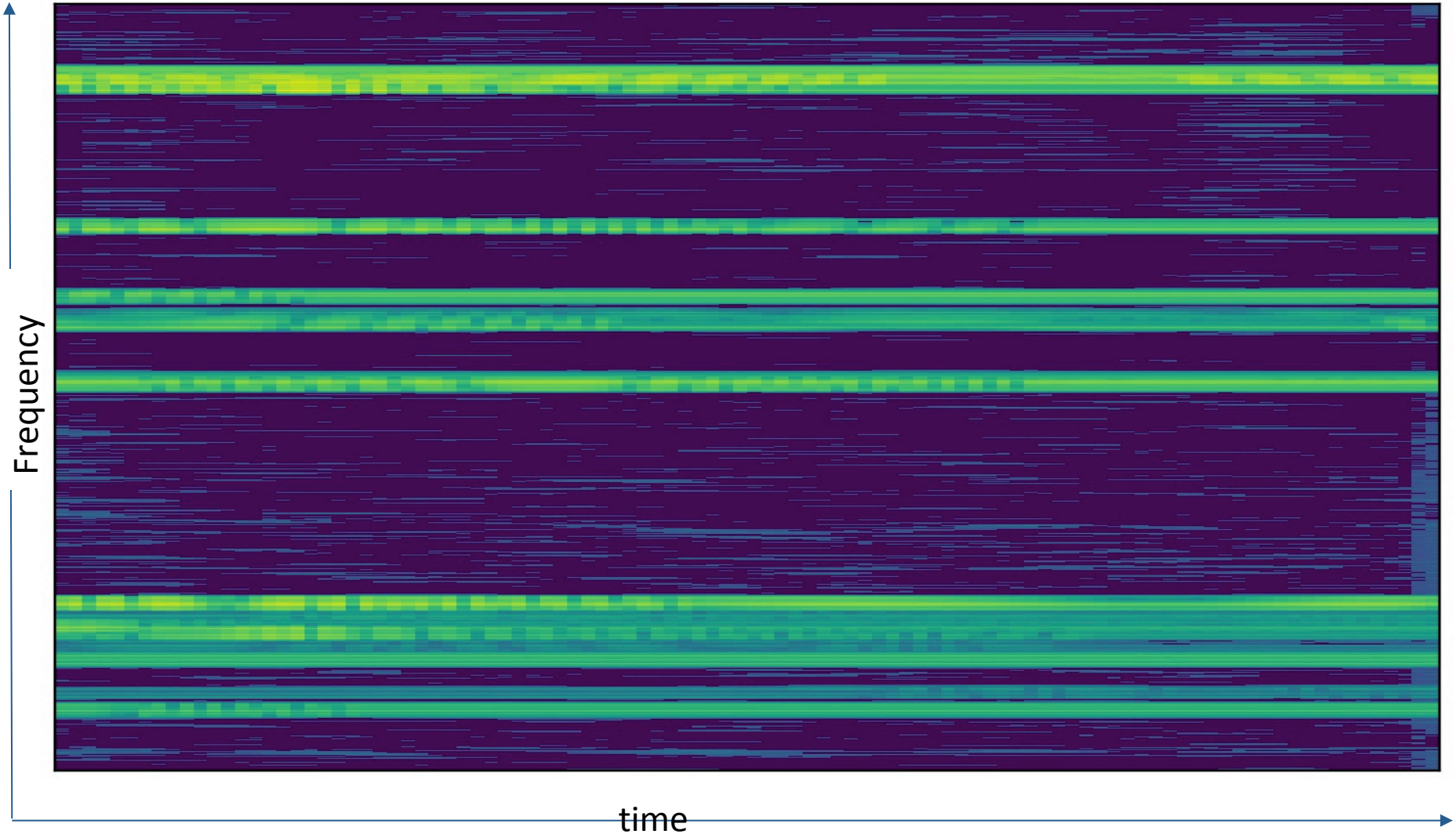
Deep learning is significantly better than AOFlagger unless AOFlagger is extensively tuned (which no one does). Our algorithm tunes automatically, and is flexible (not just a **single** False Positive Rate).

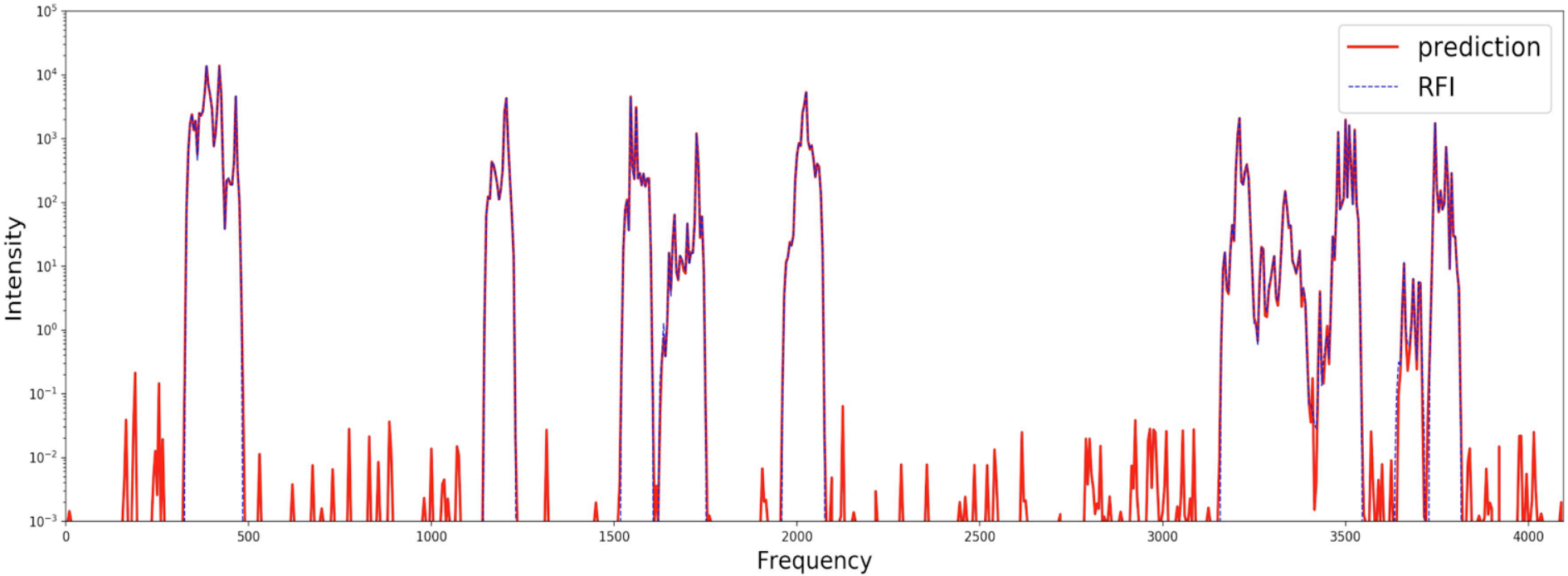
Network from KAT-7



Model	variables	exe. time(s)
AOFlagger	-	31
R-Net-5	11473	18
R-Net-6	15181	24
Unet-3-16	116770	49
Unet-3-32	465986	53


Frequency
time


Frequency
time

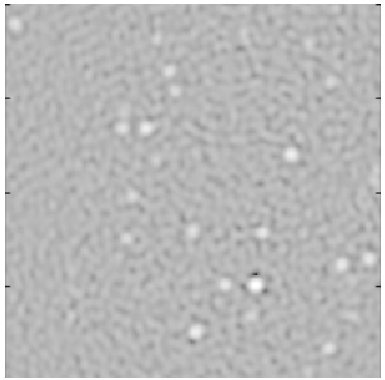


Deep Learning Prediction **vs Ground Truth**

(The MeerKAT RFI simulator)

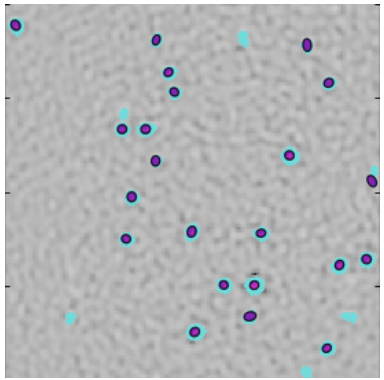
Traditional Source finding

radio image

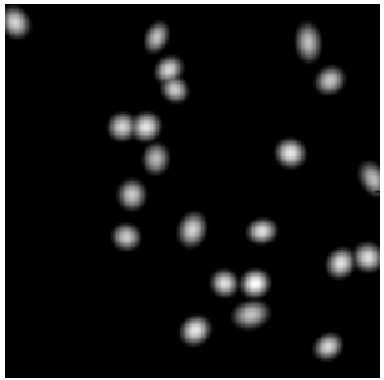


characterise background noise

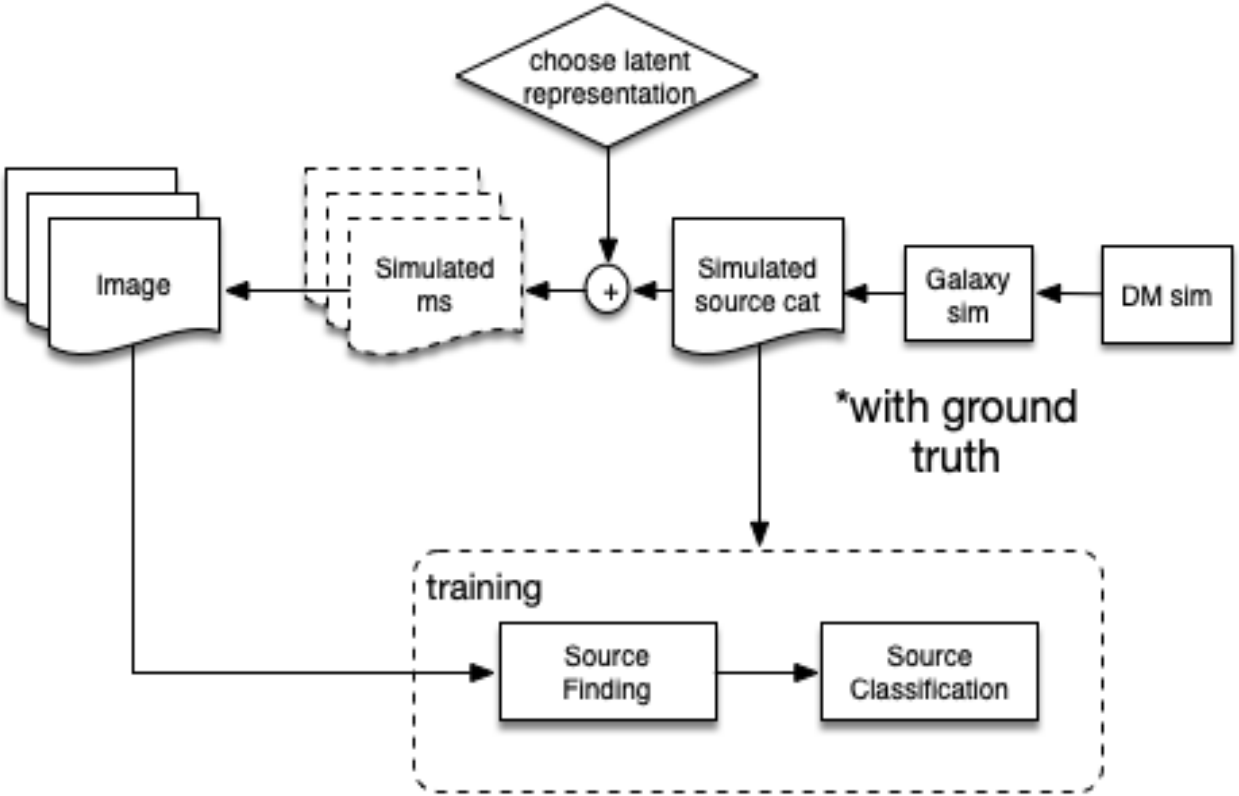
identify islands

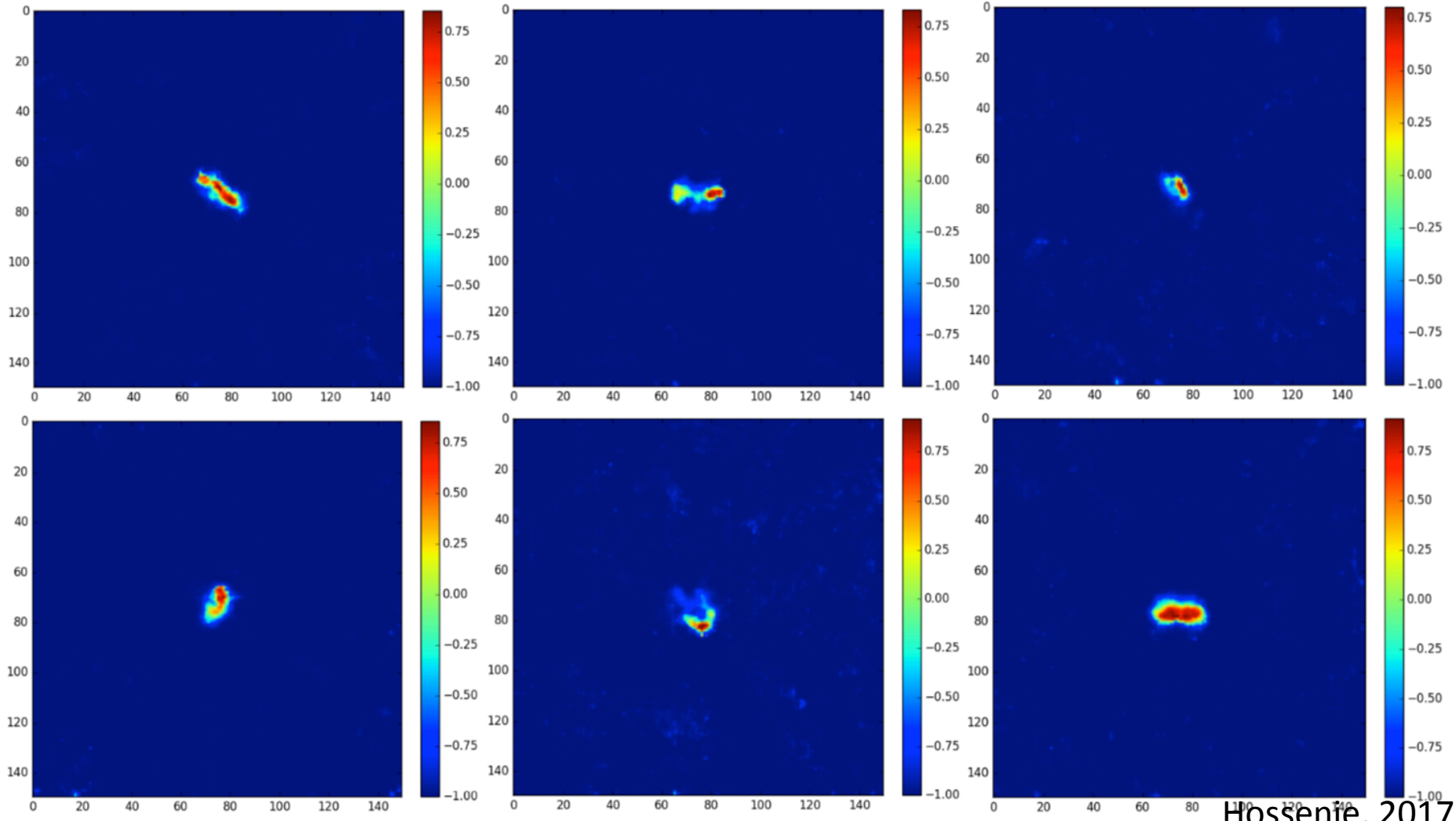


fit gaussians



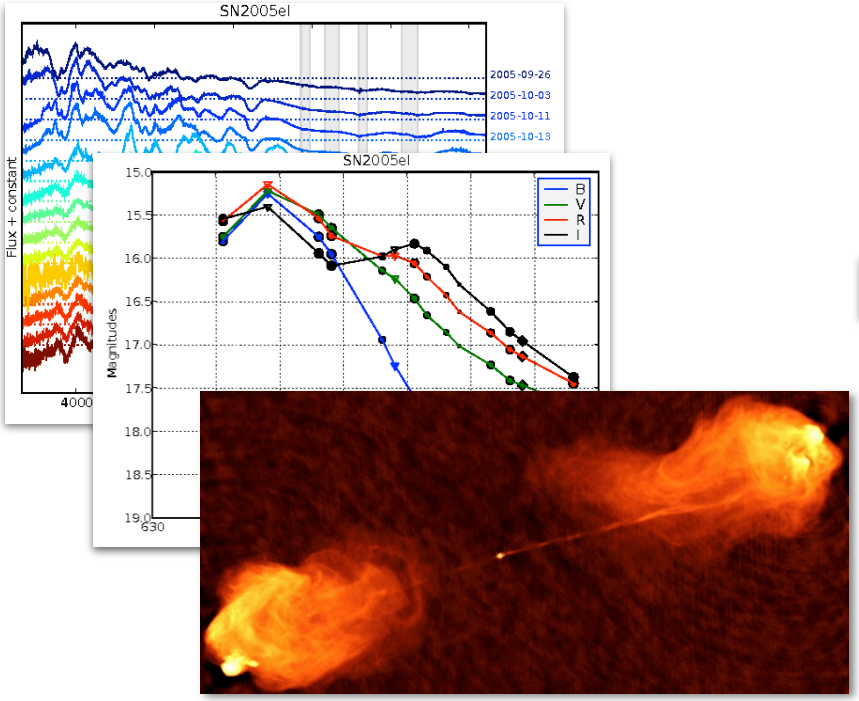
Armstrong, SARAO

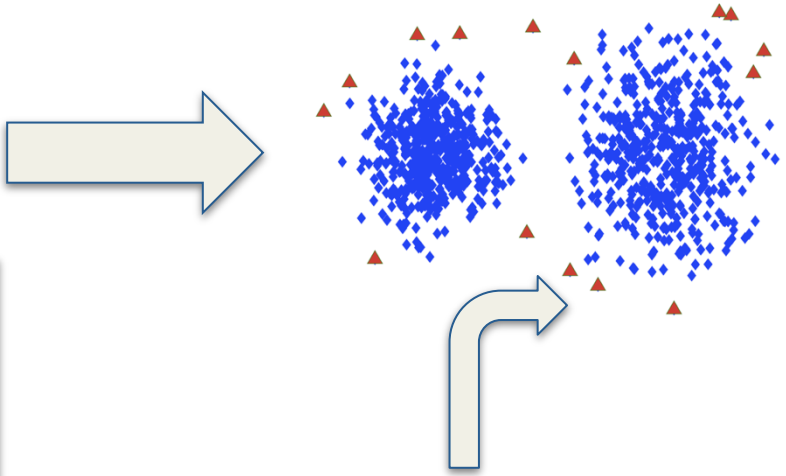

choose latent representation
Image
Simulated ms
+
Simulated source cat
Galaxy sim
DM sim
*with ground truth
training
Source Finding
Source Classification



Hossenie, 2017

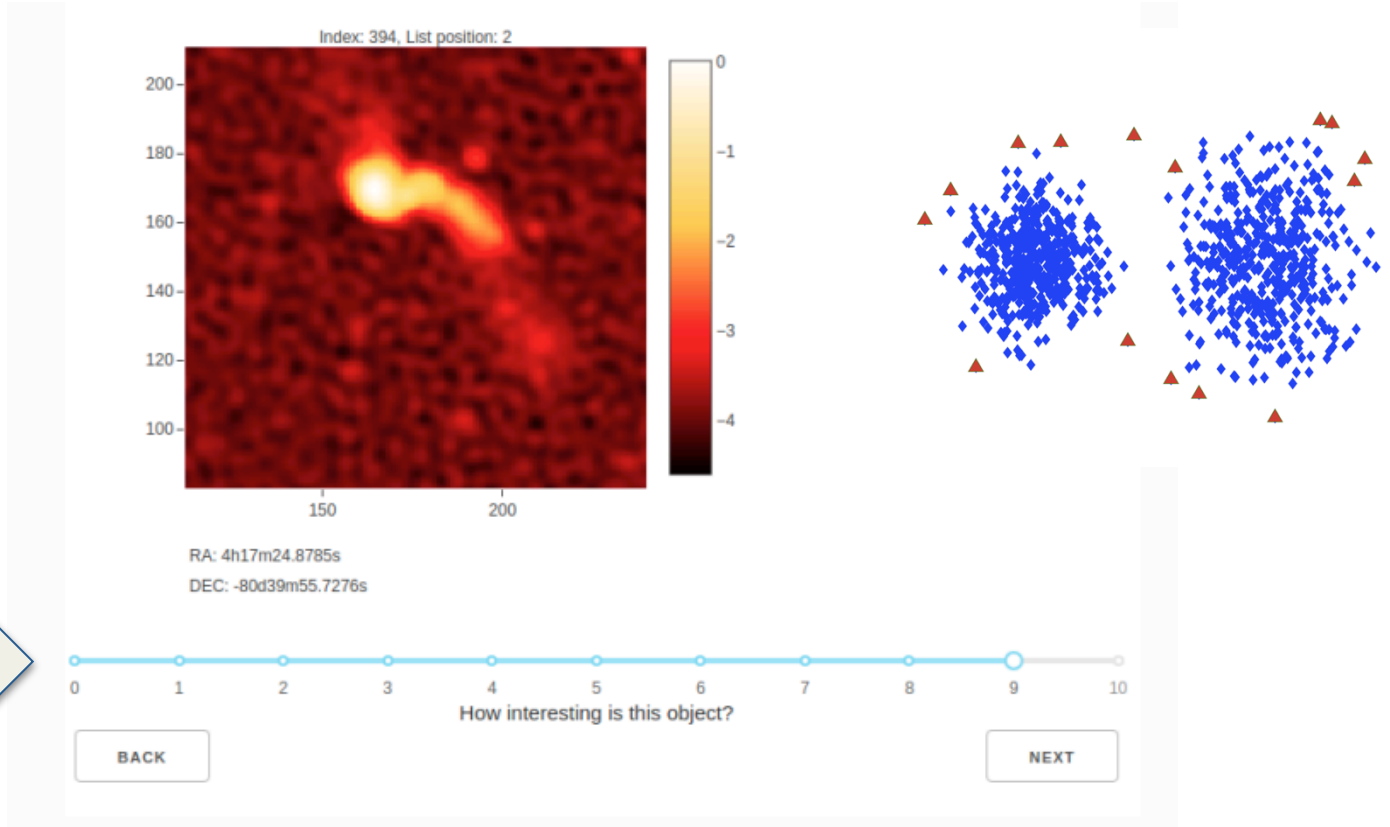
Step 1: Anomaly Detection





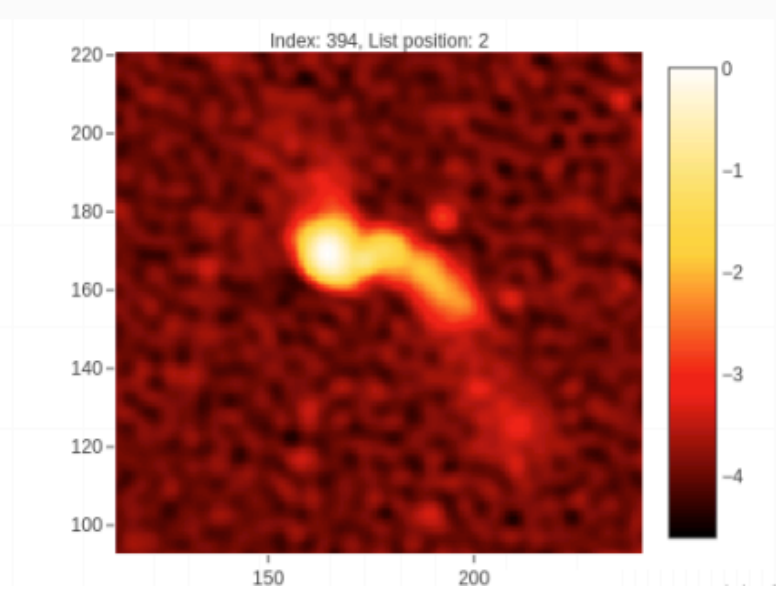
These might be anomalous but uninteresting...

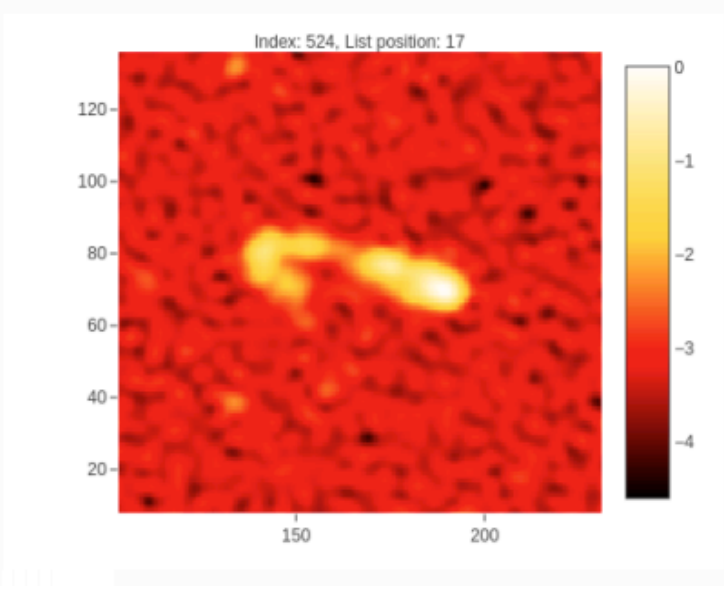
Step 2: Active Learning



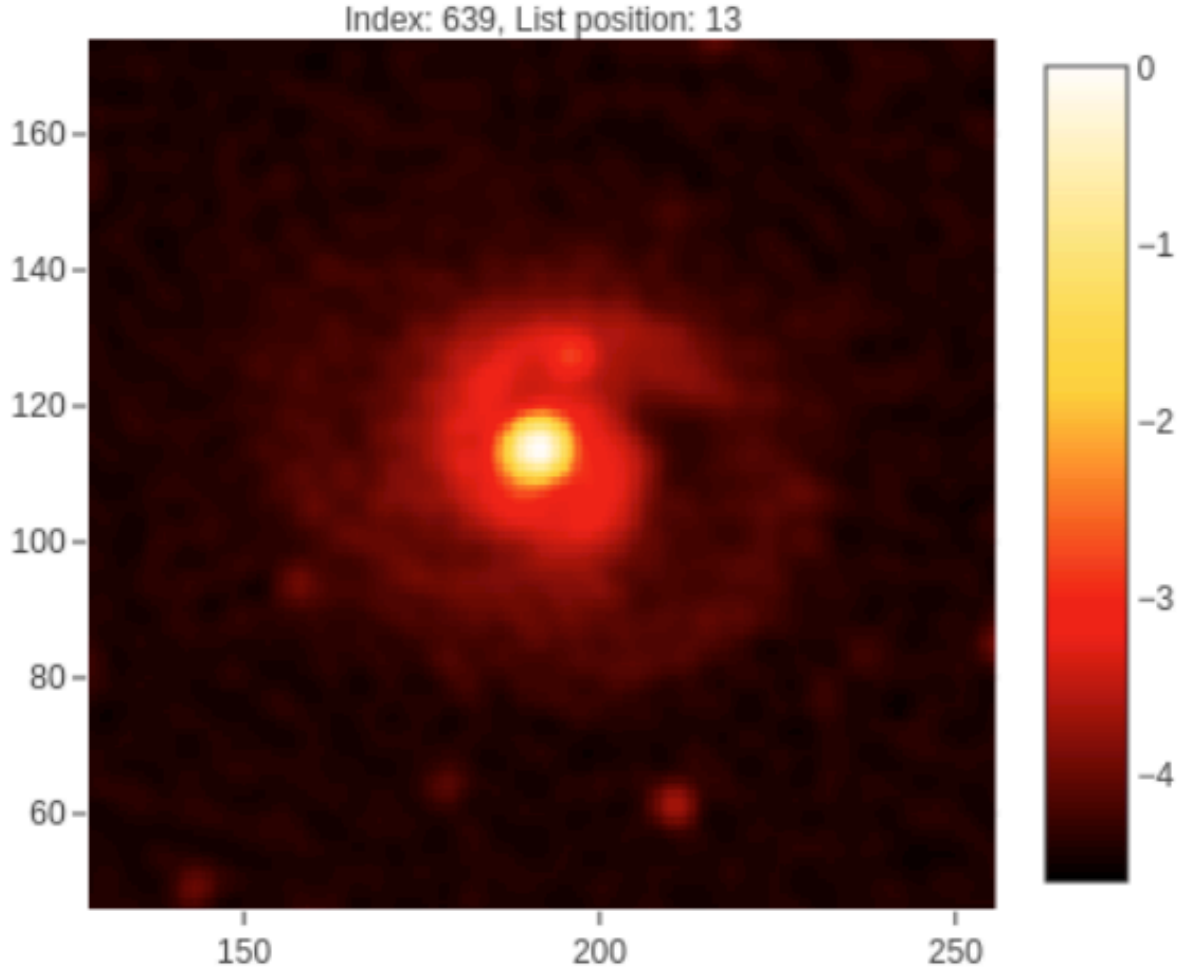
Example Results from the DEEP2 MeerKAT Data

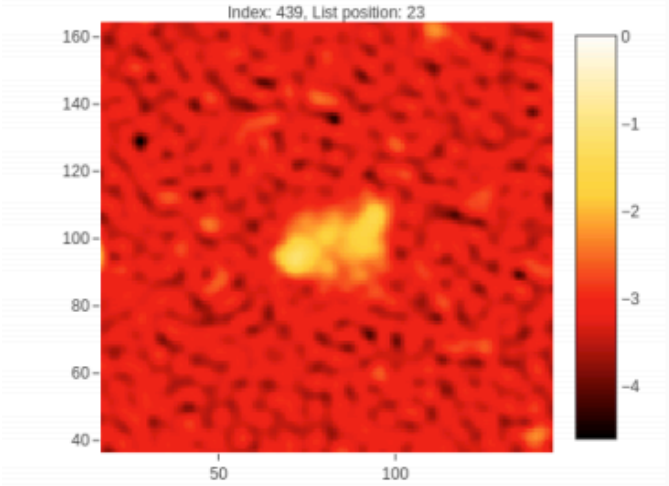
(DEEP2 credit to Tom Mauch and the SARAO team)

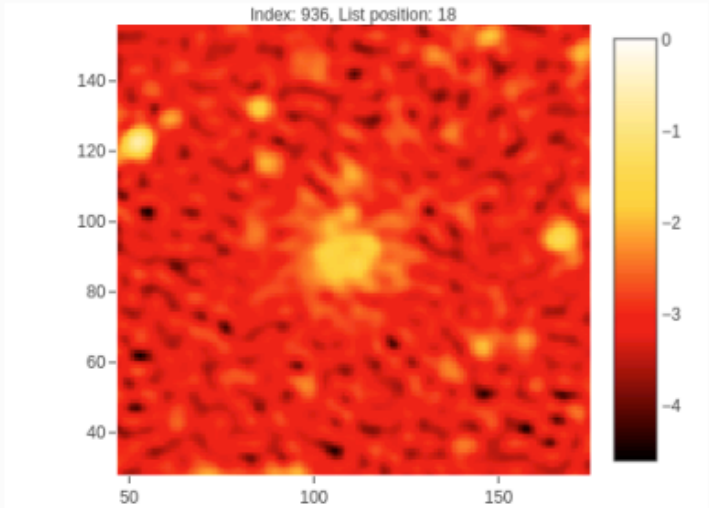


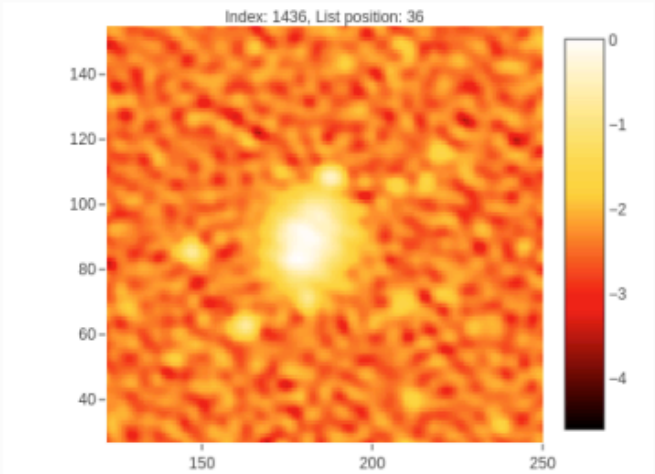


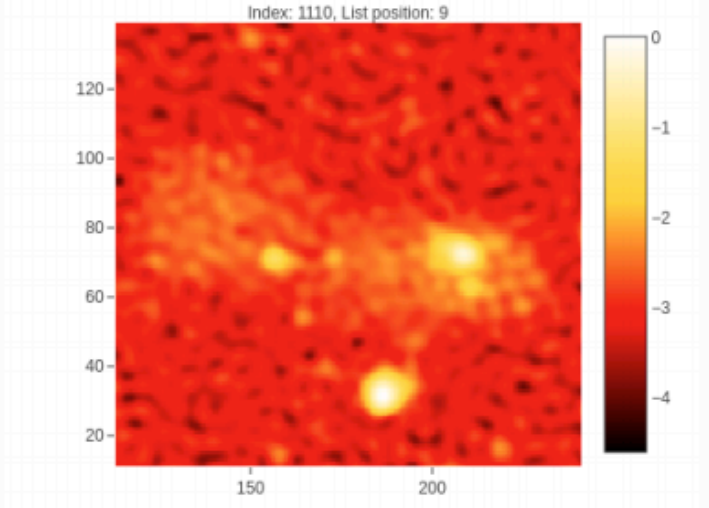
Lochner, SARAO

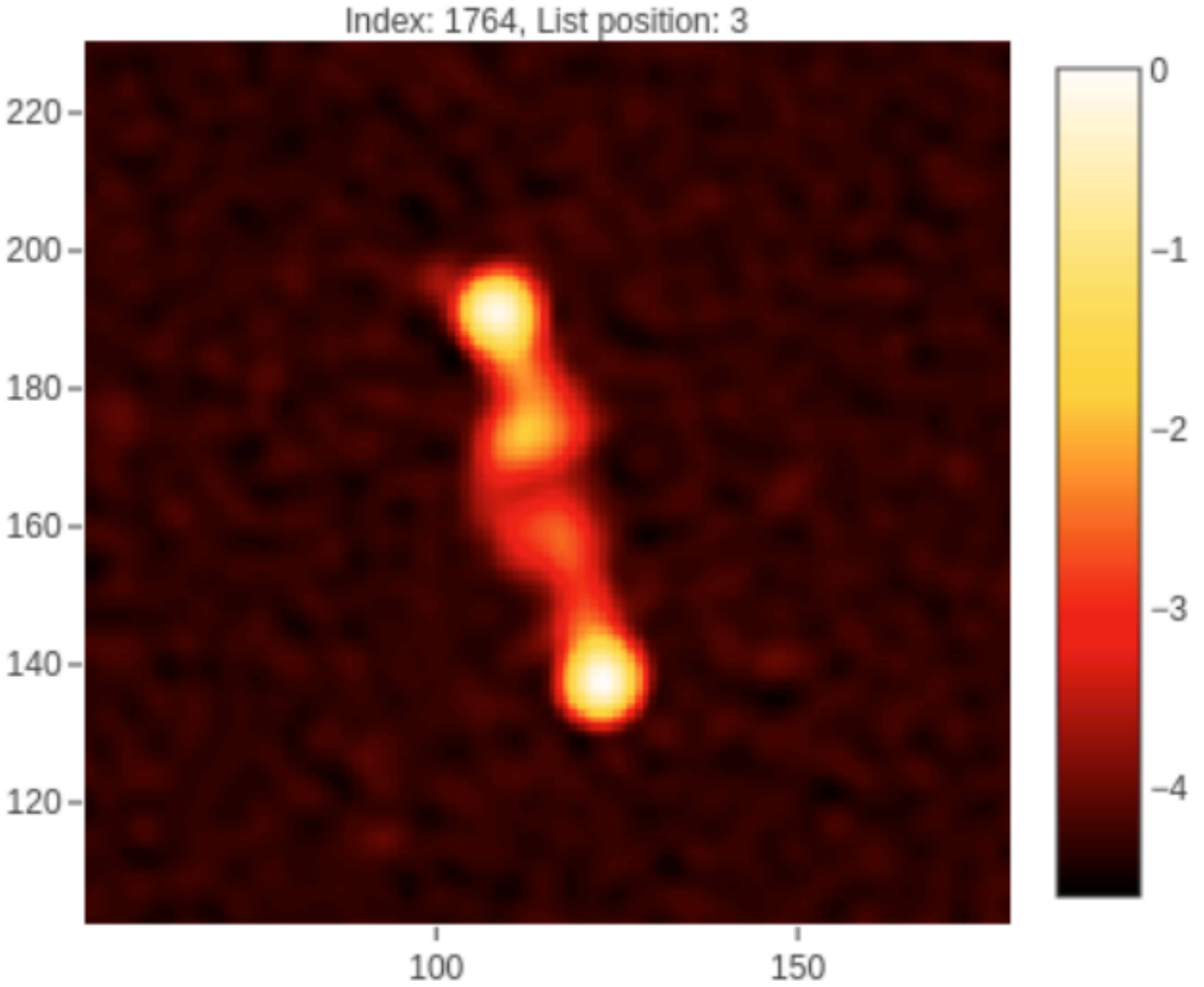

Index: 639, List position: 13
160
140
120
100
80
60
150
200
250
0
−1
−2
−3
−4

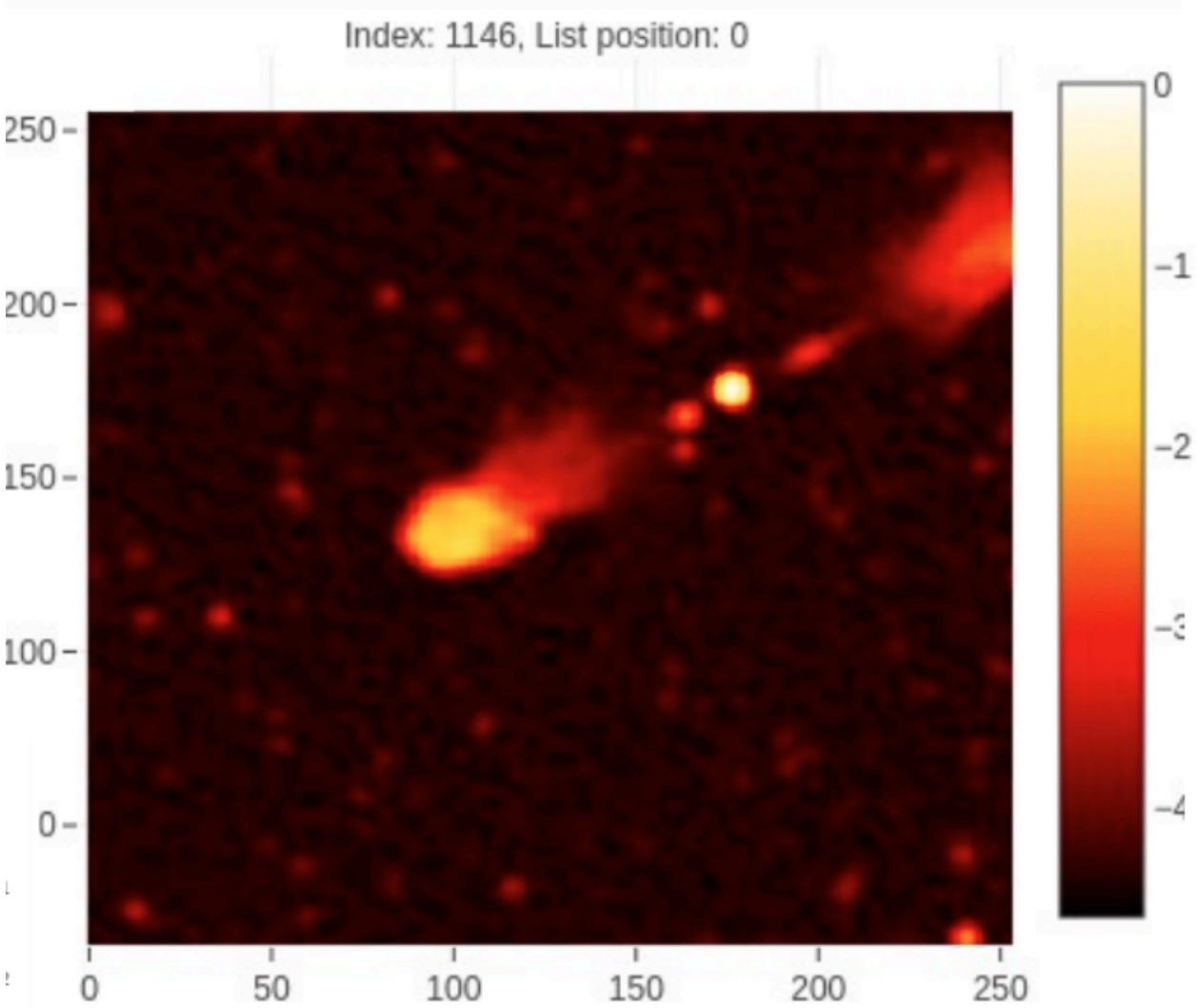

Index: 439, List position: 23
160
140
120
100
80
60
40
50
100
0
−1
−2
−3
−4


Index: 936, List position: 18
140
120
100
80
60
40
50
100
150
0
−1
−2
−3
−4


Index: 1436, List position: 36
140
120
100
80
60
40
150
200
250
0
−1
−2
−3
−4


Index: 1110, List position: 9
120
100
80
60
40
20
150
200
0
−1
−2
−3
−4


Index: 1764, List position: 3
220
200
180
160
140
120
100
150
0
−1
−2
−3
−4


Index: 1146, List position: 0
250
200
150
100
0
0
50
100
150
200
250
0
−1
−2
−3
−4