Parsec scale Faraday rotation measures in 20 AGN jets

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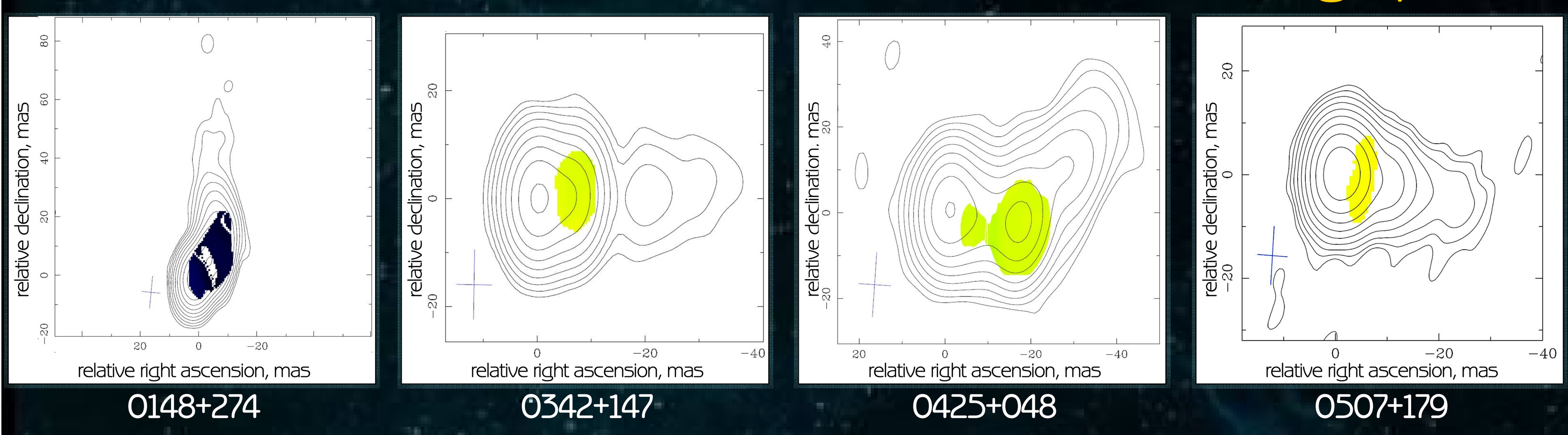
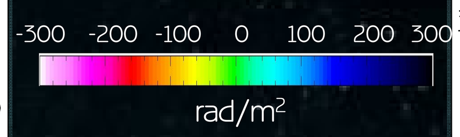
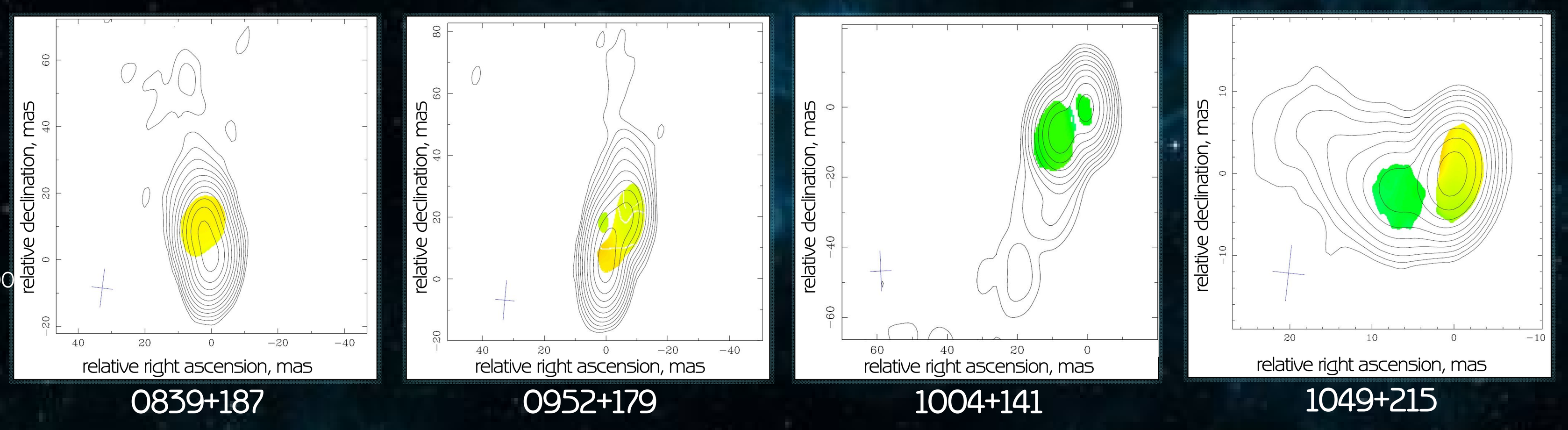
Magnetic field is a key item in driving of the AGN jets. Simultaneous multi-frequency observations are challenge for mapping of magnetic field geometry and determination of rotation measure for probing physical conditions of matter surrounding the jet.

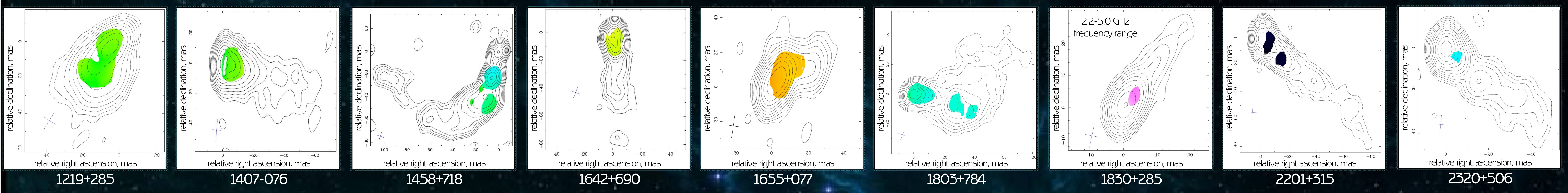
We present the parsec-scale Faraday rotation measure (RM) properties of 20 active galactic nuclei (AGN), observed with the NRAO VLBA simultaneously at 9 frequencies from 1.4 to 15.4 GHz in the full polarization mode. This sample [Sokolovsky 2011] represents sources with large apparent frequency-dependent core shifts and bright parsec-scale jets.

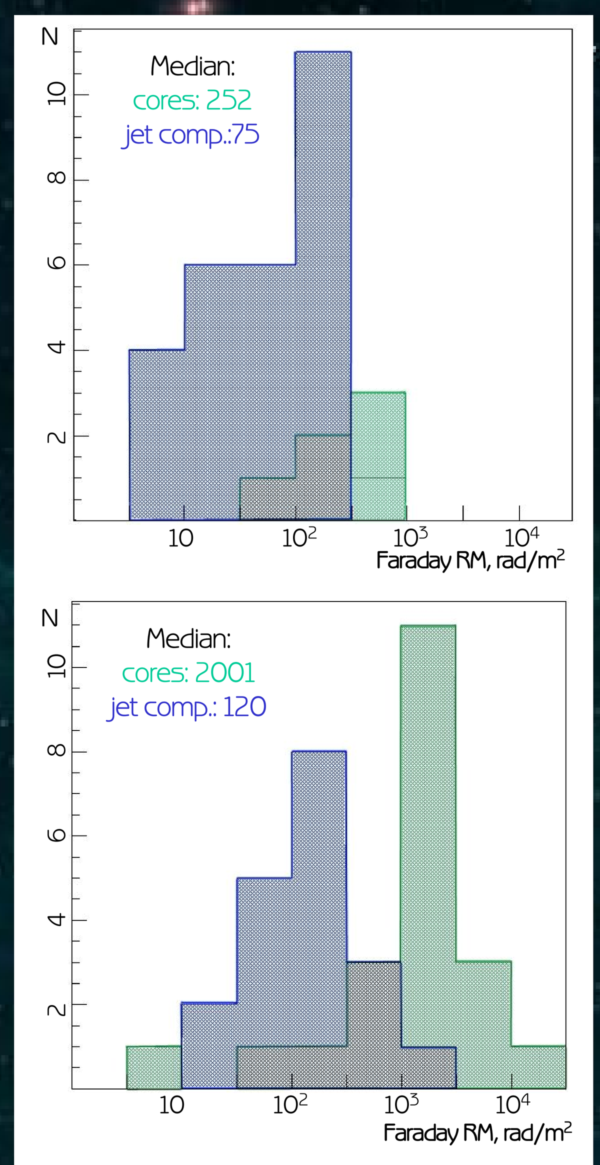


Block of figures 1.
Faraday RM maps at 1.4-2.4 GHz range, until otherwise noticed with the following colour RM range:









Block of figures 2. FRM distribution in rest frame of the sources for distant (upper) and core (bottom) components at low (blue) and high (green) frequencies.

Faraday rotation measure results

Assumption that Faraday rotation happens in the external to the source screen is found to be the case for a majority of our sources, meaning linear dependence of EVPA on square wavelength λ. Because of substantial depolarization across the beam and changing opacity in some regions, for a majority of our sources dependence of EVPA vs. λ^2 meets linear criteria at low (1.4-2.4 GHz) and high (4.6-15.4 GHz) frequency intervals separately.

We have succeeded in determination of Faraday RM for 18 sources of the sample. Two of the sources (0610+260 and 1845+797) do not show strong polarized flux in a whole frequency range. On the Block of figures 2 obtained RM statistics in the rest frame of the sources are shown for jet and core regions separately at low and high frequencies. Thus we confirm results of other authors [e.g. Trippe 2012] – high RM values can be detected only at short λ and in the cores, indicating the presence of stronger magnetic fields and denser medium upstream the jet.

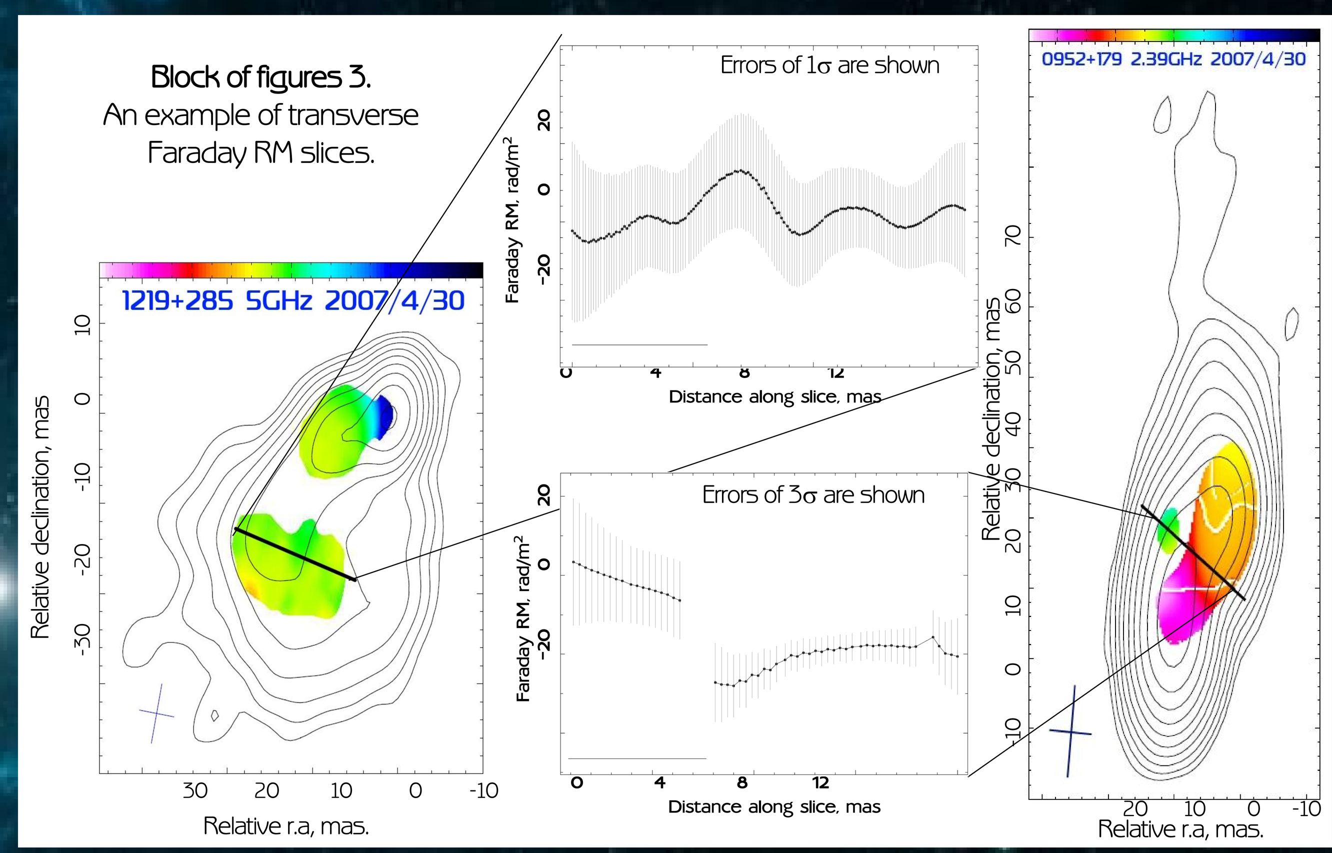
Our results confirm previous findings [Hovatta 2012, Zavala 2003, O'Sullivan 2009]: we do not see significant changes in the values of Faraday RM both in a core and distant components on time scales of the several years. This supports the assumption that observed Faraday rotation occurs mainly in external to jet medium.

Reconstruction of 3D field geometry

For 16 sources we were able to map Faraday RM in the core region. Analysis of Faraday-corrected maps of EVPAs for them shows, that in 11 cases we see parallel and in 5 cases perpendicular E-field to the jet direction. Such behavior can be accounted for by illuminating of front and rear of emitting regions of jets with different pitch angles [e.g. Algaba 2013].

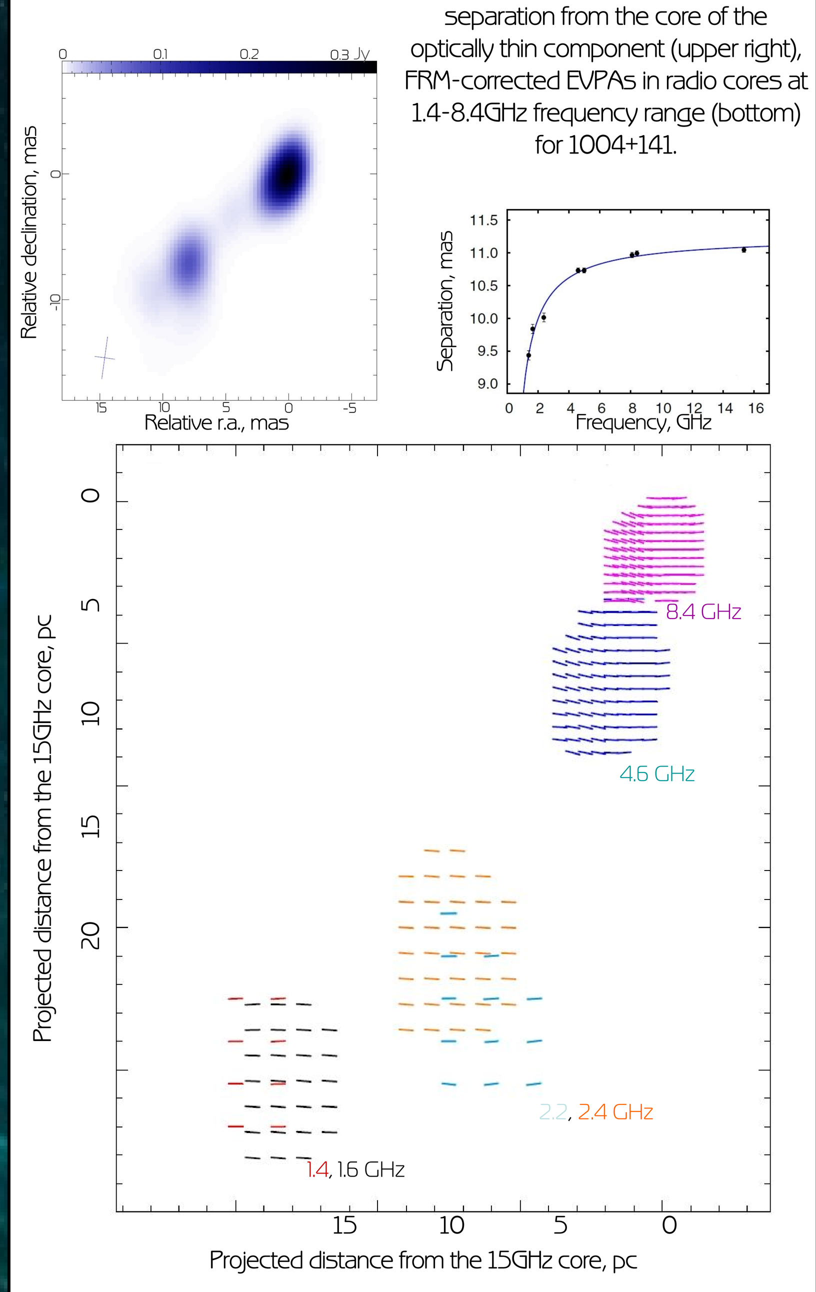
Assuming radial dependence of a magnetic field and squared decrease of electron density with a distance from a central engine [Lobanov 1998] one can translate positions of optically thick components at different frequencies to an absolute distance (in a projection on a sky plane). Thus we can recover 3D geometry of parsec-scale magnetic field in a jet base. As an example, on the Block of figures 4 reconstructed magnetic field geometry is shown for 1004+141 in 1.4-8.4 GHz range in a projection on a sky plane. It indicates to the existence of global poloidal magnetic field at least 112 pc in length.

Block of figures 3.
An example of transverse Faraday RM slices.



Block of figures 4.

Total intensity map (upper left), separation from the core of the optically thin component (upper right), FRM-corrected EVPAs in radio cores at 1.4-8.4GHz frequency range (bottom) for 1004+141.



Transversal gradients

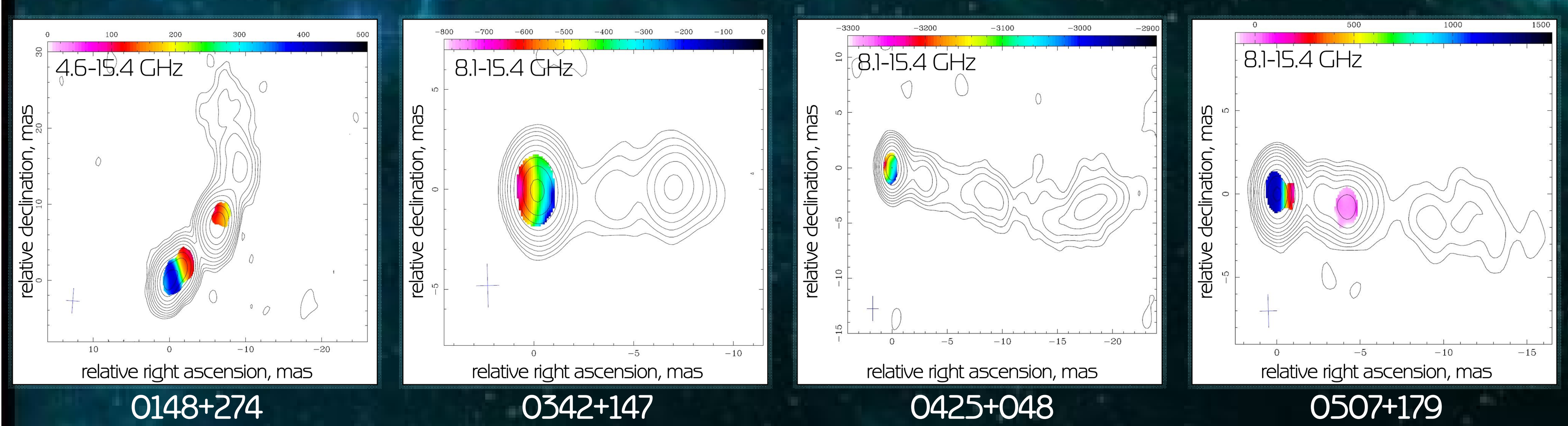
If helical magnetic field is presented in the jet, its toroidal component will produce transverse RM gradient. So far this effect was found only in a handful of source and still remains controversial [e.g. Zavala 2005, Hovatta 2012] The following criteria were used in this paper to avoid confusion between the real and spurious RM gradients [Algaba 2013, Hovatta 2012, Taylor 2010]:

- polarized flux with the value more than 3 sigma;
- only slices with the size of 1.5 beams and larger;
- only regions located more than 1 beam downward the jet.

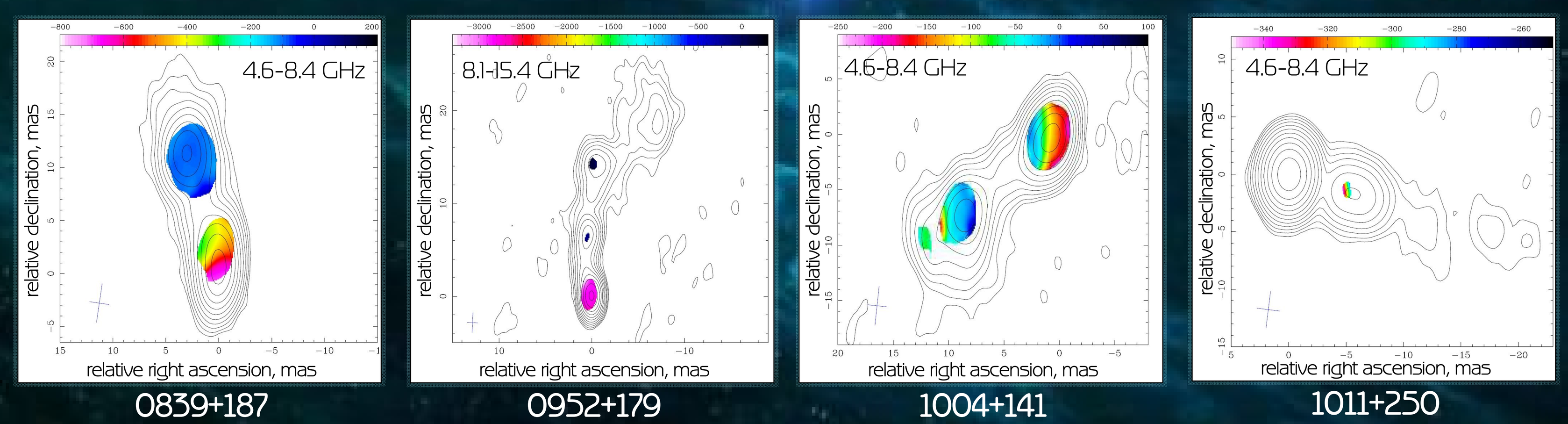
All constructed RMs maps are shown on the Block of figures 1 and 5. For the 17 out of 36 cases we have transversal slices wider than 1.5 beam size. For 7 of them we see changes in a RM at 1 sigma level and for none of them by at least three times the typical error. Two examples of transversal RM slices are shown on the Block of figures 3.

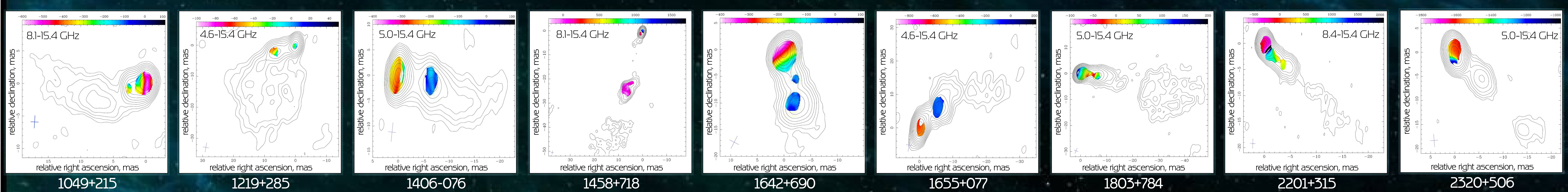
To do

- construction of 3D-maps of magnetic filed for all targets with detected FRM;
- estimation of a dependence of FRM on frequency in core regions, which can give us restrictions on magnetic field geometry and behavior of electron density;
- supplementation of the analysis by higher frequency measurements.



Block of figures 5.
Faraday RM maps at high frequency range, indicated on each of the figure (colour bars are in rad/m²).





Literature

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