Ger de Bruyn's legacy work on the Perseus cluster

M.A. Brentjens

Radio Observatory and R&D divisions
ASTRON, Dwingeloo, The Netherlands

IAUS Perseus in Sicily

Prof. Ger de Bruyn 1948 – 2017

Scientific interests

Current

- Interstellar scintillation and the local ISM: AGN, Pulsars, GRB's, (any) transients, ...
- Galactic synchrotron foreground polarimetry
- Active Galactic Nuclei: nuclear variability, double–double radio galaxies and recurrent activity
- Clusters of galaxies (diffuse emission)
- High redshift HI: damped Ly-α absorbers, Epoch of Reionization (LOFAR)

Past

- Radio emission from young (extragalactic) SNR
- Optical spectrophotometric monitoring of Seyfert galaxies
- Radio gravitational lensing
- Surveys of the sky, e.g. WENSS/WISH

Other interests

Technical / radio interferometry

- synthesis array calibration (WSRT, LOFAR, SKA)
- extreme dynamic range issues ($> 10^6 : 1$)
- radio polarization methods (RM-synthesis)

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Well-being of others

Academic genealogy

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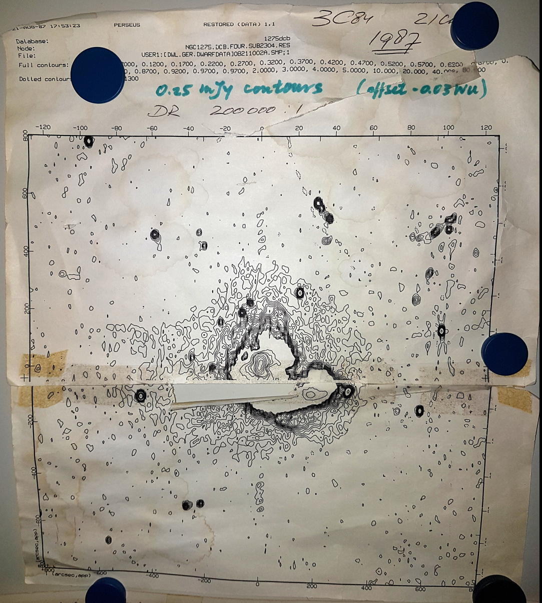
- George Stokes
- a couple more…
- Isaac Newton

3C84
1987
PERSEUS
RESTORED (DATA) 1.1
1275dbb
NGC1275.ICB.FOUR.SUB2304.RES
Database:
Mode:
File:
Full contours:
Dotted contours:
0.25 mJy contours (offset -0.03WU)
DR 200000 : 1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3C84 21c
1987
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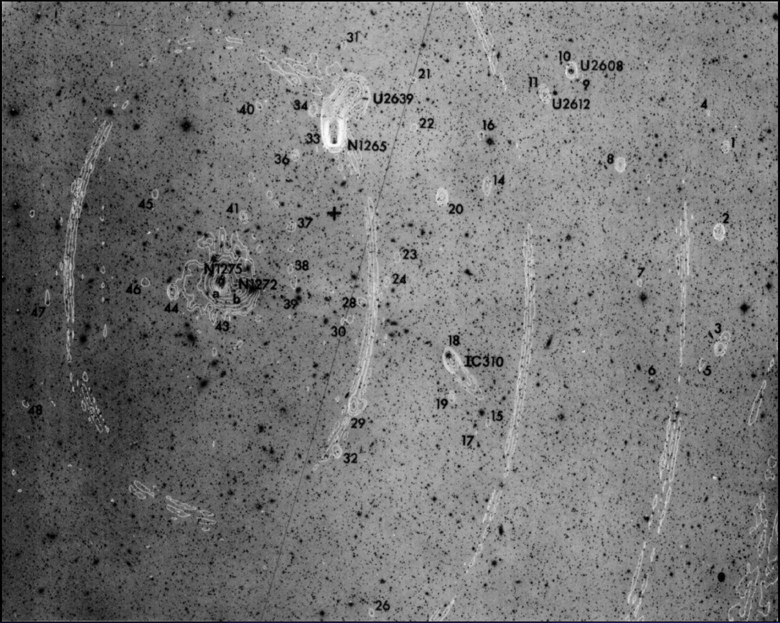
0.8700, 0.9200, 0.9700, 0.9700, 2.0000, 3.0000, 4.0000, 5.0000, 10.000, 20.000,
Dotted contour
0.25 mJy contours (offset -0.03 Wu)
DR 200000 : 1
(arcsec,app)

Gisler & Miley (1979) 610 MHz; 1,000:1



ARTICLES

High dynamic range mapping of strong radio sources, with application to 3C84

J. E. Noordam & A. G. de Bruyn

Radiosterrenwacht, Postbus 2, 7990 AA Dwingeloo, The Netherlands

A new reduction procedure is described to correct data obtained by the Westerbork Synthesis Radio Telescope. The technique allows very high dynamic range mapping of strong radio sources by also using redundant interferometers. The performance is illustrated with 6-cm and 21-cm continuum maps of 3C84, which have a dynamic range of about 10,000:1.

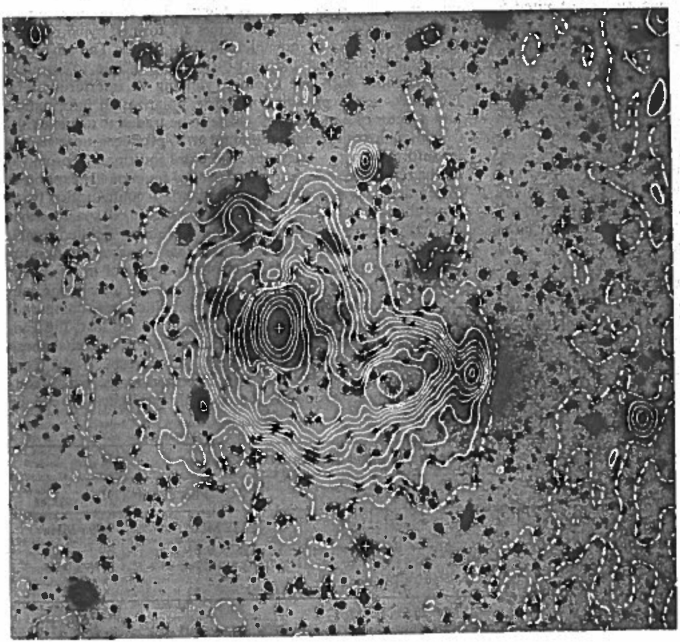


Fig. 2 The convolved 21-cm map of August 1980 superimposed on a deep optical photograph[16]. North is up and east to the left; the area shown measures 16.5×18 arc min. The resolution (30×45 arc s FWHM) can be judged from the appearance of the point source in the upper-right quadrant. A point source of flux density 13.2 Jy has been subtracted at the position of the cross centred on NGC1275. The displayed contour levels are −5, 0 (2.5) 10 (5) 40, 60, 80, 160, 320 and 640 mJy per beam; the peak brightness is at 2,060 mJy per beam. The true zero level varies slightly across the map but lies at about −2.5 mJy in the inner 10 arc min of the map.

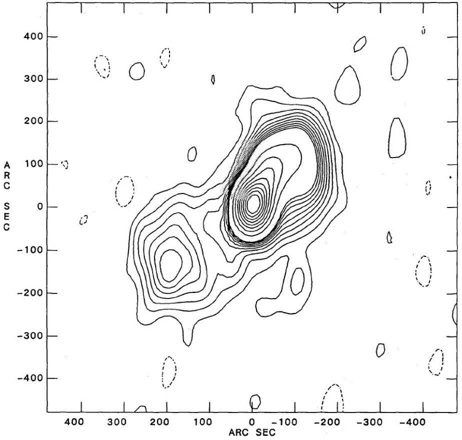


Figure 2: Contour map of the radio source 0309+411 obtained with the WSRT at 327 MHz. The contour levels are 1.6 x (-6,-3,3,6,9,12,15,18,21,24,27,30) and 1.6 x (60,90,120,150,180,210,240,270) mJy/beam. The factor 1.6 corrects for the primary beam attenuation. The peak flux density of the source is 480 mJy. The coordinates are in arc seconds relative to the core of 0309+411. North is up, east to the left.

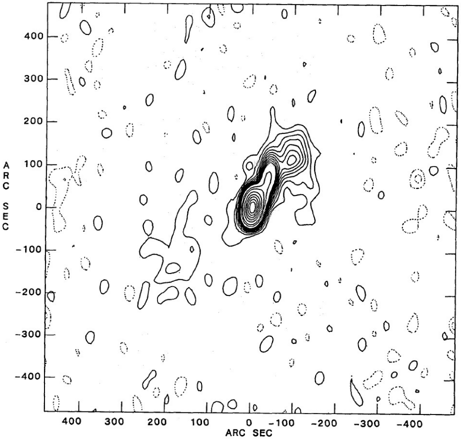


Figure 3: Contour map of the radio source 0309+411 obtained with the WSRT at 608 MHz. Contour levels are 5.9 x (-1.2,-0.6,0.6,1.2,1.8,2.4,3,3.6,4.2,4.8,5.4,6.0) and 5.9 x (9,12,18,24,30,36,42,48) mJy/beam. The factor 5.9 corrects for the primary beam attenuation. The peak flux density of the source is 380 mJy. The coordinates are relative to the core.

NGC 1265, IC 310 (49 and 92 cm) *Sijbring (1997)*

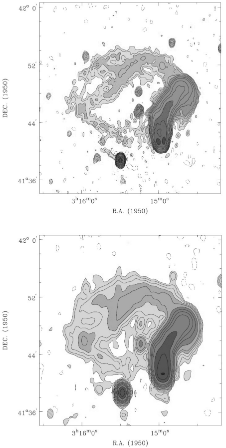


Fig. 1. a (upper) Total intensity distribution of the radio galaxy NGC 1265 at 49 cm uncorrected for primary beam response. The contour levels are −0.8 (*dashed*), 0.8, 1.5, 2.5, 5, 8, 15, 25, 50, 80, 150, 250, 500 and 800 mJy/beam. The greyscales represent values of 0.8, 2.5, 8, 150 and 500 mJy/beam. The maps are not primary beam corrected. The primary beam response is 0.80. The small filaments connecting to the strong point source (3C 83.1A) south-east of NGC 1265 are instrumental artifacts. **b** (lower) Same as **a** at 92 cm. The contour levels are −4 (*dashed*), 4, 8, 15, 25, 40, 80, 150, 250, 400, 800, 1500 and 2500 mJy/beam. The greyscales represent values of 4, 25, 80, 800

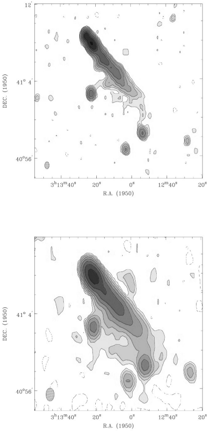


Fig. 3. a (upper) Total intensity distribution of IC 310 at 49 cm uncorrected for primary beam response. The contour levels are −0.8 (*dashed*), 0.8, 1.5, 2.5, 5, 8, 15, 25, 50, 80 and 150 mJy/beam. The greyscales have the same intensity levels. The primary beam response is 0.70. **b** (lower) Same as **a** at 92 cm. The contour levels are −2.5 (*dashed*), 2.5, 5, 10, 20, 40, 80, 160 and 320 mJy/beam. The greyscales have the same intensity levels. The primary beam response is 0.90. The beamsizes are indicated by the shaded ellipses in the lower left corners.

Perseus returns: proposals

3. Short title (10 words maximum) of proposed programme

Nature of the polarized diffuse emission in the Perseus cluster

4. Abstract (Concise summary of the proposal)

We propose a new deep radio continuum study of the Perseus cluster at 21cm. The main science driver is the nature of the diffuse polarized emission, first discovered in 1995. If, as we suspect, the emission is due to Thomson scattering of the central radio source by the hot diffuse gas in the cluster we can study the latter distribution, providing an X-ray independent handle on the baryonic mass in the cluster. Using the Rotation Measure of the polarized emission we can also derive the strength and topology of the large scale cluster magnetic field. The observations will complement new high quality 80-100 cm observations obtained in Dec 2002.

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In 1995 the cluster was re-observed in 21cm continuum radiation by de Bruyn in an attempt to image the polarized emission in the cluster. The results of this 6x12h 21cm continuum observation using the 8x5 Mhz DCB in 1995 are shown in Figure 1abcd. The peak flux divided by the rms noise in clean areas is more than 1 million to 1 (de Bruyn, 1996, High Sensitivity Radio Astronomy Workshop, Jodrell Bank, Ed. N. Jackson, CUP). The noise level in these images is about 25 microJy/beam and revealed in the Stokes V image. This is not the place to discuss the origin of the various artefacts in the Stokes Q and U images. Suffice it to say that there is no doubt that there is wide-spread diffuse polarized emission approximately centered on 3C84 and extending over at least 30', predominantly in the SW-NE direction.

Stokes IQUV 21 cm (1995 unpublished)

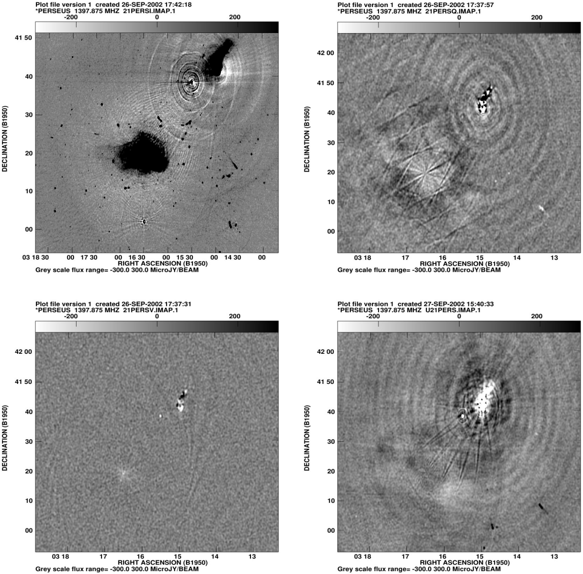
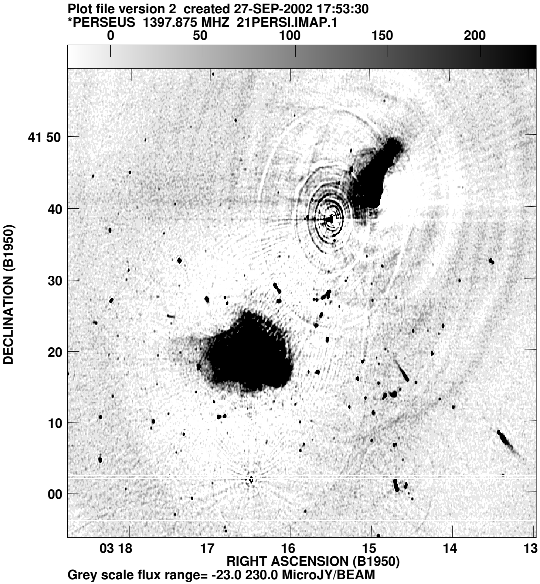
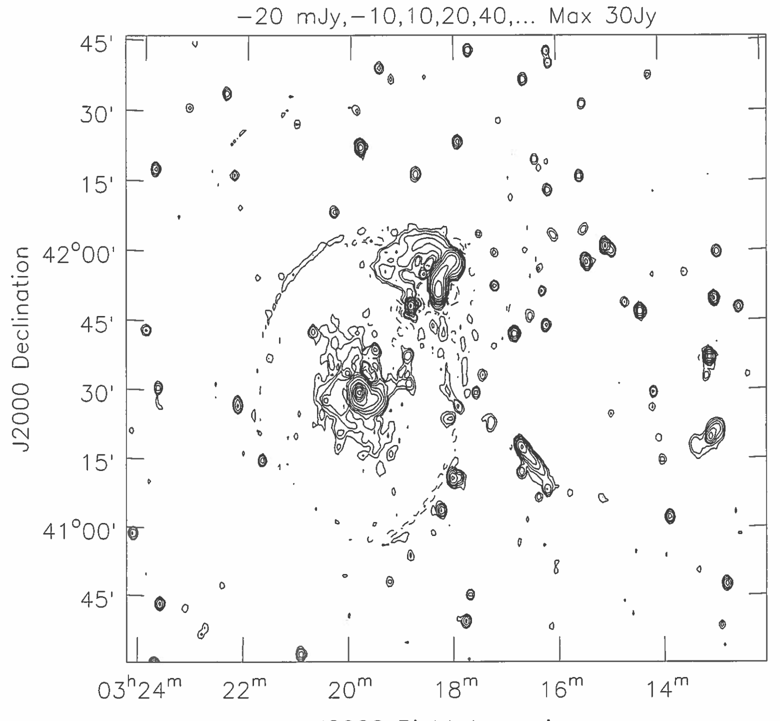


FIG. 3.— From top left clockwise: Stokes I, Q, U and V. These are 21 cm WSRT observations of Perseus by de Bruyn (unpublished, see also: de Bruyn (1996a)). The scale of the I images differs slightly from that of the polarized images. The Q and U images show diffuse linearly polarized emission in the central parts of the cluster. An RM study of this emission may reveal its origin.

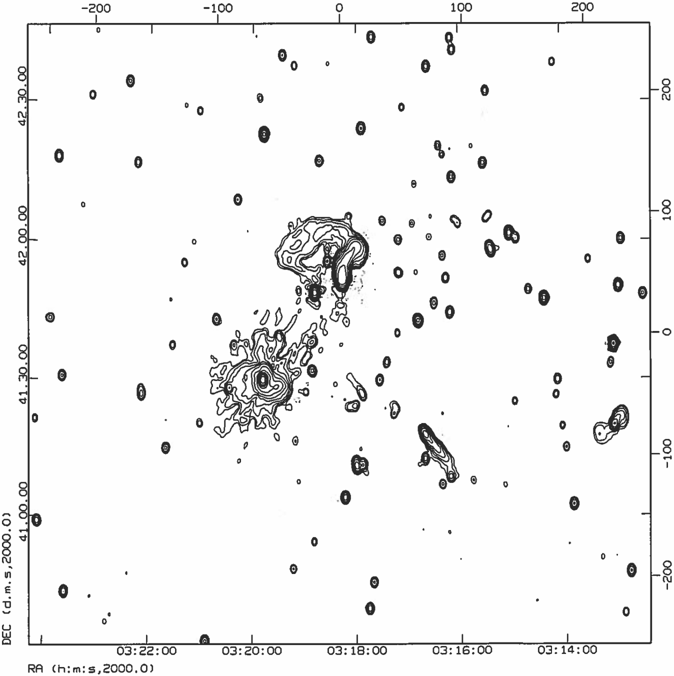
Perseus 1,000,000:1



“The description of the analysis plan "de Bruyn will reduce the data in Newstar" is unsatisfactory for such a significant request of 156 hrs.”

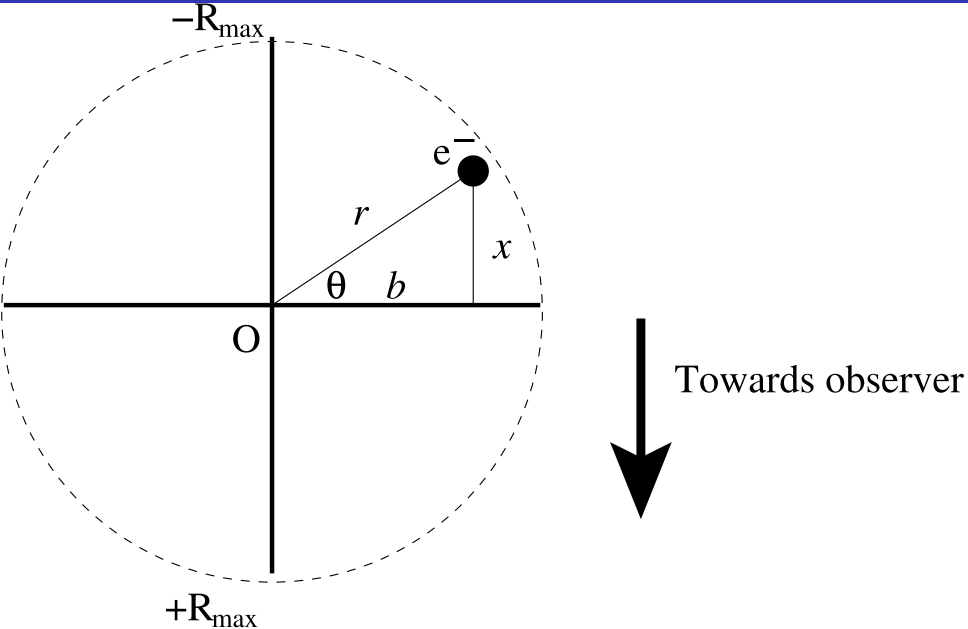


-20 mJy,-10,10,20,40,... Max 30Jy
J2000 Declination
45'
30'
15'
42°00'
45'
30'
15'
41°00'
45'
03ʰ24ᵐ
22ᵐ
20ᵐ
18ᵐ
16ᵐ
14ᵐ

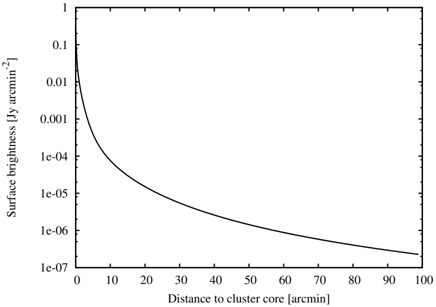


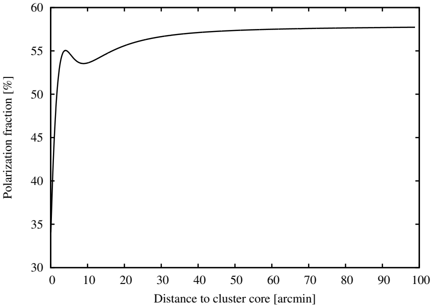
-200
-100
0
100
200
42 30 00
42 00 00
41 30 00
41 00 00
200
100
0
-100
-200
03:22:00
03:20:00
03:18:00
03:16:00
03:14:00
DEC (d.m.s,2000.0)
RA (h:m:s,2000.0)

Thomson scattering



Thomson scattering





ASTRON

NETHERLANDS FOUNDATION FOR
RESEARCH IN ASTRONOMY

NOTE 655

RM-synthesis via wide-band low-frequency polarimetry

MAART 1996

BY A.G. de Bruyn

Future applications

We expect the new tool to be particularly powerful in the study of weakly polarized extended sources, such as giant radio galaxies where the *RM*'s are known to be small. Small changes in the *RM* across the surface of extended sources should be easily traceable, especially if these *RM*s are showing some spatial coherence.

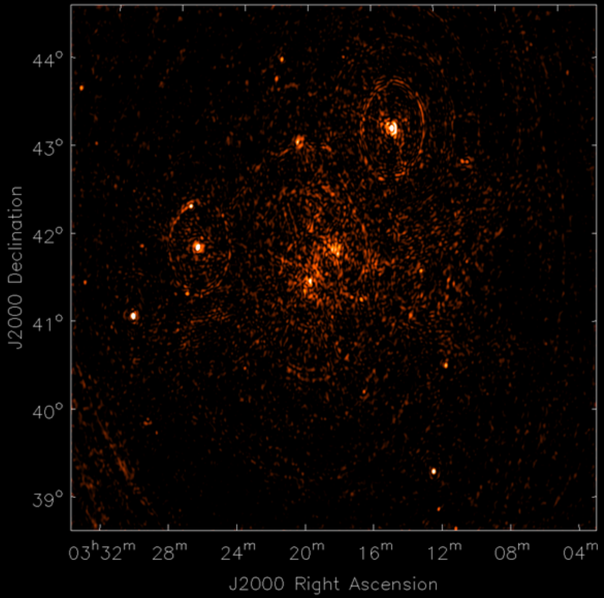
The wideband spectrometer (the DZB) currently being built for the WSRT makes it possible to search for and study weakly polarized structure over a much wider range of *RM*. The side-lobe levels in the RMTF that occur with an 8-channel system will be much reduced when 128 frequency channels can be used to cover a wide (80 MHz) low frequency band.

Very small variations in *RM* can be expected to occur close to the core of AGN when polarized structure moves relative to a foreground Faraday screen. With a sensitivity of 0.1 rad/m^2 extremely sensitive measurements of the ionized gas around polarized radio sources can be made. If several sources with a well-determined *RM* are found wihin the synthesized field of view the fundamental limit imposed by the uncertainty of the ionospheric *RM* can be avoided by the study of *differential RM* variations. The diffuse galactic background emission, which is highly polarized at low frequencies, and has a typical *RM* of $\approx$ 5–10 rad/m^2, may well be useful as a non-variable *RM* reference.

The range in *RM* where the RM-synthesis technique will be a useful tool depends on frequency. At 1400 MHz, and a bandwidth of 160 MHz, this range begins at a few hundred rad/m^2. A practical limit, in real radio sources, will occur when depolarization due to fine-scale structure in *RM* within the beam, i.e. beam-depolarization, begins to dominate over bandwidth-depolarization.

A final intriguing possibility opened up by low frequency wide-band polarimetry is the study of the Faraday rotating material *within* radio sources. The Fourier-relationship between the complex polarization and the 'Faraday depth' suggests that observations over a large range in frequency may be used to derive information about the spatial disposition of the emitting and depolarizing material.

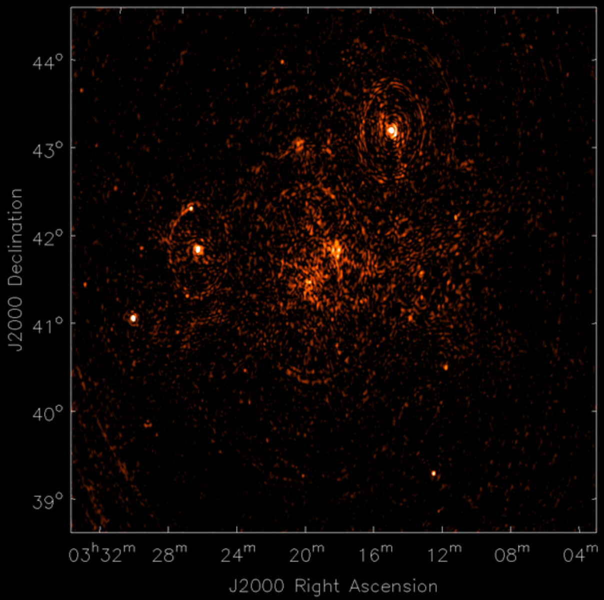
RM = -30 rad/m^2



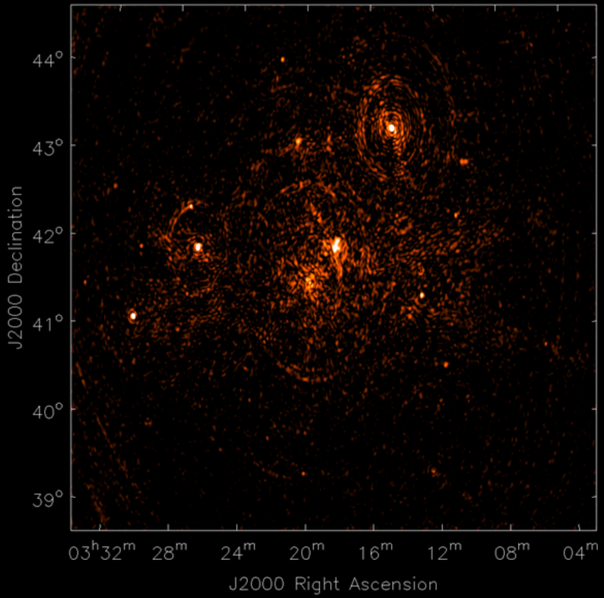
44°
43°
42°
41°
40°
39°
J2000 Declination
03^{h}32^m
28^m
24^m
20^m
16^m
12^m
08^m
04^m
J2000 Right Ascension

RM = -27 rad/m^2

ASTRON

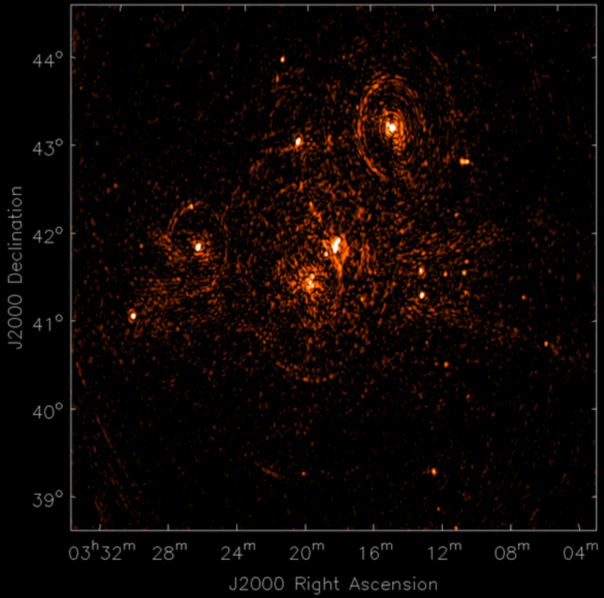


RM = -24 rad/m^2



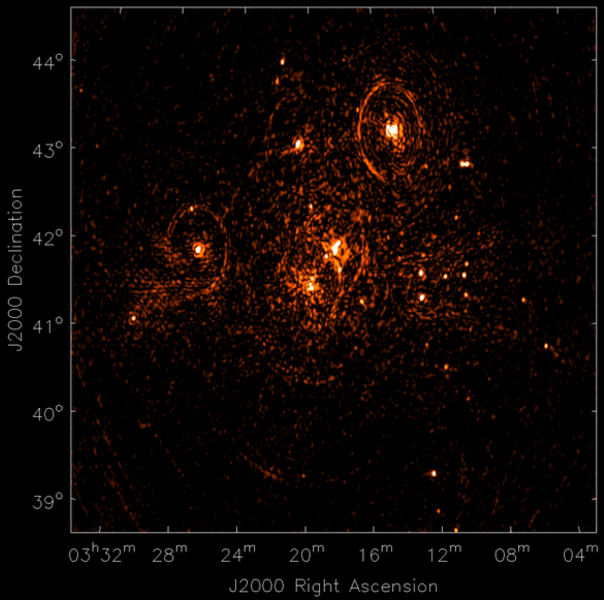
44°
43°
42°
41°
40°
39°
J2000 Declination
03h32m 28m 24m 20m 16m 12m 08m 04m
J2000 Right Ascension

RM = -21 rad/m^2



J2000 Declination
44°
43°
42°
41°
40°
39°
03h32m
28m
24m
20m
16m
12m
08m
04m
J2000 Right Ascension

RM = -18 rad/m^2



44°
43°
42°
41°
40°
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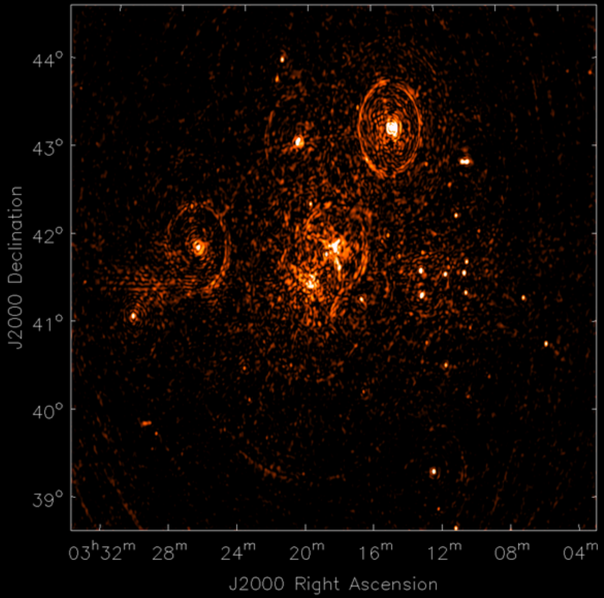
J2000 Declination
03h32m
28m
24m
20m
16m
12m
08m
04m
J2000 Right Ascension

RM = -15 rad/m^2



44°
43°
42°
41°
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39°
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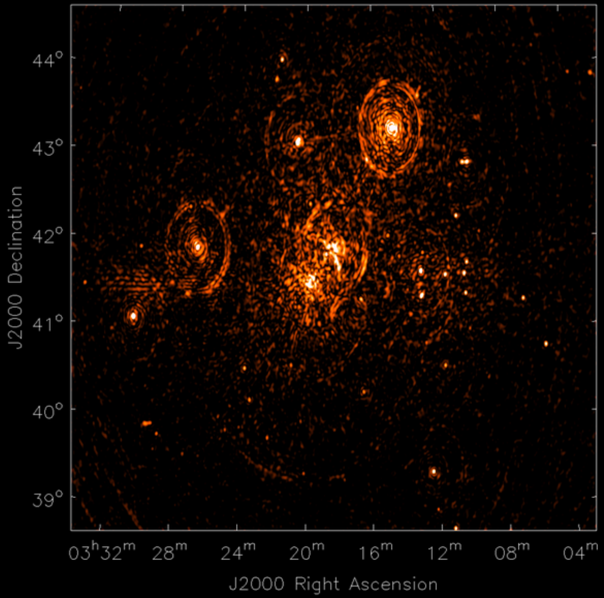
28m
24m
20m
16m
12m
08m
04m
J2000 Right Ascension

RM = -12 rad/m^2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J2000 Declination
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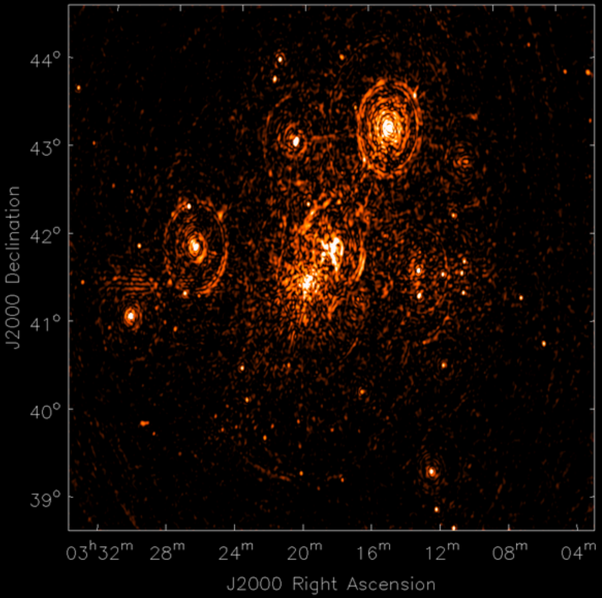
J2000 Right Ascension

RM = -9 rad/m^2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J2000 Declination
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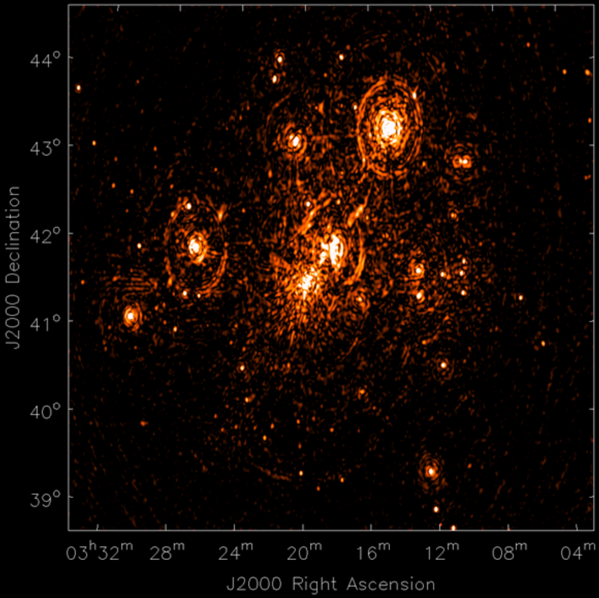
J2000 Right Ascension

RM = -6 rad/m^2



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J2000 Declination
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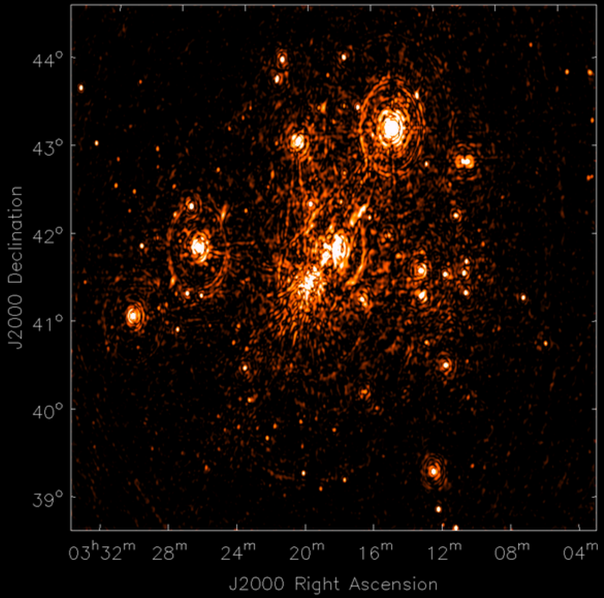
J2000 Right Ascension

RM = -3 rad/m^2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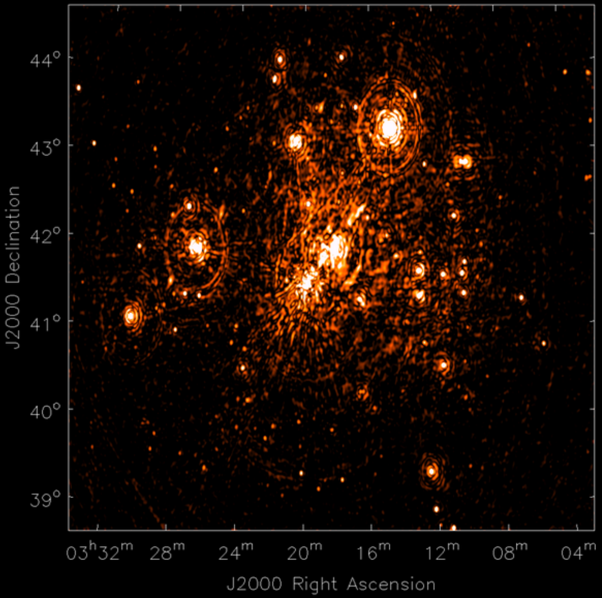
J2000 Right Ascension

RM = 0 rad/m^2



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J2000 Declination
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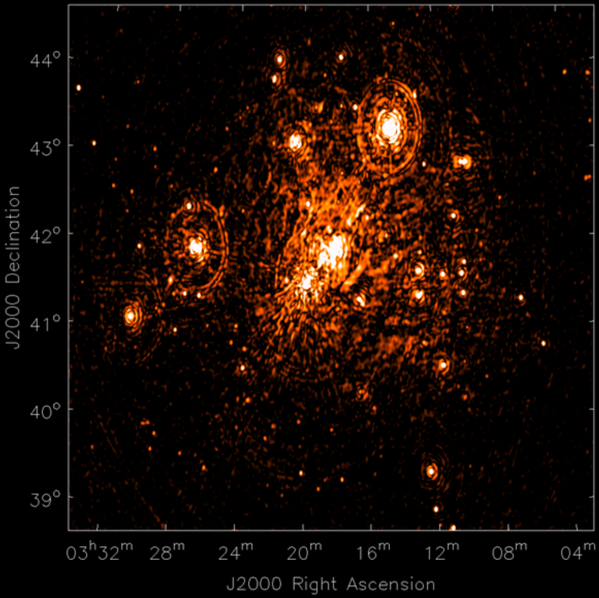
J2000 Right Ascension

RM = 3 rad/m^2


44°
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J2000 Declination
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28m
24m
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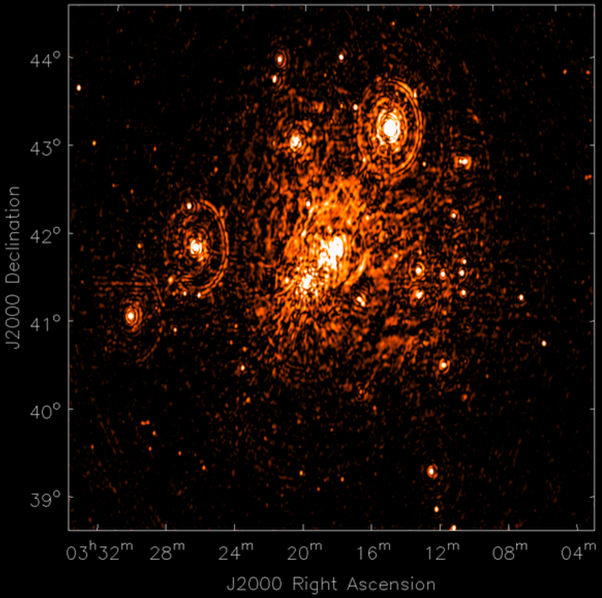
04m
J2000 Right Ascension

RM = 6 rad/m^2



44°
43°
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J2000 Declination
03h32m
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24m
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16m
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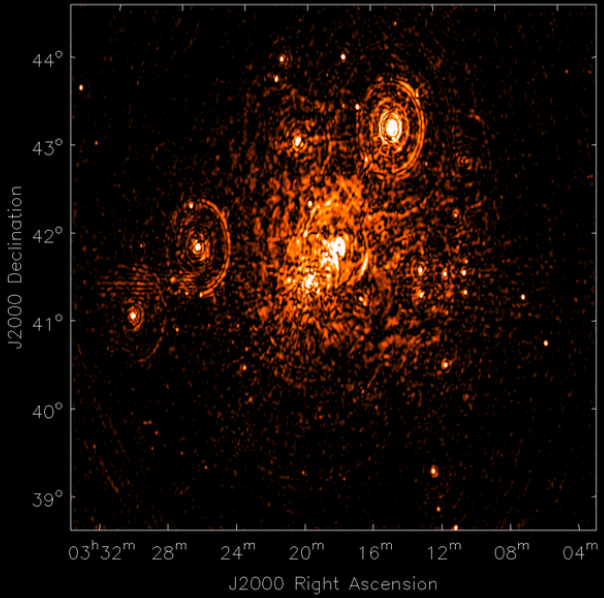
04m
J2000 Right Ascension

RM = 9 rad/m^2



44°
43°
42°
41°
40°
39°
J2000 Declination
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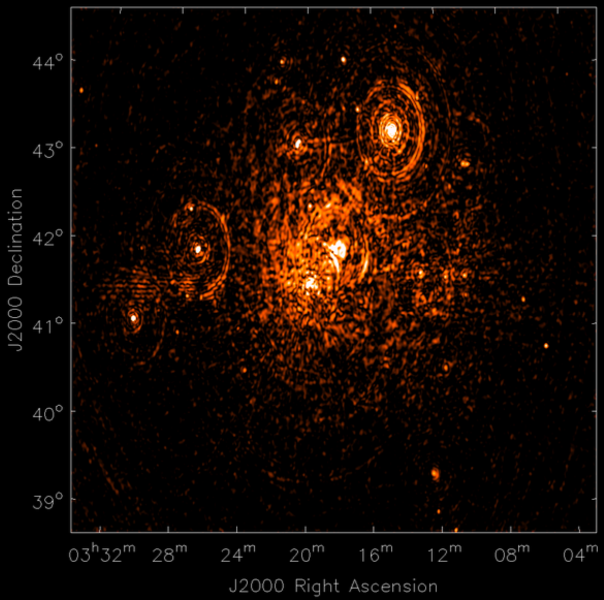
28m
24m
20m
16m
12m
08m
04m
J2000 Right Ascension

RM = 12 rad/m^2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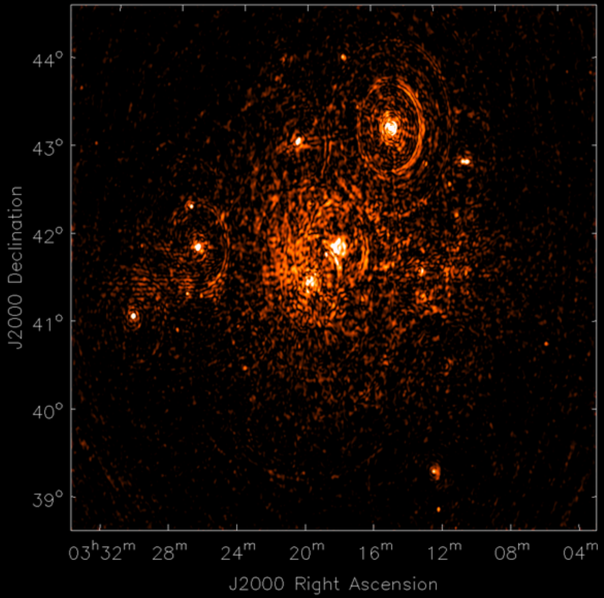
43°
42°
41°
40°
39°
J2000 Declination
03h32m
28m
24m
20m
16m
12m
08m
04m
J2000 Right Ascension

RM = 15 rad/m^2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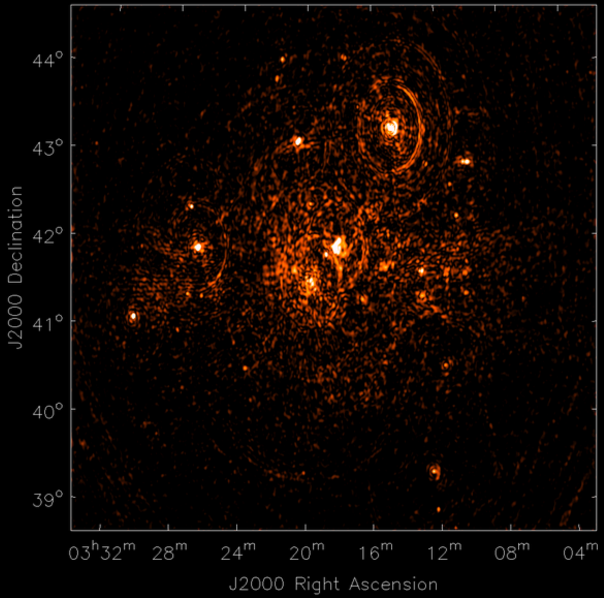
RM = 18 rad/m^2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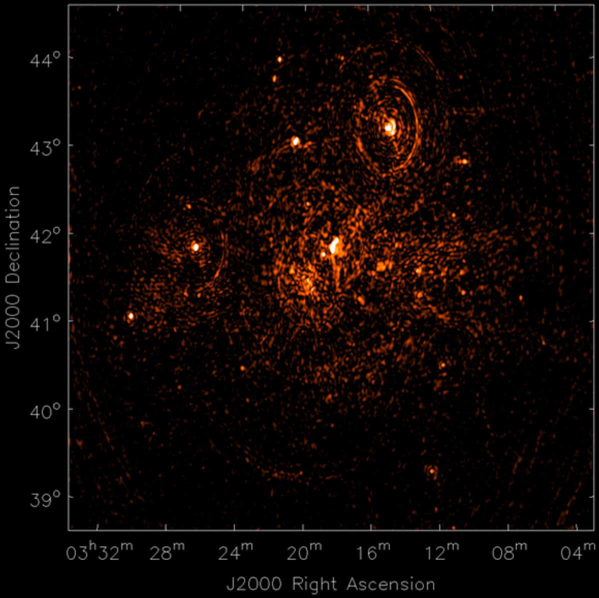
J2000 Right Ascension

RM = 21 rad/m^2



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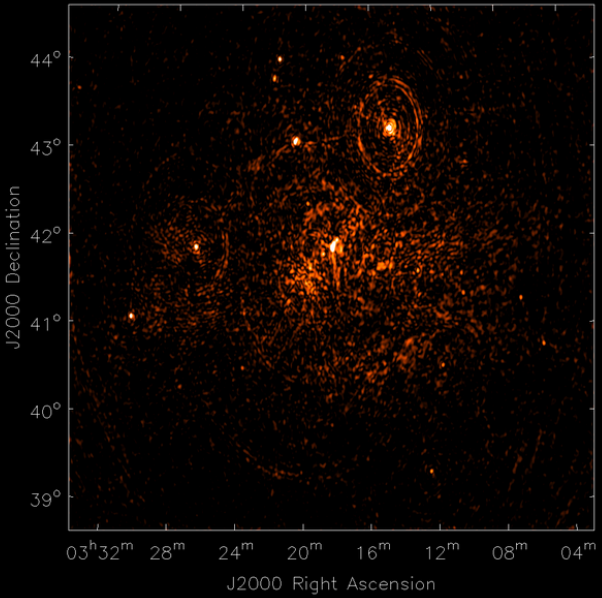
J2000 Right Ascension

RM = 24 rad/m^2



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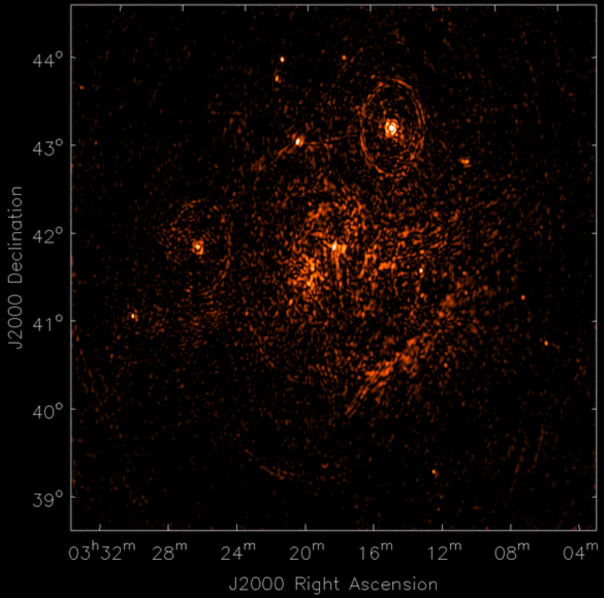
RM = 27 rad/m^2



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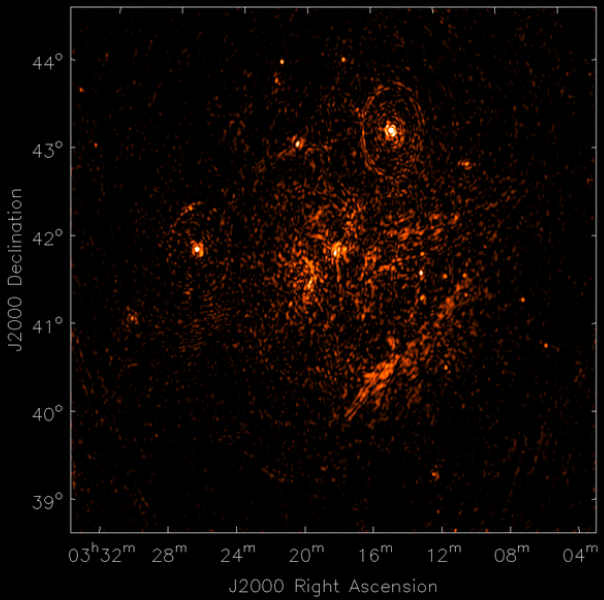
RM = 30 rad/m^2



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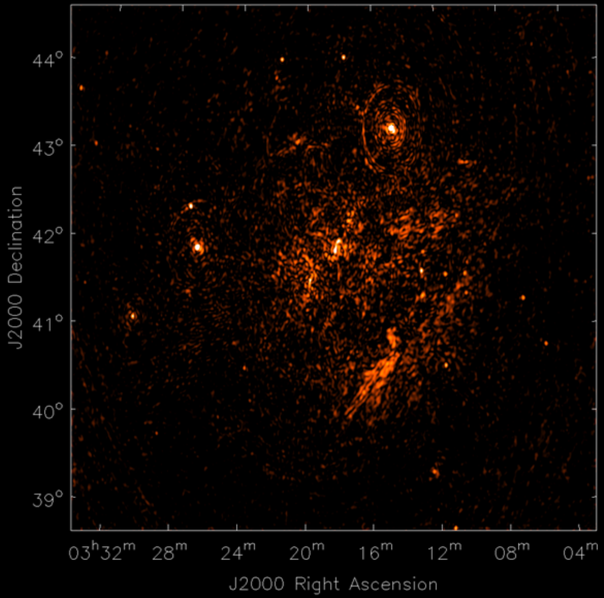
RM = 33 rad/m^2



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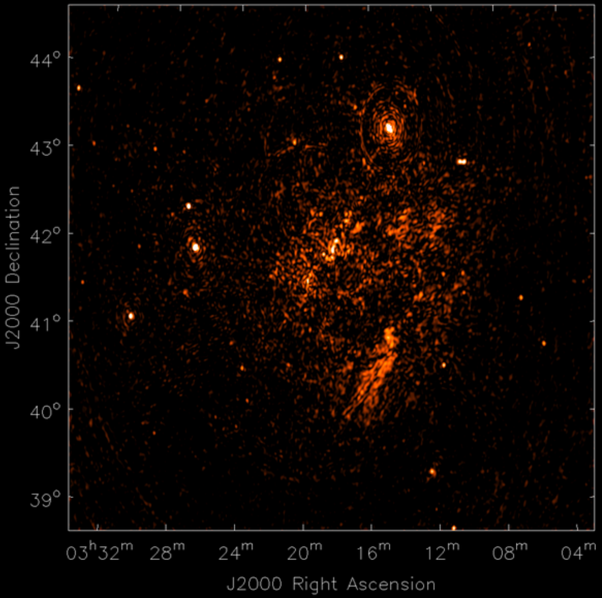
RM = 36 rad/m^2



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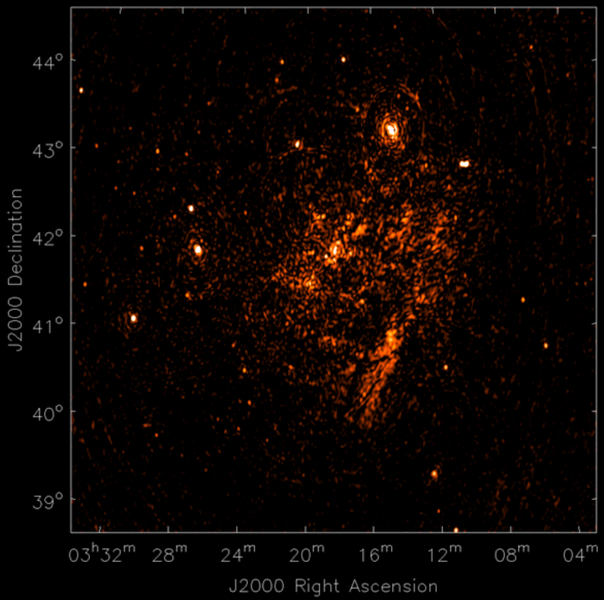
J2000 Right Ascension

RM = 39 rad/m^2



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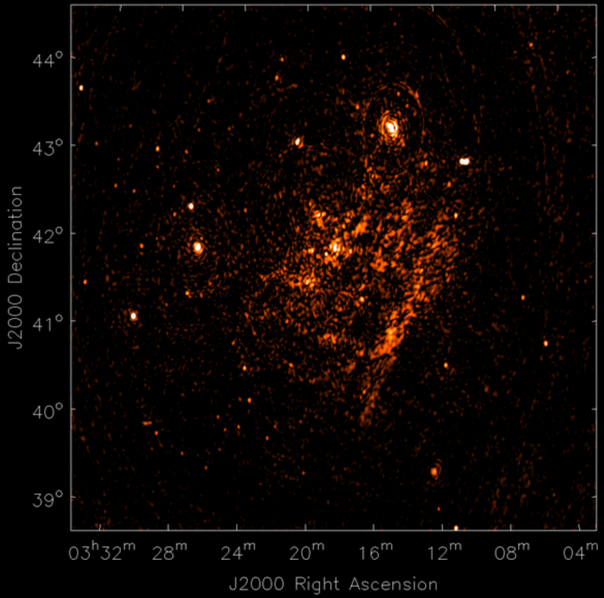
J2000 Right Ascension

RM = 42 rad/m^2



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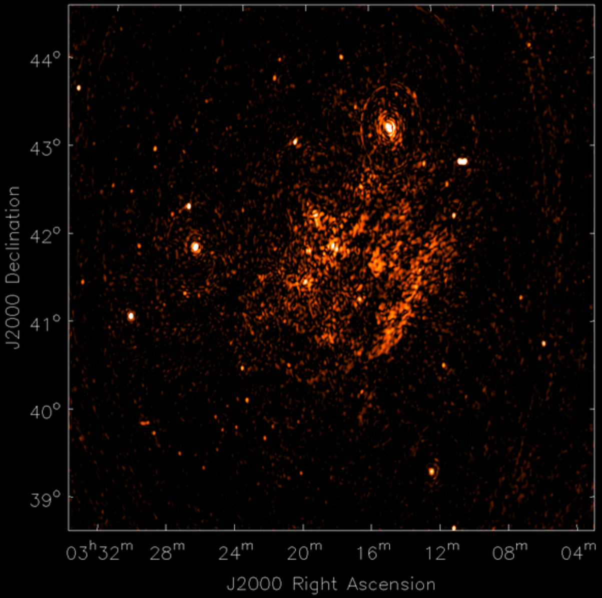
J2000 Right Ascension

RM = 45 rad/m^2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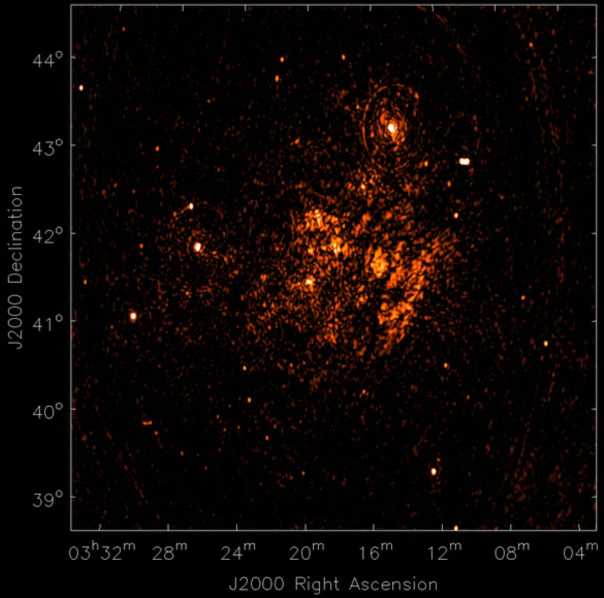
J2000 Right Ascension

RM = 48 rad/m^2



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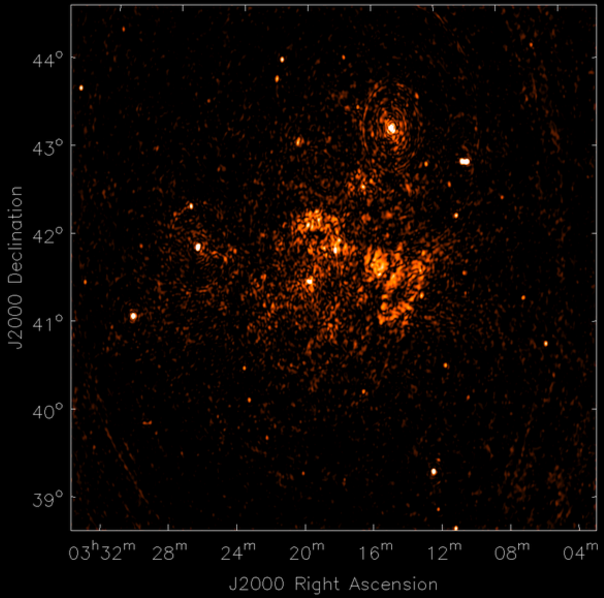
J2000 Right Ascension

RM = 51 rad/m^2



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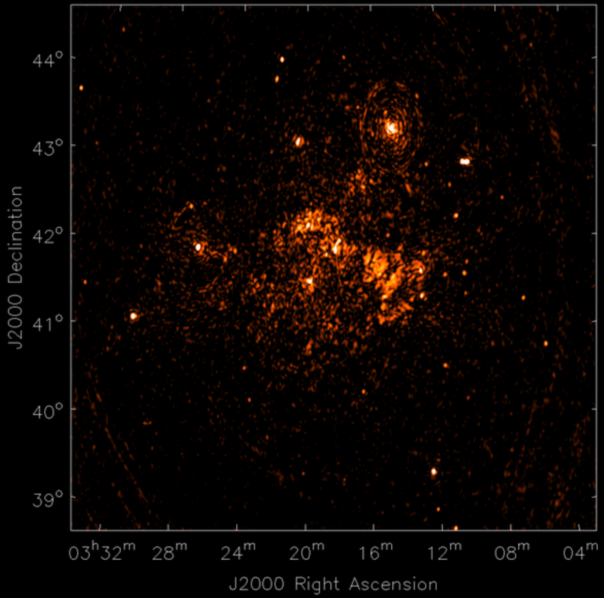
J2000 Right Ascension

RM = 54 rad/m^2



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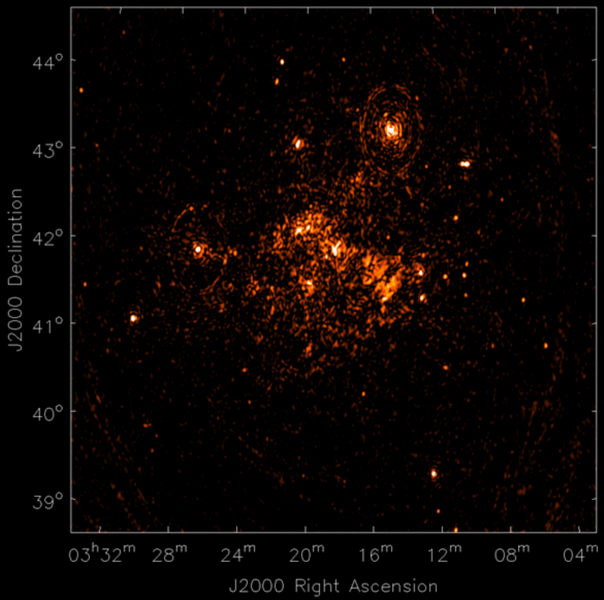
J2000 Right Ascension

RM = 57 rad/m^2



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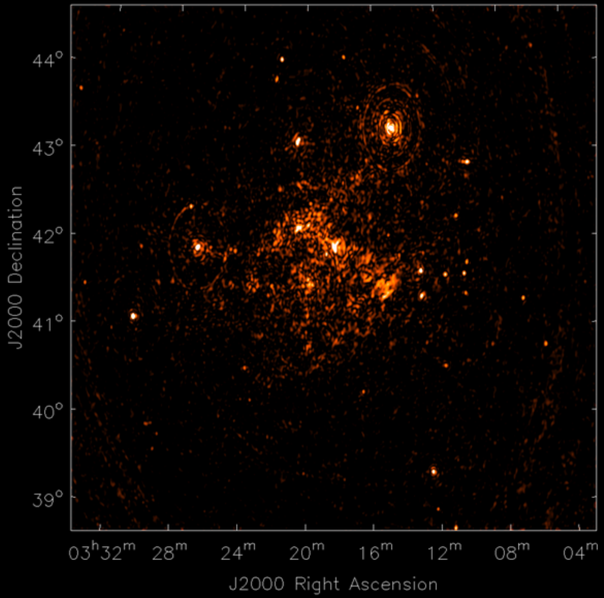
J2000 Right Ascension

RM = 60 rad/m^2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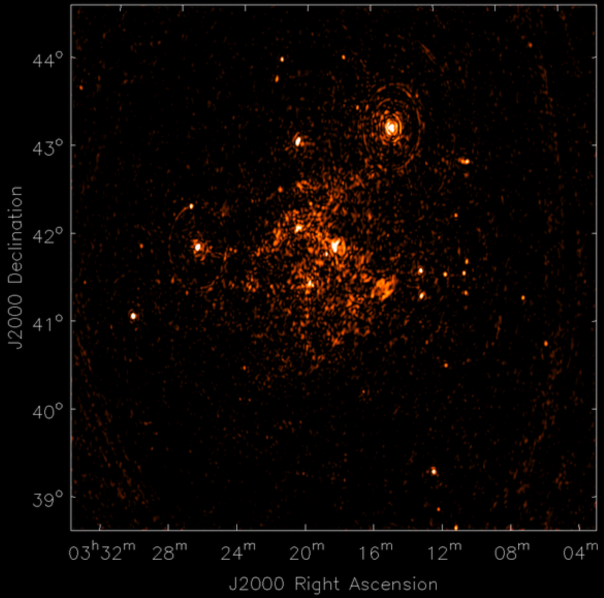
RM = 63 rad/m^2



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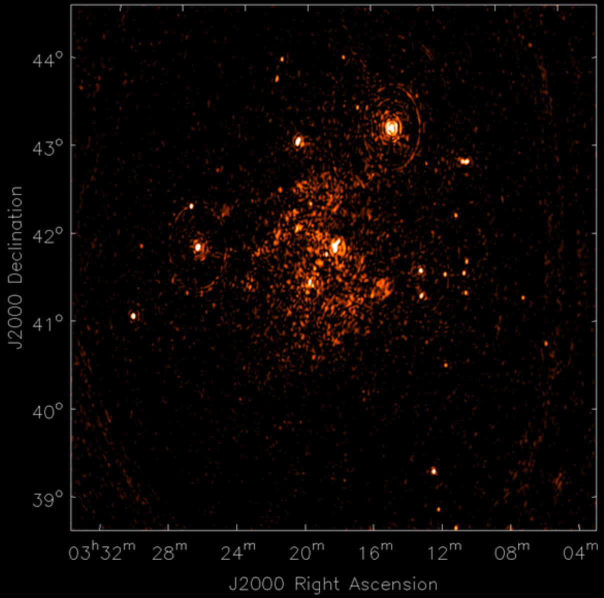
J2000 Right Ascension

RM = 66 rad/m^2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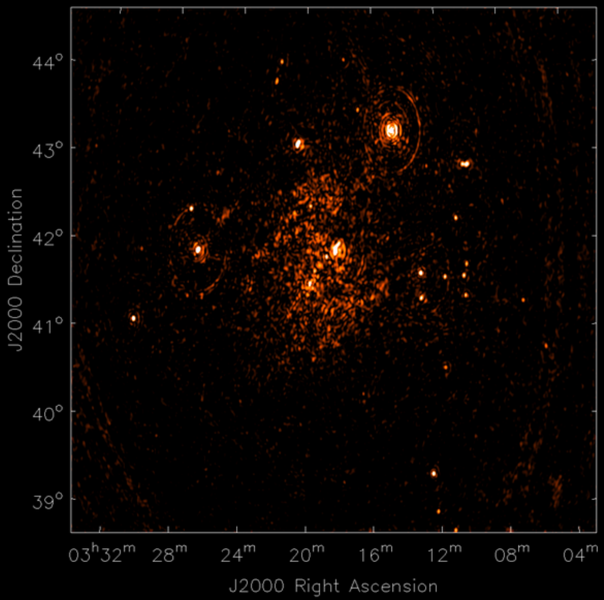
RM = 69 rad/m^2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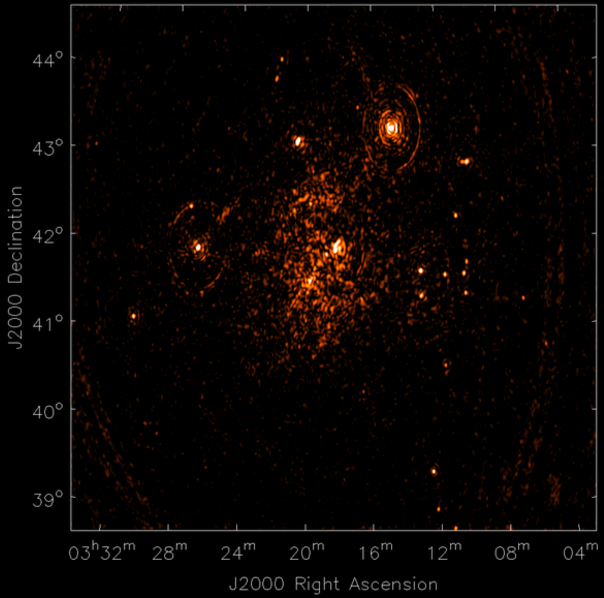
RM = 72 rad/m^2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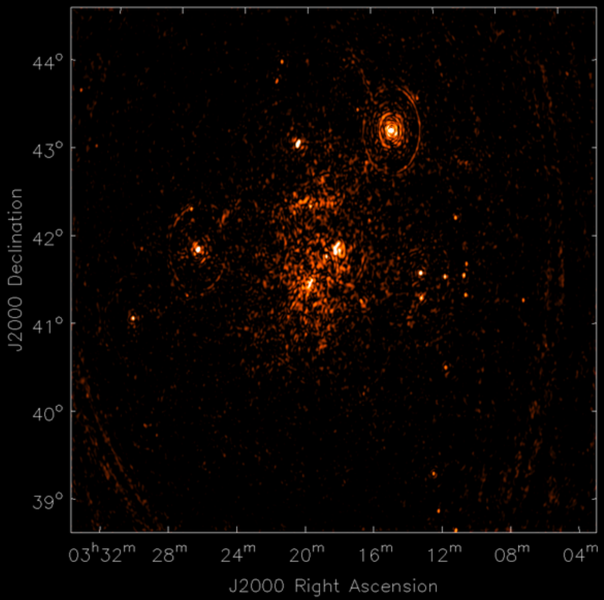
J2000 Right Ascension

RM = 75 rad/m^2



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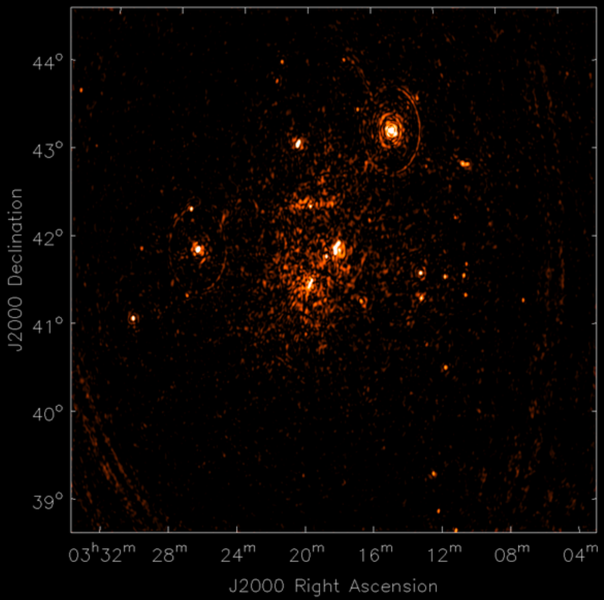
J2000 Right Ascension

RM = 78 rad/m^2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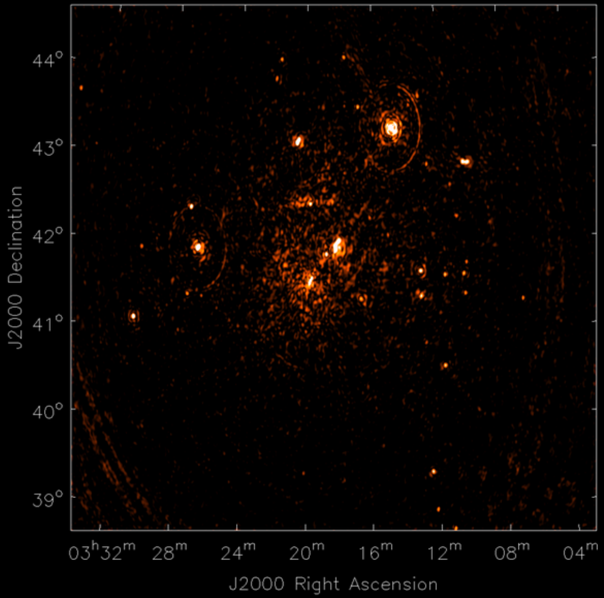
RM = 81 rad/m^2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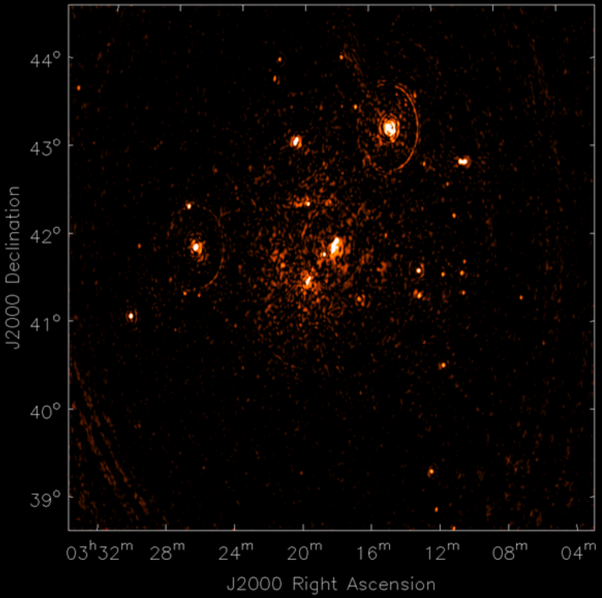
J2000 Right Ascension

RM = 84 rad/m^2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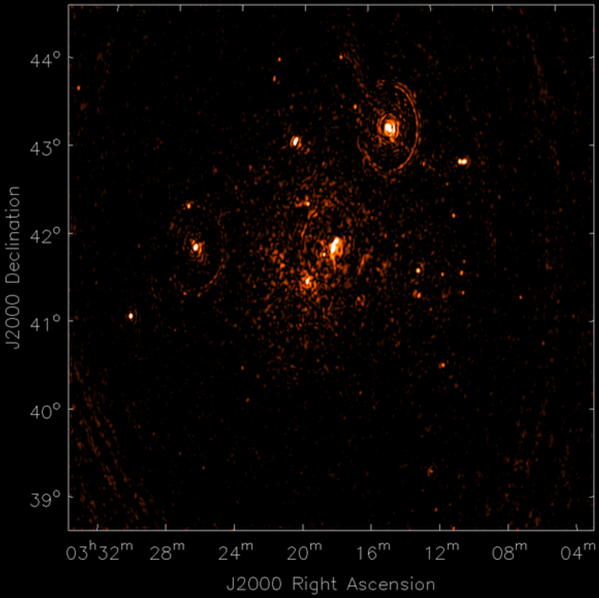
J2000 Right Ascension

RM = 87 rad/m^2



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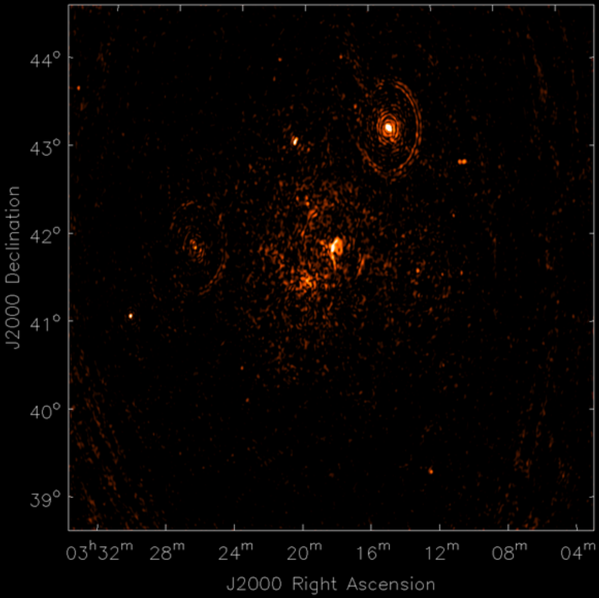
J2000 Right Ascension

RM = 90 rad/m^2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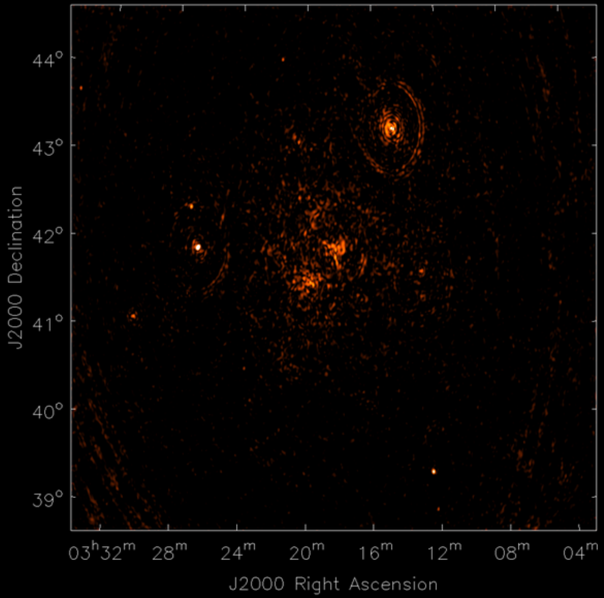
J2000 Right Ascension

RM = 93 rad/m^2



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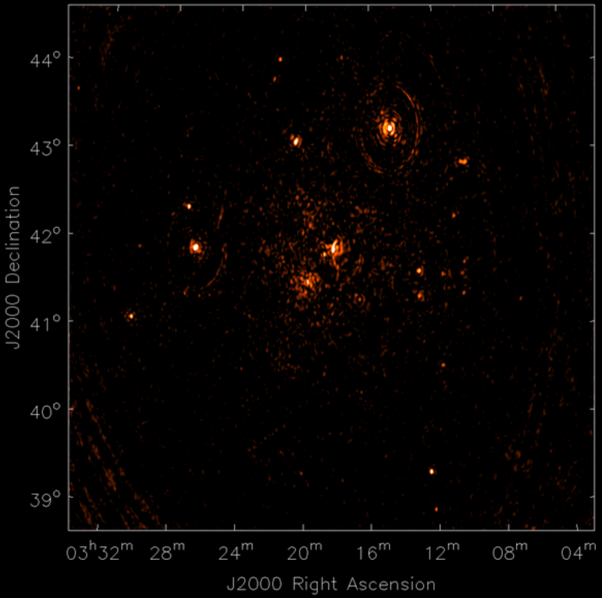
RM = 96 rad/m^2



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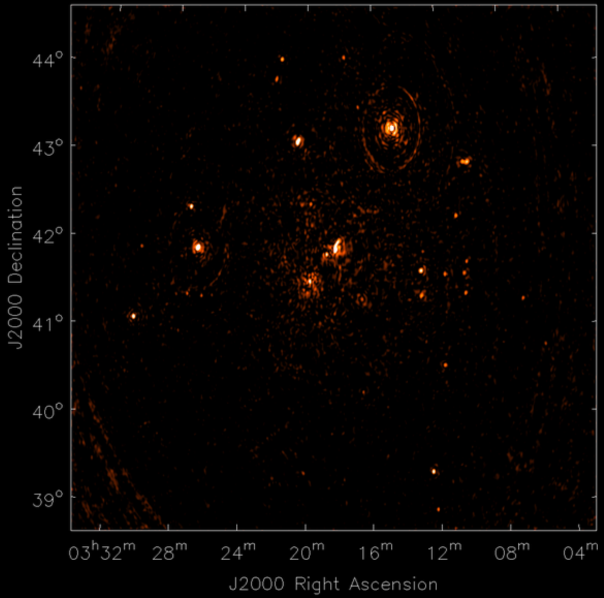
RM = 99 rad/m^2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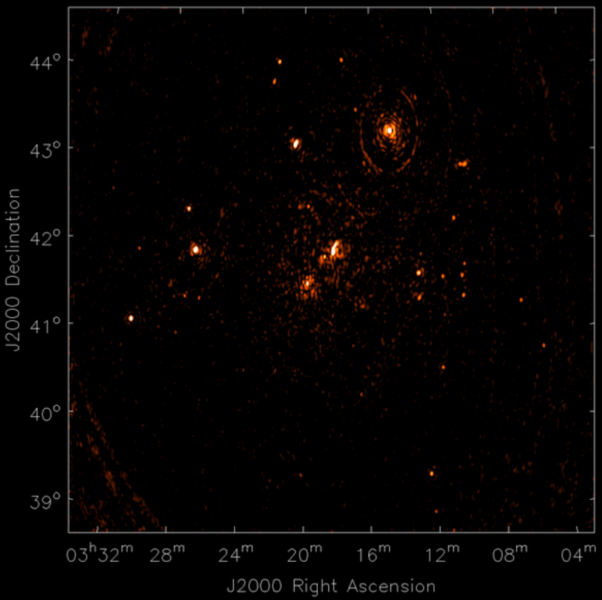
RM = 102 rad/m^2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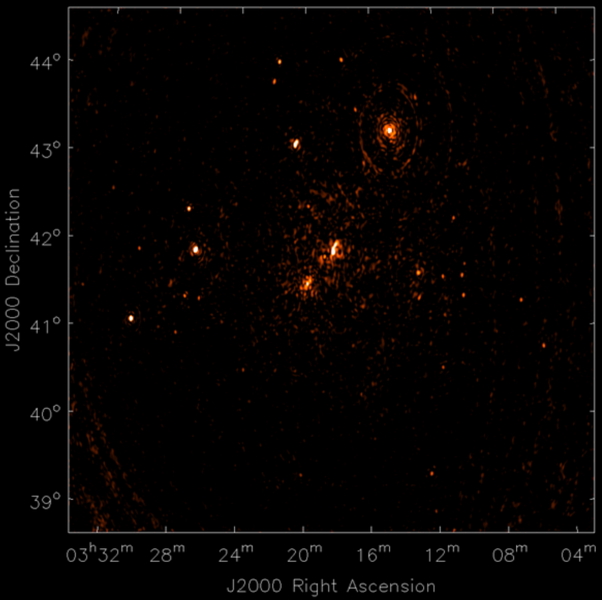
RM = 105 rad/m^2



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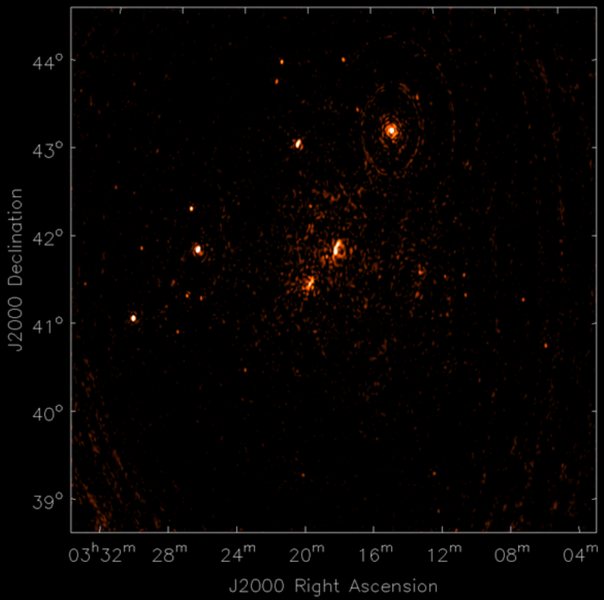
RM = 108 rad/m^2



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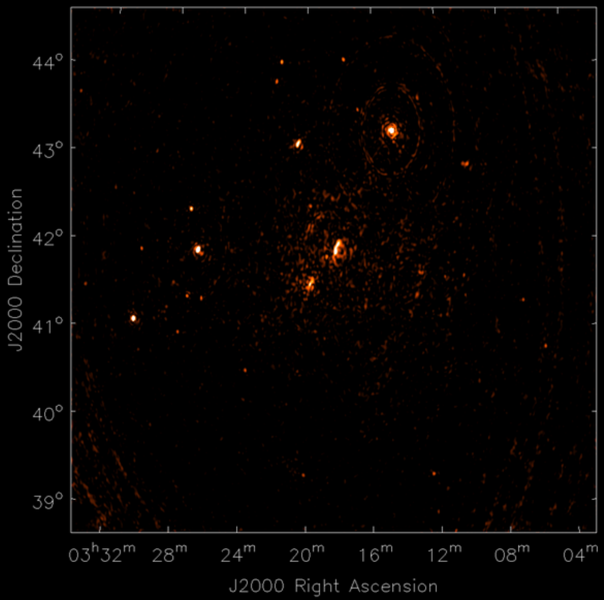
J2000 Right Ascension

RM = 111 rad/m^2



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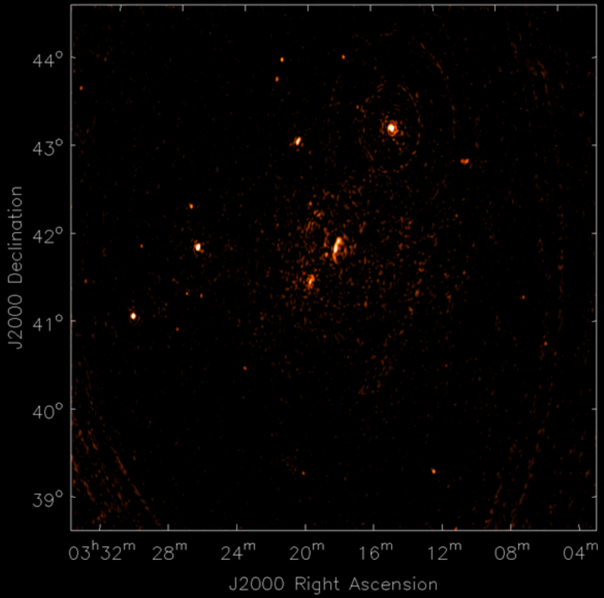
RM = 114 rad/m^2



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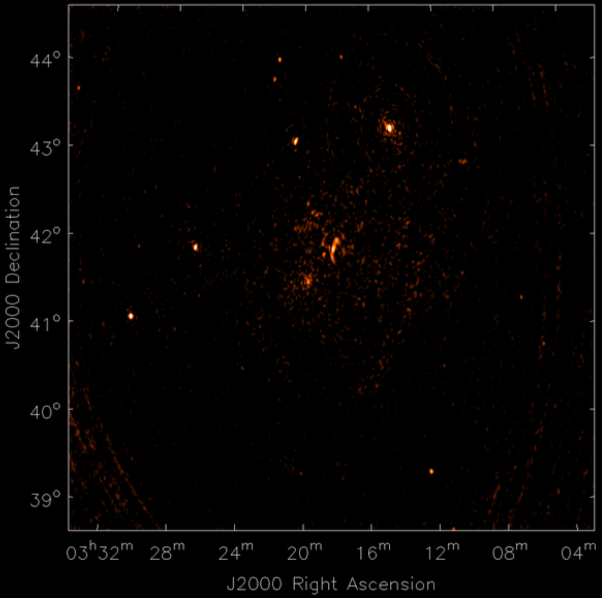
RM = 117 rad/m^2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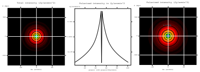
J2000 Right Ascension

Diffuse Radio Emission From the Perseus Cluster

M.A. Brentjens and A.G. de Bruyn
ASTRON, Dwingeloo and Kapteyn Institute, Groningen

Introduction and simulations



Most clusters of galaxies contain enormous amounts of hot gas that is easily visible with X-ray telescopes. However, there may be a large amount of cooler gas as well (Kaastra, private communication). It most probably resides in the outer regions of clusters and may be due to infalling groups of galaxies or the large scale cosmic web.

It is difficult to detect this cooler gas using X-rays. Therefore we attempt to detect it using (temperature- and frequency-independent) Thomson scattering of radiowaves. With current sensitive radio arrays like the Westerbork Synthesis Radio Telescope (WSRT) it is possible to find the polarized signature of an electron scattering halo around bright sources in dense cluster environments.

The total intensity (in W Hz^{-1} Sr^{-1}) of the scattered radiation is given by

$$I_\nu = \int_{s=-\infty}^{\infty} F_\nu(\mathbf{r}) n_e(\mathbf{r}) \frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} \mathrm{d}s, \qquad (1)$$

where $F_\nu(\mathbf{r})$ is the flux at location $\mathbf{r}$ due to the central source, $n_e(\mathbf{r})$ is the electron density and $\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}$ is the differential Thomson cross section.

We numerically integrated equation (1) using the following conditions:

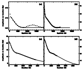
Voxelsize	7.5 kpc
n_e	$\frac{3.9\times10^{-2}}{\left[1+\left(\frac{r}{80}\right)^2\right]^{1.8}} + \frac{4.05\times10^{-3}}{\left[1+\left(\frac{r}{280}\right)^2\right]^{0.87}}$ cm^{-3}
Luminosity	9.4×10^{24} W Hz^{-1}
Distance	72 Mpc
Scale	21.5" per pixel
ν	327 MHz

This corresponds roughly to the conditions in the Perseus cluster. The luminosity is that of the central 30" component. We have ignored the pointsource and the extended haloes. The Thomson echo of the central pointsource in NGC 1275 is only 45 lightyears across, thus unimportant. If the $10'$ halo is taken into account, the scattered intensity will almost double (see figure on the top right).

Contours in the simulator output are drawn at 1, 0.3, 0.1, 0.03, … mJy per square arcminute. At $10'$ distance from the center, the surface brightness of the polarized intensity is approximately 10 μJy per square arcminute. One can detect this with the WSRT if one compensates for Faraday rotation and calculates suitable radial averages.

Powers of ten

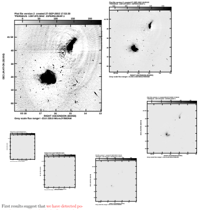
Epoch 1987



The figure on the left shows the visibility amplitude as a function of baseline length (spatial frequency on the sky). From left to right and top to bottom: 6 cm, 21 cm, 49 cm, and 92 cm. Per figure there are three components visible: The central pointsource (long baselines), the 30″ component (intermediate baselines), and the extended halo of NGC 1275 (only the shortest baselines).

Shown below are 21 cm total intensity data taken before the WSRT upgrade. Every image is a factor of 10 deeper then its precursor. The brightness ratio of the peak to the weakest extended feature is a stunning $10^6 : 1$. The dynamic range far off-axis is probably limited by pointing errors.

The three largest images show the main radiosources in the cluster: the halo and 30″ component of NGC 1275 in the center and NGC 1265, a beautiful head-tail galaxy to the north-west.



First results suggest that we have detected polarized emission from both the Perseus cluster and the Galactic foreground. The detected polarized emission is at a level of 0.5 to 1 mJy/2′ beam.

WSRT Polarization imaging and RM synthesis

The highly polarized signal resulting from Thomson scattered emission will be added to, and confused by, any polarized diffuse emission from the cluster itself. The inner parts of clusters ($\theta < 10'$) are depolarized by the combined effects of the very high RM, its small scale structure and beam and depth depolarization effects. There is, however, also weak 92 cm diffuse emission in the region bounded by NGC 1275, NGC 1265 and IC 310, where depolarization effects are expected to be significantly smaller.

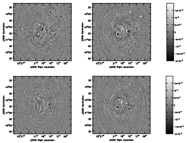
Our Galaxy interferes with this polarized emission in two ways. First, it Faraday-rotates any extragalactic polarized signal from the Perseus cluster, and second, it adds its own often strongly polarized emission.

Previous 21 cm observations of the Perseus cluster have shown faint (about 30 μJy/30" beam) but highly structured polarized emission spread over about 30' diameter and approximately centered at 3C 84 / NGC 1275. The improved sensitivity and new wide bandwidth correlator at the WSRT should allow us to characterize this emission and through its RM distribution ascertain its origin.

In order to disentangle the Faraday rotation and foreground emission effects we have acquired new low frequency observations with the WSRT in December 2002. We obtained a total of 6×12 hours spanning 70 MHz total bandwidth divided in 512 channels, ranging from 315 to 385 MHz.

The new wideband data allows a sensitive search in 'RM-space' across a field of view (about 3 degrees), hence extending well beyond the Perseus cluster. It should therefore allow us to separate cluster and foreground contributions. Images in RM space are coherently summed Q and U images for a range of acceptable RM values. We expect the polarization sensitivity to be better than 100 μJy/$1'$ beam. We hope to acquire new 21 cm observations next winter.

Shown below are pairs of Q and U images (hor.) for RMs of 50 and 60 rad m^{-2} (vert).



References

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The Westerbork Synthesis Radio Telescope is operated by the ASTRON (Netherlands Foundation for Research in Astronomy) with support from the Netherlands Foundation for Scientific Research (NWO).

WSRT Polarization imaging and RM synthesis

The highly polarized signal resulting from Thomson scattered emission will be added to, and confused by, any polarized diffuse emission from the cluster itself. The inner parts of clusters ($\theta < 10'$) are depolarized by the combined effects of the very high RM, its small scale structure and beam and depth depolarization effects. There is, however, also weak 92 cm diffuse emission in the region bounded by NGC 1275, NGC 1265 and IC 310, where depolarization effects are expected to be significantly smaller.

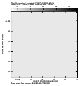
Our Galaxy interferes with this polarized emission in two ways. First, it Faraday-rotates any extragalactic polarized signal from the Perseus cluster, and second, it adds its own often strongly polarized emission.

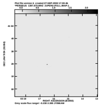
Previous 21 cm observations of the Perseus cluster have shown faint (about 30 μJy/30" beam) but highly structured polarized emission spread over about 30' diameter and approximately centered at 3C 84 / NGC 1275. The improved sensitivity and new wide bandwidth correlator at the WSRT should allow us to characterize this emission and through its RM distribution ascertain its origin.

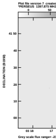
In order to disentangle the Faraday rotation and foreground emission effects we have acquired new low frequency observations with the WSRT in December 2002. We obtained a total of 6×12 hours spanning 70 MHz total bandwidth divided in 512 channels, ranging from 315 to 385 MHz.

The new wideband data allows a sensitive search in 'RM-space' across a field of view (about 3 degrees), hence extending well beyond the Perseus cluster. It should therefore allow us to separate cluster and foreground contributions. Images in RM space are coherently summed Q and U images for a range of acceptable RM values. We expect the polarization sensitivity to be better than 100 μJy/$1'$ beam. We hope to acquire new 21 cm observations next winter.

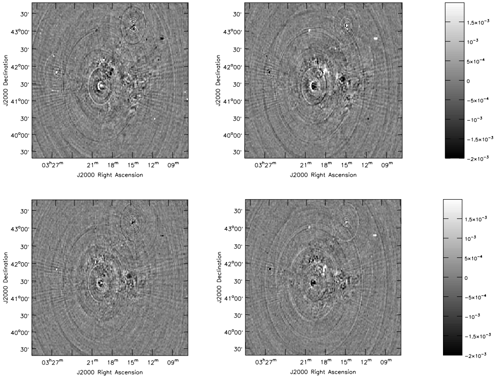
Shown below are pairs of Q and U images (hor.) for RMs of 50 and 60 rad m^{-2} (vert).







First results suggest that we have detected polarized emission from both the Perseus cluster and the Galactic foreground. The detected polarized emission is at a level of 0.5 to 1 mJy/$2'$ beam.



The Westerbork Synthesis Radio Telescope is operated by the ASTRON (Netherlands Foundation for Research in Astronomy) with support from the Netherlands Foundation for Scien

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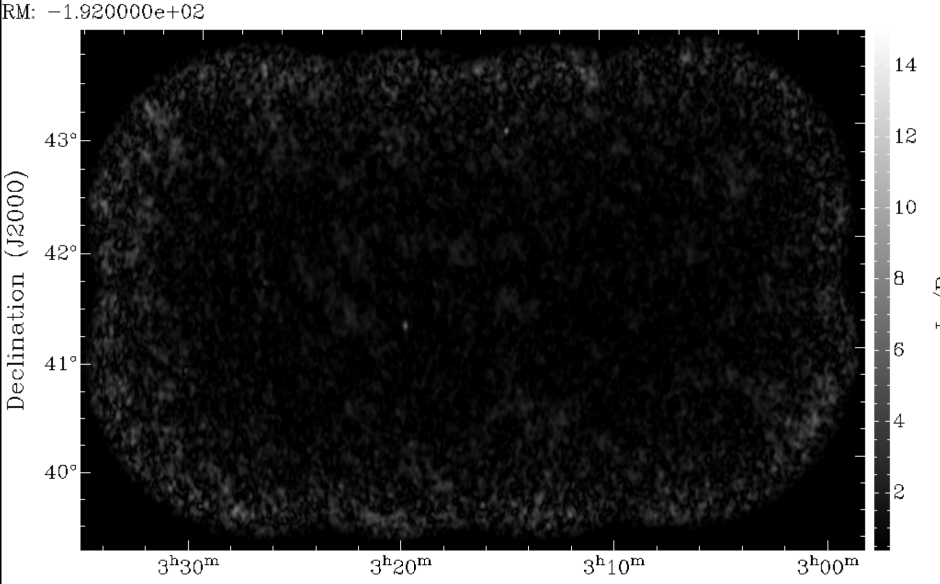

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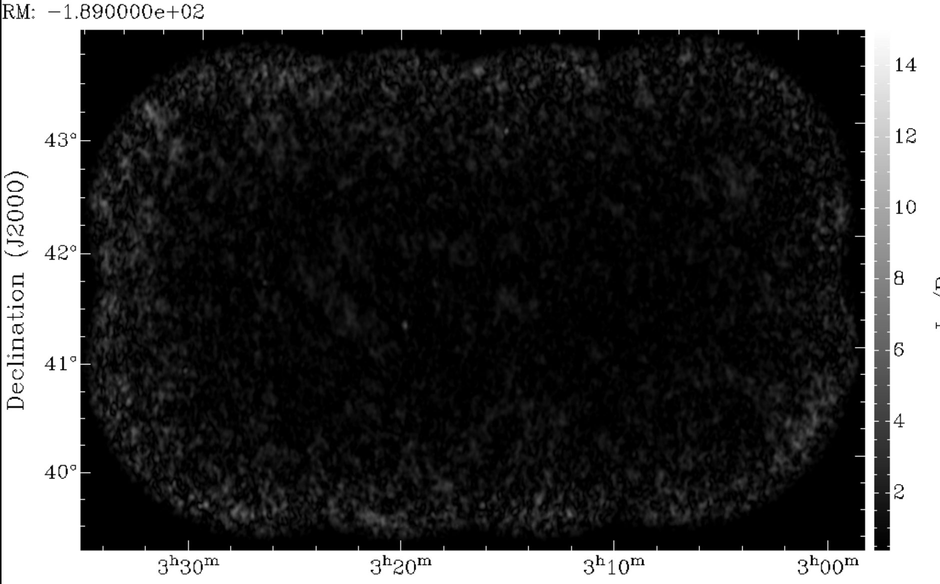

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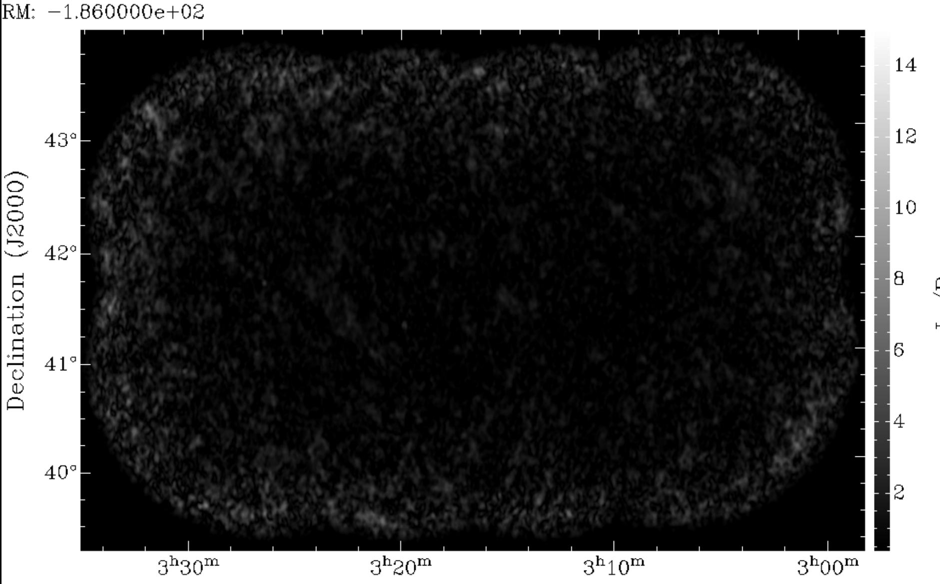

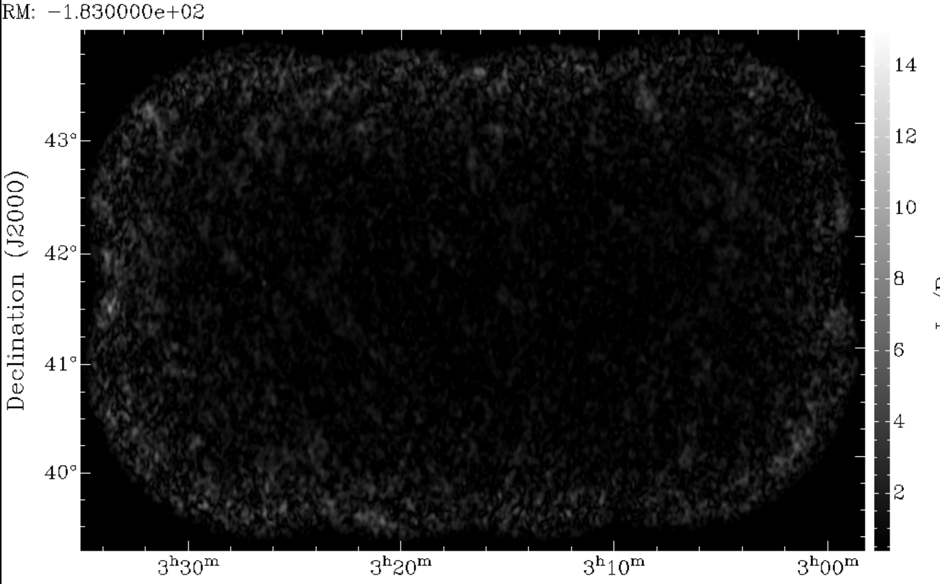
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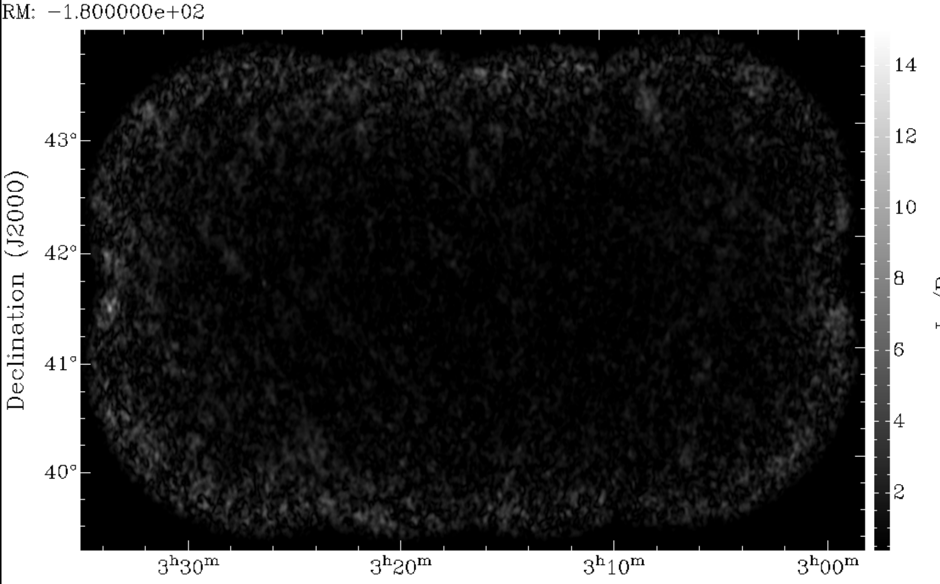

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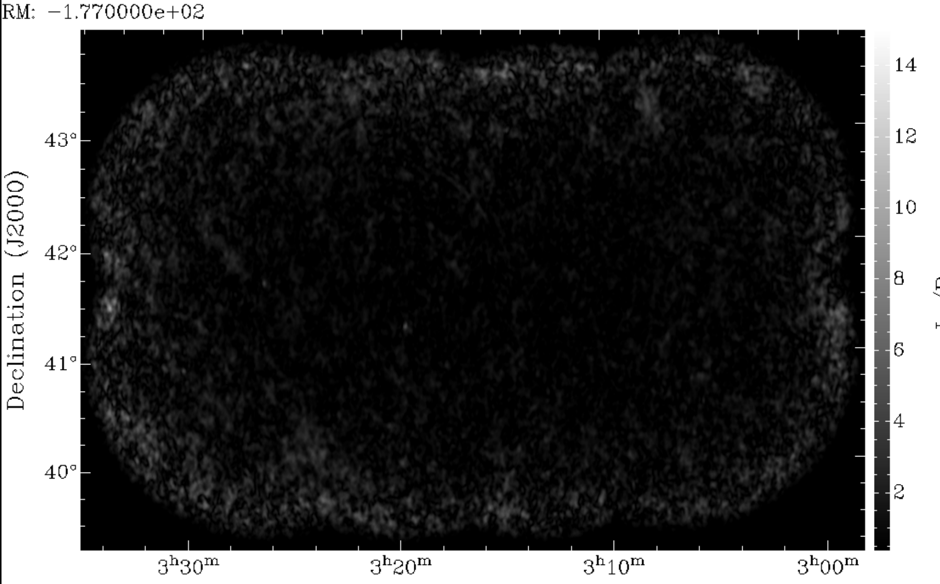

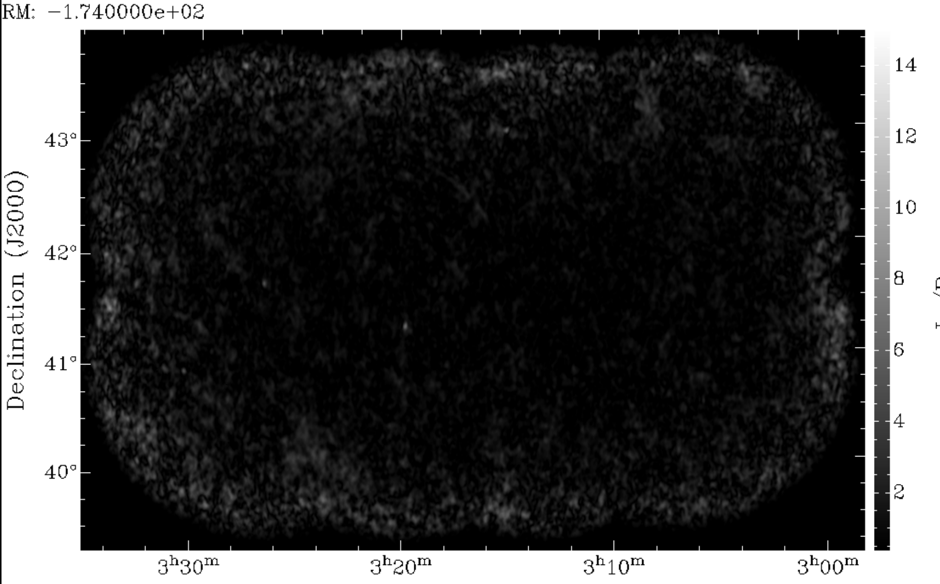
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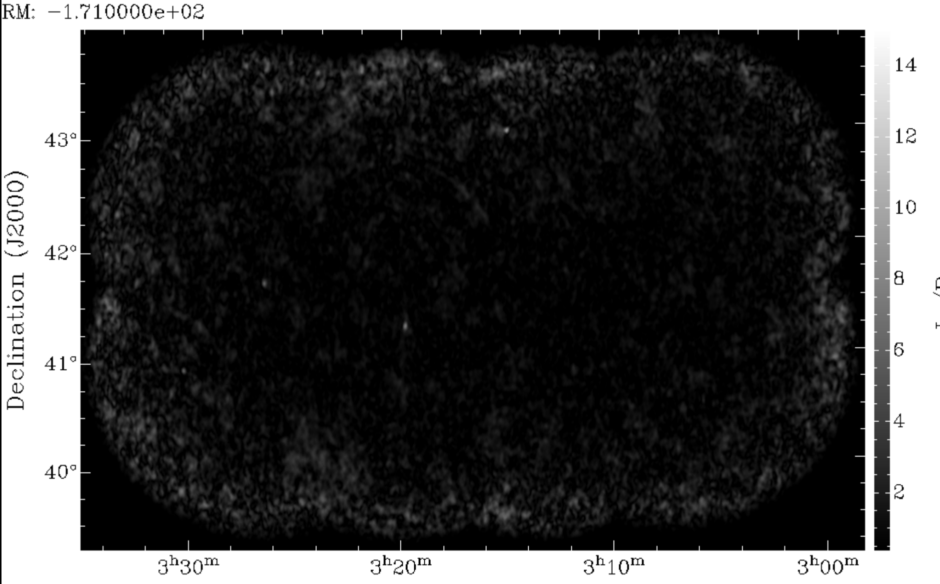
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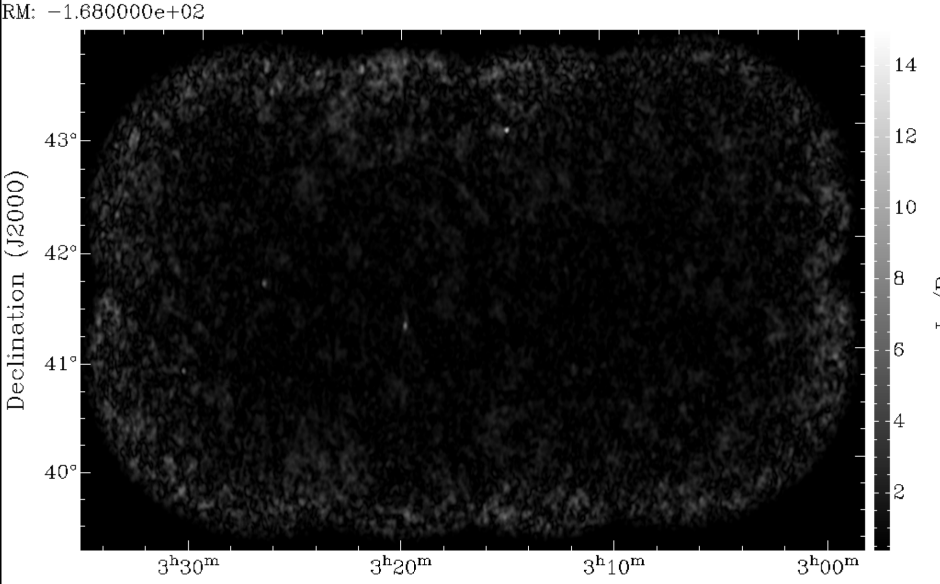

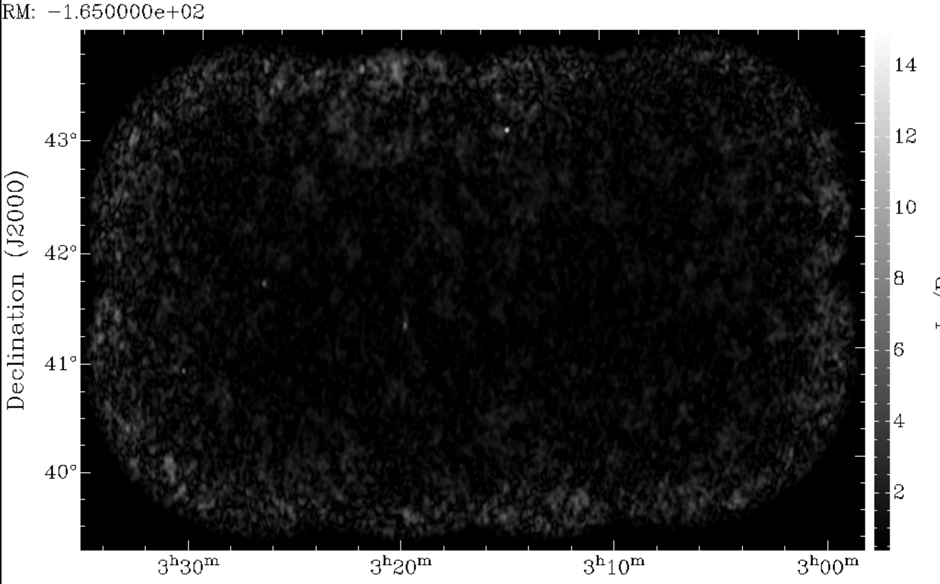

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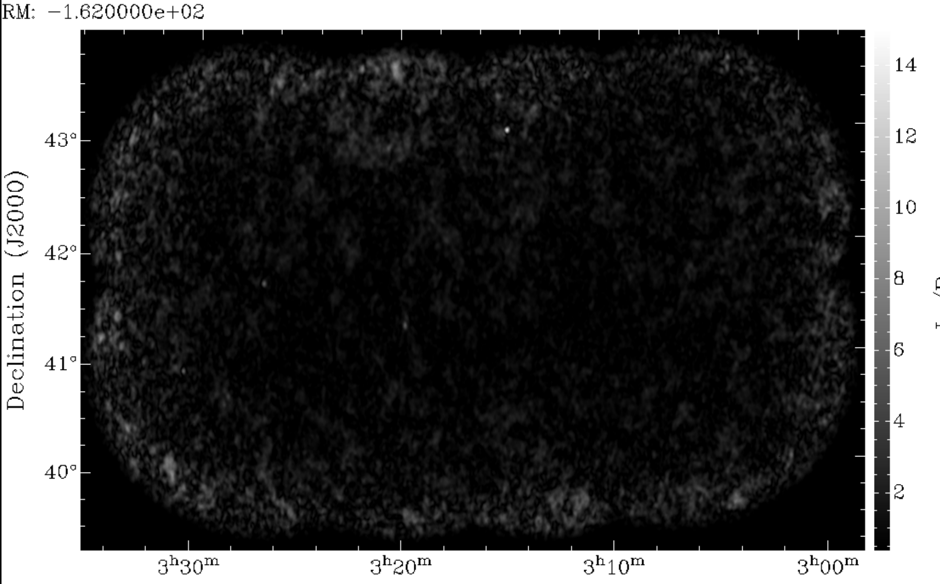

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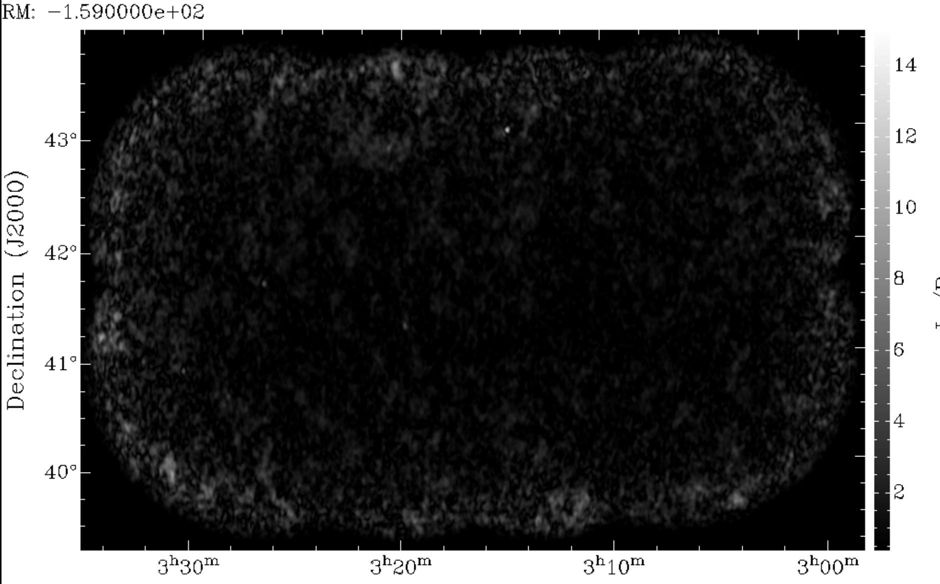

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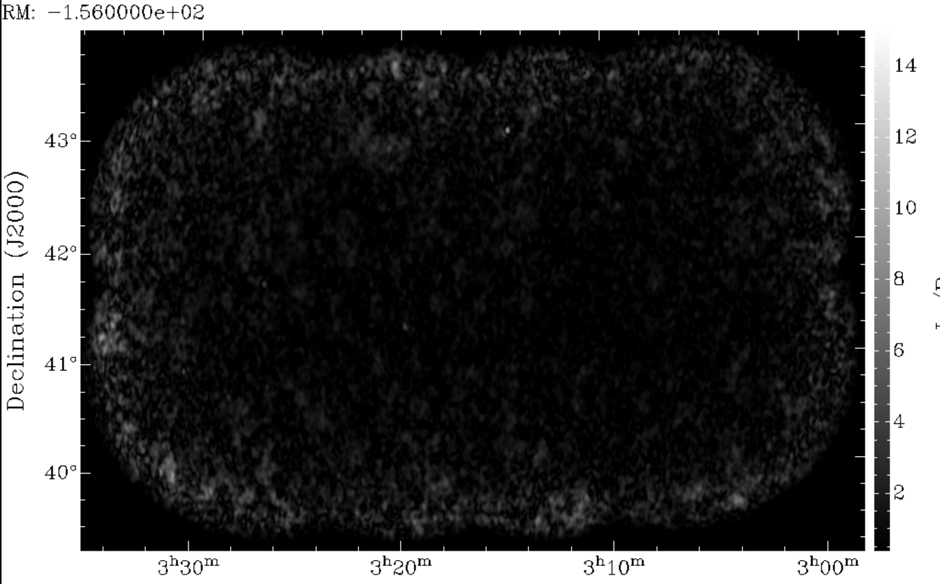

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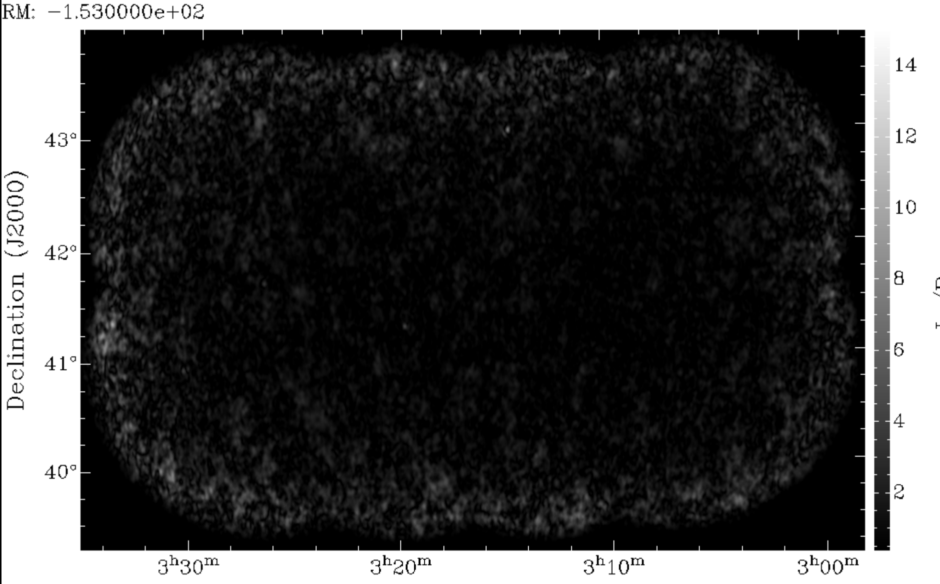

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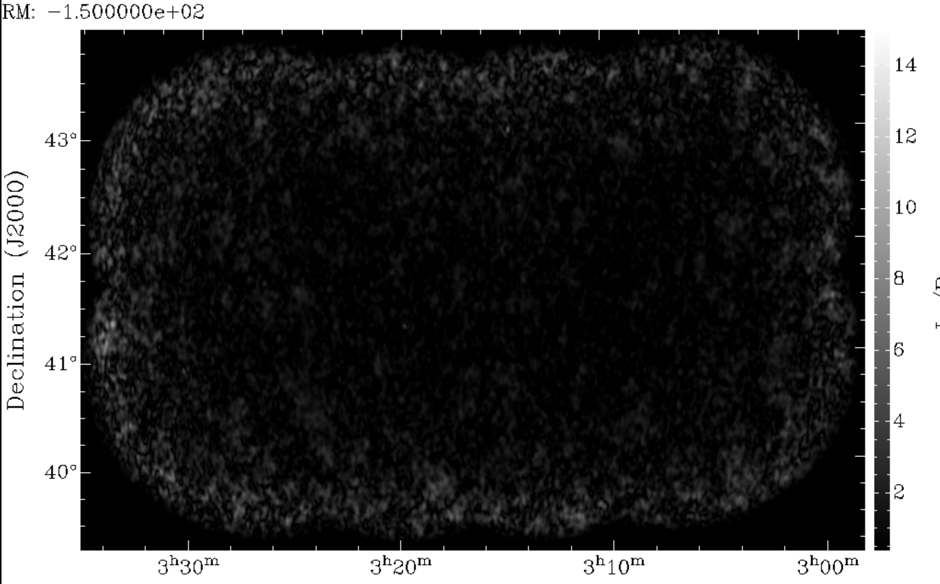

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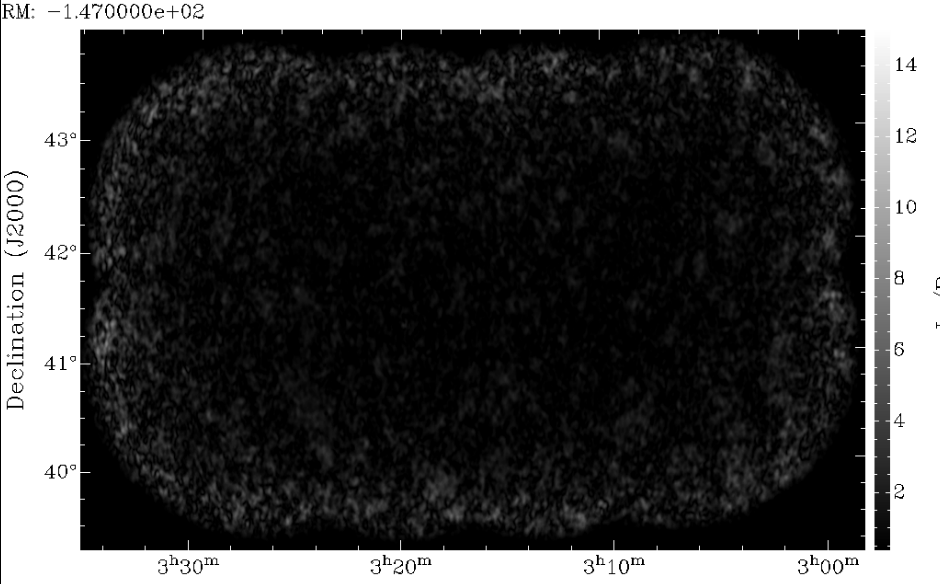

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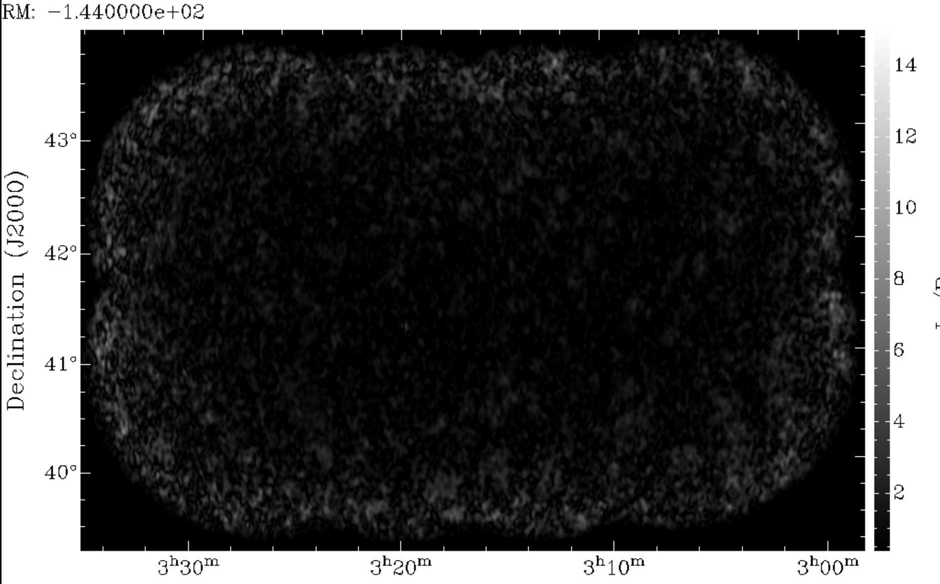

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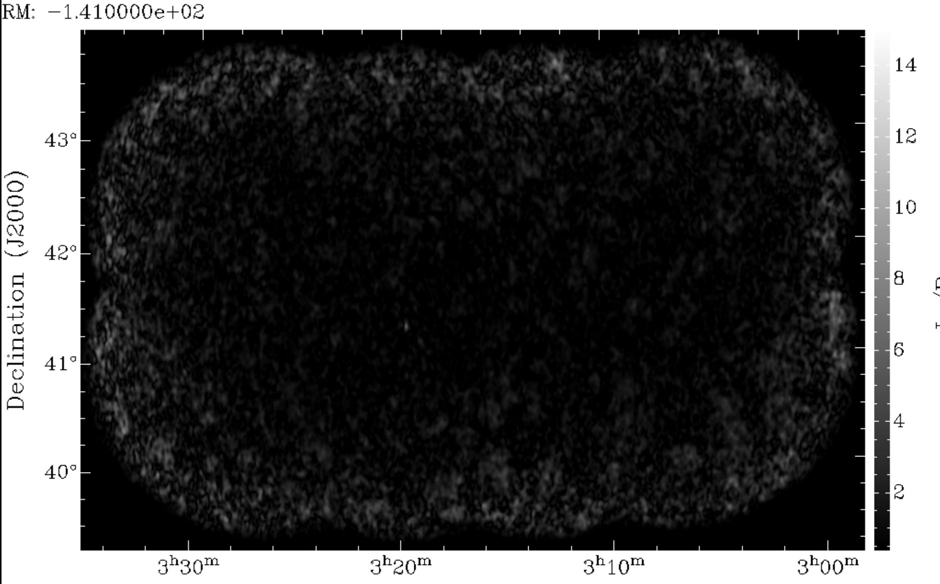

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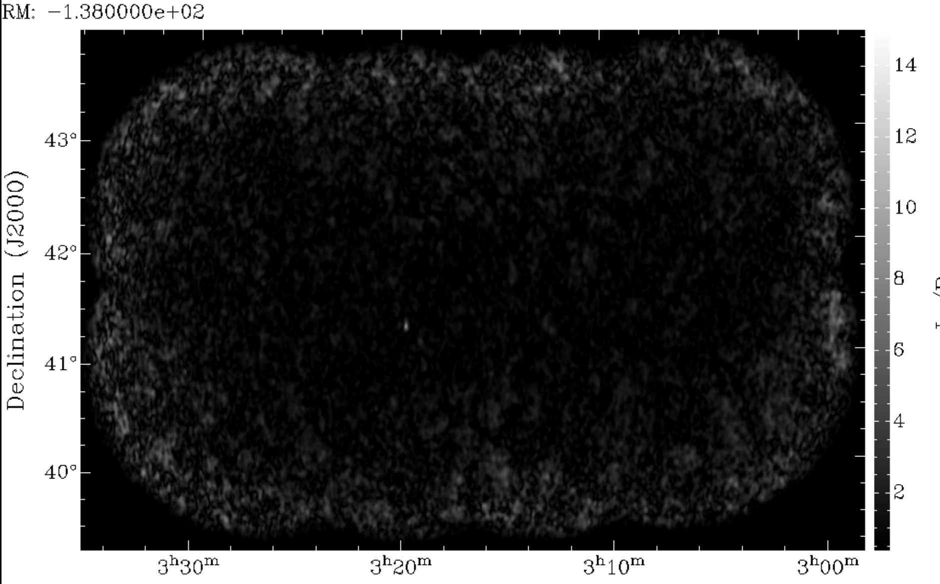

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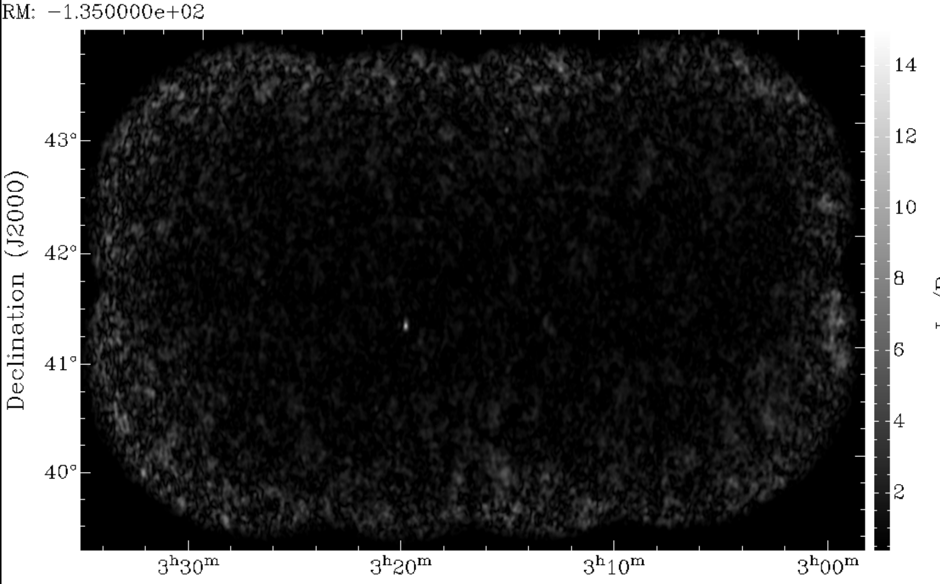

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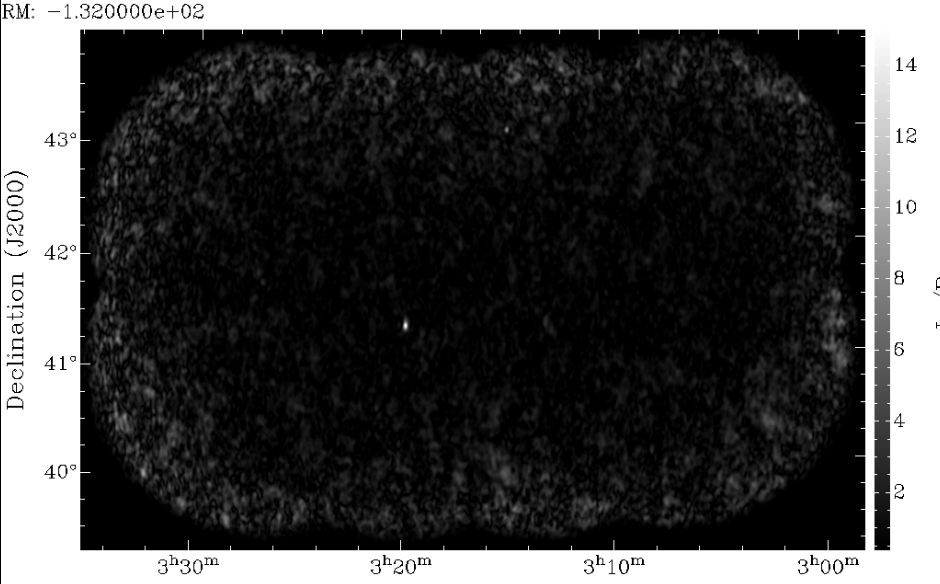

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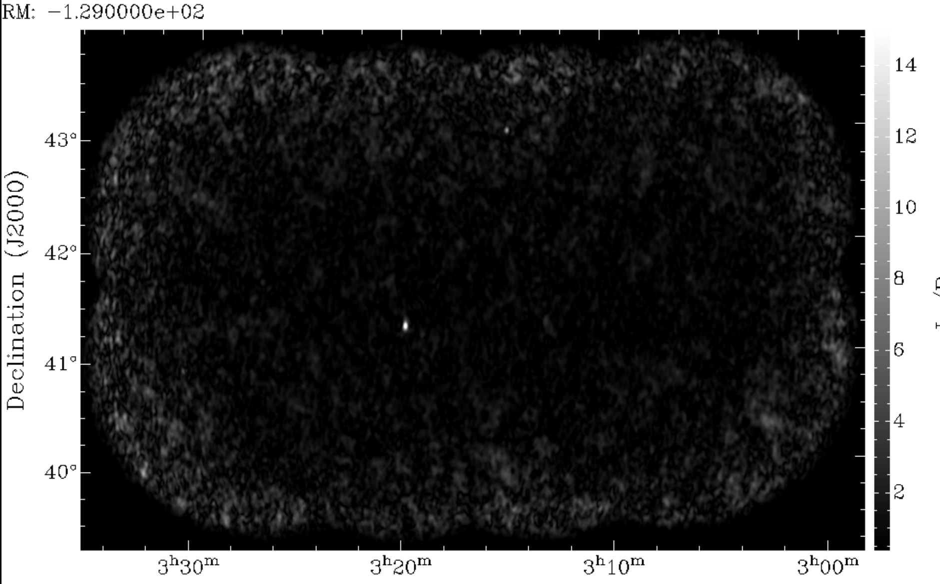

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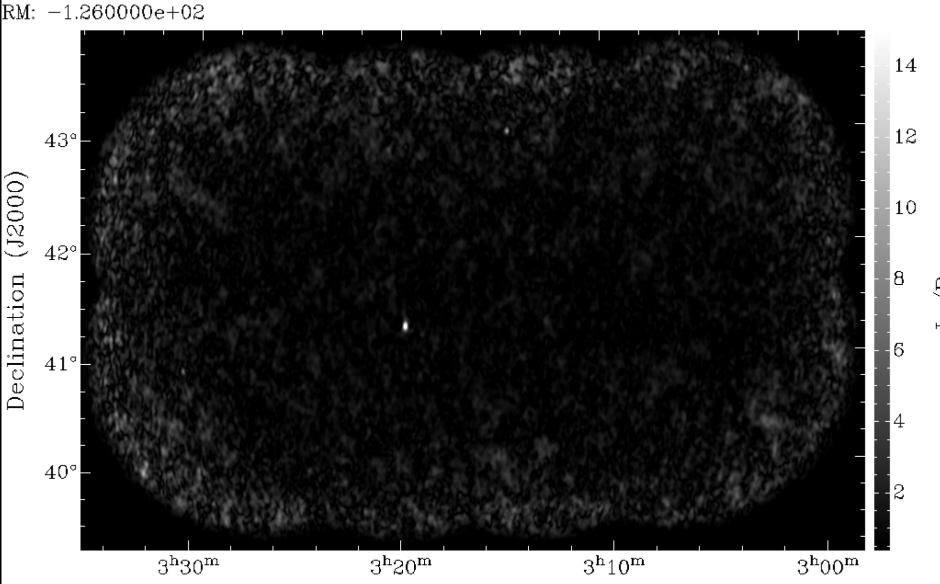

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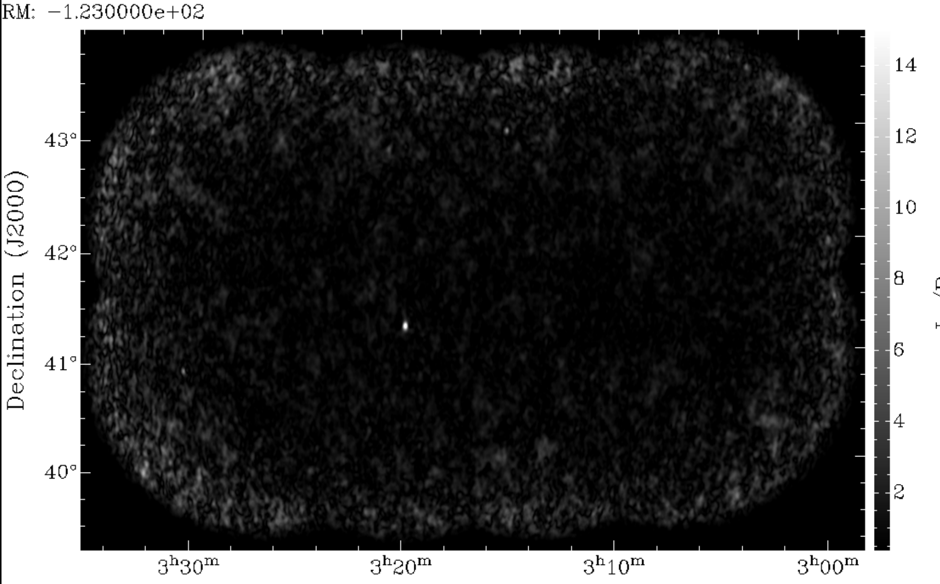

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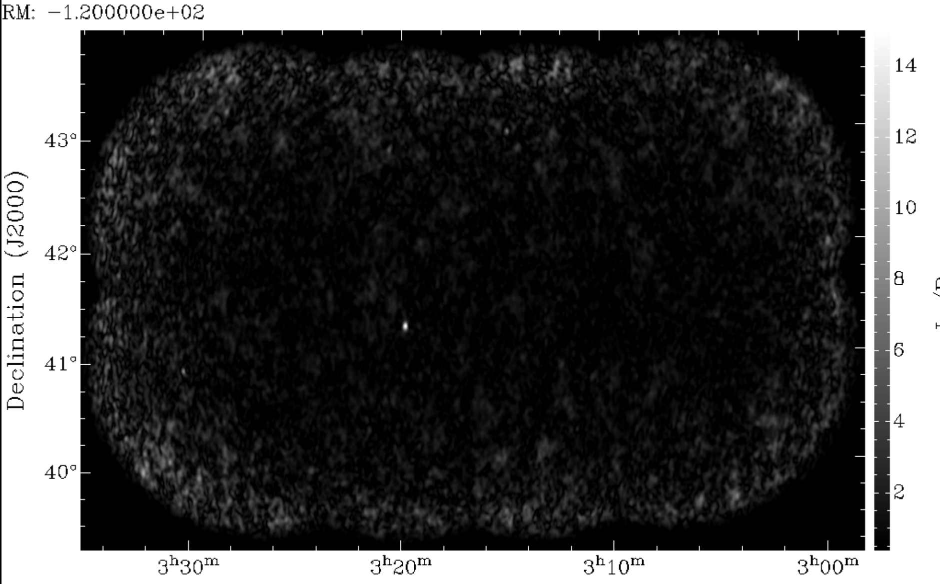

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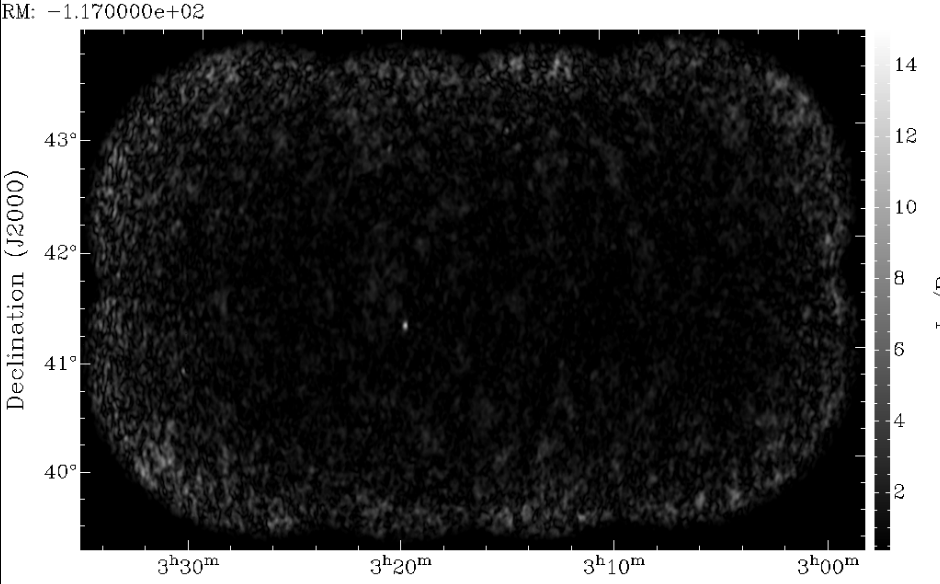

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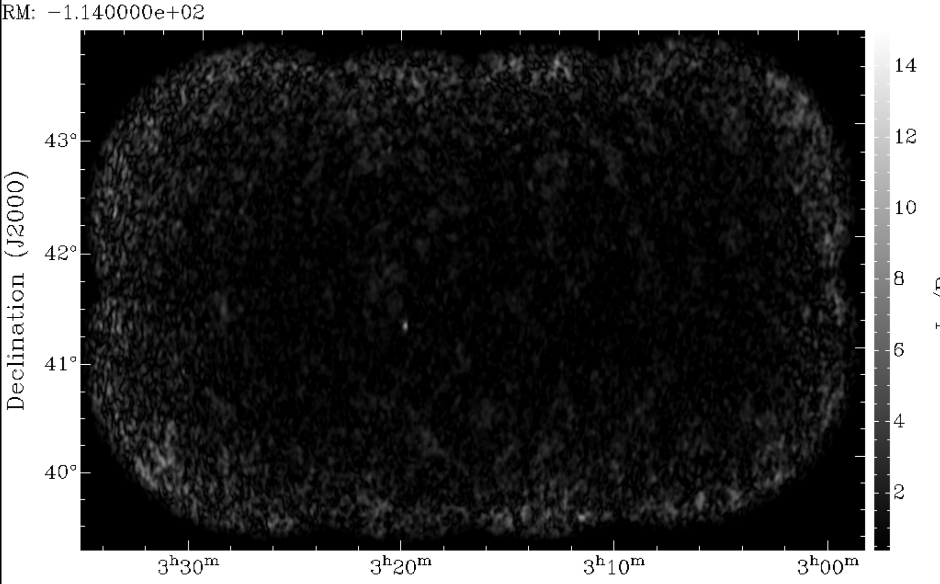

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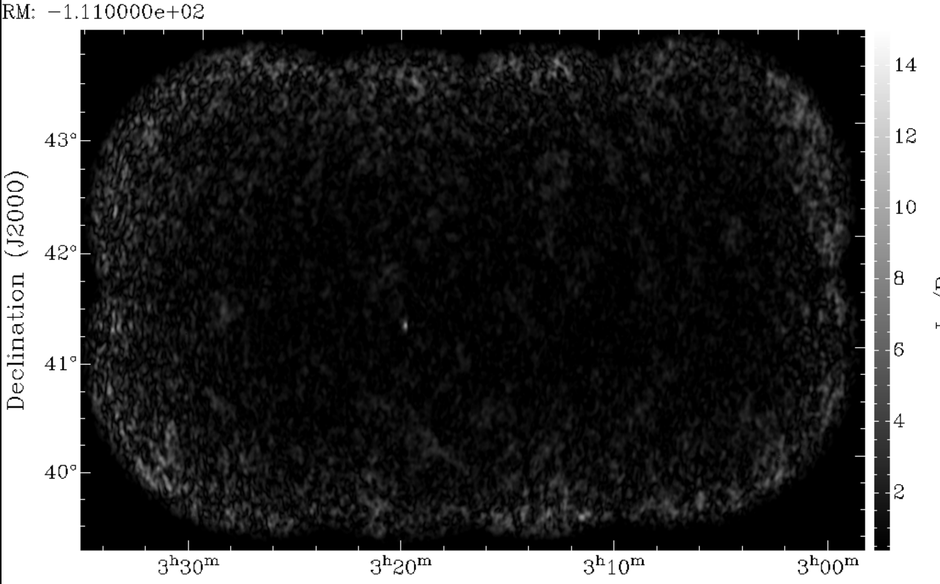

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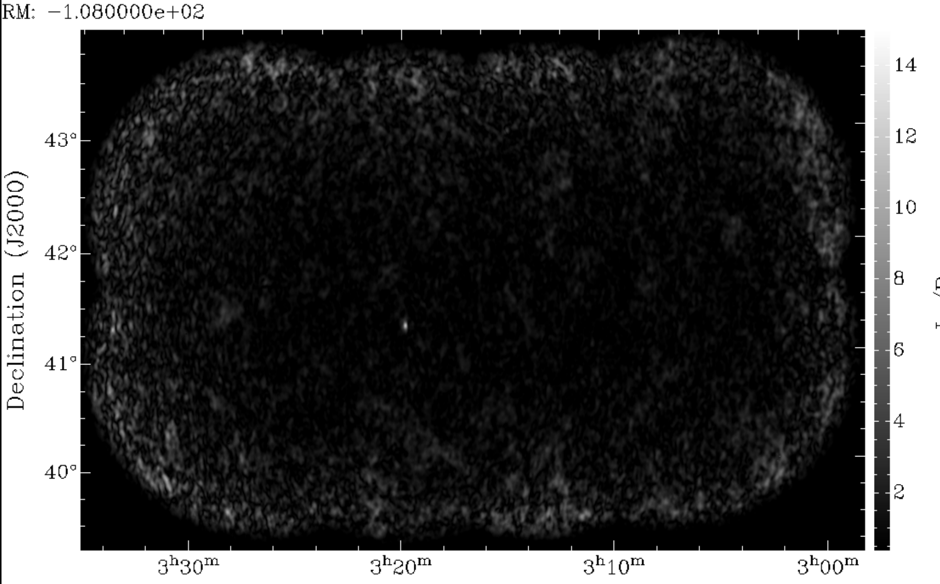

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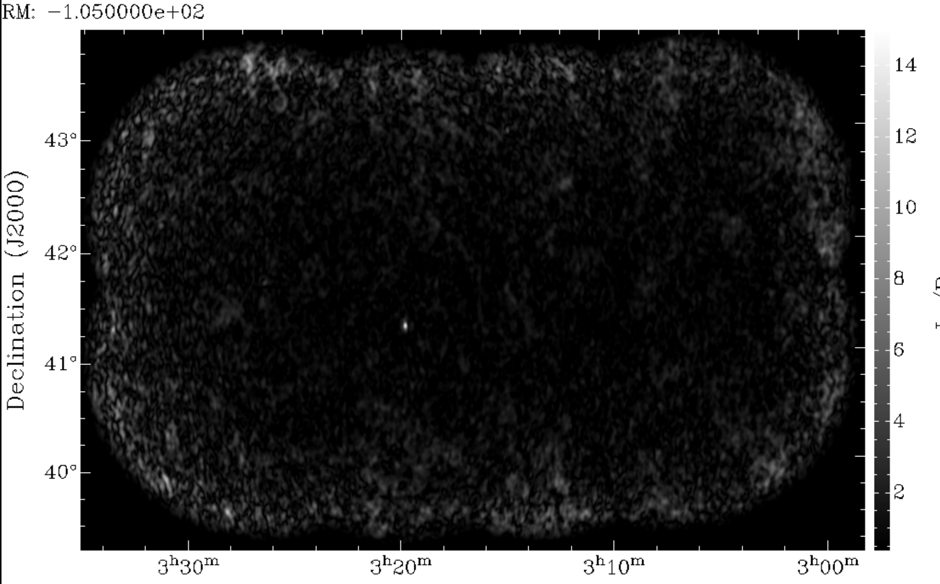

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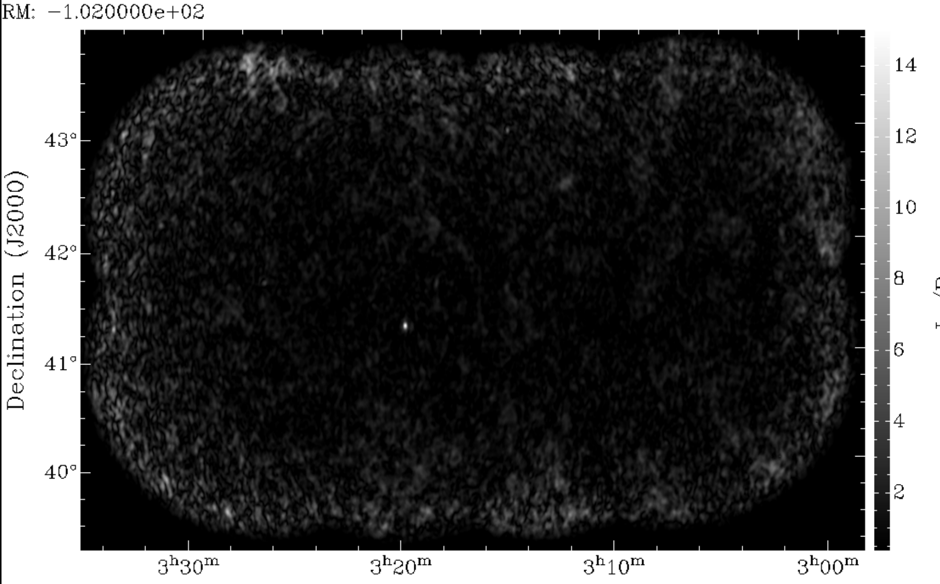

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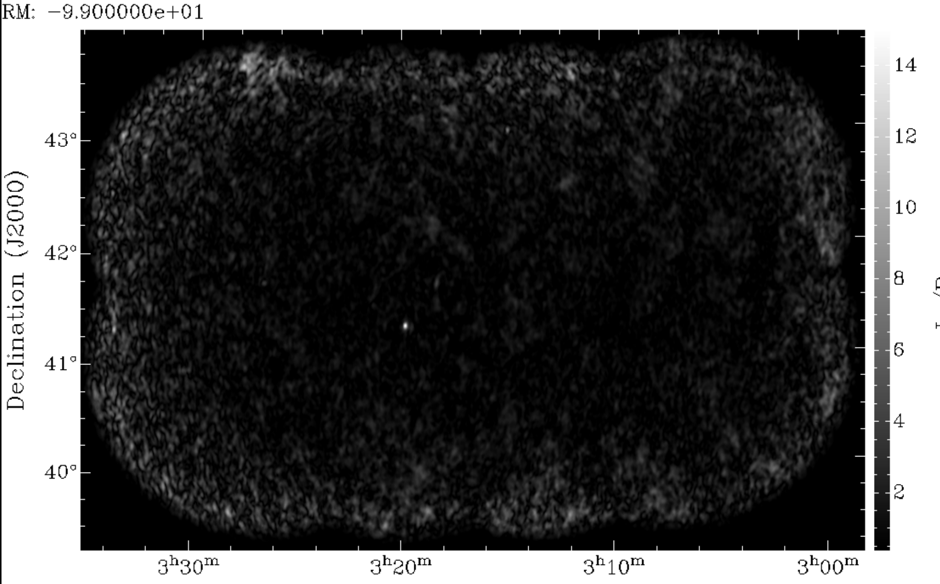

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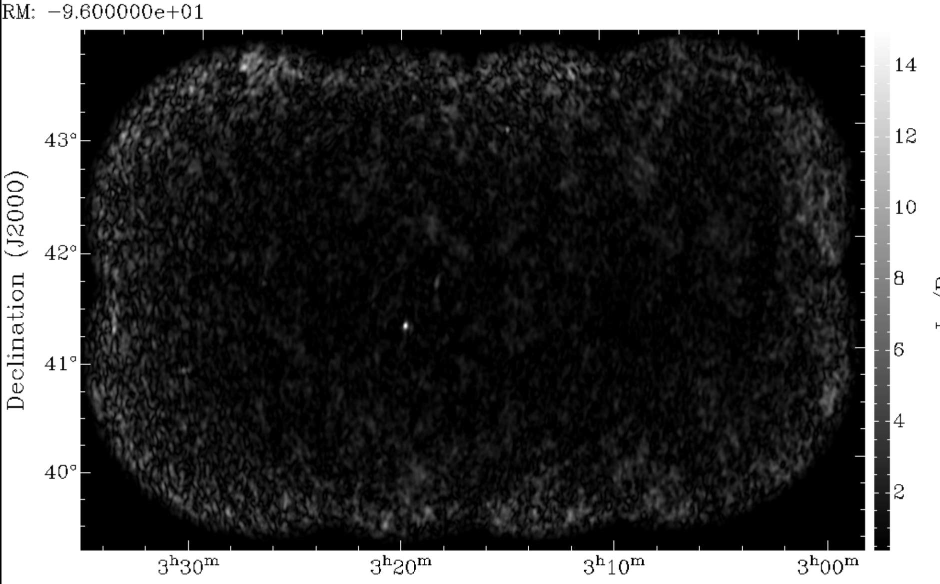

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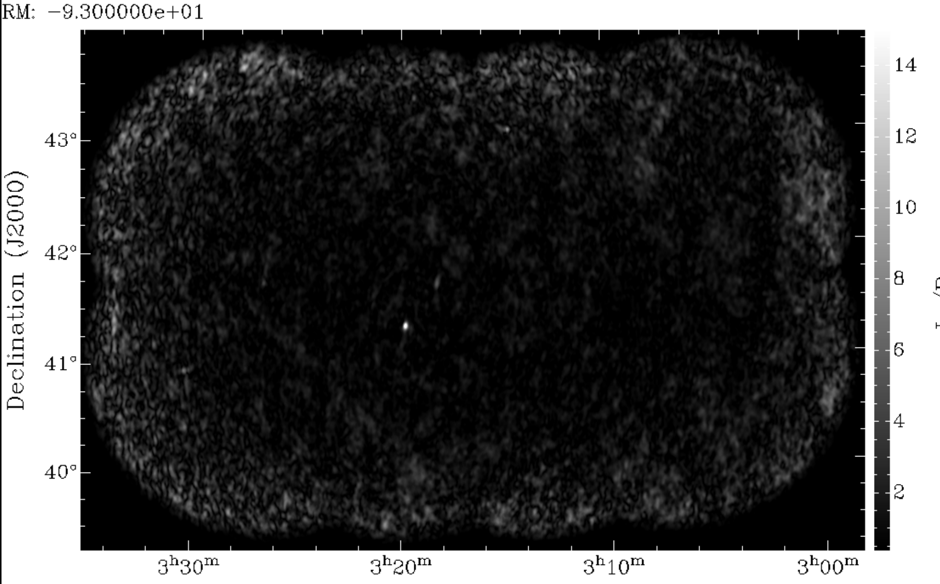

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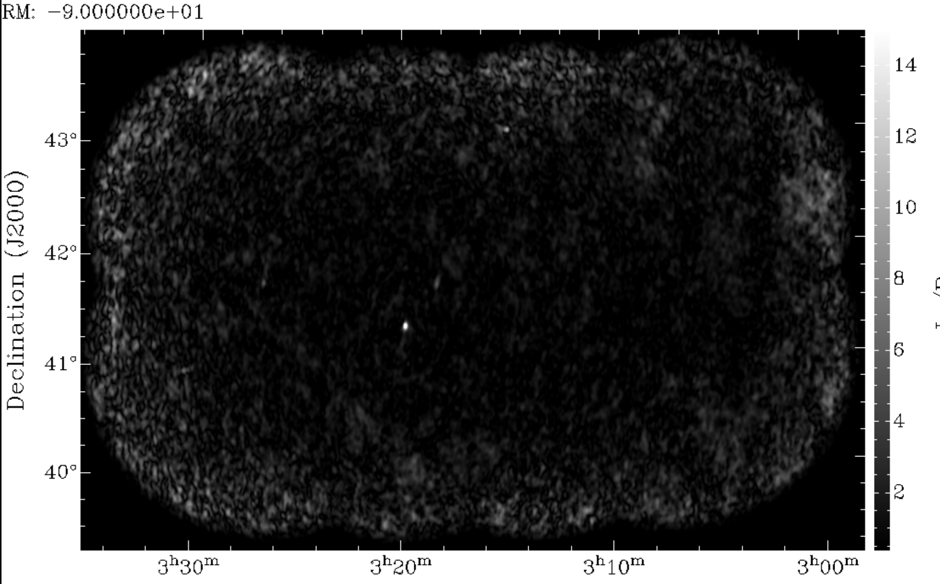

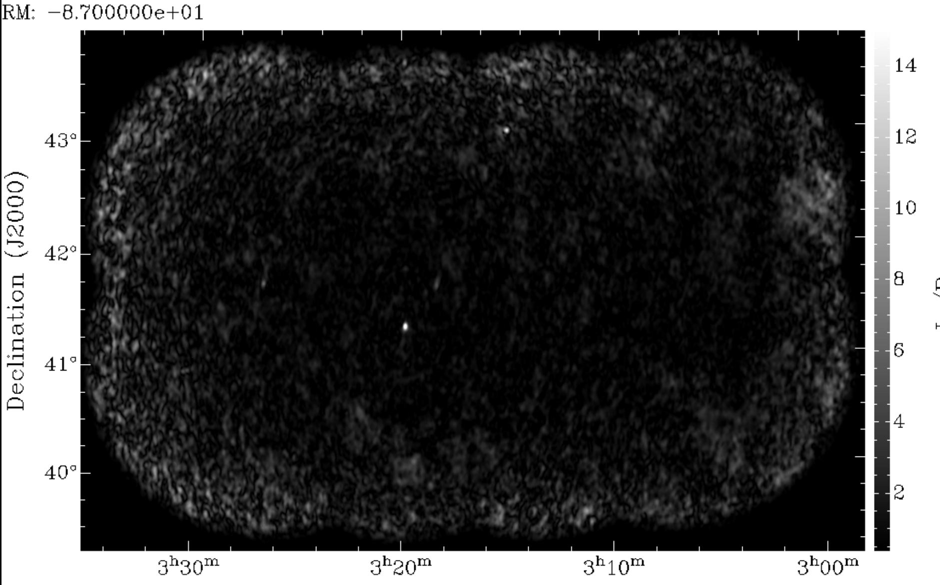
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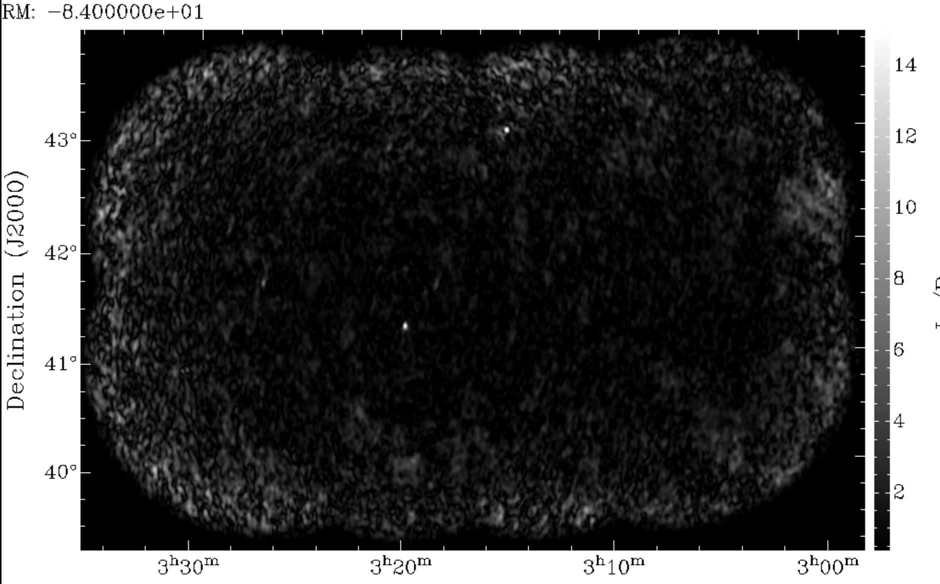

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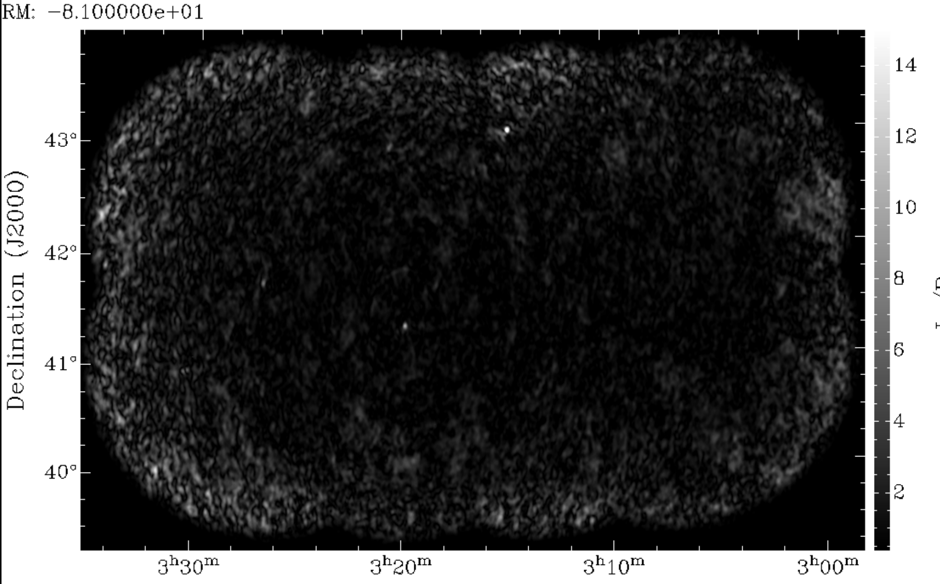

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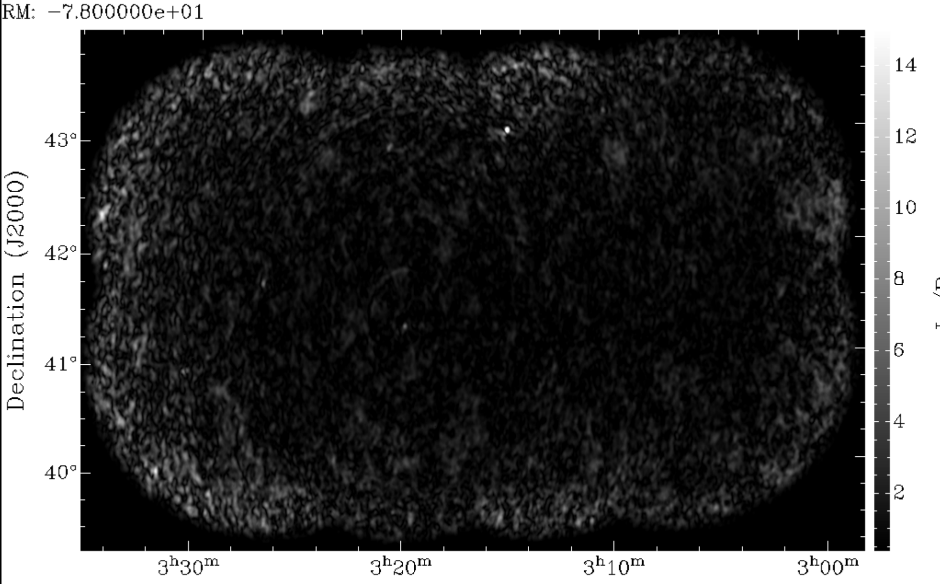

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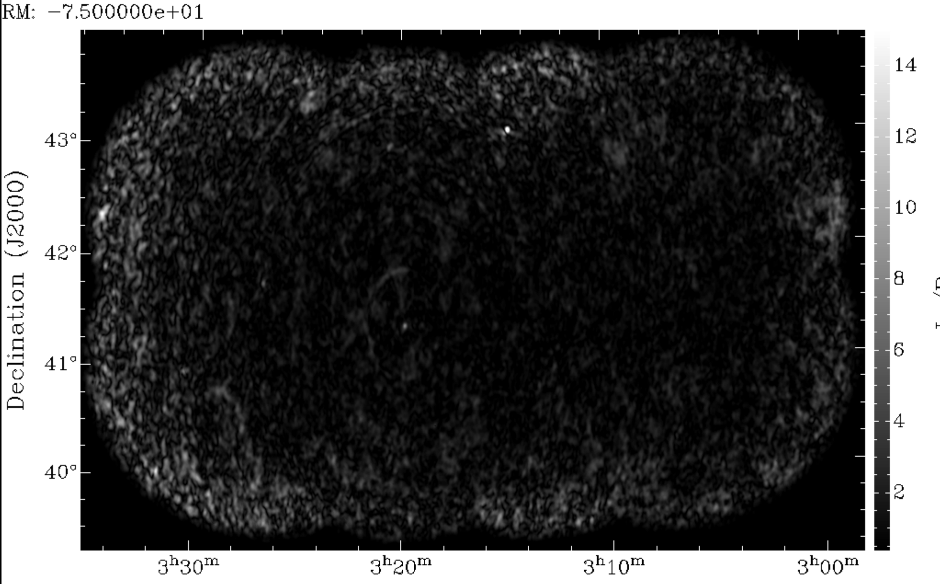

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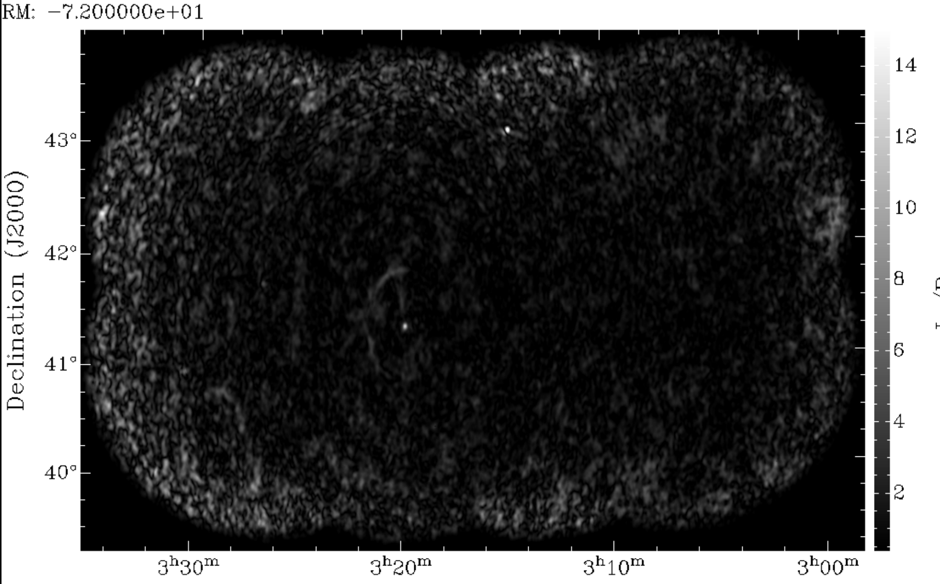

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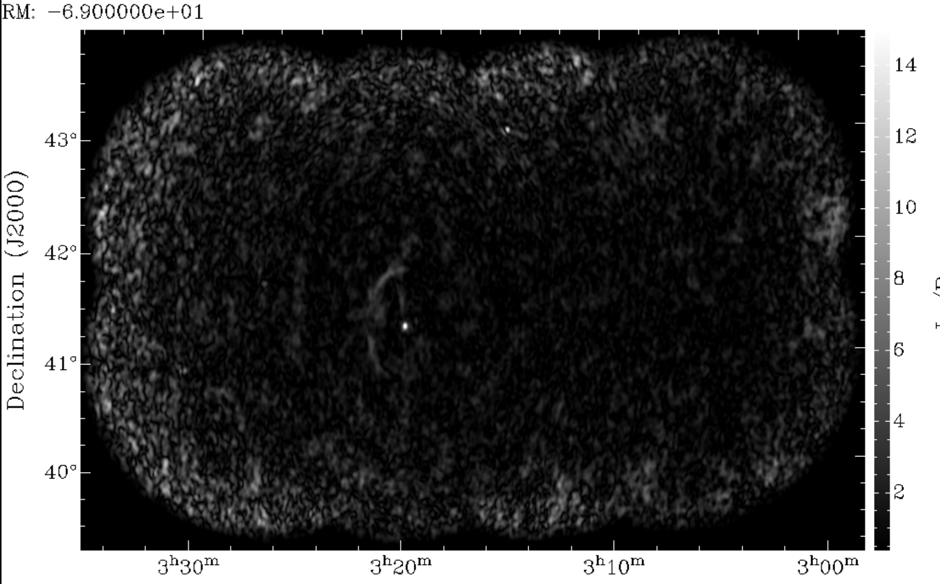

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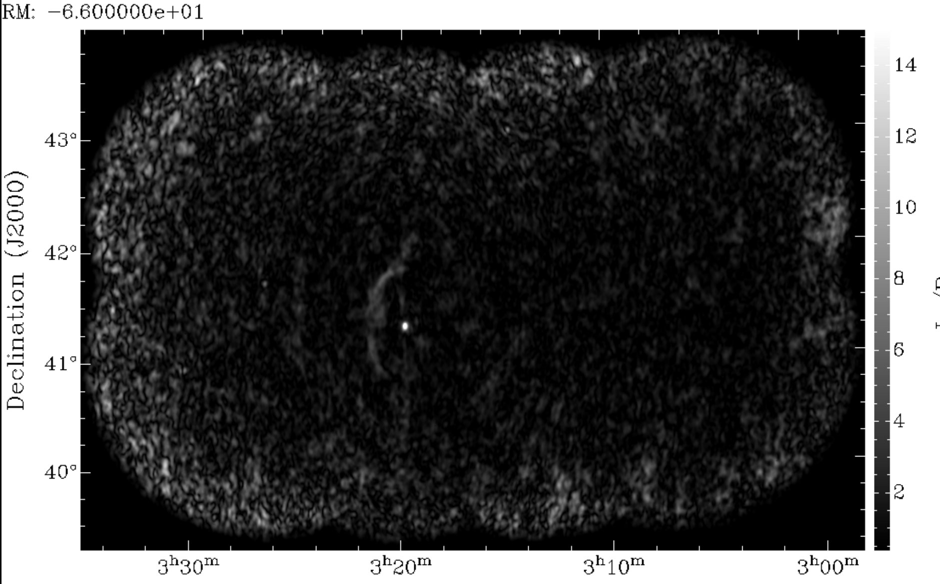

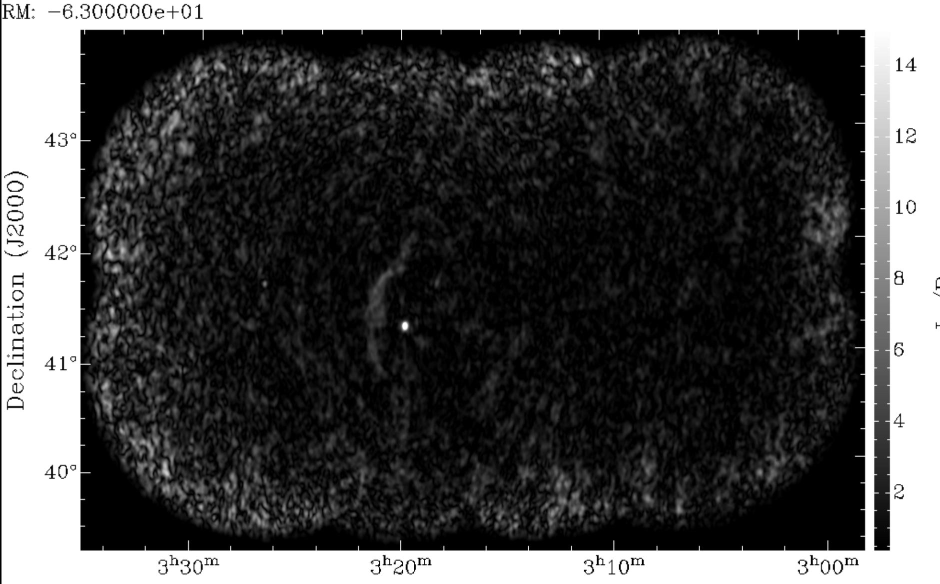
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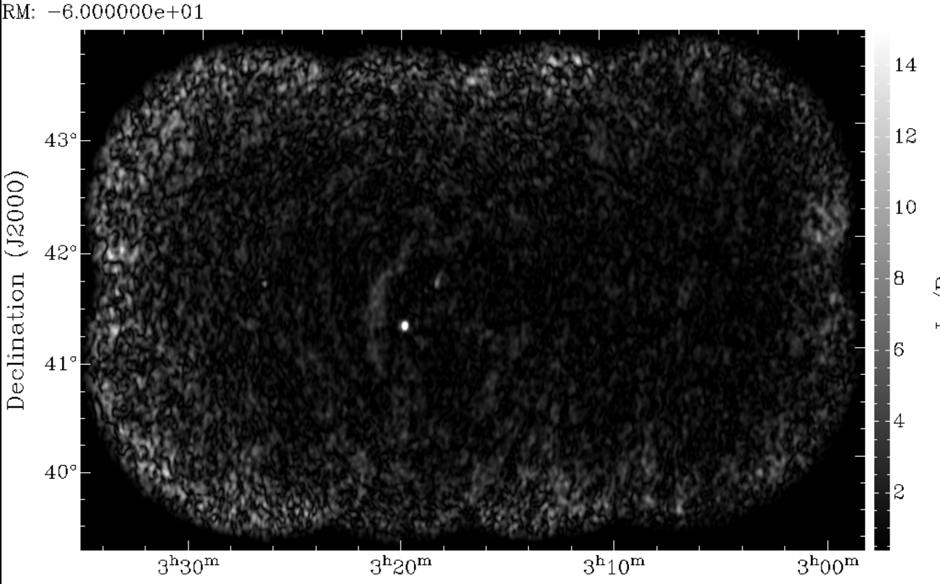

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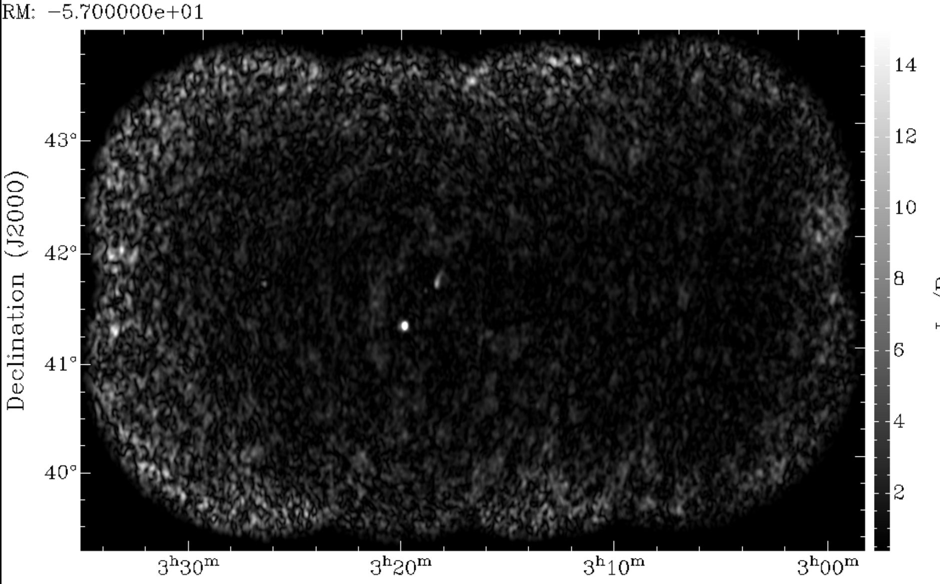

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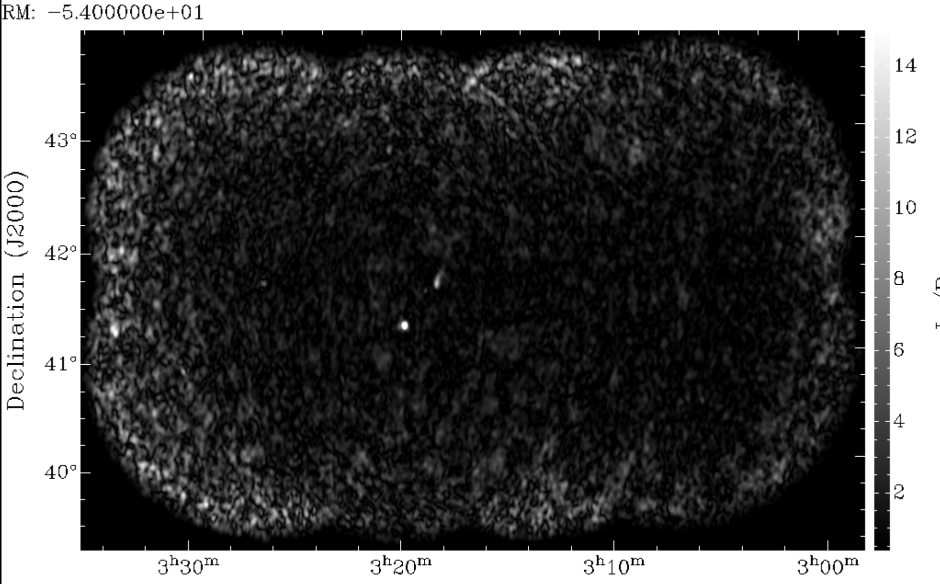

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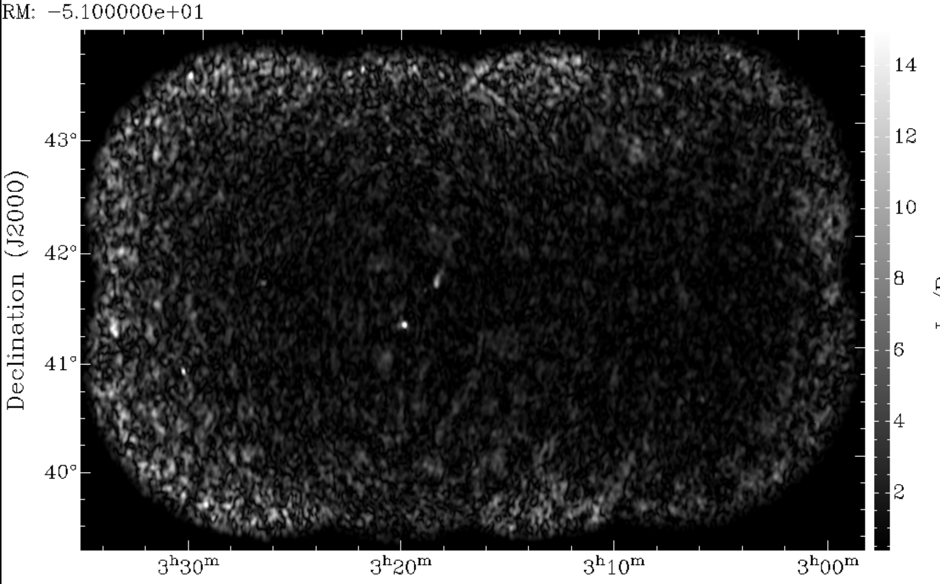

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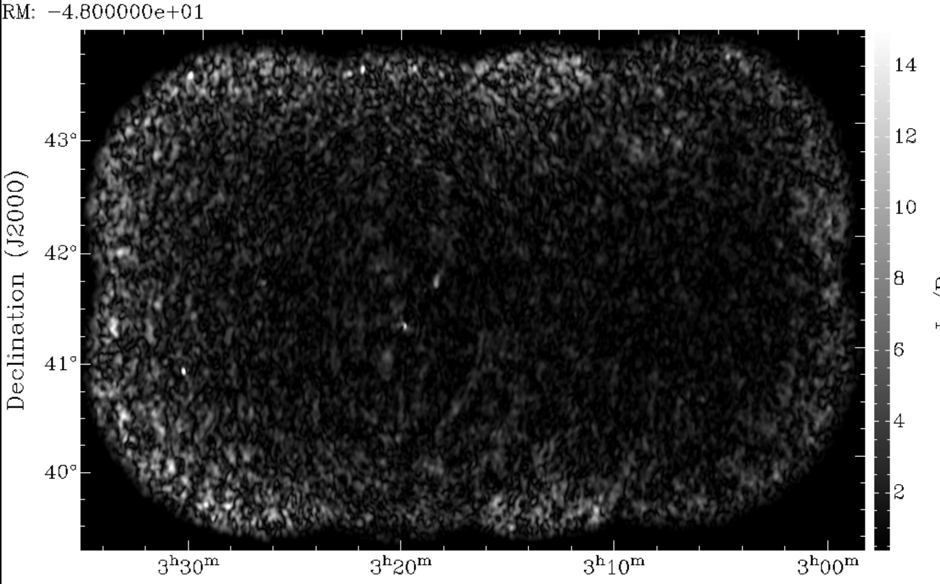

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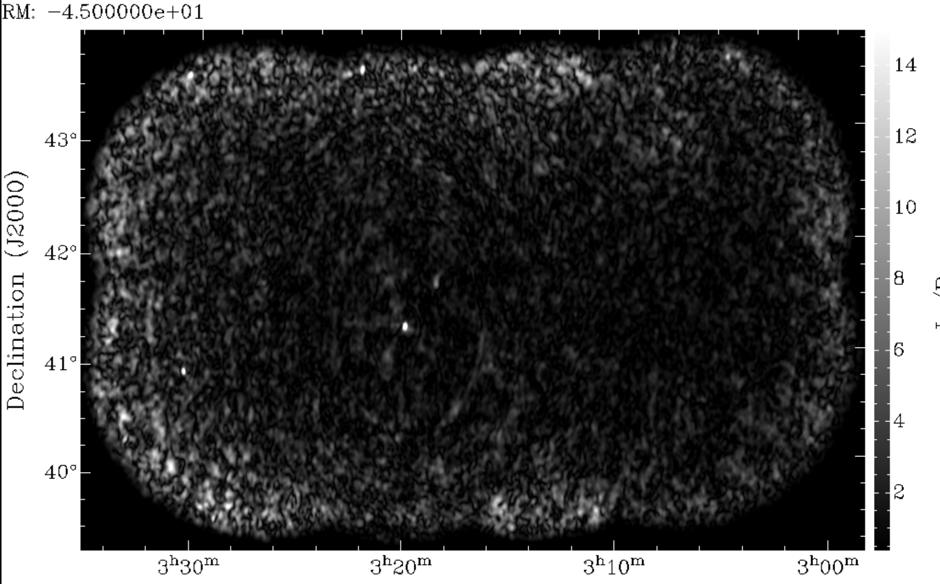

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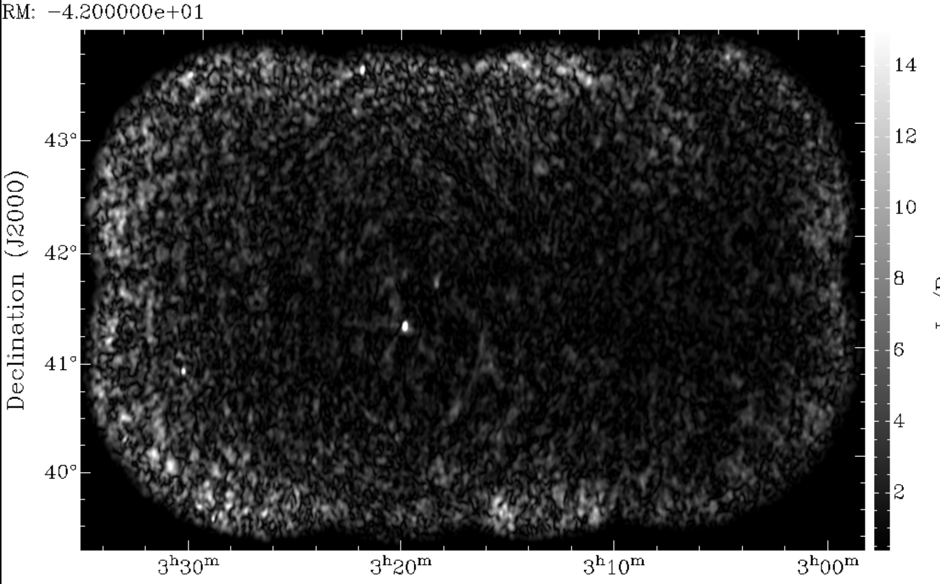

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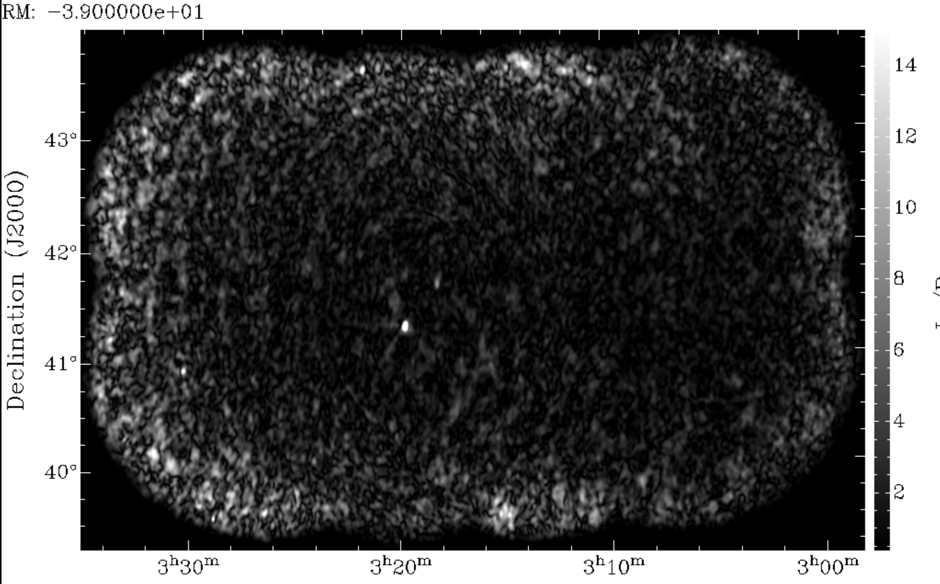

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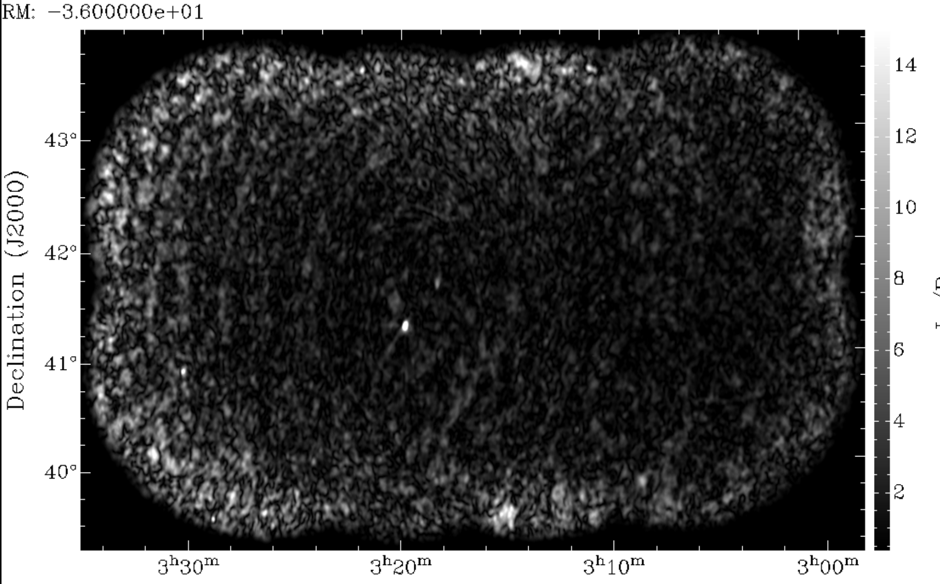

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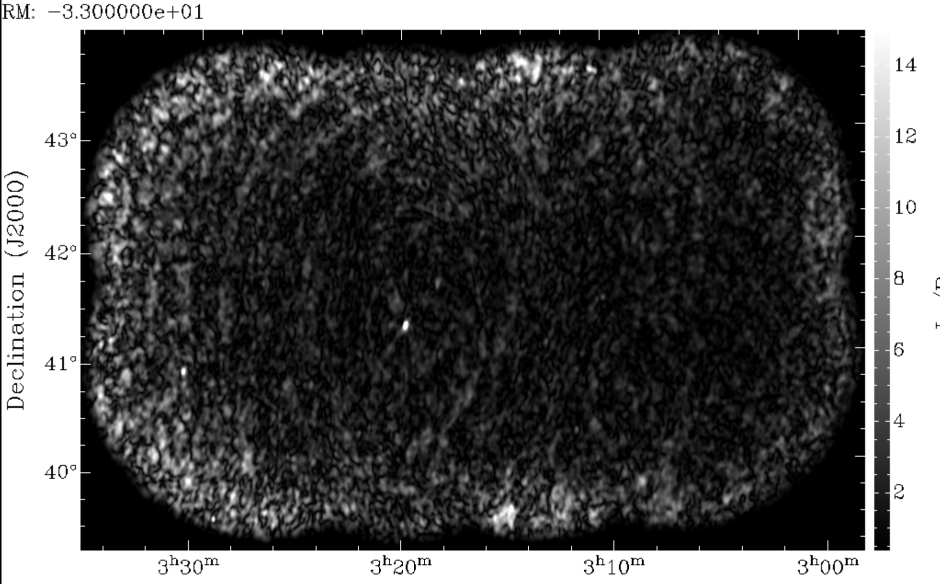

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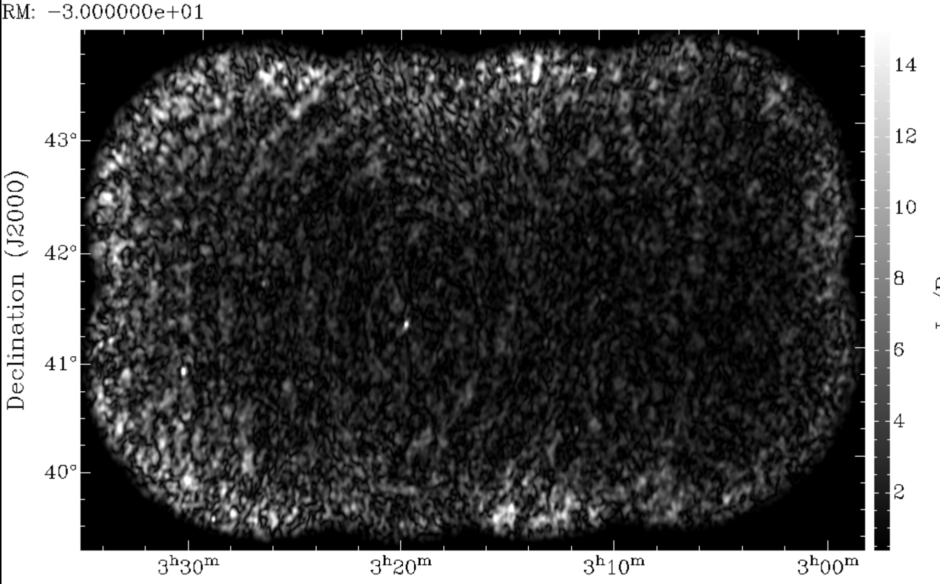

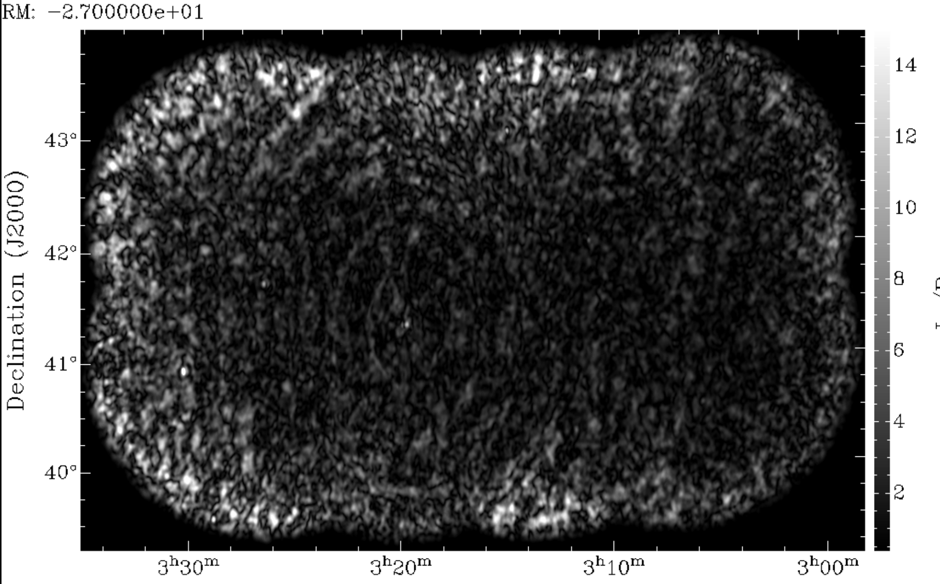
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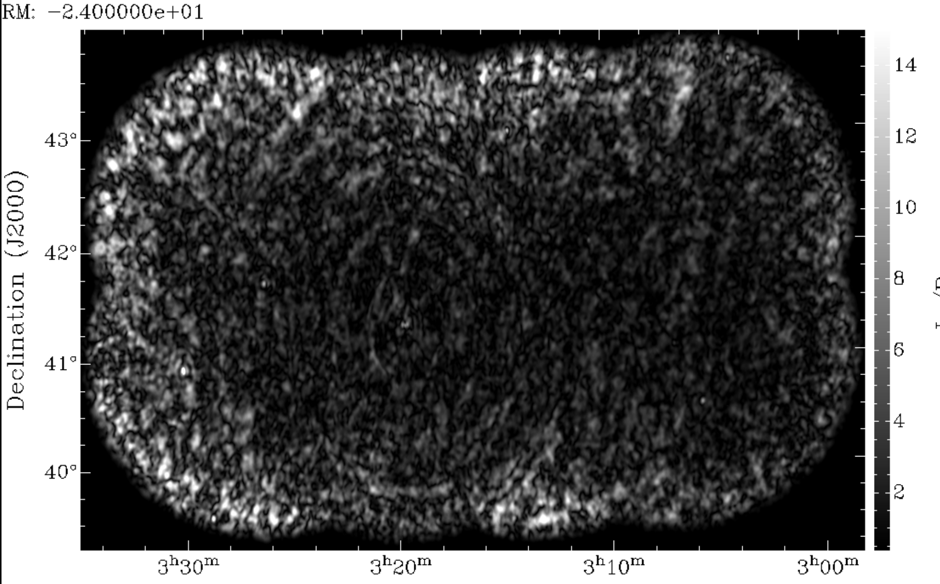
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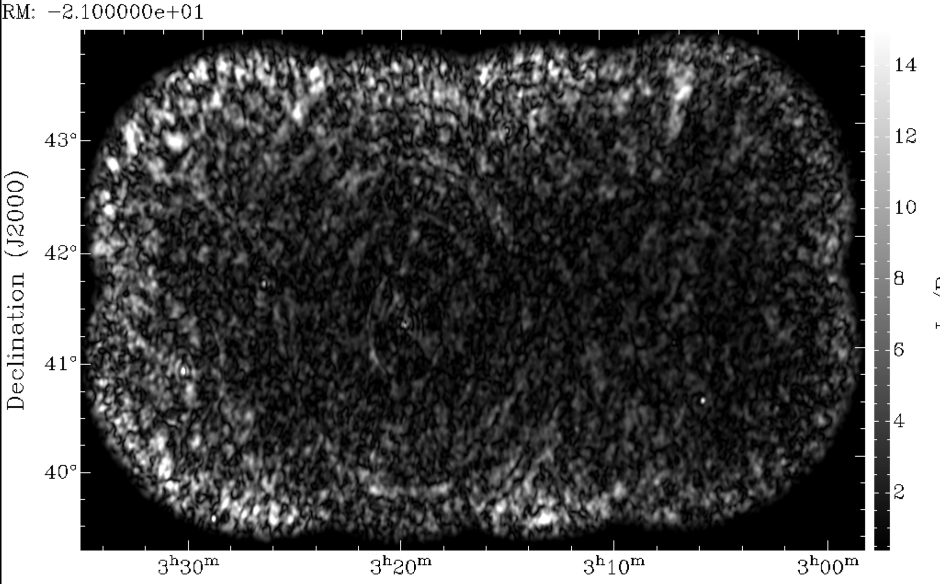

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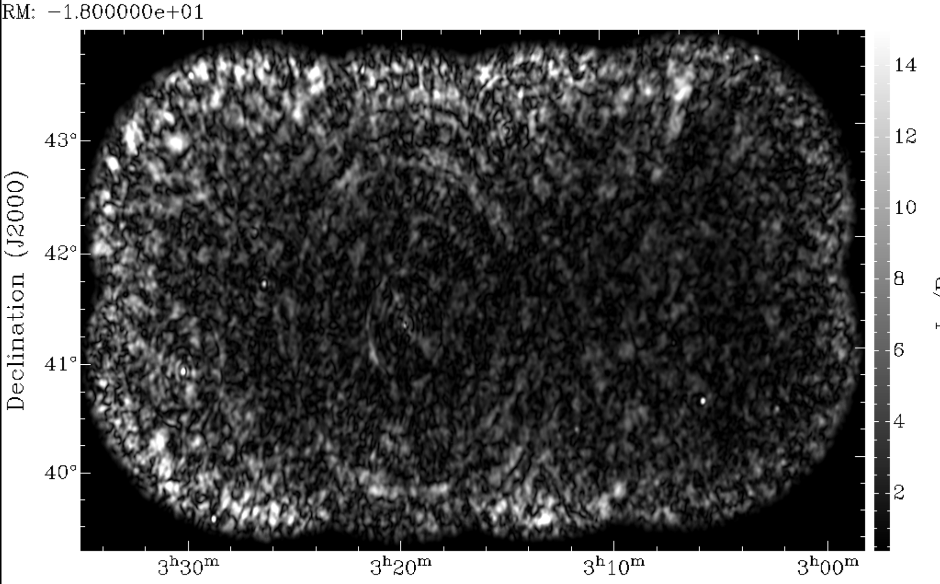

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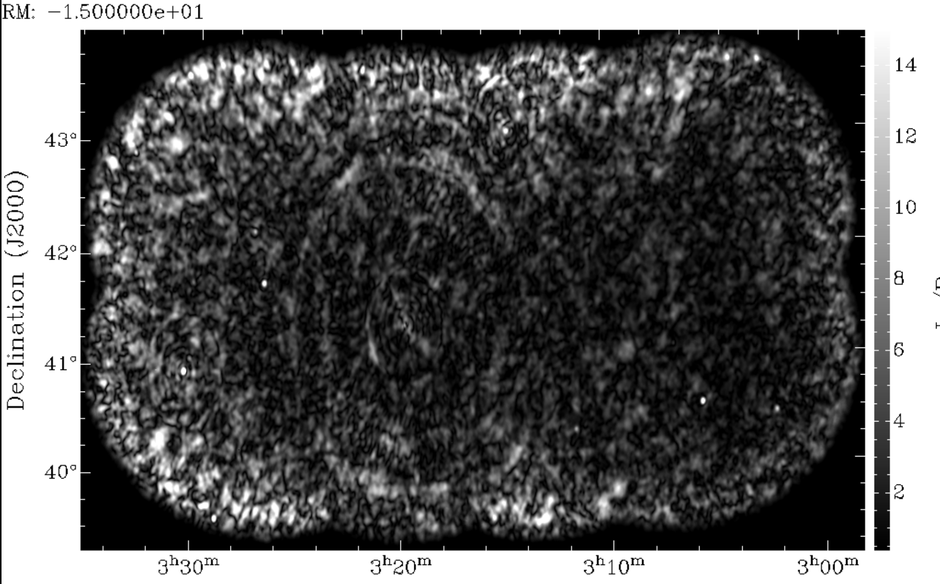

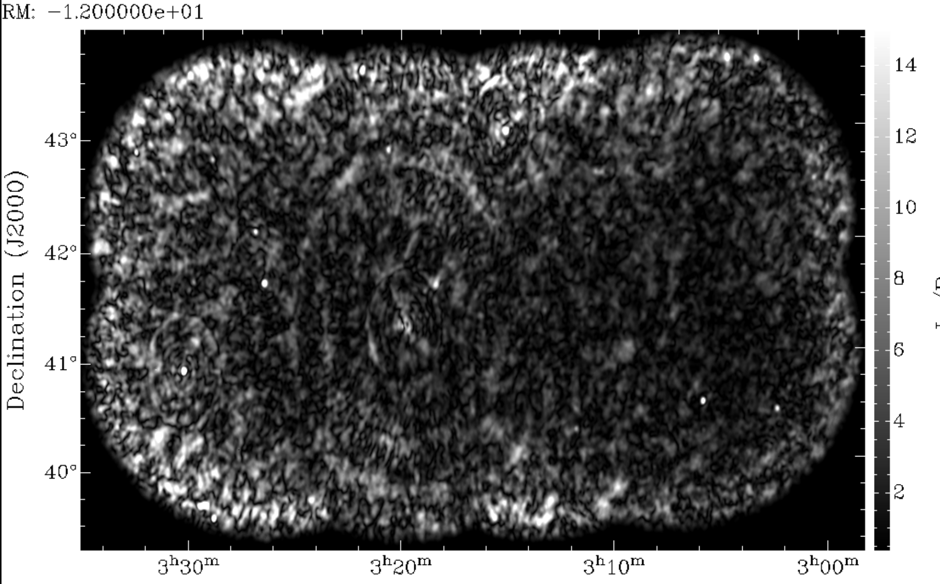
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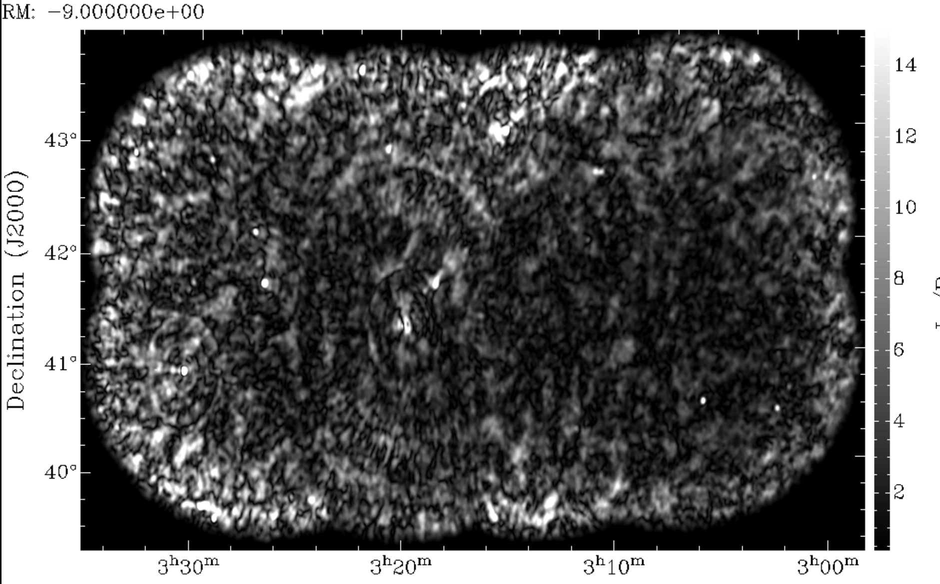

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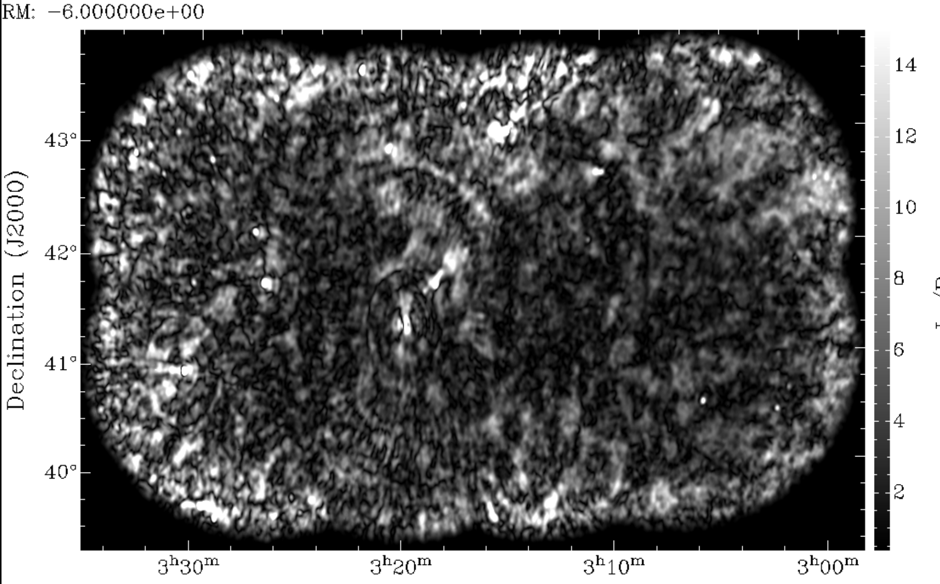

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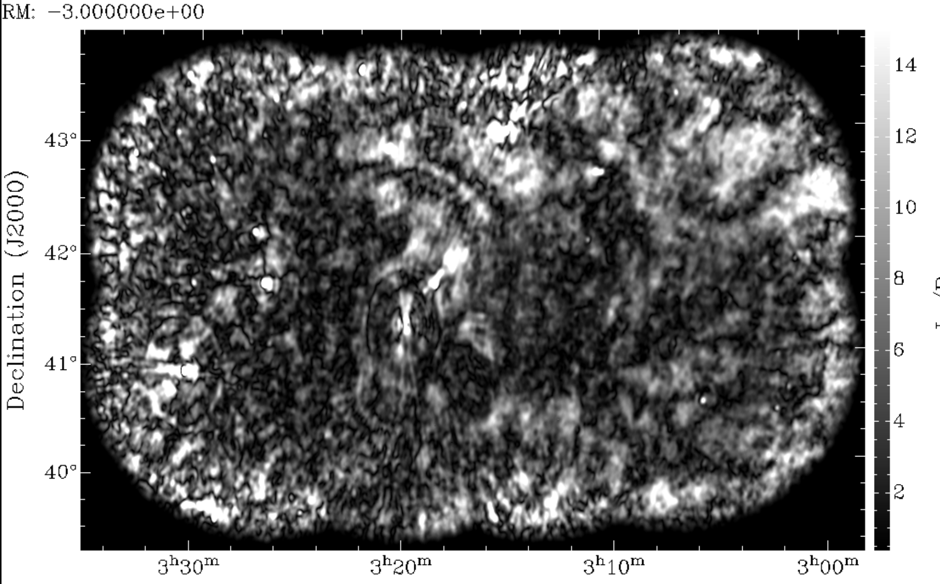

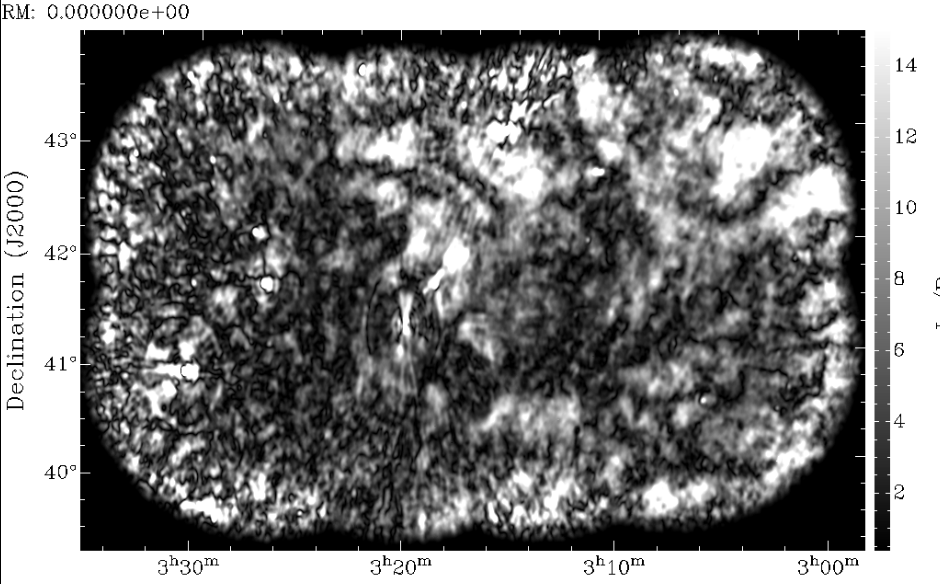
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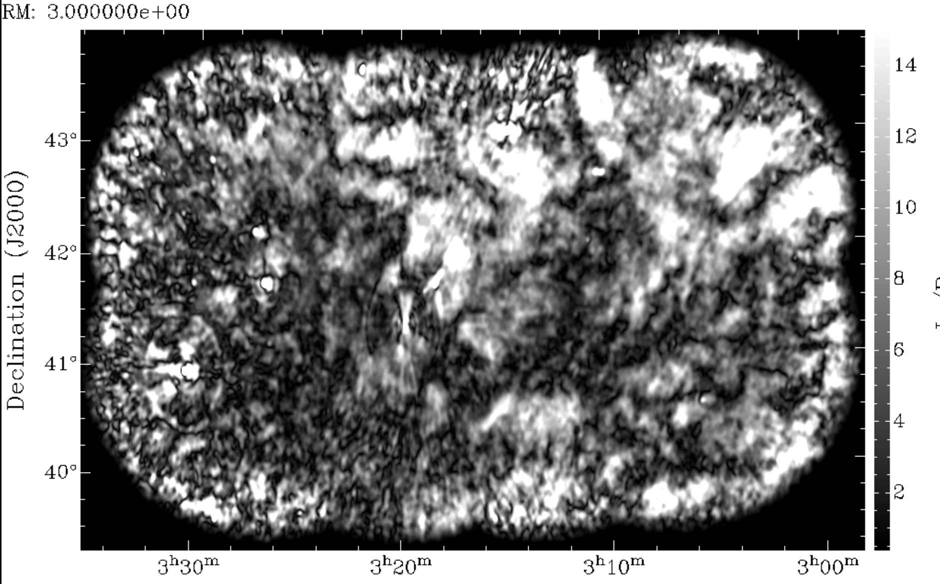

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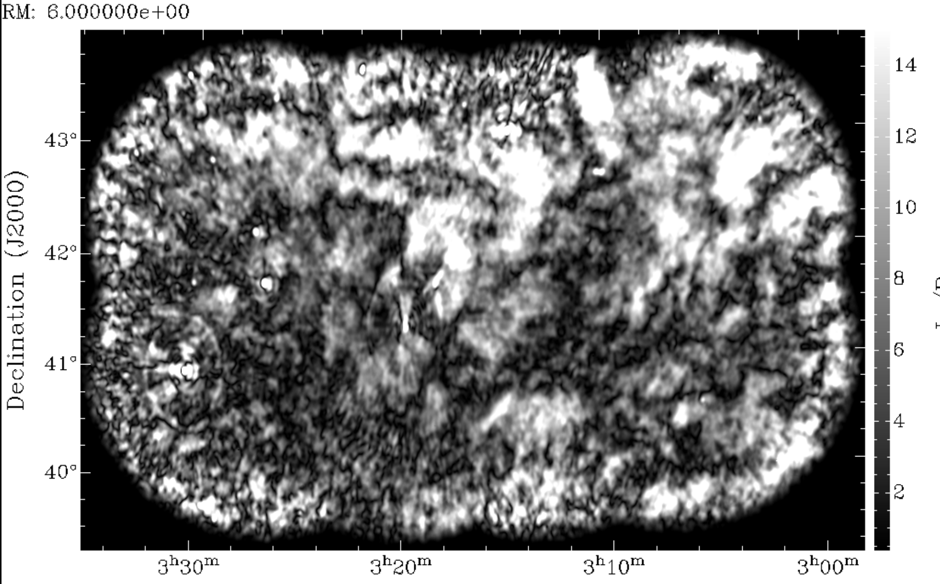

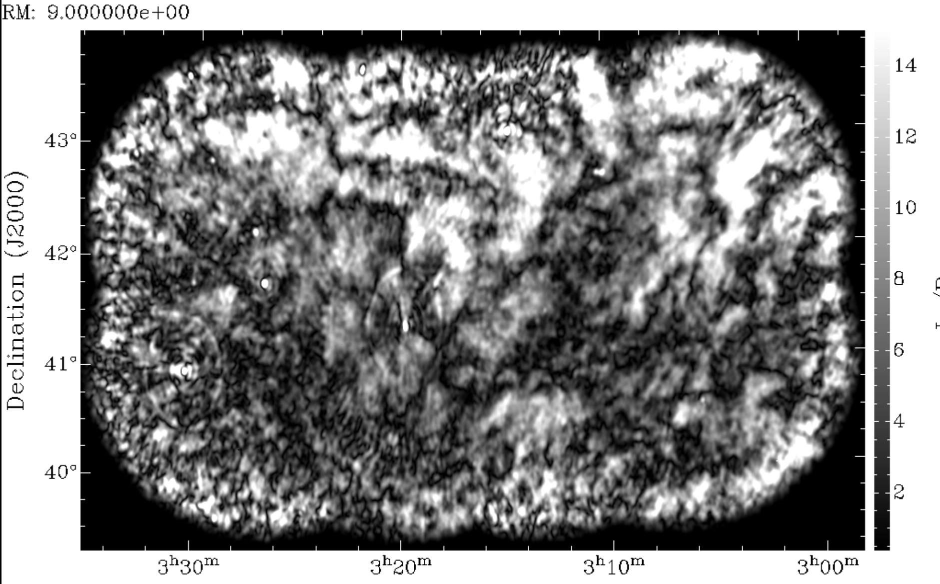
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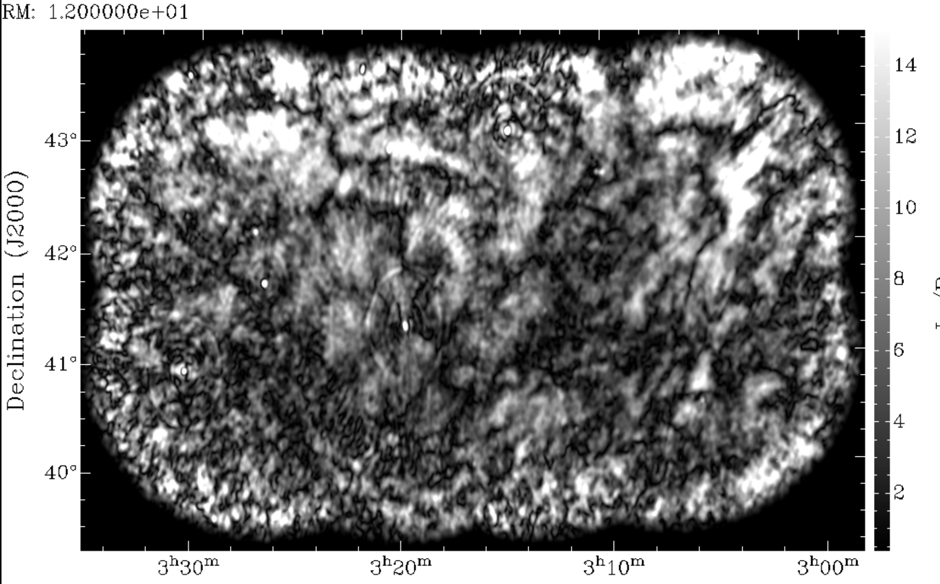

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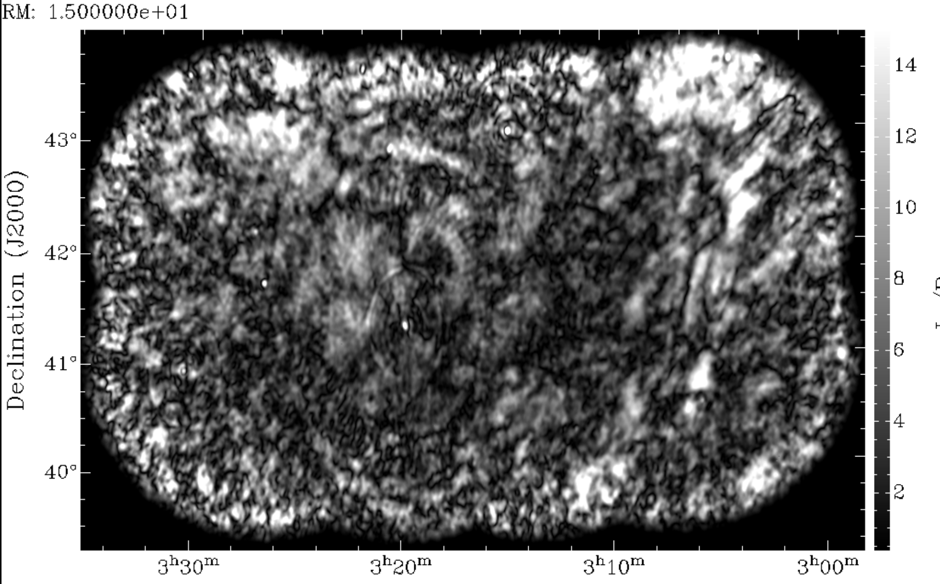

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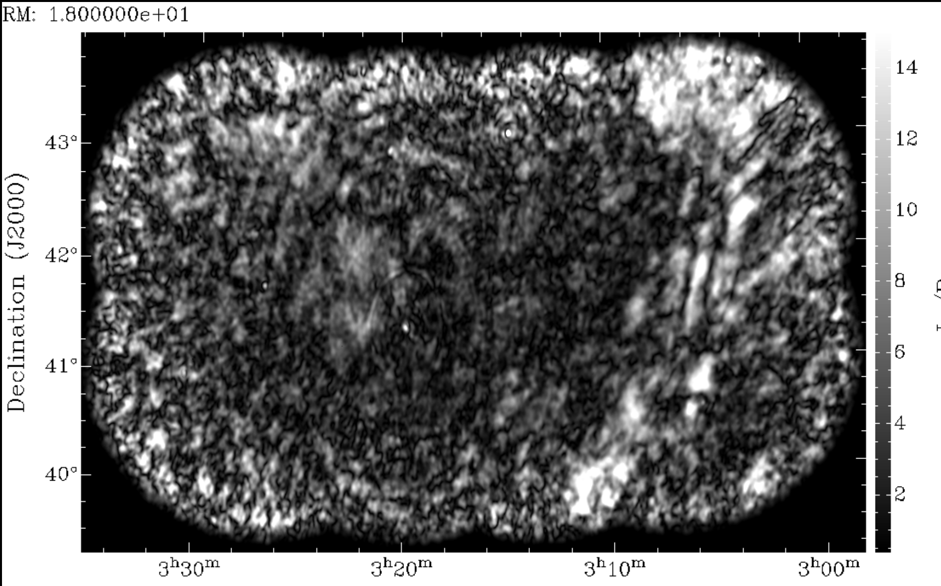

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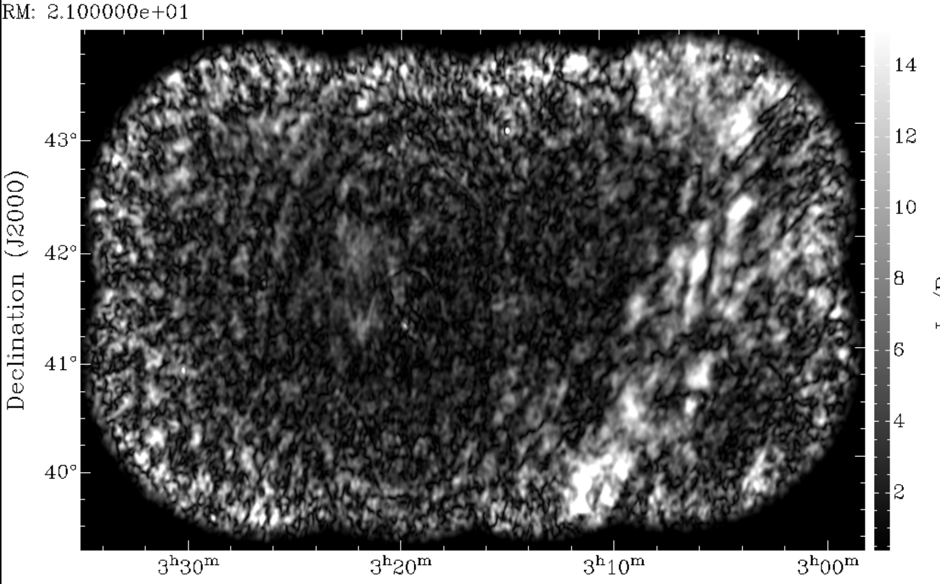

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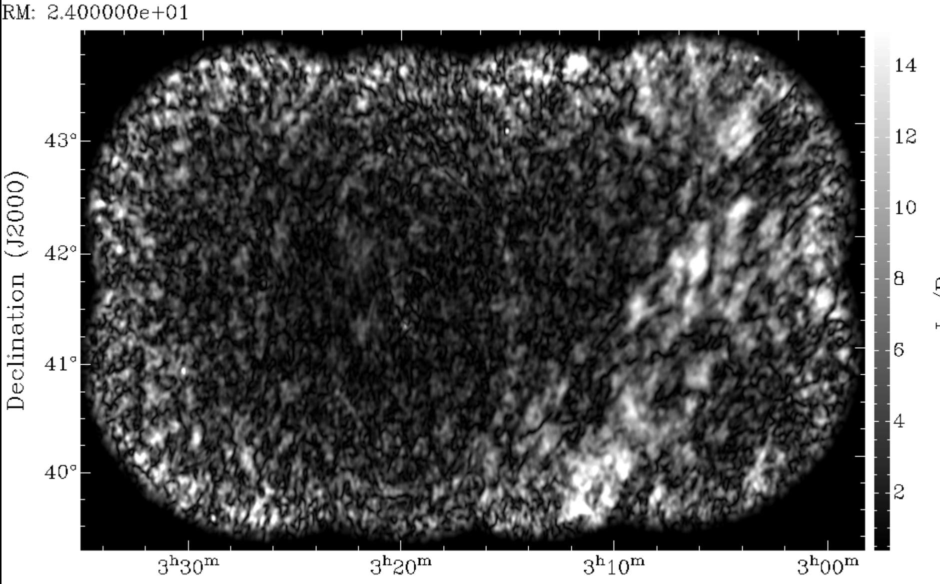

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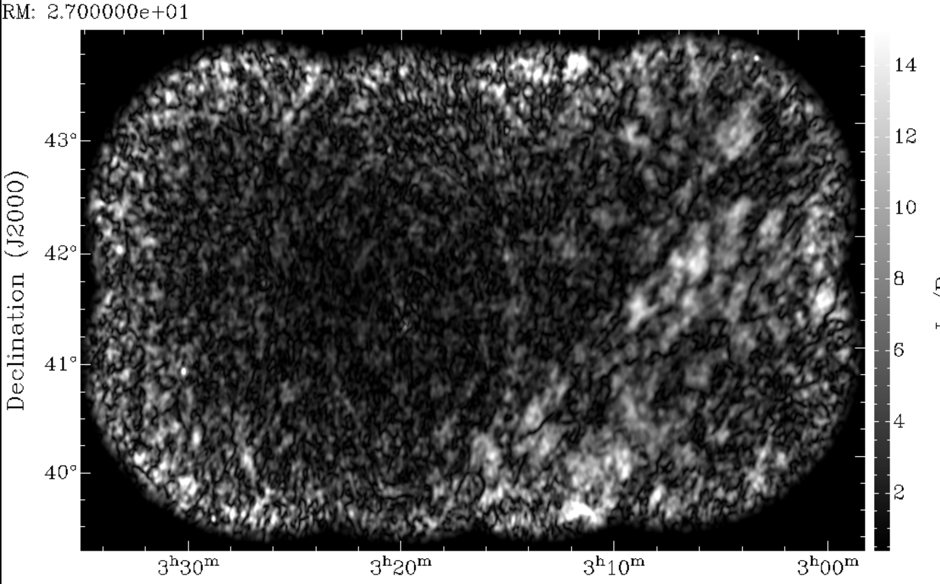

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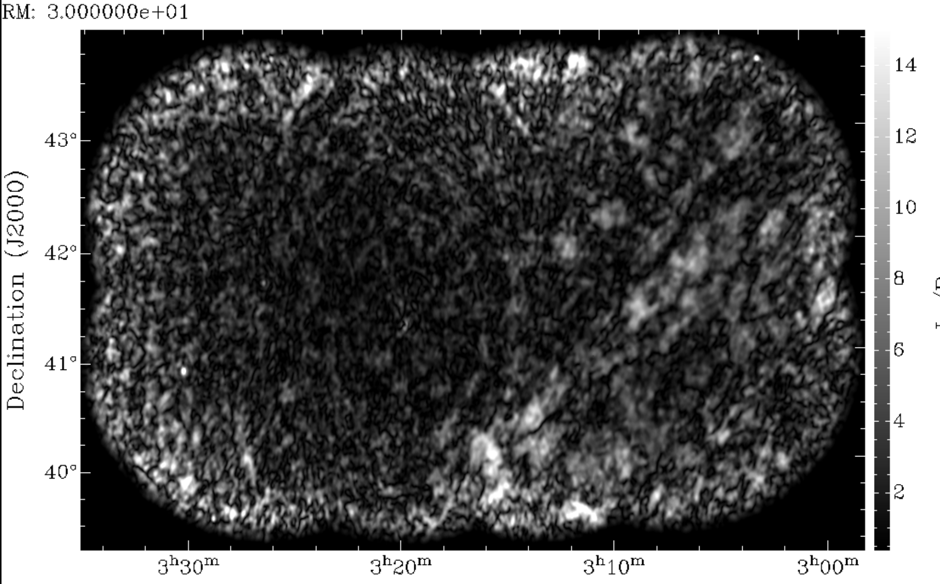

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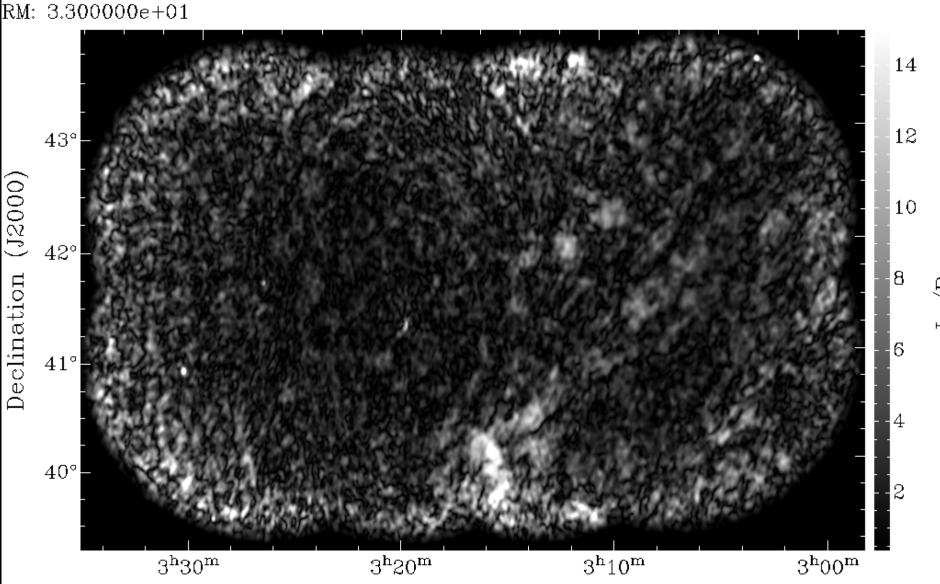

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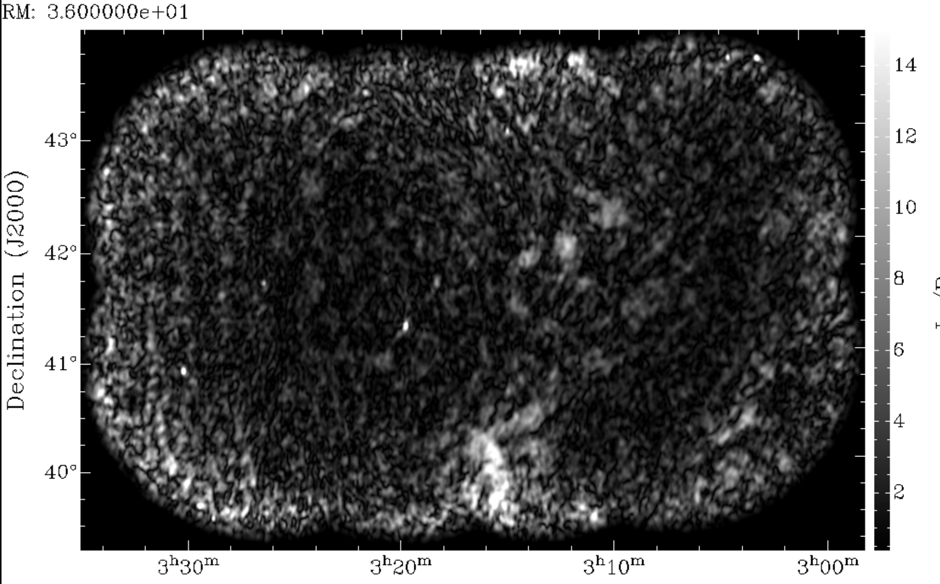

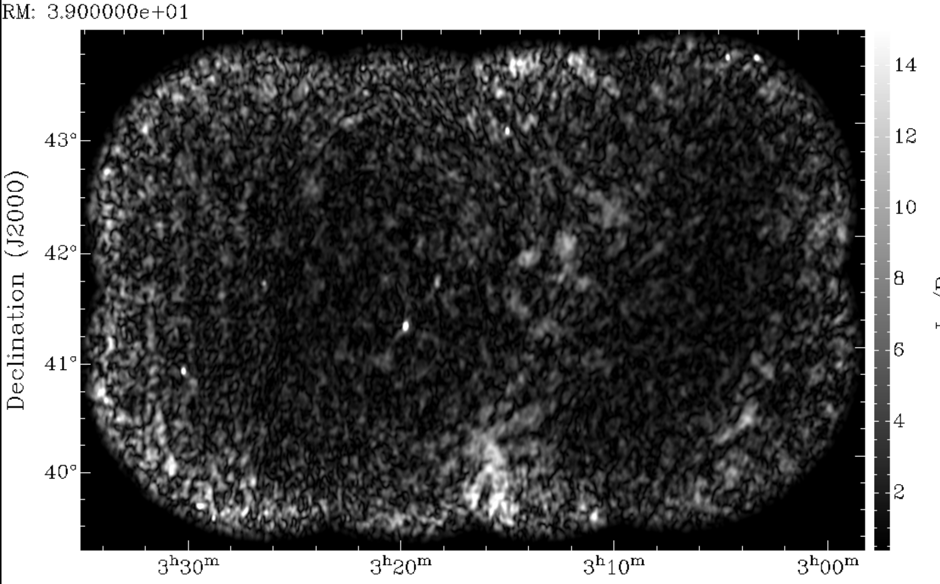
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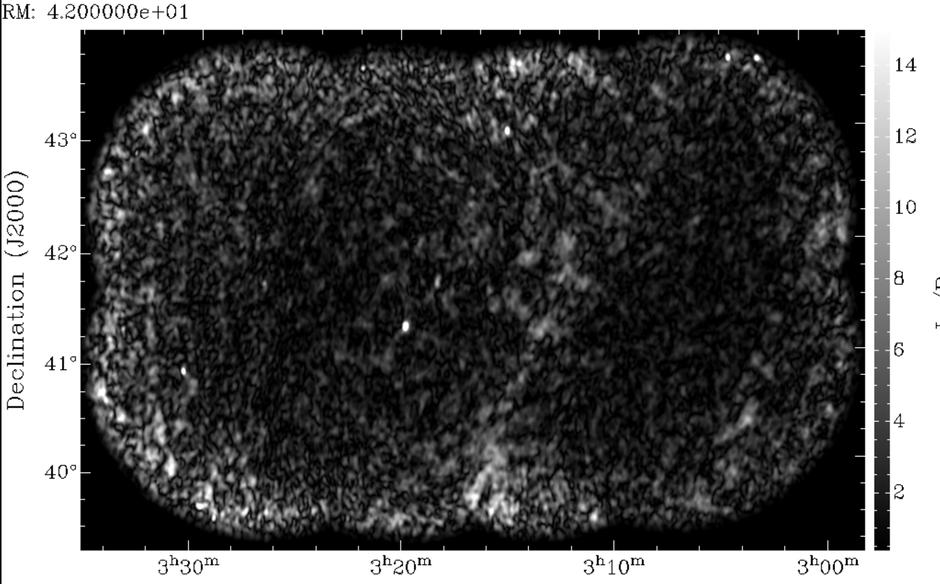

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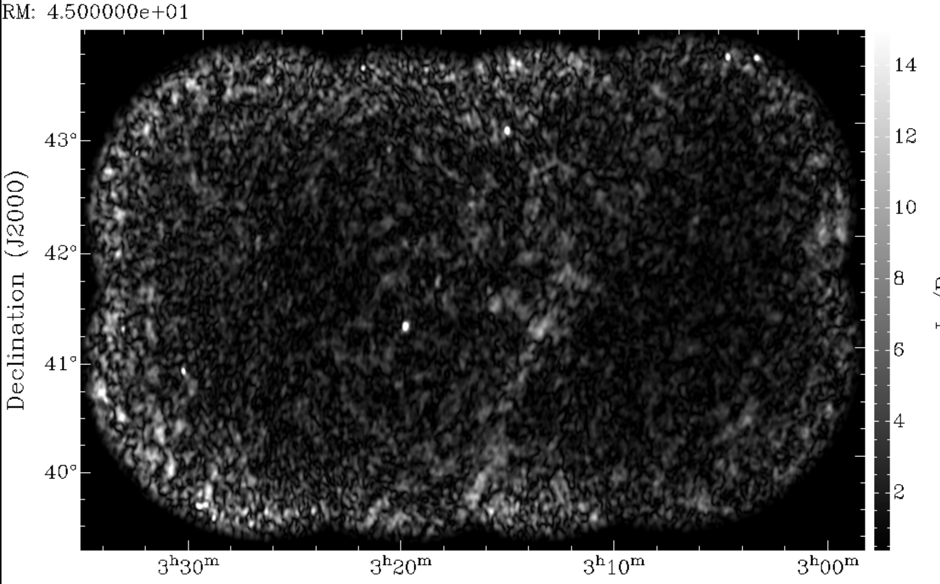

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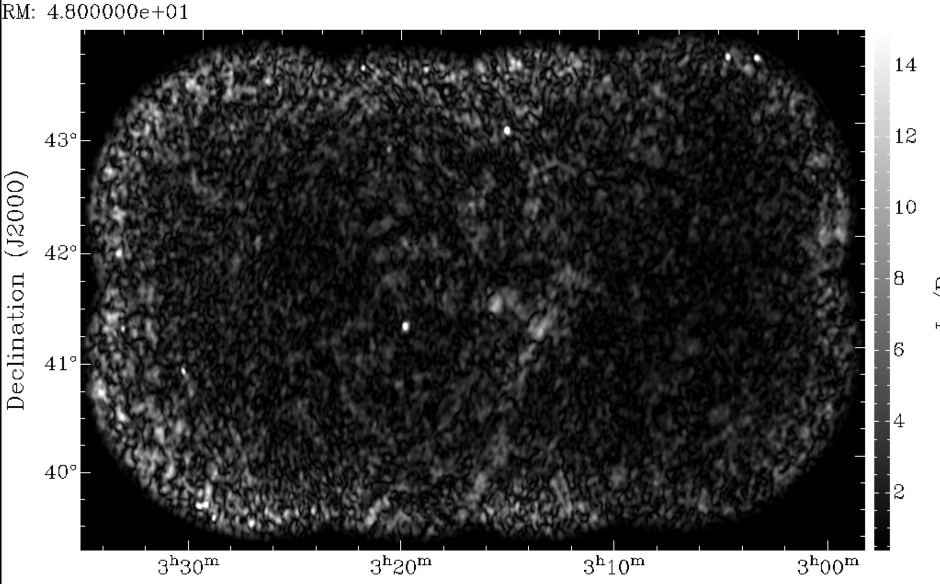

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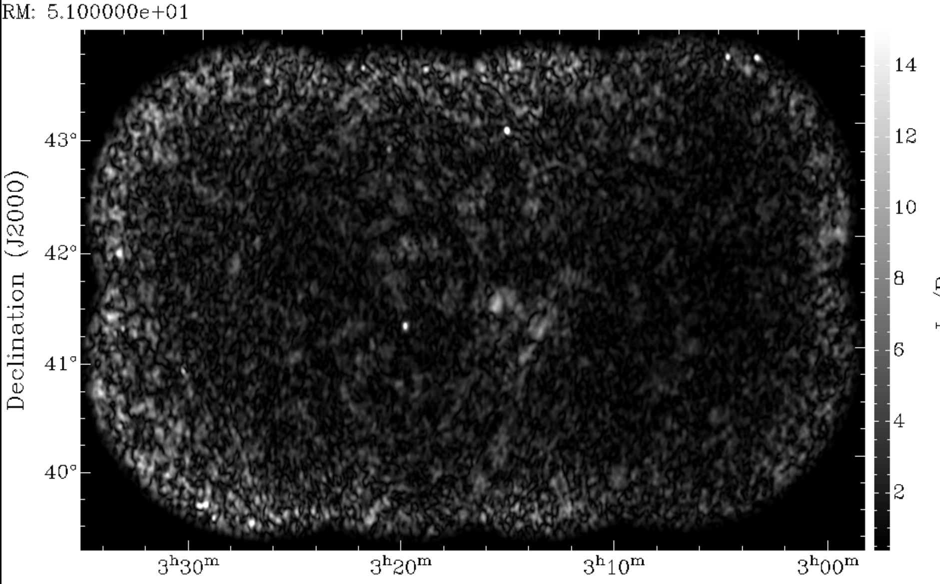

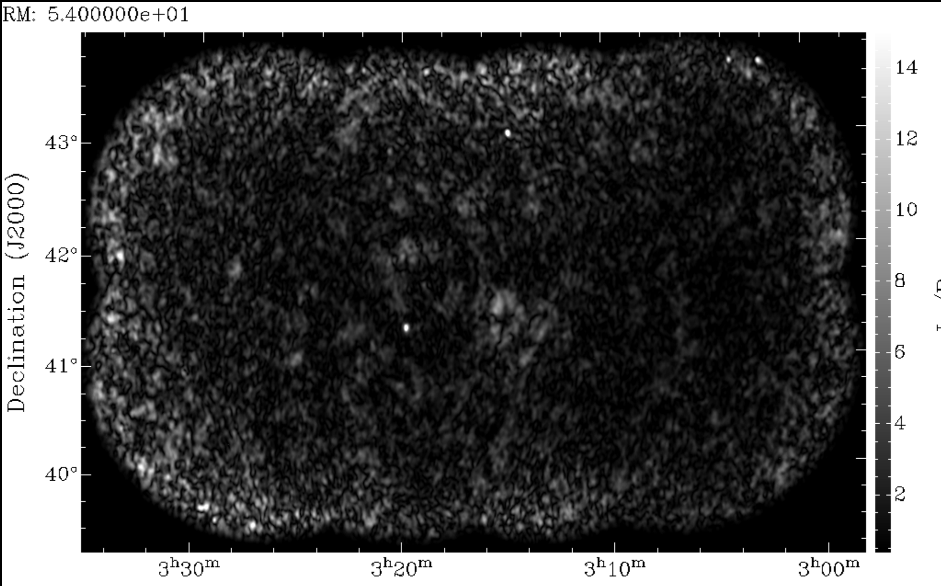
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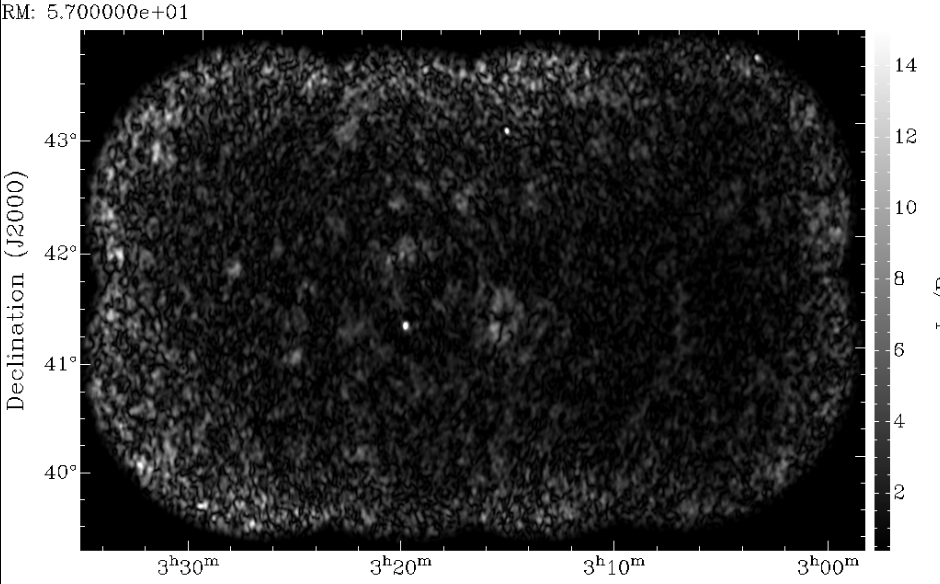

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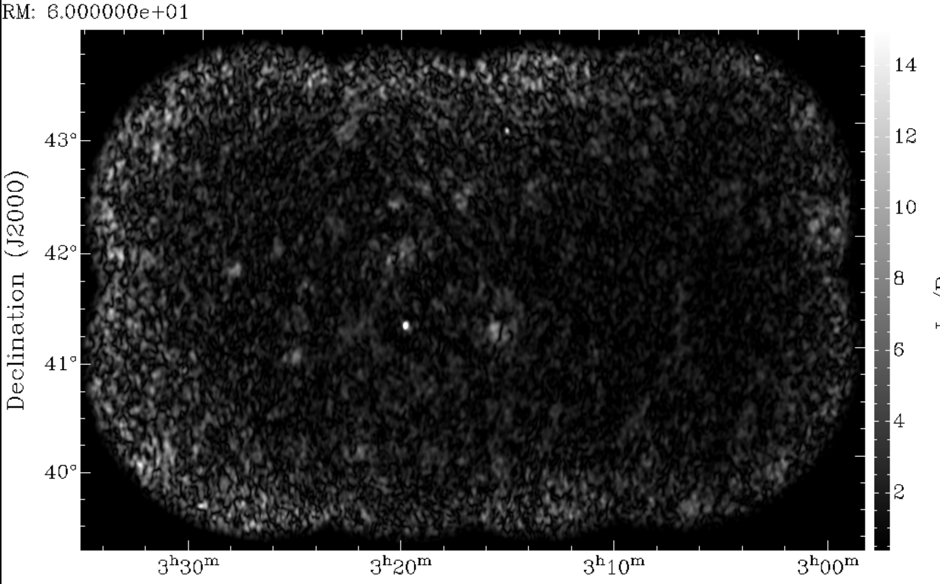

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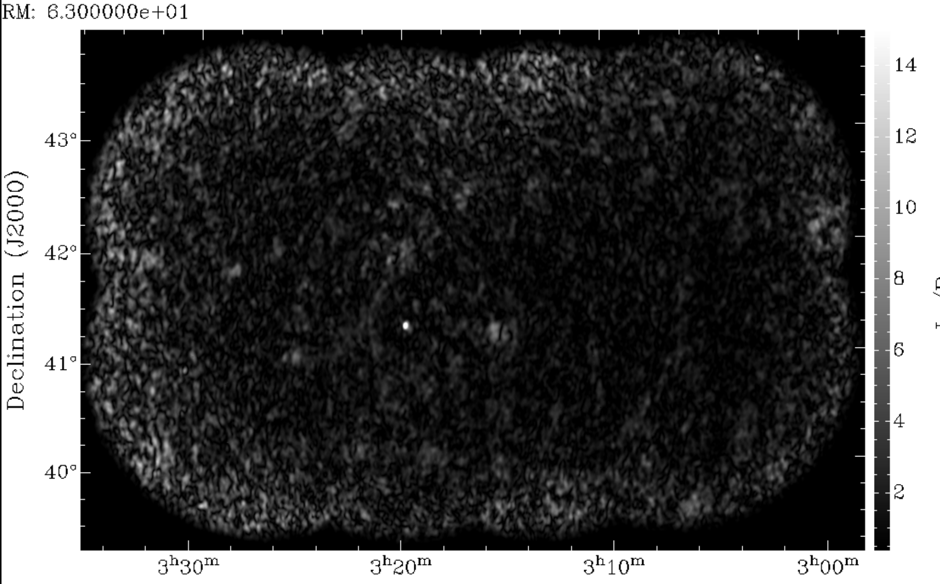

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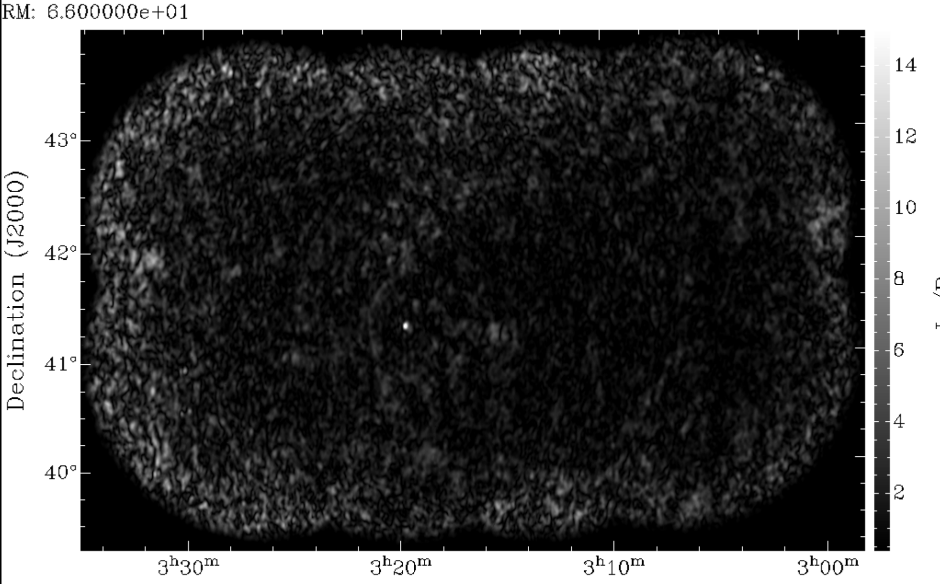

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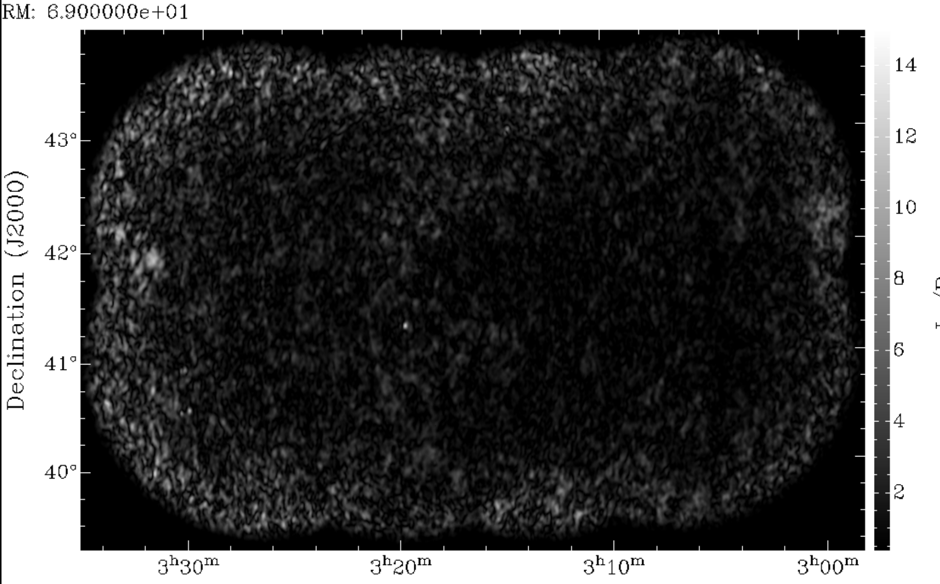

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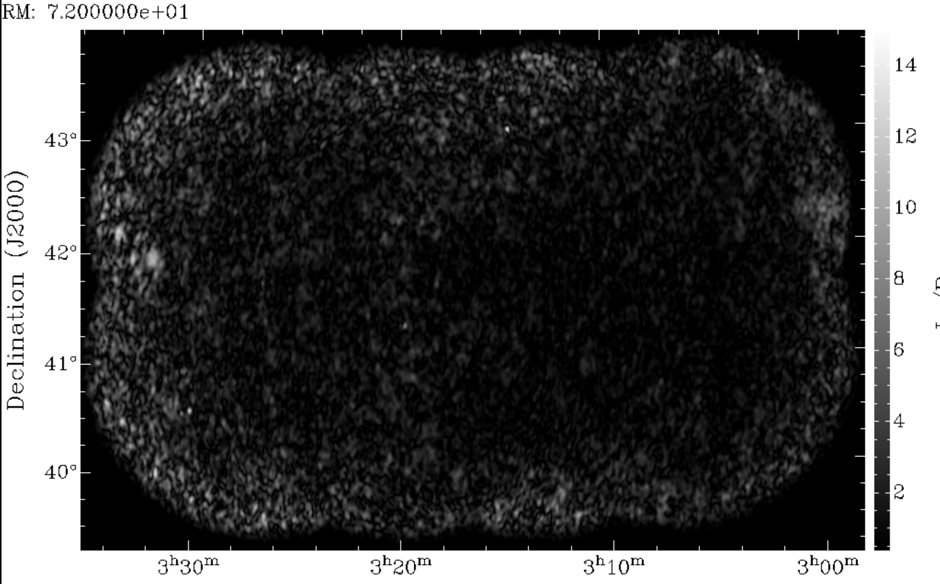

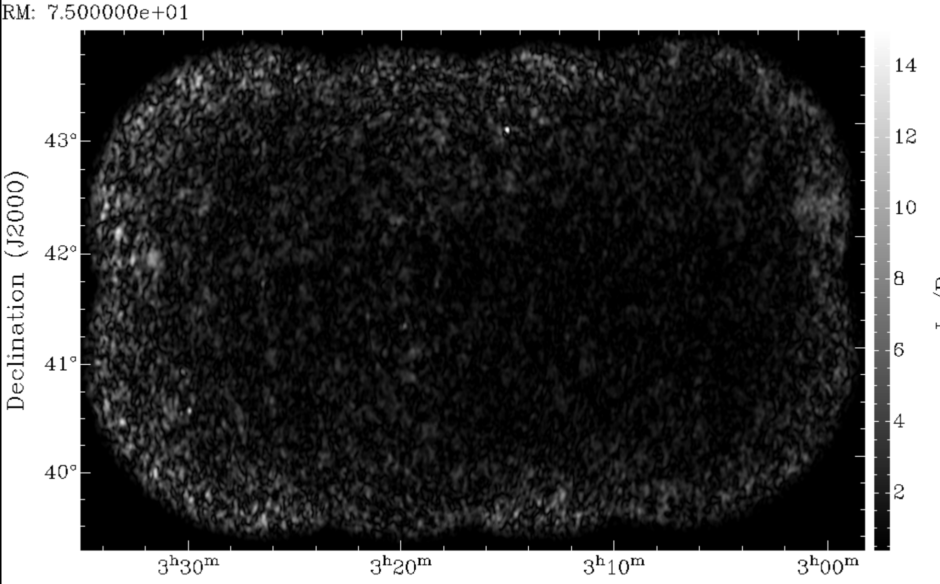
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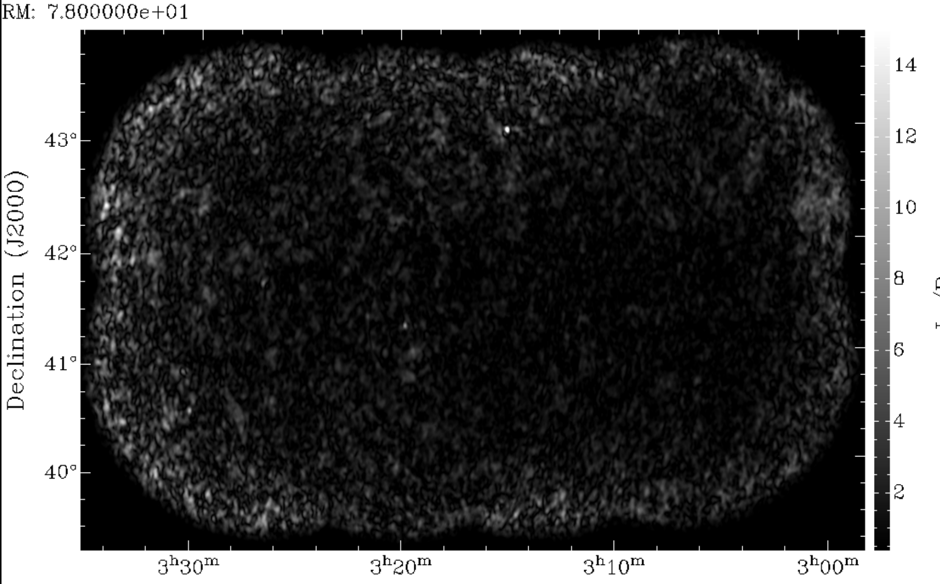

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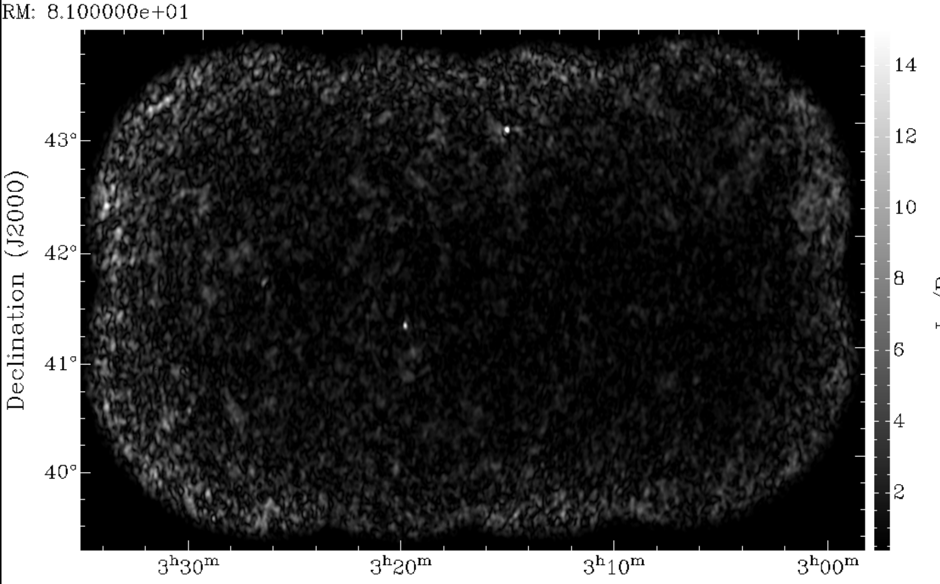

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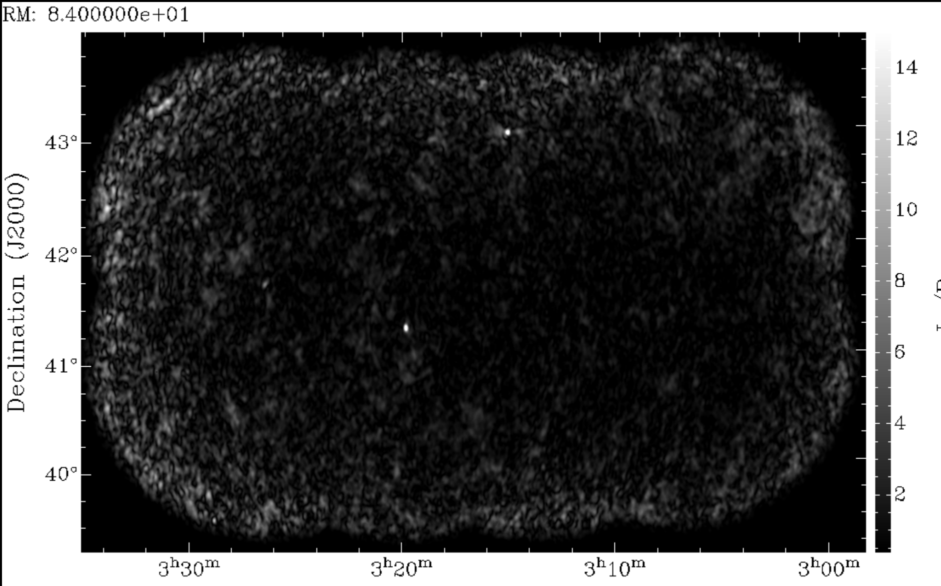

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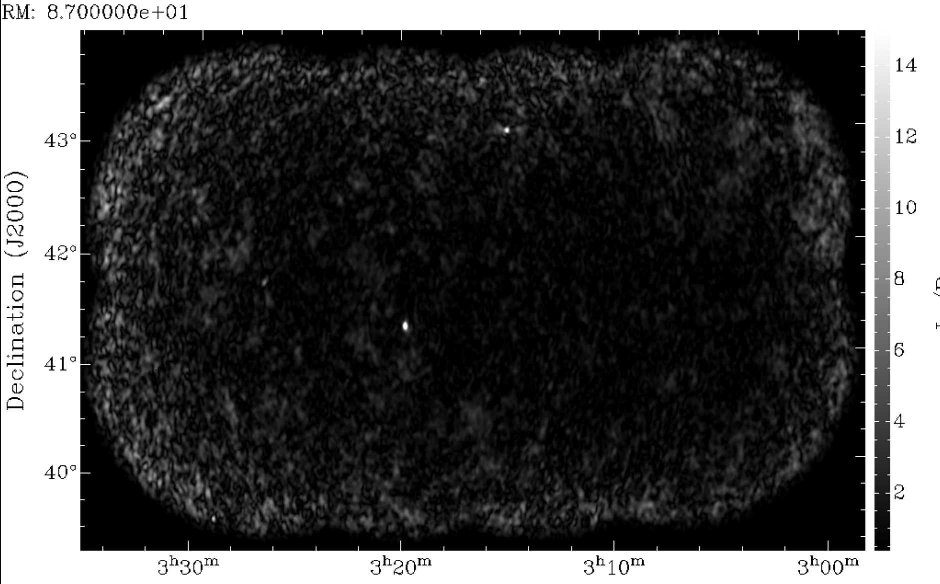

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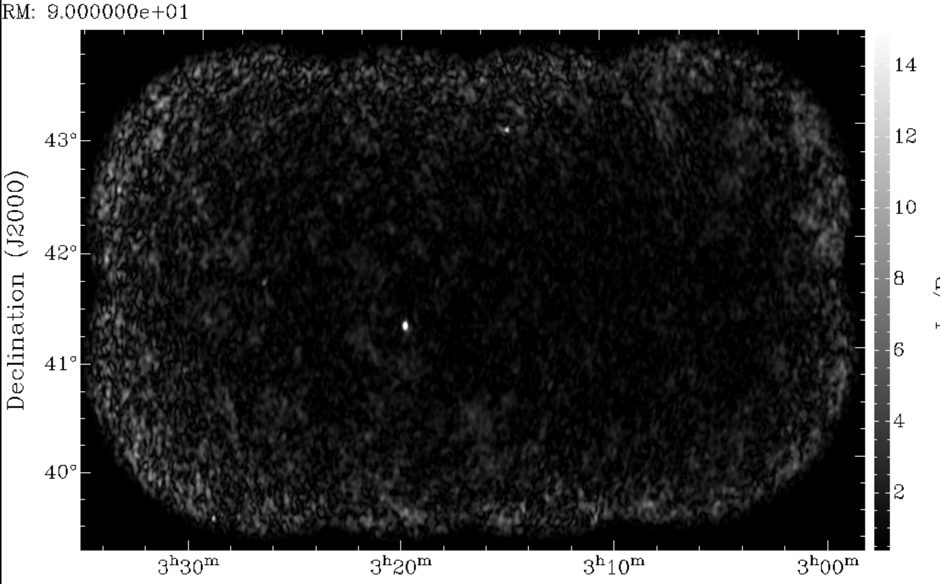

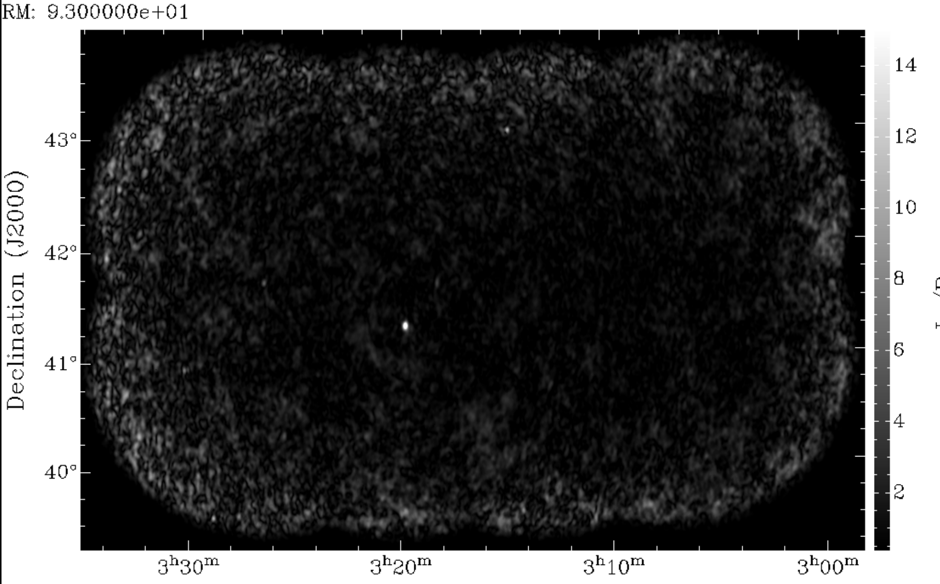
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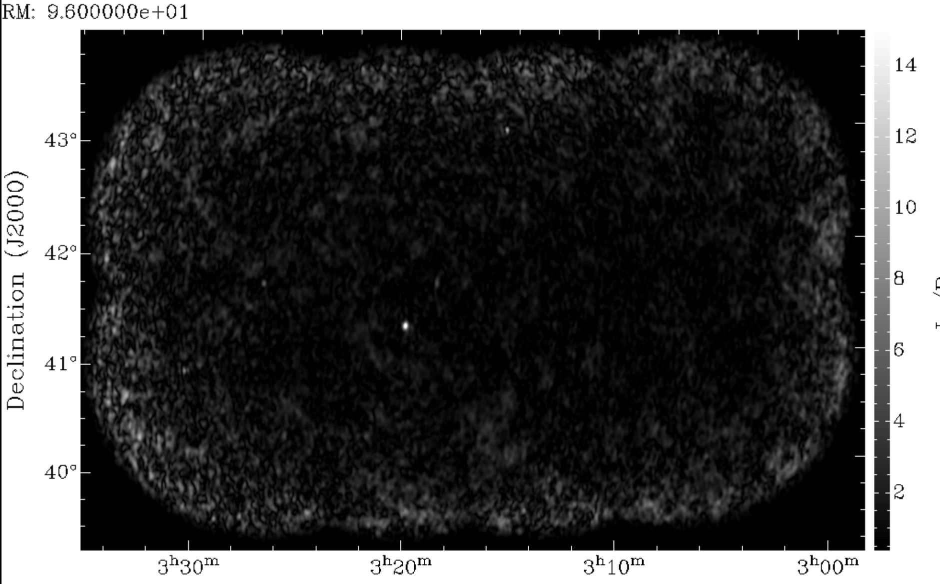

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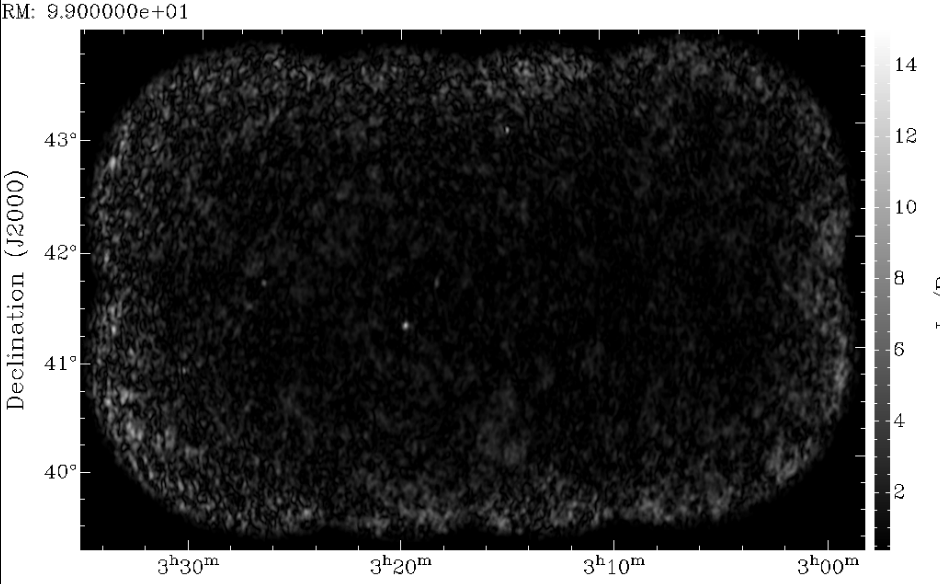

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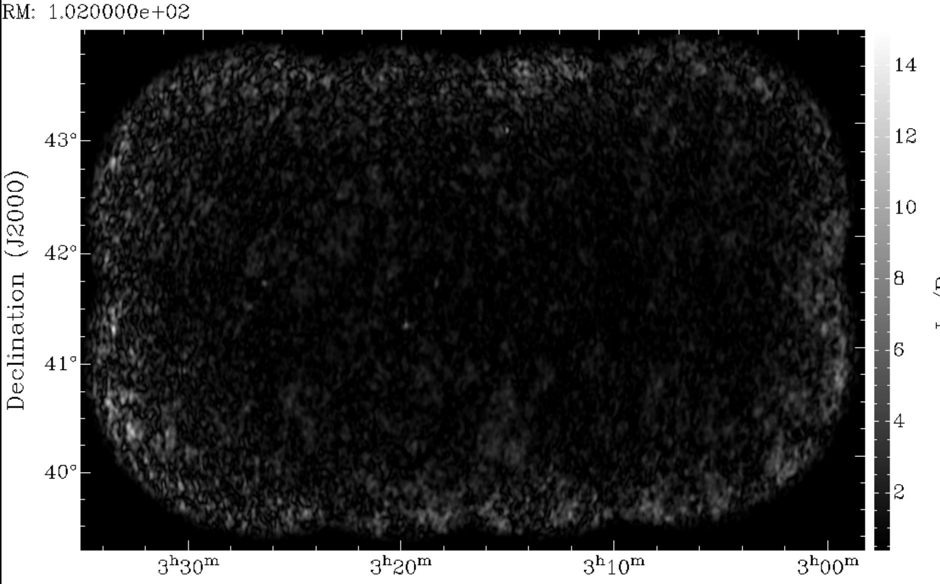

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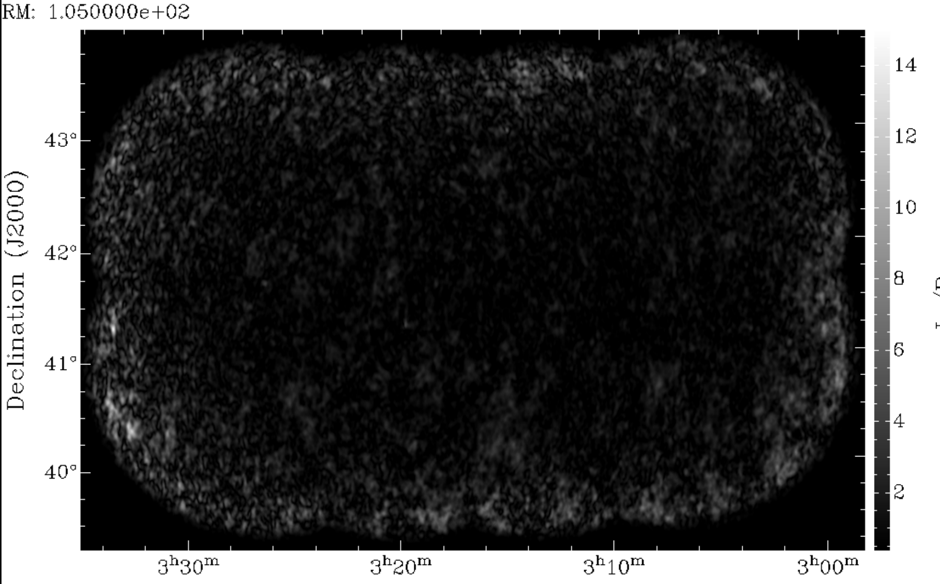

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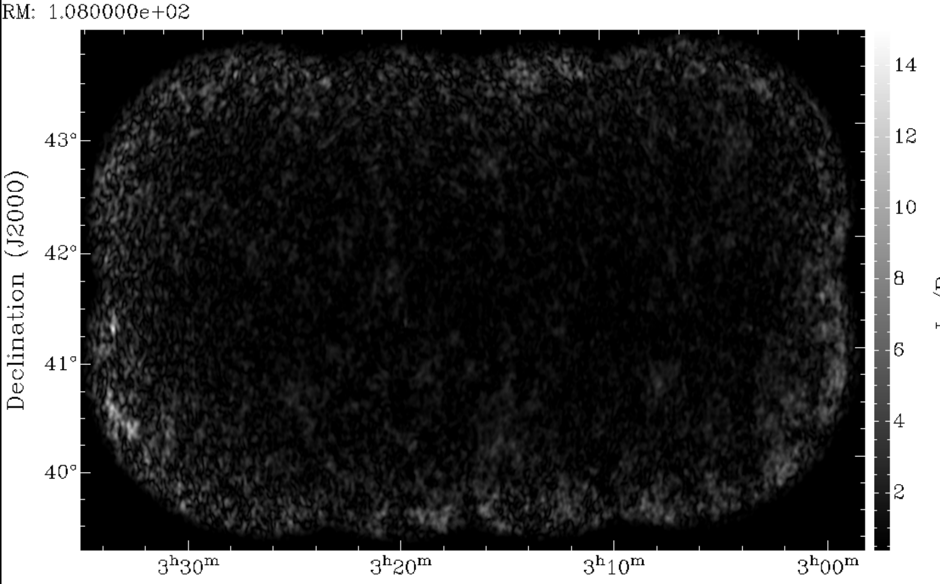

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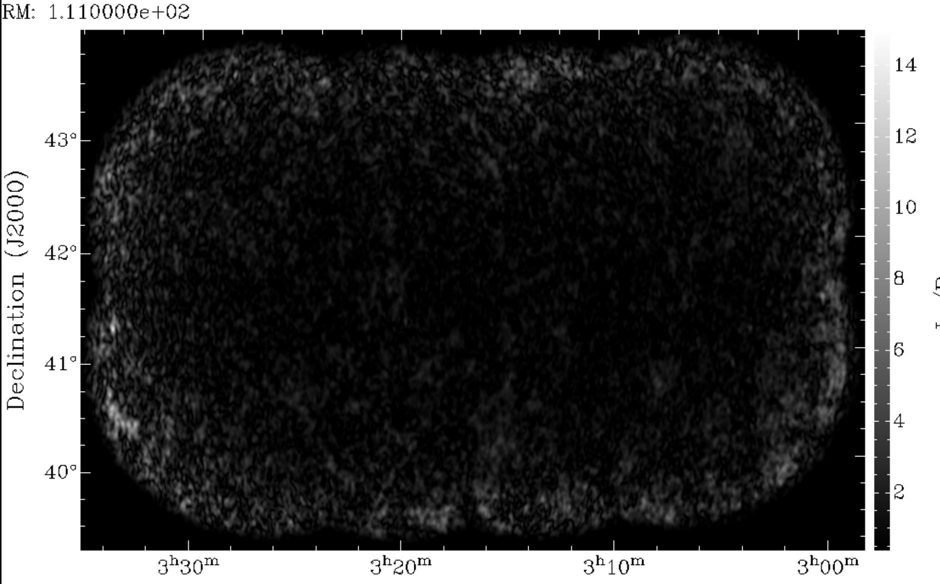

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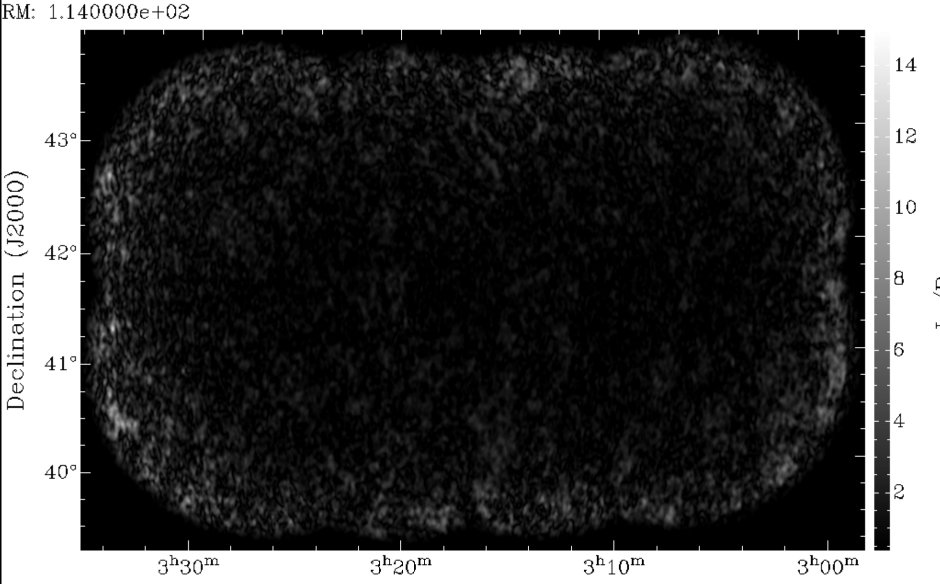

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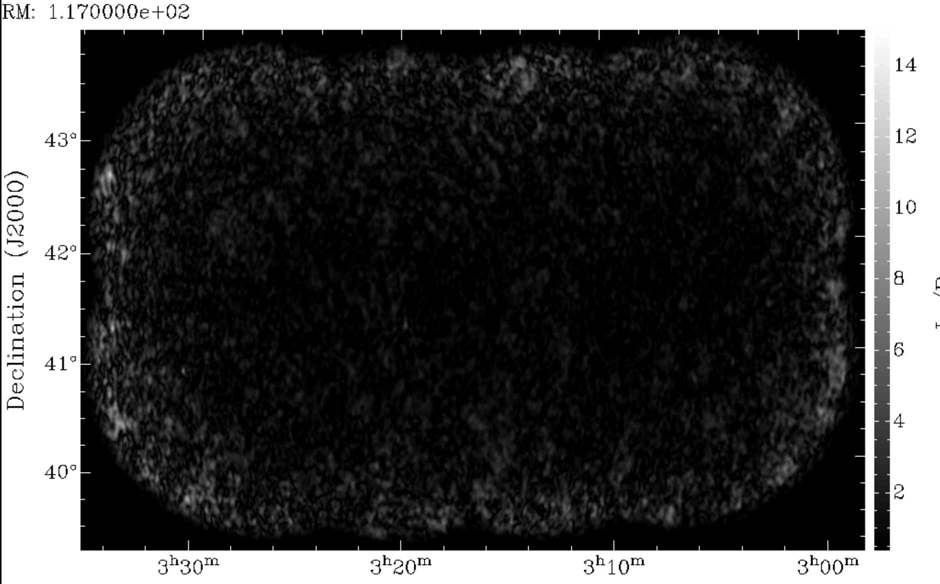

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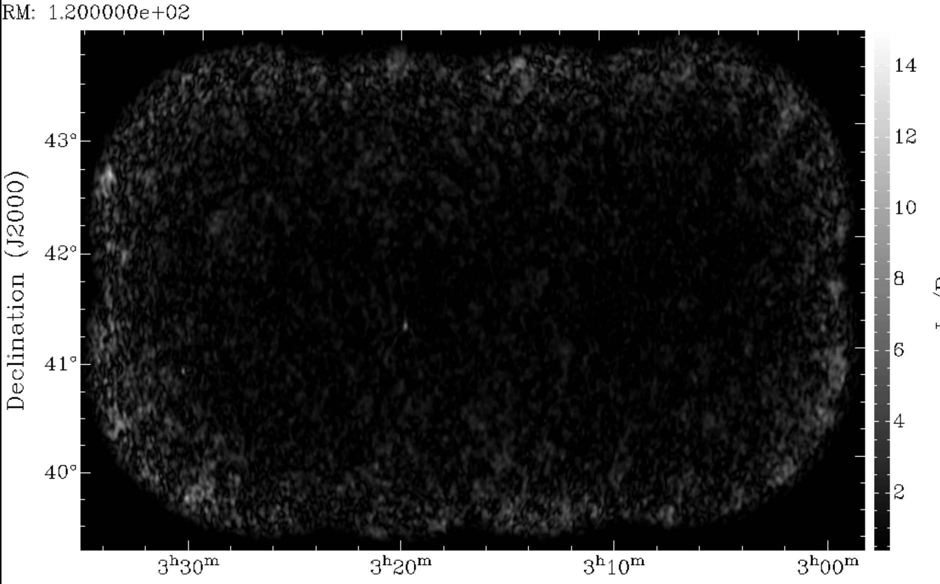

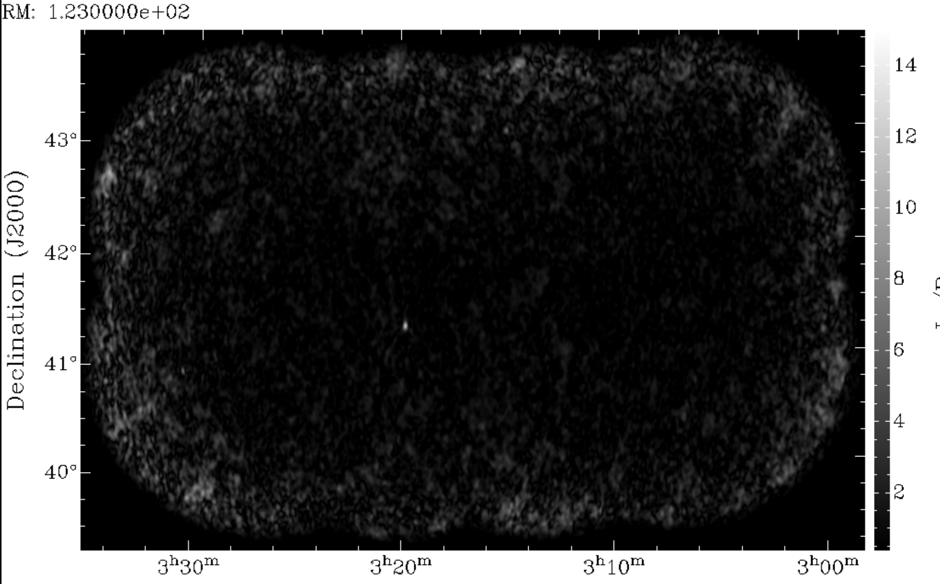
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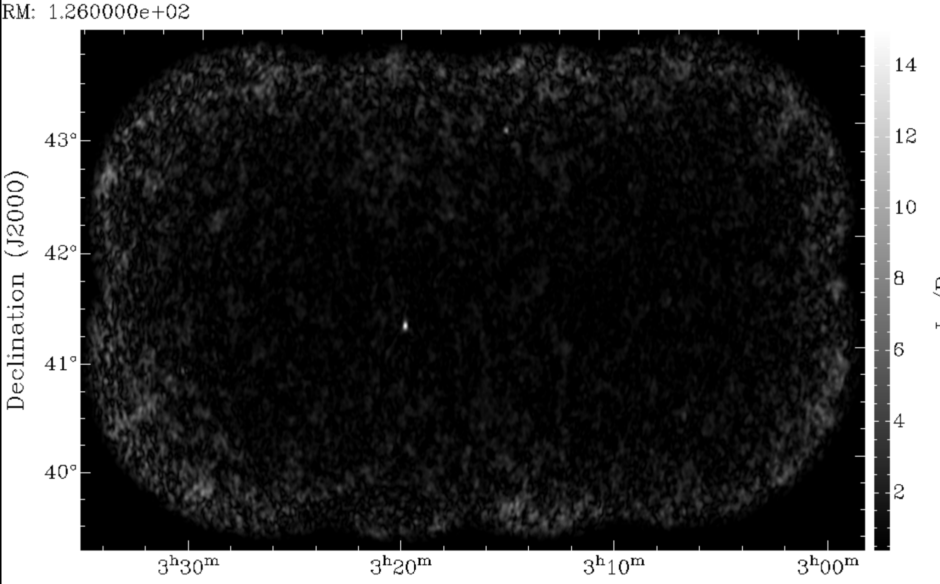

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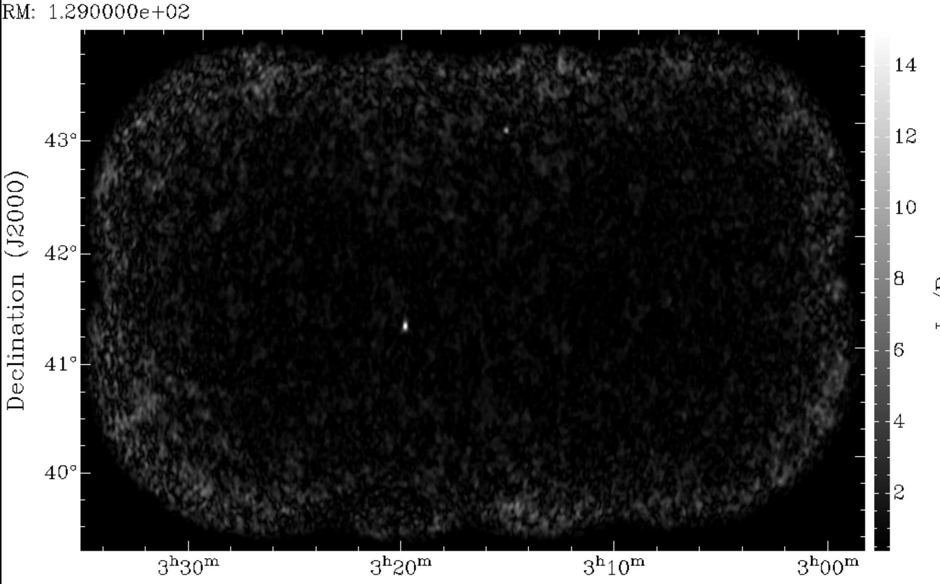

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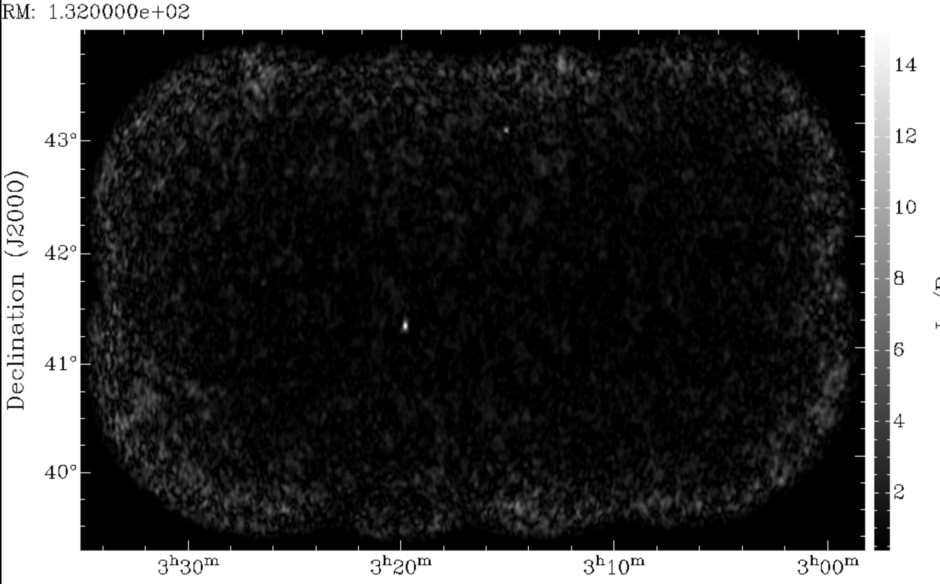

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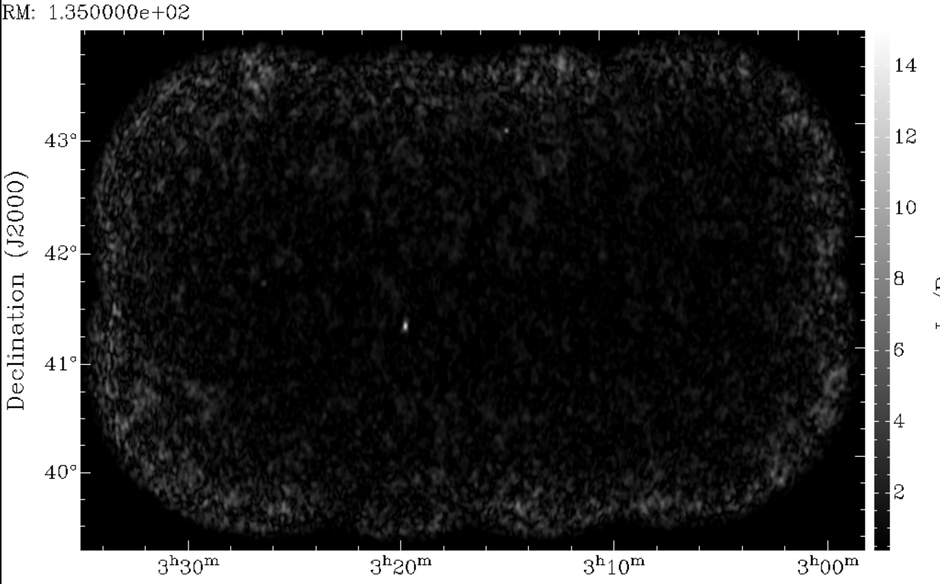

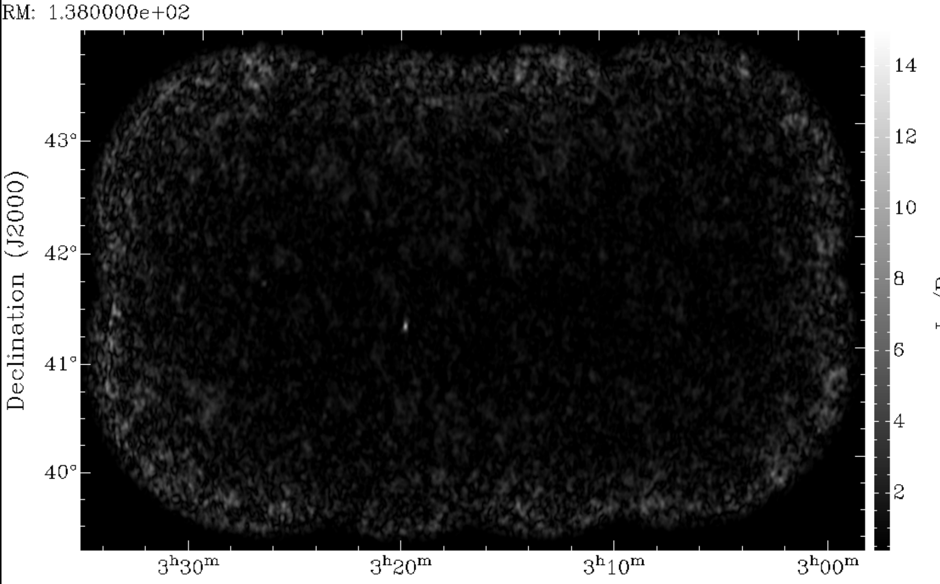
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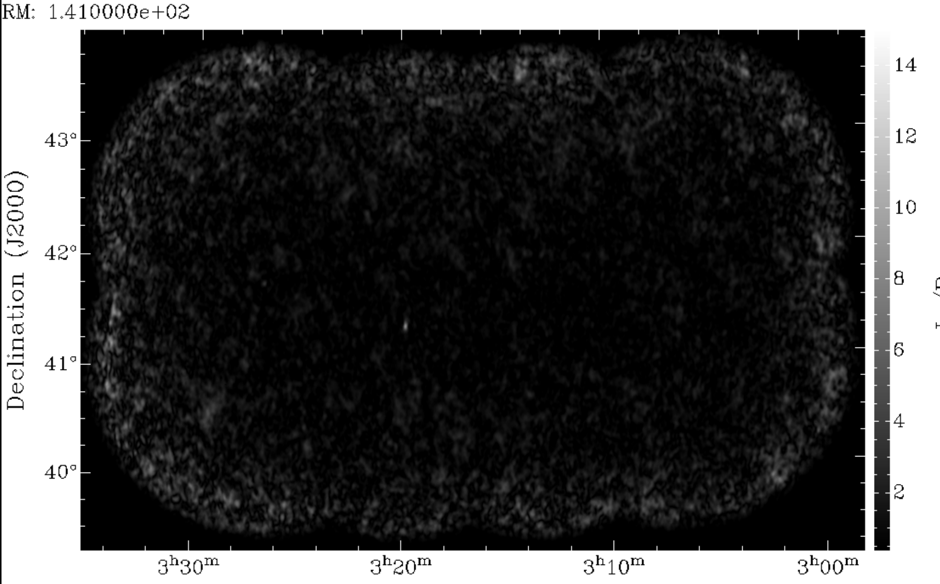

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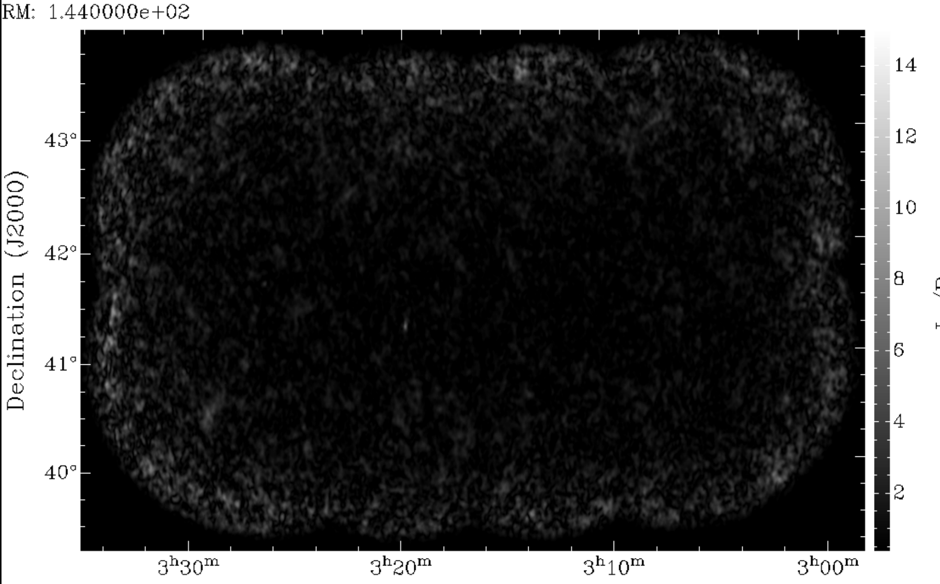

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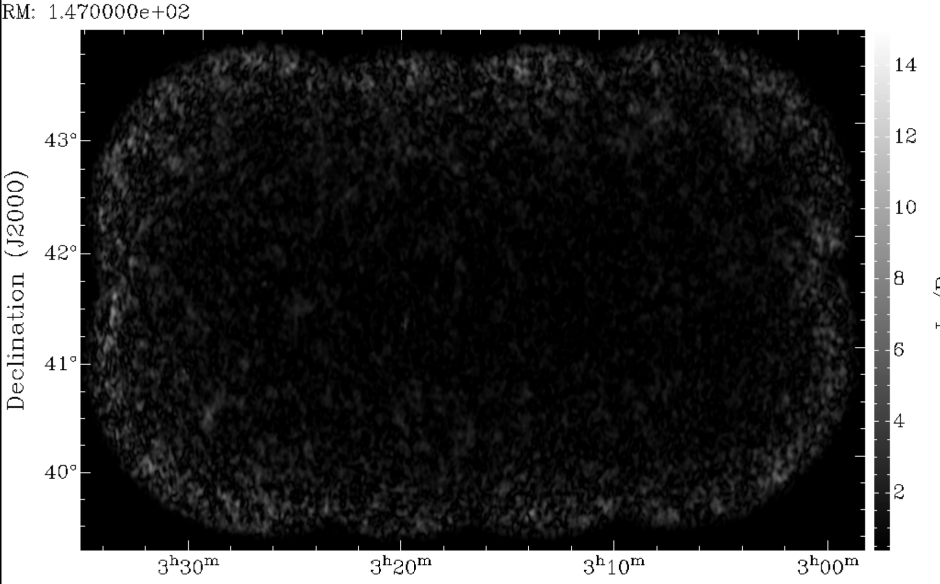

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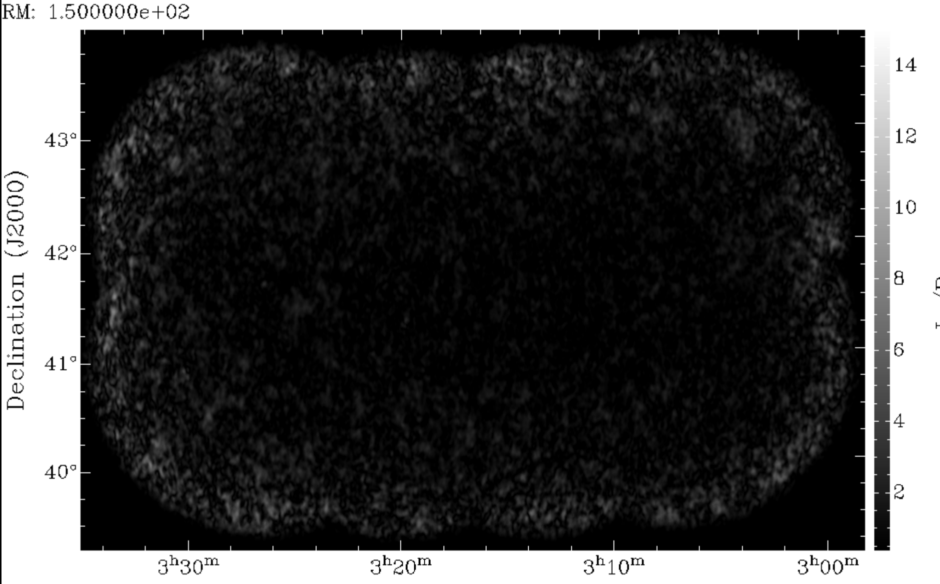

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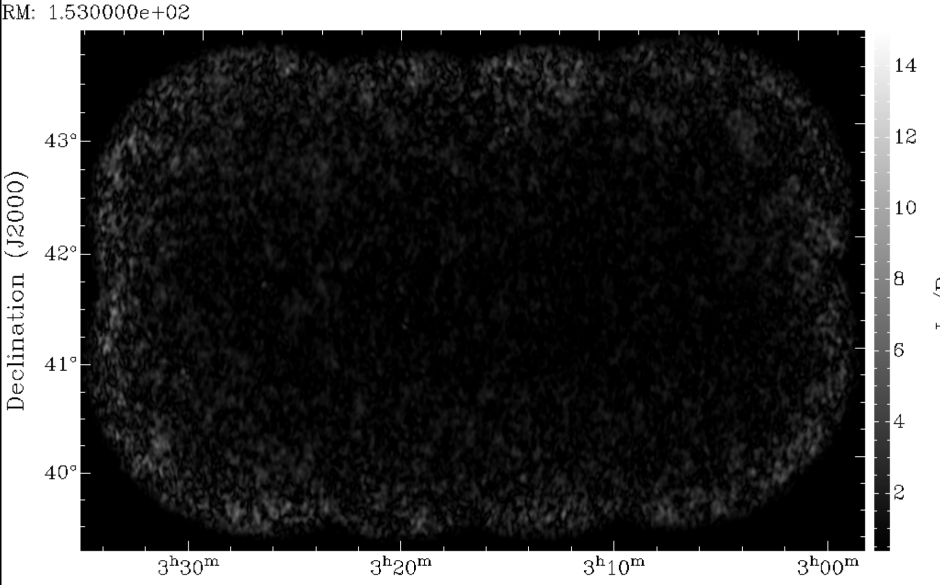

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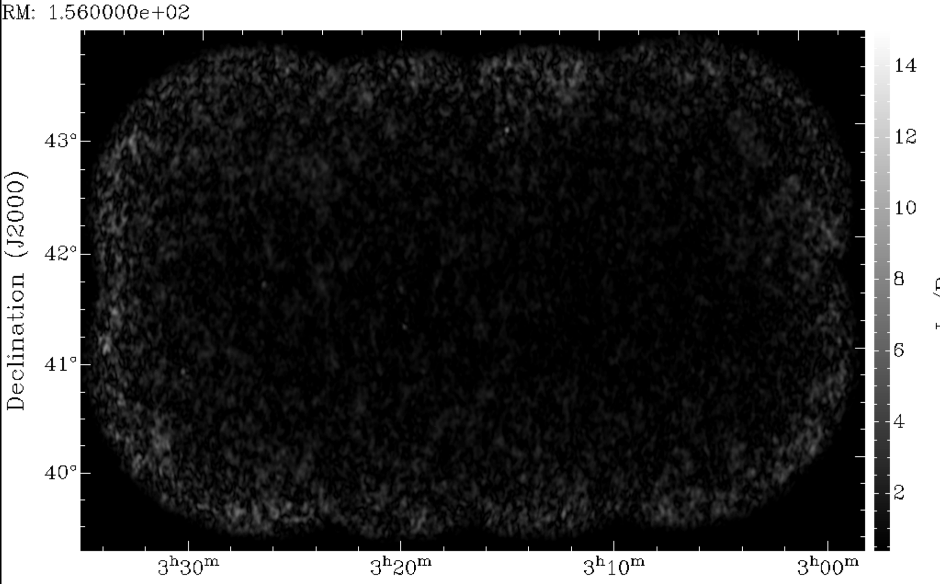

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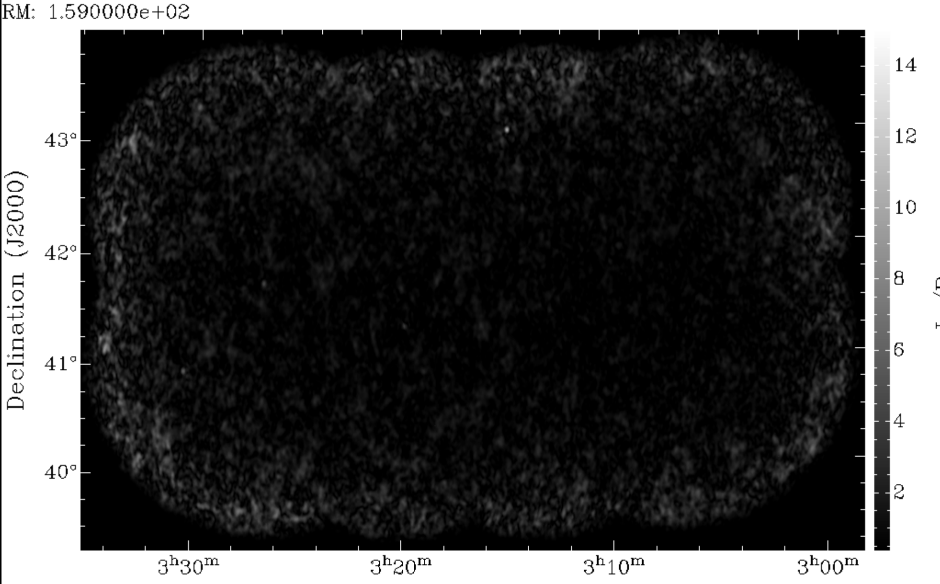

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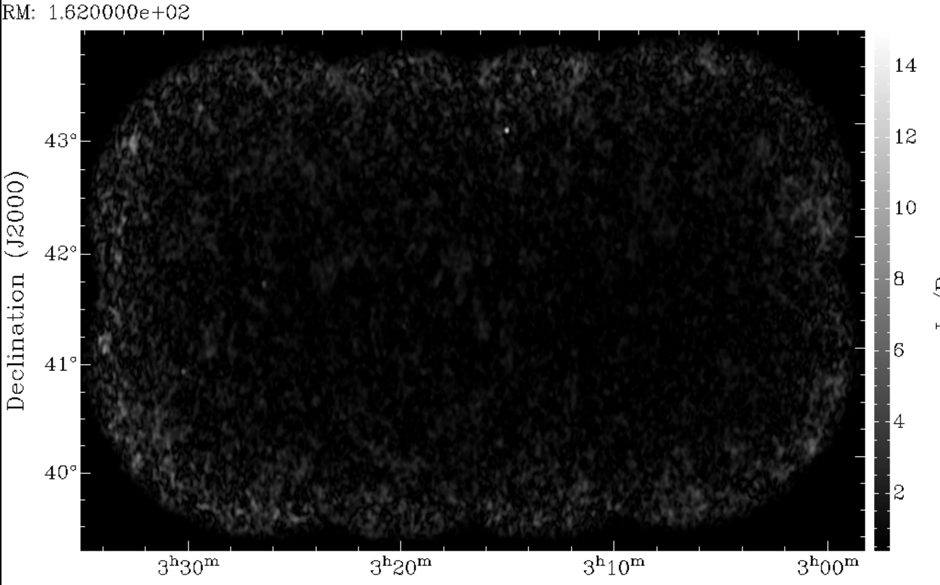

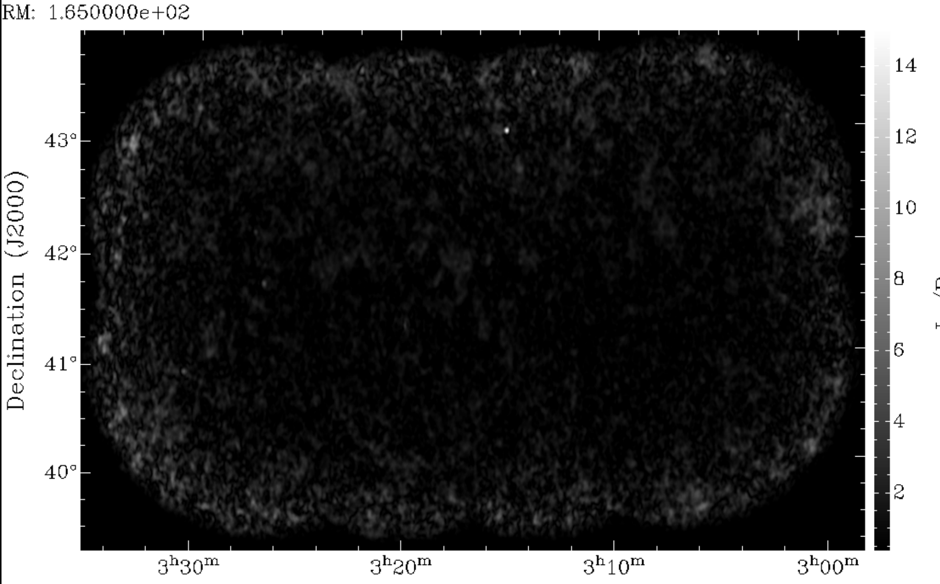
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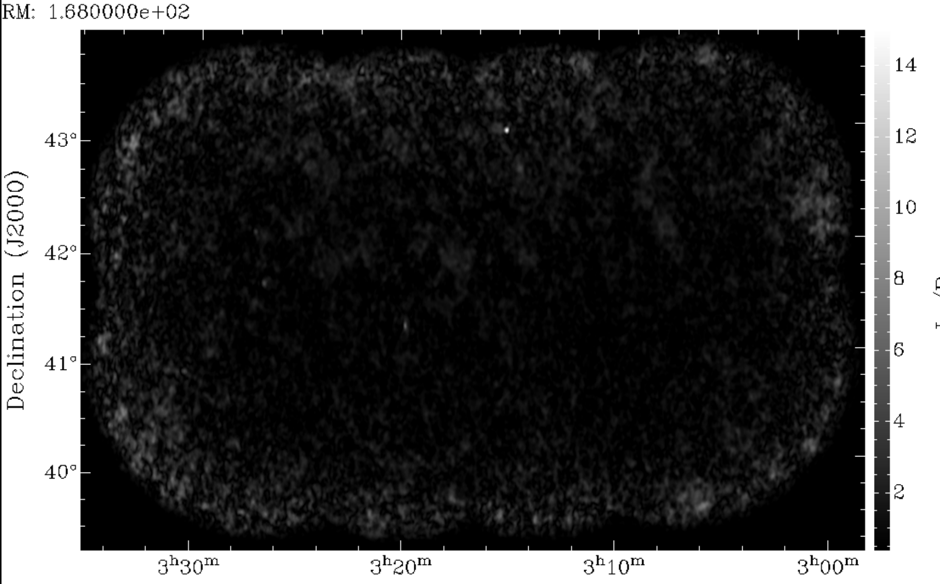

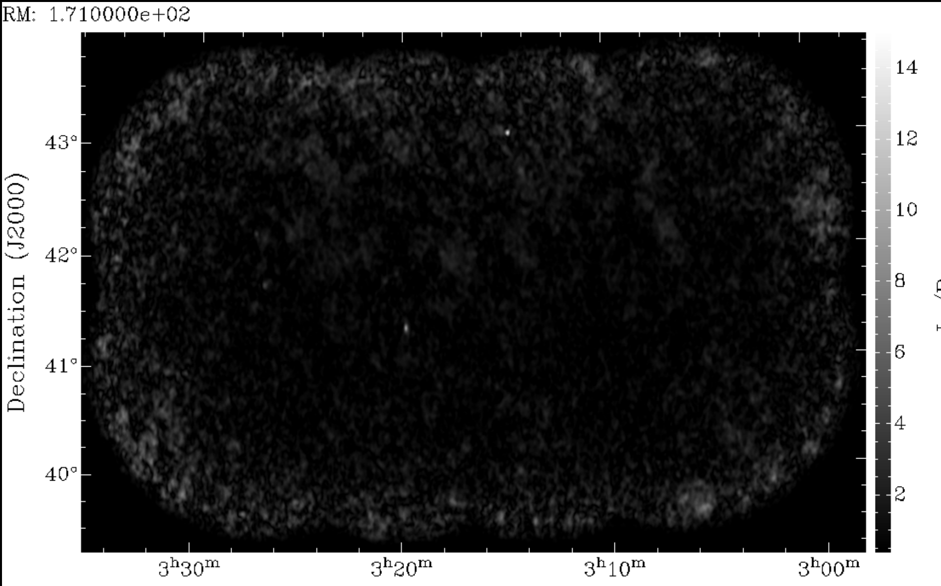
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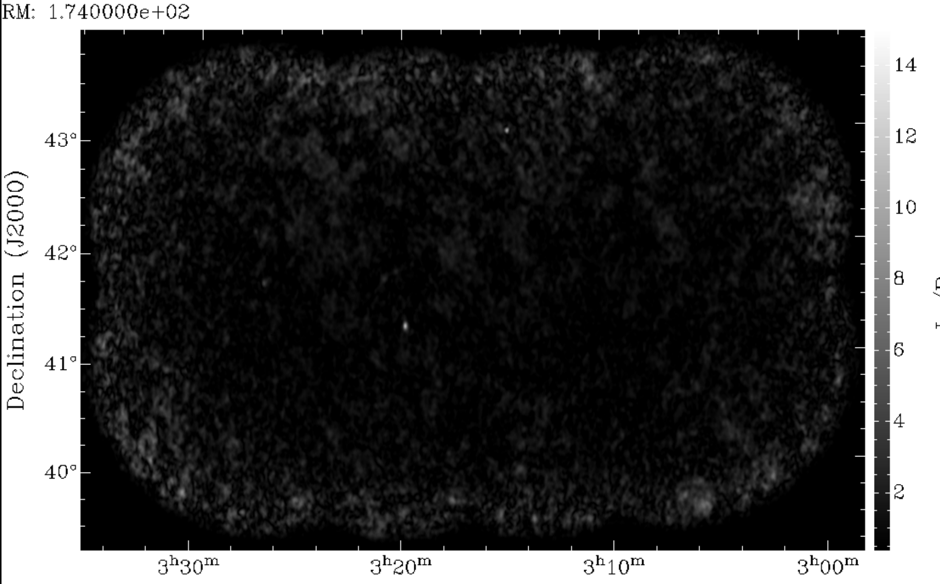
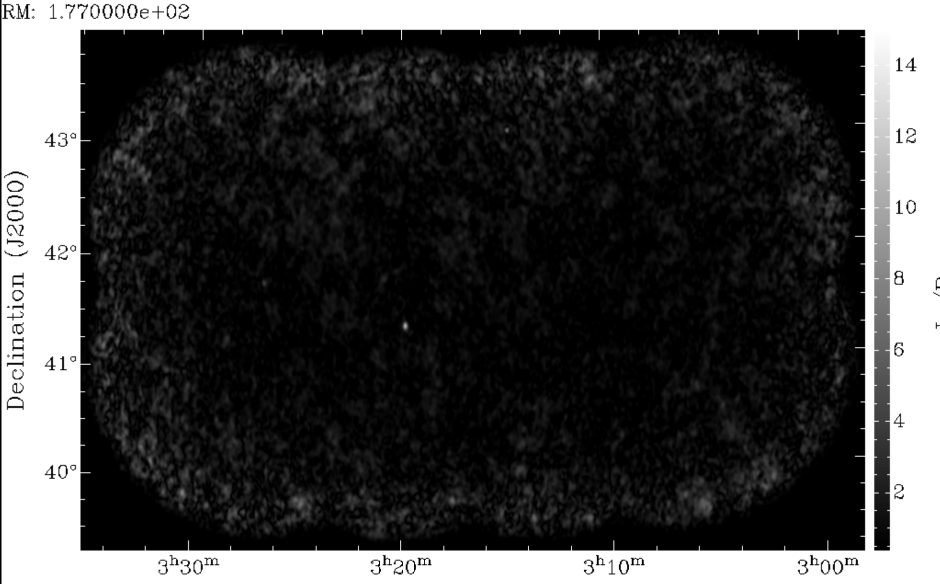
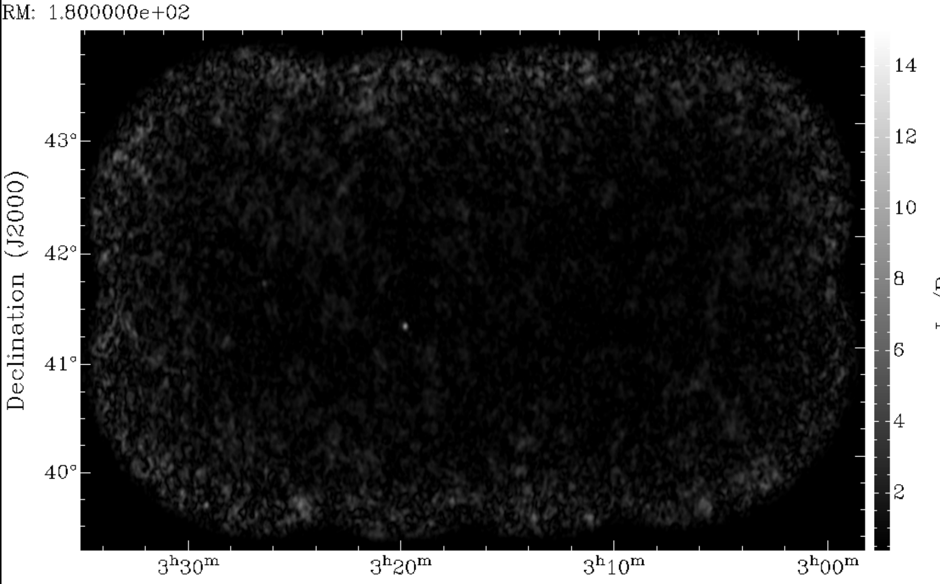
Perseus 2004

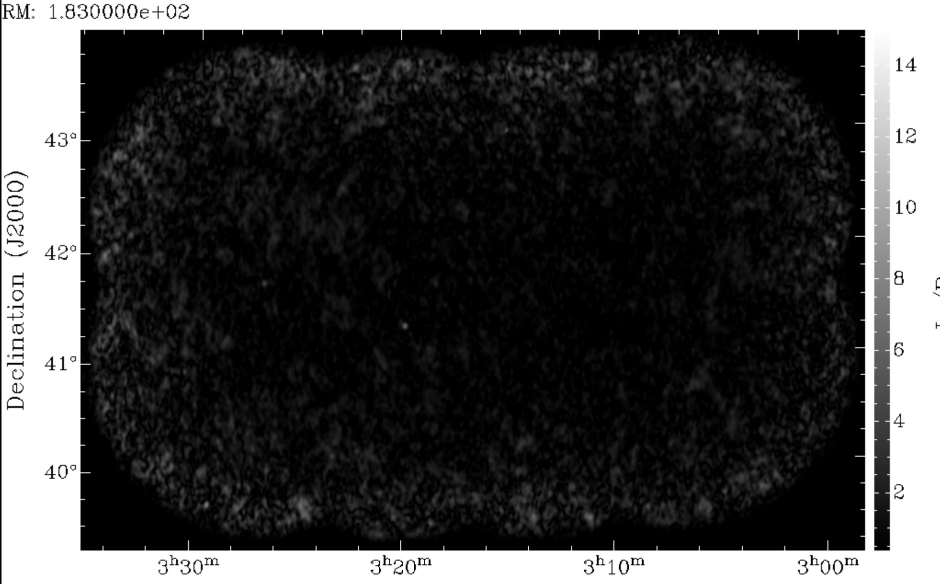


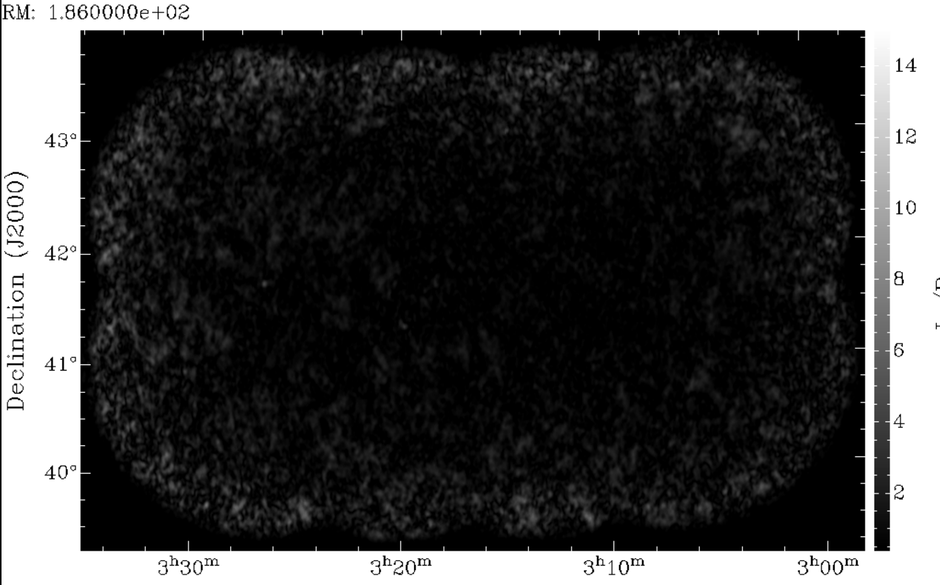
Perseus 2004




RM: 1.800000e+02
Declination (J2000)
43°
42°
41°
40°
3h30m
3h20m
3h10m
3h00m
14
12
10
8
6
4
2

Perseus 2004

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Declination (J2000)
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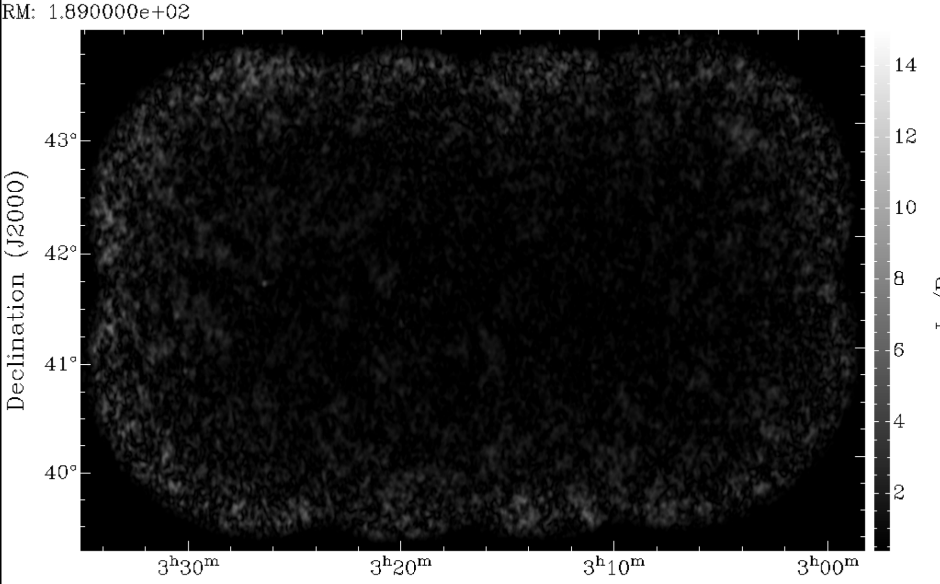
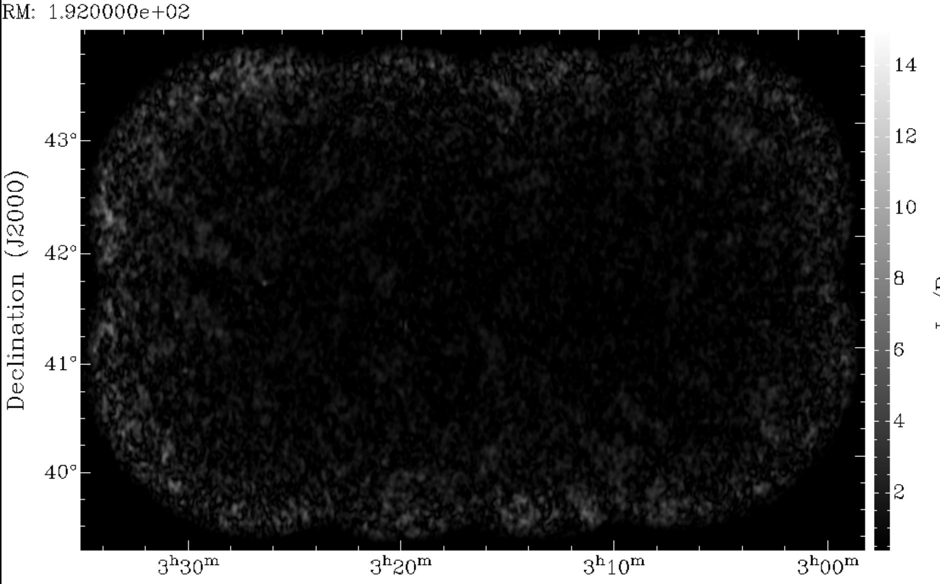
42°
41°
40°
3h30m
3h20m
3h10m
3h00m
14
12
10
8
6
4
2

Perseus 2004



Perseus 2004



Existing, but unpublished/(un?)processed data

- WSRT at 150 MHz (Low Frequency Frontends / LFFEs 2005
- WSRT at L-band 2004 6x 12h
- WSRT at L-band (MFFE test with Tom Oosterloo, see Morganti)
- LOFAR (nov 2013)