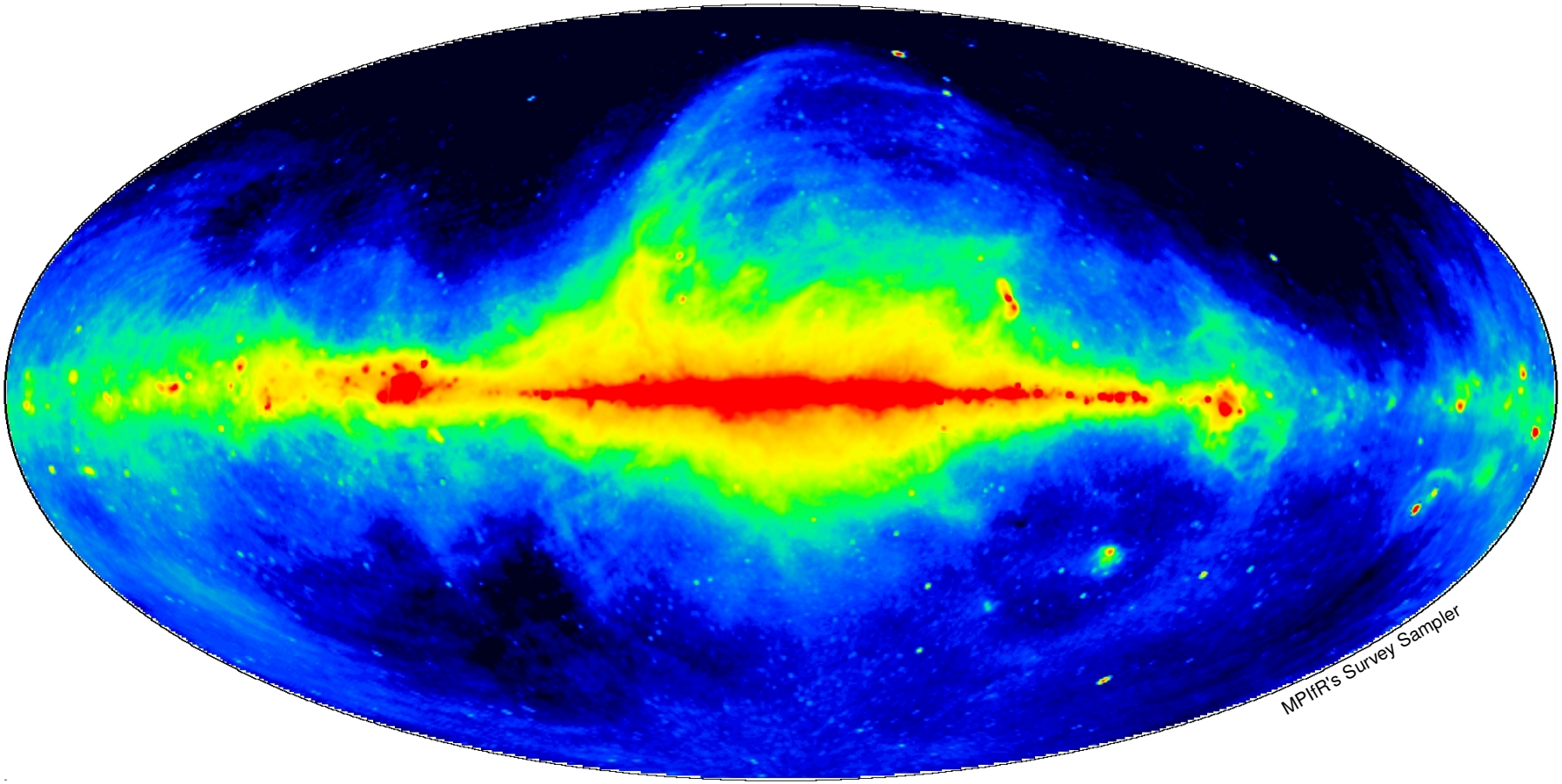
The Unresolved Radio Background



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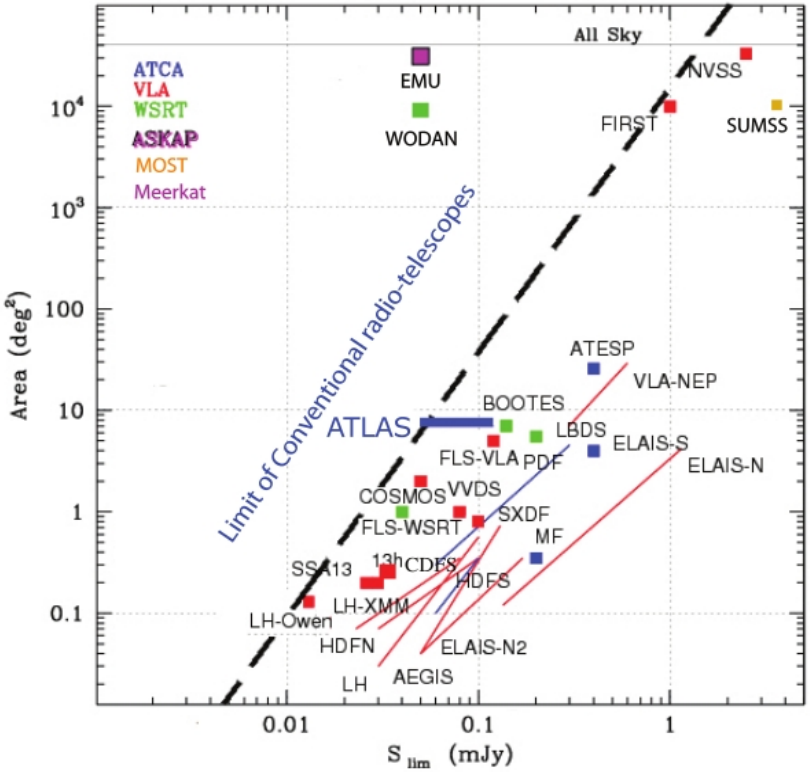
Essential summary of EMU

Angular resolution ~ 10 arcsec

Sky coverage ~ 3 x 10^4 deg^2

Number of sources ~ 7 x 10^7



A simple computation

FWHM = 10 arcsec
$A_{tot} = 3 \times 10^4$ deg^2
$N_s = 7 \times 10^7$

What is the fraction of EMU sky which is NOT occupied by detected sources?

Size of a "pixel" $S_p \sim \pi\,(FWHM/2)^2 \sim 6 \times 10^{-6}$ deg^2

Total number of "pixels" $N_{tot} = A_{tot}/S_p = 5 \times 10^9$

Number of "pixels" (i.e., syntesized beams) per source = $N_{tot} / N_s = 70$

Let's say a source affects on average 10 "pixels"
(i.e., confusion limit ~ 10 syntesized beams per source)

$$f_{sky} = (70-10)/70 \sim 86\%$$

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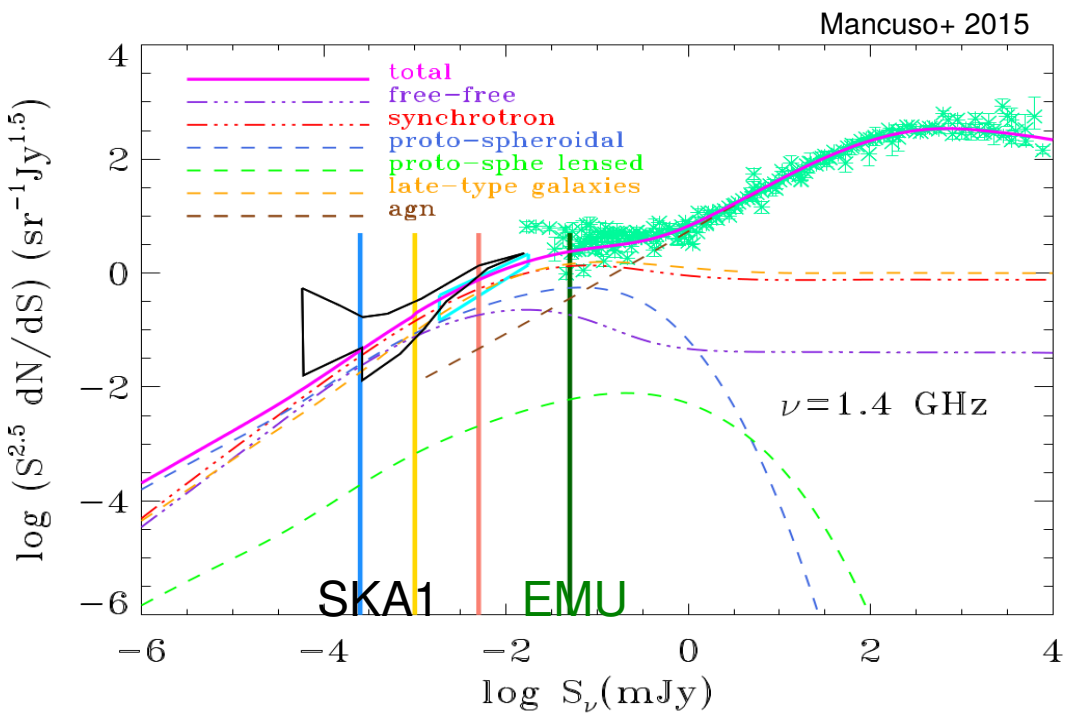
Shall we trash > 80% of pixels ?

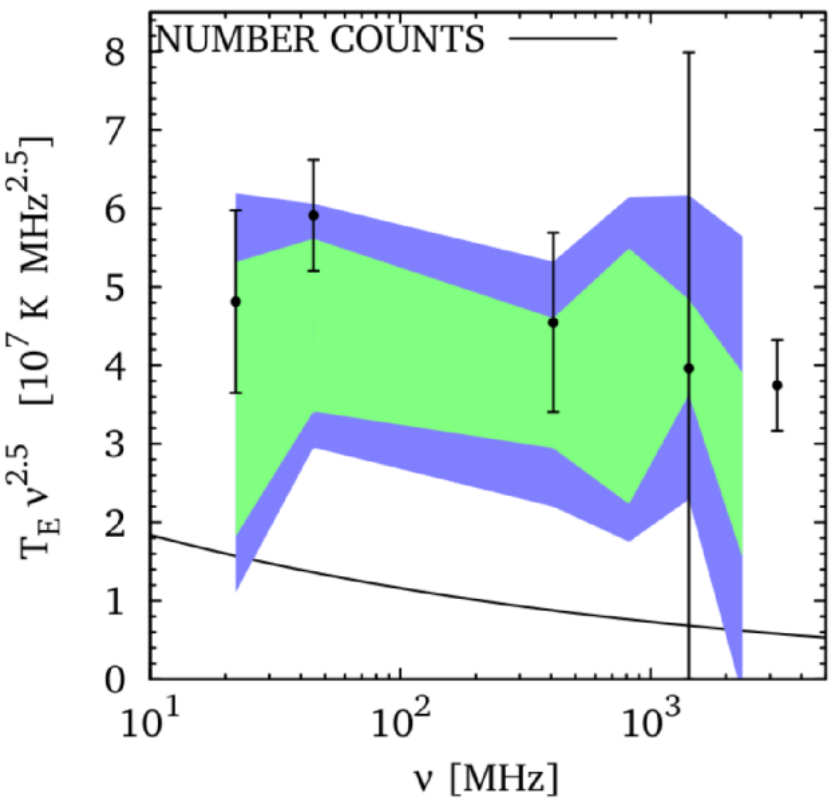
Why can the unresolved radio background be interesting?



The ARCADE excess

The extragalactic radio background appears to be **brighter** than extrapolation from number counts of AGN and SFG (**ARCADE-2** Collaboration 2009)

Fornengo,MR+ JCAP 2014



Possible explanations: (Singal, MR+ 2017)

I) Observations: issues on **calibration of zero level** for the low-frequency maps?
disfavoured?

II) **Galactic foreground**: rather peculiar underhanded aspects?
disfavoured?

III) Extragalactic sources

↓

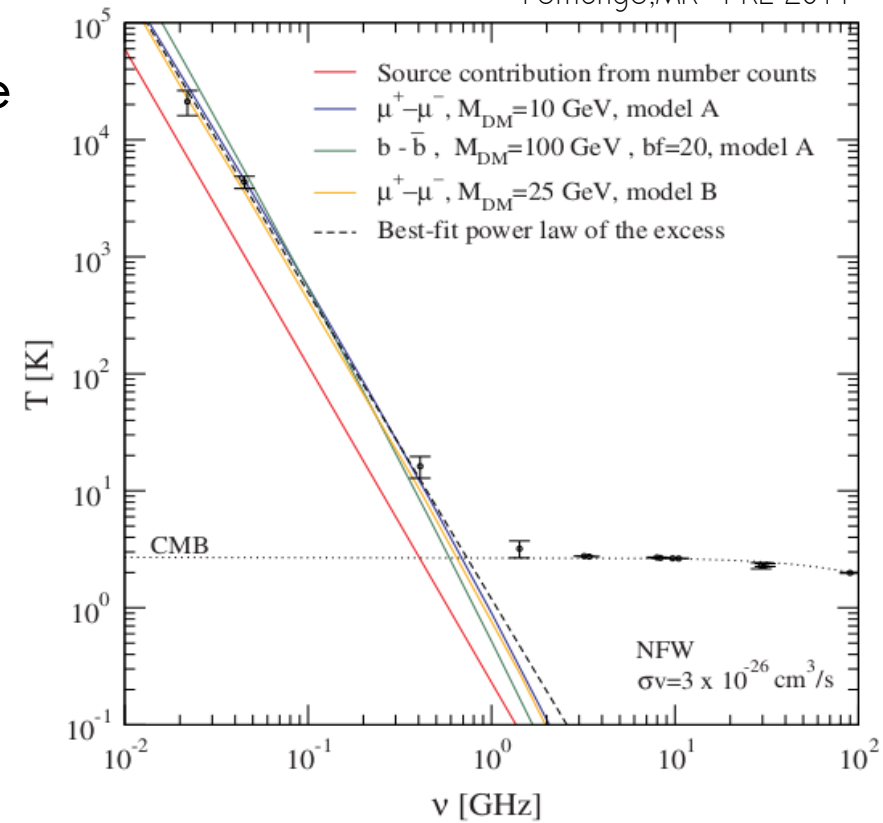
faint (<μJy), diffuse (Mpc scale) and/or exceptionally numerous population
(or truly diffuse/high-z cosmological sources)

Proposed interpretations

"New" radio source population taking over in the number counts at μJy level
(Singal+ 2010, Ysard&Lagache 2012, ...)

Galaxies would violate FIR-radio relation.

Fornengo,MR+ PRL 2011



Some "exotic" solutions:

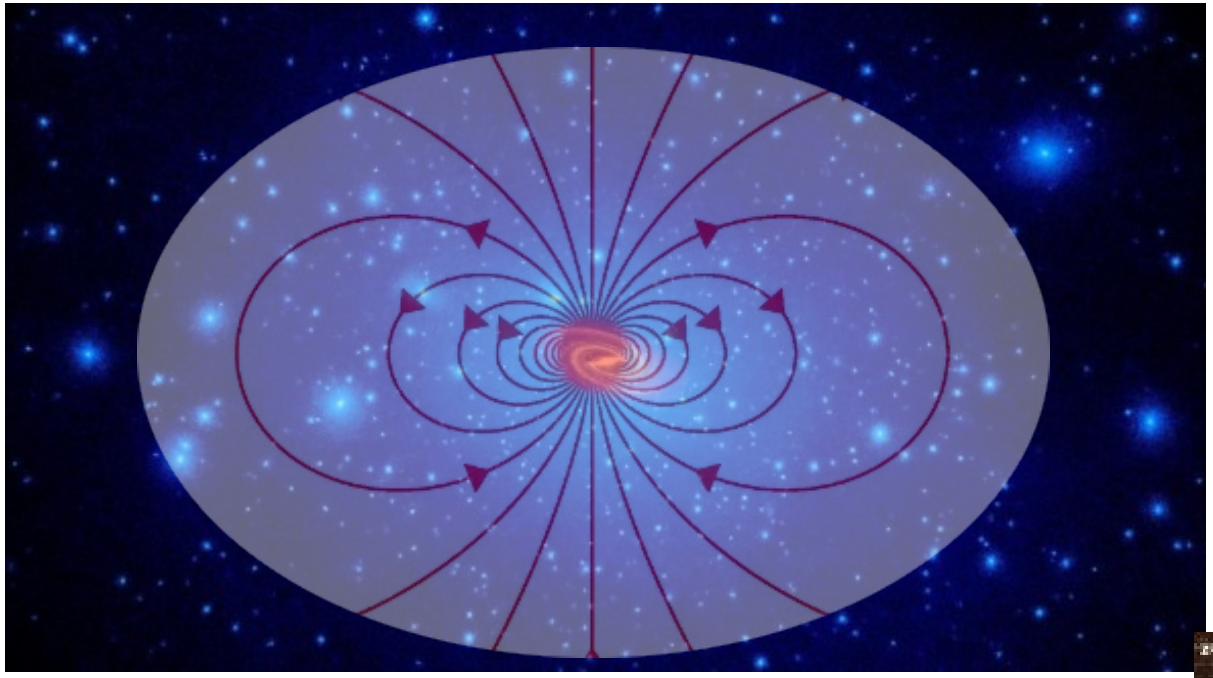
- WIMP DM annihilations (Fornengo, MR+2011, Hooper+ 2012, Fang&Linden 2015)
- late decay of metastable particle (Cline&Vincent 2013)
- ultracompact minihalos (Yang+ 2013)
- quark nugget dark matter (Lawson&Zhitnitsky 2013)
- cluster mergers (Fang&Linden 2015)
- fast radio transient (Kehayias+ 2015)

Where DM solution can work

"Traditional" structure
with non-quiescient baryonic distribution

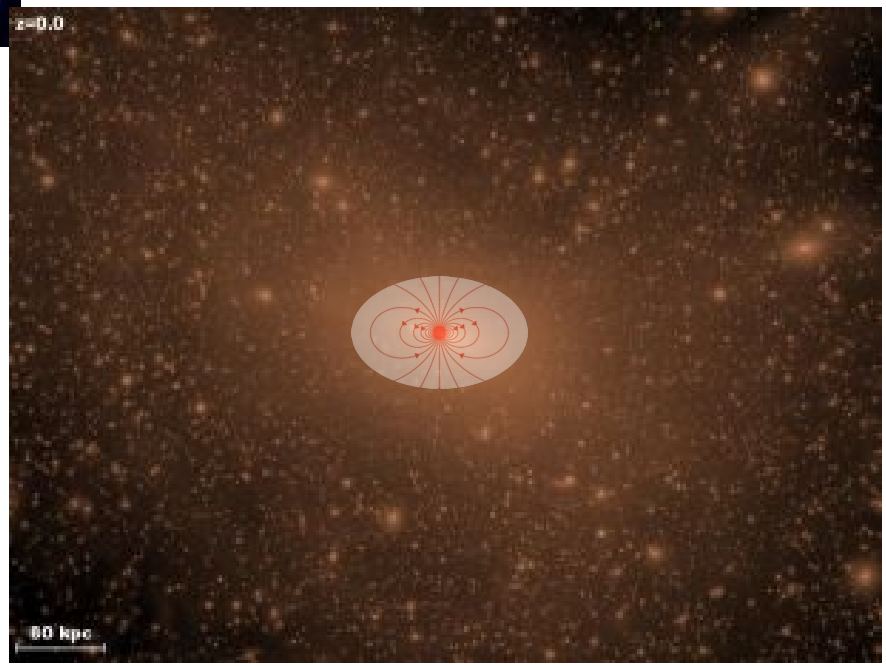
Dark structure

Where DM solution can work



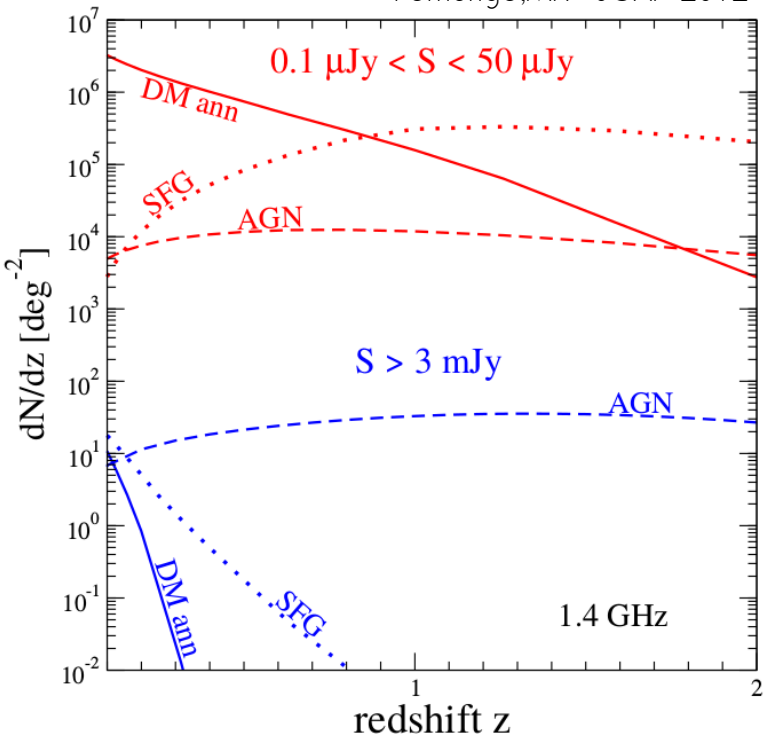
"Traditional" structure
with non-quiescient baryonic distribution
but large scale magnetic field

Dark structure
+ magnetic field



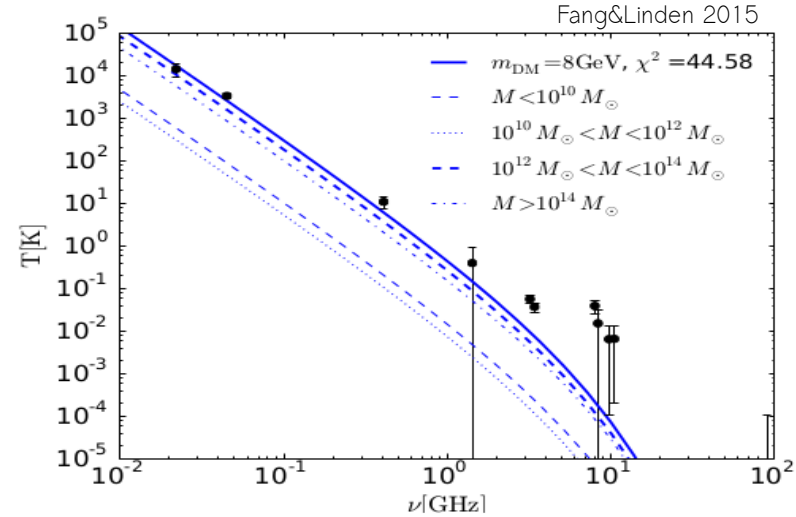
Dark matter interpretation

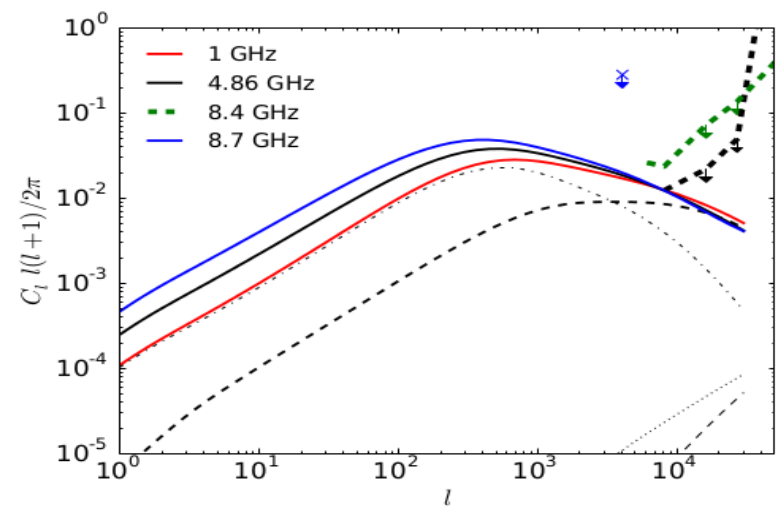
Fornengo,MR+ JCAP 2012



Synchrotron emission induced by WIMP annihilations is a viable solution

Fang&Linden 2015





Requires **significant substructure contributions** and **large-scale magnetic fields**.

Constraints from other probes
(such as the local e^+-e^- flux that would be injected by DM)

How to test the source of ARCADE excess?

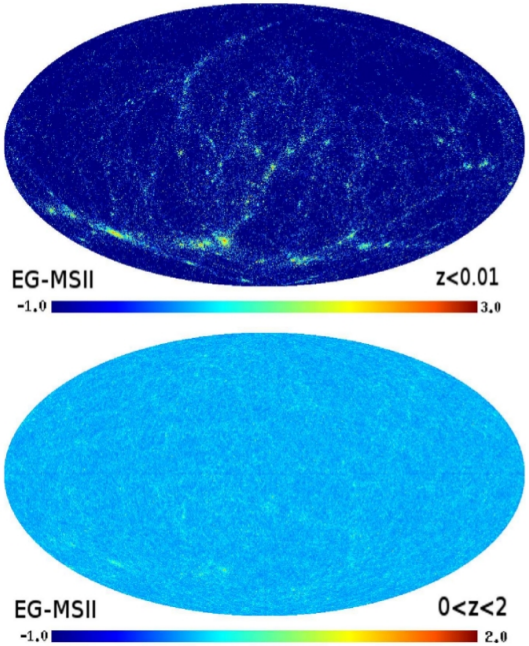
Deep observations of **individual sources**:
- Dwarf spheroidal galaxies
- Clusters of galaxies
- Big (and edge-on) galaxies
- Filaments?

⇨ "Stacking-like" analysis with EMU

Digging into the **unresolved** radio background:

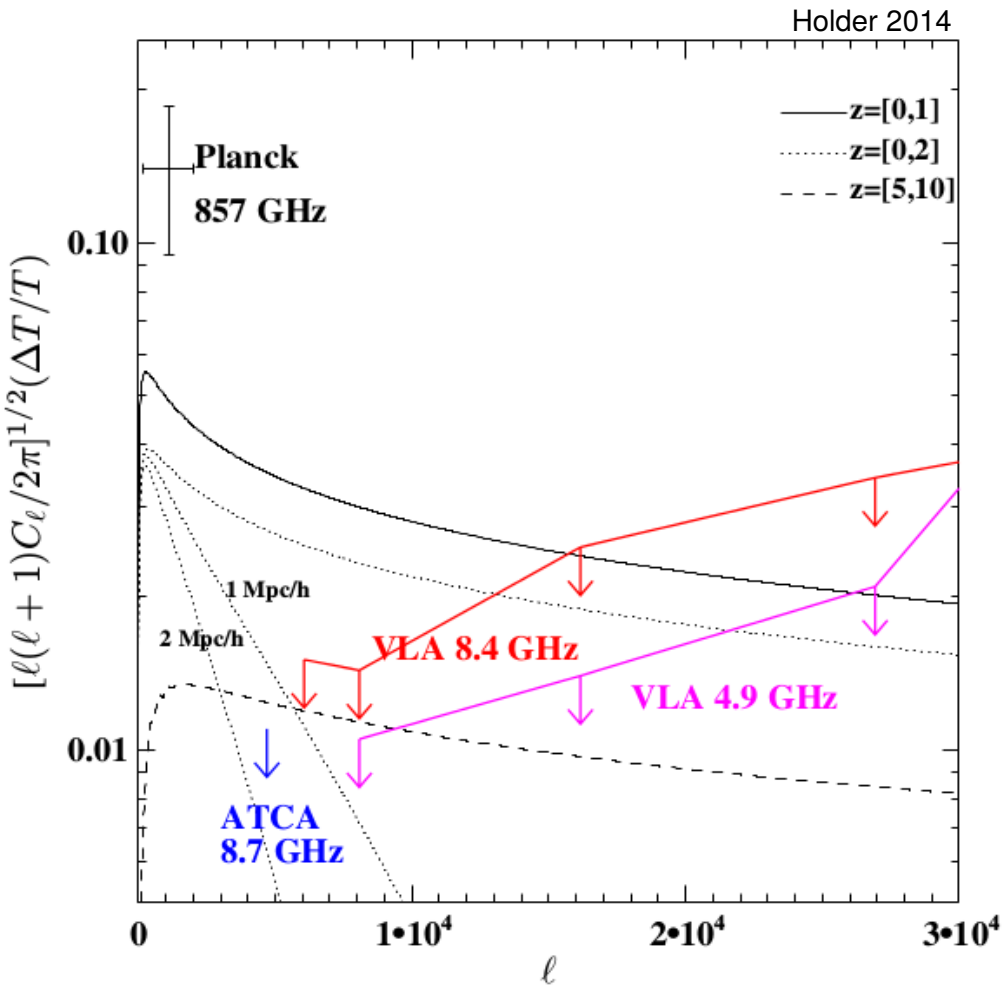
- 1-point statistics: P(D) (see e.g., Vernstrom+ 2015)

- 2-point statistics: auto and cross correlations



Maps from Fornasa et al., 2013

Auto correlation



Anisotropy bounds
suggest the ARCADE excess to be compatible only with:

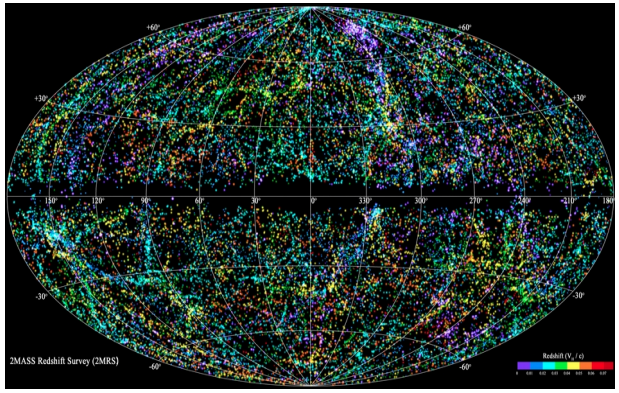
- diffuse (Mpc scale) sources

and/or

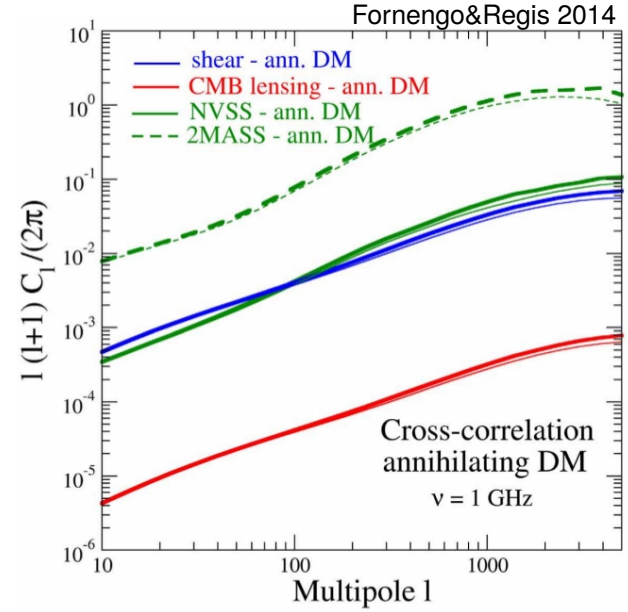
- high-z cosmological sources

Cross correlations

CROSS CORRELATION with tracers of the DM distribution/galaxies of certain types



Fornengo&Regis 2014



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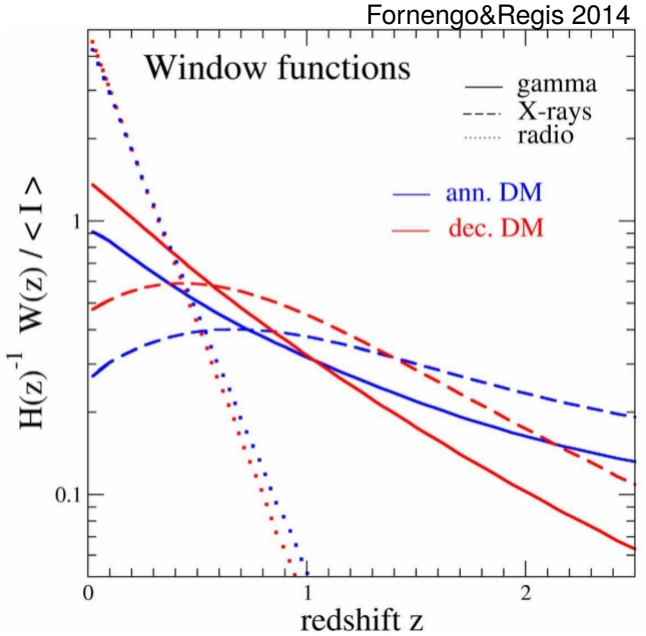
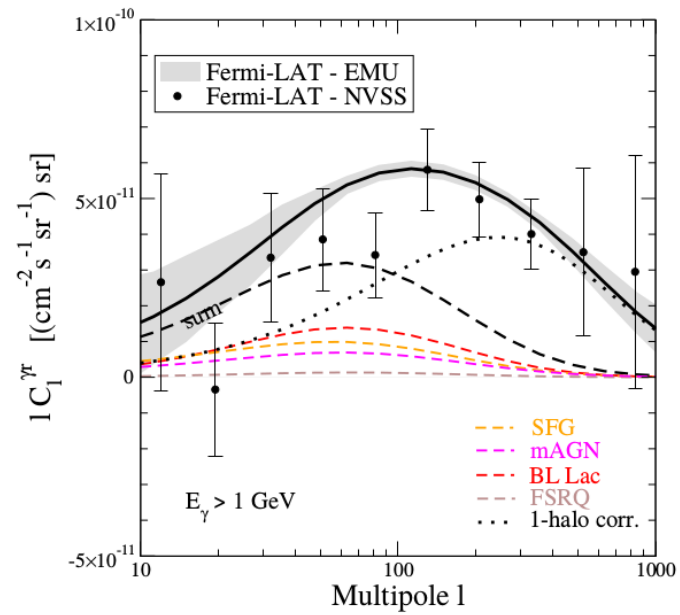


Synchrotron signal from particle DM is concentrated at low z

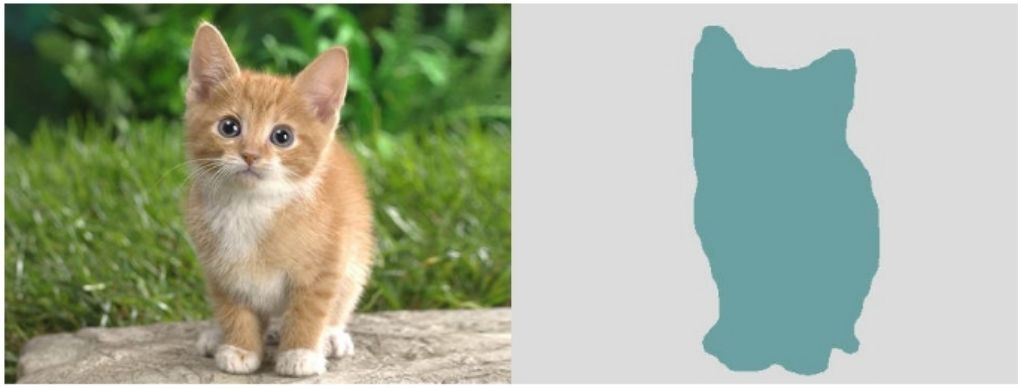


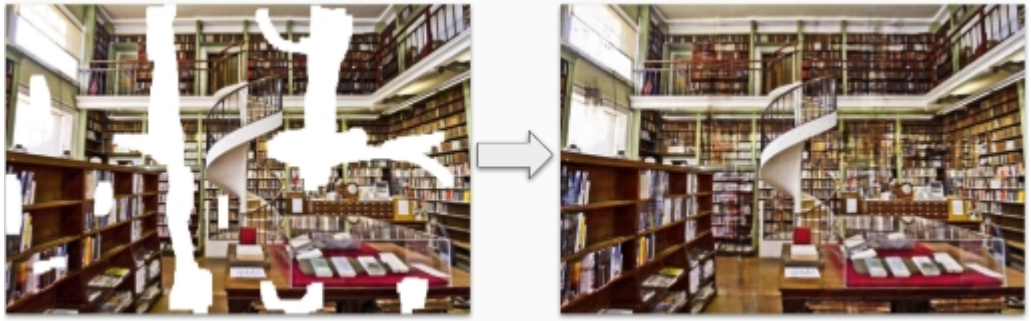
Using Convolutional Neural Network to estimate angular correlations of the unresolved EMU sky

Why Machine Learning ?

Interferometric images do contain **artifacts** → significant limitation when trying to study **statistical properties**, in particular of the unresolved background

Machine learning techniques (especially **deep neural networks**) are generally speaking an excellent tool "to dig-out" the properties of images.



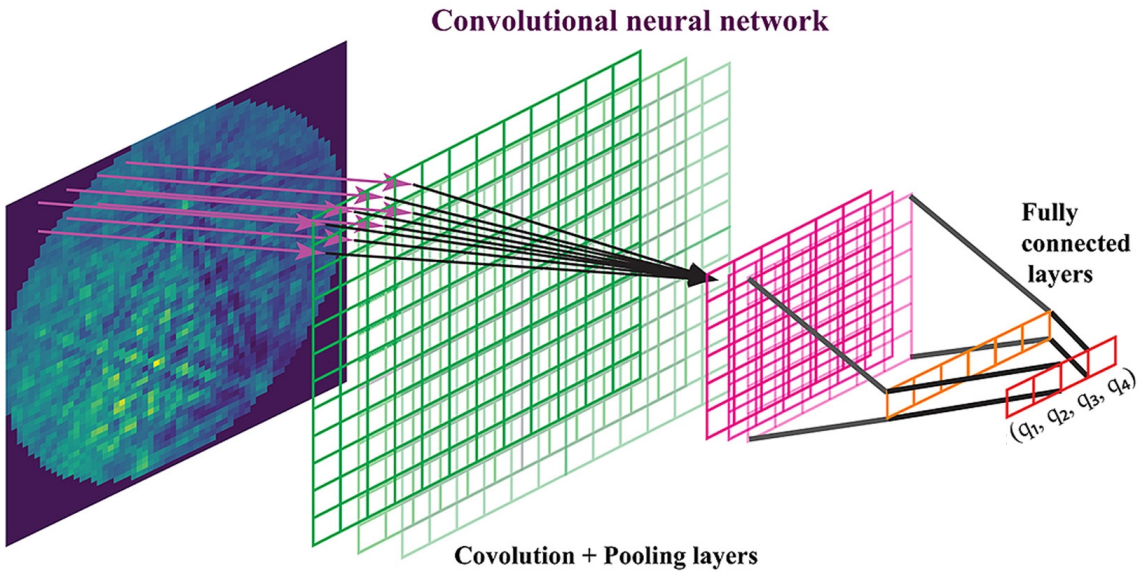


Deep neural networks applied to EMU data

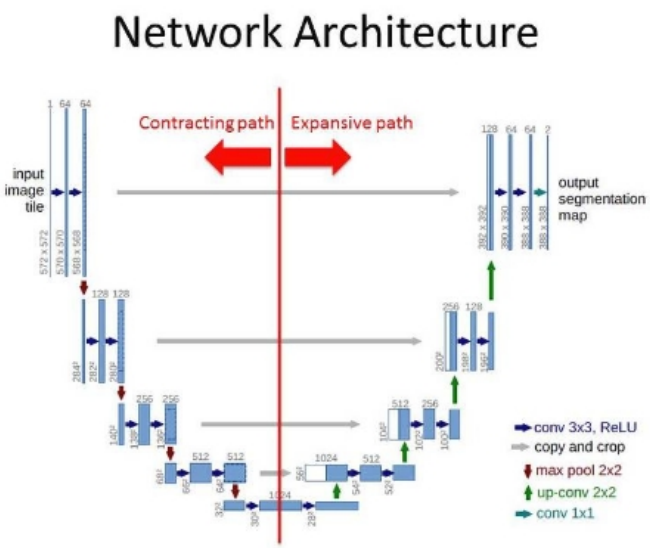
Goal: reconstruct the 2-point angular power spectrum of EMU images

<u>Two approaches</u>:

- POWER SPECTRUM based
Tool: CNN



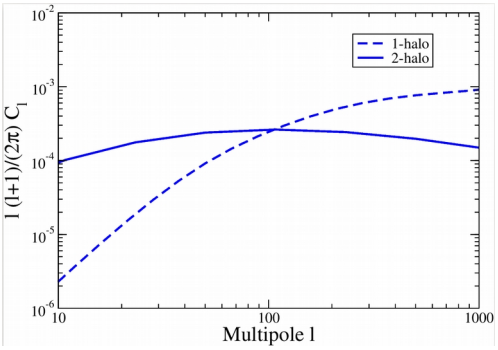
- IMAGE based
Tool: U-Net



Plan of the project

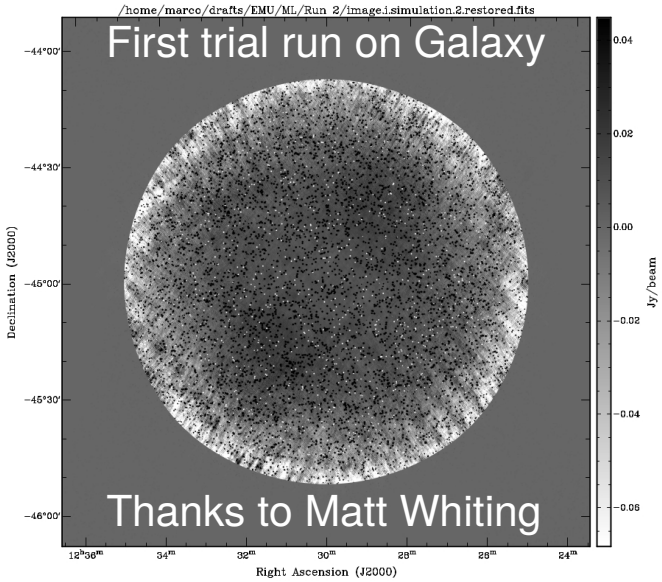
COLLABORATORS:
S. Ammazzalorso (post-doc in Turin), L. Thomas (Master student), D. Parkinson

CURRENT STATUS
Training the network on "simplified" simulations of radio images



+ Noise + Beaming

NEXT STEP
To train the network on ASKAPsoft simulations obtained from T-RECS catalogues



FINAL GOAL
To apply the analysis to EMU Pilot Survey Data

Summary

The **radio background below EMU detection threshold** might contain very interesting features (→ ARCADE excess)

We can investigate it in a statistical sense through the **2-point correlation function**

Convolutional neural networks might be a good tool to overcome limitations due to interferometric imaging