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Comparative evaluation of METIS image compression algorithms

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Title and Authors

Comparative Evaluation of METIS Image Compression Algorithms

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1 Abstract

This report is aimed at evaluating the errors introduced by different compression algorithms and compression factors for the METIS images. Three different algorithms (TER, JPEG-LS and JPEG-2000) with three different compression factors (5, 10 and 15) were analysed and compared. We conclude that the TER compression algorithm have to be excluded, because of large errors and artificial features introduced even for low compression factors (5). JPEG-LS and JPEG-2000 algorithms are equivalent (almost lossless) for low compressions (5), while for larger compression factors (10, 15) the JPEG-2000 algorithm produces smaller errors with respect to the JPEG-LS algorithm.

2 IMAGE COMPRESSION ALGORITHMS

This document is aimed at describing the possible effects of data compression in the images acquired with the Visible Light (VL) channel of the METIS instrument. To this end, we applied the following methodology: as input data we employed the images acquired by the Turin Observatory (OATo) Team with the Liquid Cristal Tunable filter Polarimeter (LCTP) during the 2006 total solar eclipse observational campaign (Libia). In particular, 4 different images, acquired with 4 different polarization stages, have been provided to the Politecnico di Torino (PoliTo): Mosaic_4.5V.fits, Mosaic_5.4V.fits, Mosaic_7V.fits and Mosaic_10V.fits. Numbers in each filename followed by a "V" letter indicate the different voltages applied to the LCTP, providing different orientations of the polarization vector. Moreover, the resulting polarized Brightness (pB) image computed with the above Mosaic images (file pBseq2.fits) has been also provided to the PoliTo Team for compression.

Each one of these 5 images (4 with different polarization angles and 1 pB image) has then been compressed and de-compressed again by the PoliTo Team. Image compression has been performed with 3 different compression algorithms: JPEG-LS, TER and JPEG-2000. For each one of these 3 compression algorithms, the PoliTo Team provided images resulting from 3 different compression factors: 5, 10, and 15. Hence a total of 45 compressed and de-compressed images were released by PoliTo. Algorithm names and compression factors were added at the end of the fits file name, after the voltage, so that for instance Mosaic_7V10ter.fits file contains the Mosaic_7V.fits image compressed with TER algorithm with a compression factor 10. Moreover, PoliTo provided the same input images rescaled to 16 bit level and quantisized (V + algorithm_name in the fits file), in order to compare directly the effects of compression and neglect those due to the discretization.

3 EFFECTS OF DIFFERENT COMPRESSION ALGORITHMS

Compressed and de-compressed images (hereafter C_i , with i=1, 2, 3 for different compression algorithms) have then been compared by the OATo Team with the original uncompressed images (hereafter U_i). Figures 1-3 show a comparison along a radial direction between the original data U_i (acquired with a polarization stage given by 10V - plus symbols) and those resulting from C_i images with the JPEG-LS (Fig.1), JPEG-2000 (Fig.2) and TER (Fig.3) compression algorithms for compression factors by 5 (dashed lines), 10 (solid lines) and 15 (dotted lines). In order to better show the effects of compression in the single images, relative differences D_i between the compressed and original images, i.e. $D_i = | C_i - U_i | / U_i$ (%), are shown in the subsequent Figures for the JPEG-LS (Fig.4), JPEG-2000 (Fig.5) and TER (Fig.6) compression algorithms. In each Figure we show the images D_i for compression factors by 5 (bottom left panel), 10 (top left), and 15 (top right), together with the original U_i image (bottom right). Relative images are plotted with a linear color scale (ranging from 0% to 40% of relative difference), while the original image is plotted with a logarithmic scale (ranging from -9 to -6).

Because the polarized Brightness (pB) and coronal electron densities will be estimated combining images acquired with different polarization stages, it is important to compare not only how different compression algorithms affect a single image, but also how differences between images acquired with different polarizations are affected, in order to quantify the effects on diagnostic capabilities. To this end, subsequent images show the 2D distribution of quantities DD_i defined as

$$DD_i = | \, |C_i \, (10V) - C_i \, (4.5V)| - |U_i \, (10V) - U_i \, (4.5V)| \, | \, / \, |U_i \, (10V) - U_i \, (4.5V)| \qquad (\%)$$

Quantities DD_i represent the relative variation between a polarization difference image computed for 2 different polarization stages with C_i images and the same difference image computed with the original U_i images. Quantities DD_i are shown in the subsequent Figures for the JPEG-LS (Fig.7), JPEG-2000 (Fig.8) and TER (Fig.9) compression algorithms. In each Figure we show the images DD_i for compression factors by 5 (bottom left panel), 10 (top left), and 15 (top right), together with the quantities DD_i computed with the original U_i images (bottom right). Relative images are plotted with a linear color scale (ranging from 0% to 50% of relative difference), while the original DD_i images are plotted with a logarithmic scale (ranging from -10 to -7).

In order to also test the effects of compression directly on the resulting pB images, relative differences D_i have been also computed with the compressed and decompressed pB images. Subsequent Figure (Fig.10) show the resulting $D_i(pB)$ images (1%) for the JPEG-2000 (top left), JPEG-LS (top right) and TER (bottom left) compression algorithms, all for a compression factor of 5, together with the original pB image (bottom right panel).

4 ANALYSIS AND CONCLUSIONS

Figures 4-6 show that different compression algorithms introduce different degradations producing different artificial patterns in the resulting de-compressed images. In particular: TER and JPEG-2000 compressions result in what one may expect by binning the image along almost concentrical circular areas and over square boxes, respectively, while the JPEG-LS compression produces a binning only along a single axis (the X axis in Figures provided here). Taking into account the typical radial shape of coronal structures, we may conclude from Figs. 1 and 4 that the JPEG-LS compression algorithm is not suitable for our purposes if compression factors by 10 and 15 are employed, while this algorithm could be employed for small compression factor (5). Figs. 2 and 5 show that the JPEG-2000 compression is almost not sensitive to the shape of coronal features (streamers), while Figs. 3 and 6 show that the opposite occurs for the TER compression algorithm, that produces artificial "shadows" basically aligned with the coronal streamer boundaries. These artificial features are produced by the TER compression even for a low (5) compression factor. This suggests that the TER compression algorithm is not suitable for our purposes for any compression factor.

Images simulating the effects of compression on the capability of pB determination and density diagnostic (Figs. 7-9) clearly confirm that TER compression algorithm will also introduce large errors even for a low (5) compression factor. The same occurs also for pB image, as shown by Fig. 10: errors (up to 1%) introduced by the JPEG-2000 and JPEG-LS TER algorithms are comparable, while errors introduced by the TER algorithm are much larger. This leads us to exclude the TER compression algorithm. In order to understand if larger errors will be introduced by the JPEG-LS or the JPEG-2000 compression algorithms, Figure 11 shows the difference DD_i (JPEG-LS) – DD_i (JPEG-2000) (%) between quantities DD_i computed with a compression factor by 5 (top), 10 (middle) and 15 (bottom). This Figure shows that for smaller compression factor (5) both compression algorithms are almost lossless (as also shown by the bottom left panels of previous Figures), while for larger compression factors (10, 15) the JPEG-LS algorithm introduces larger errors with respect to the JPEG-2000 algorithm.

In conclusion: the TER compression algorithm is excluded, because of large errors and artificial features introduced even for low compression factors (5). JPEG-LS and JPEG-2000 algorithms are equivalent (almost lossless) for low compressions (5), while for larger compression factors (10, 15) the JPEG-2000 algorithm produces smaller errors with respect to the JPEG-LS algorithm.

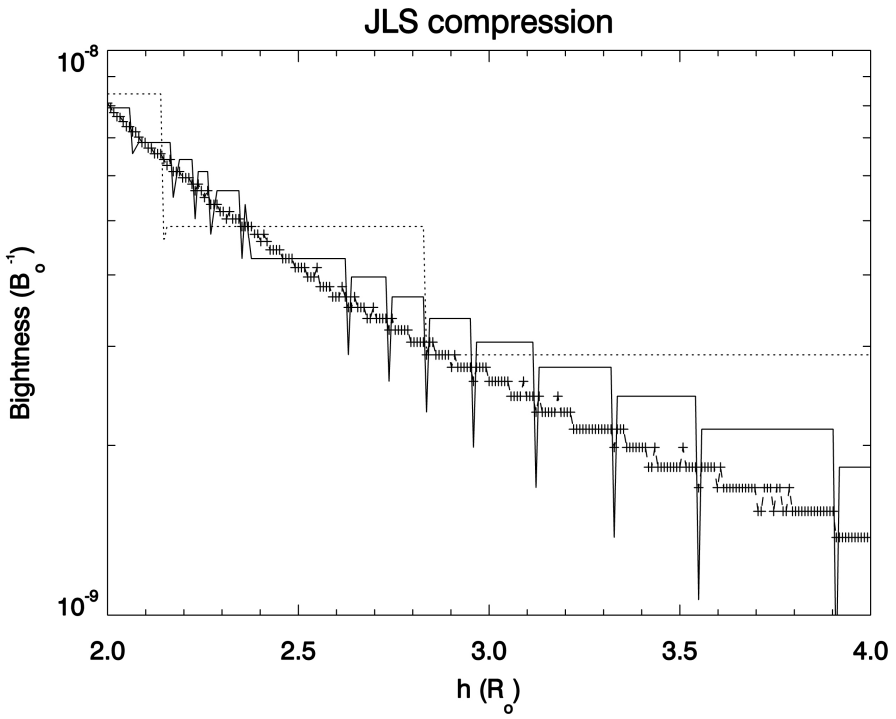

Figure 1: comparison between original data (plus symbols) and data resulting from JPEG-LS compression with a compression factor by 5 (dashed), 10 (solid) and 15 (dotted line).

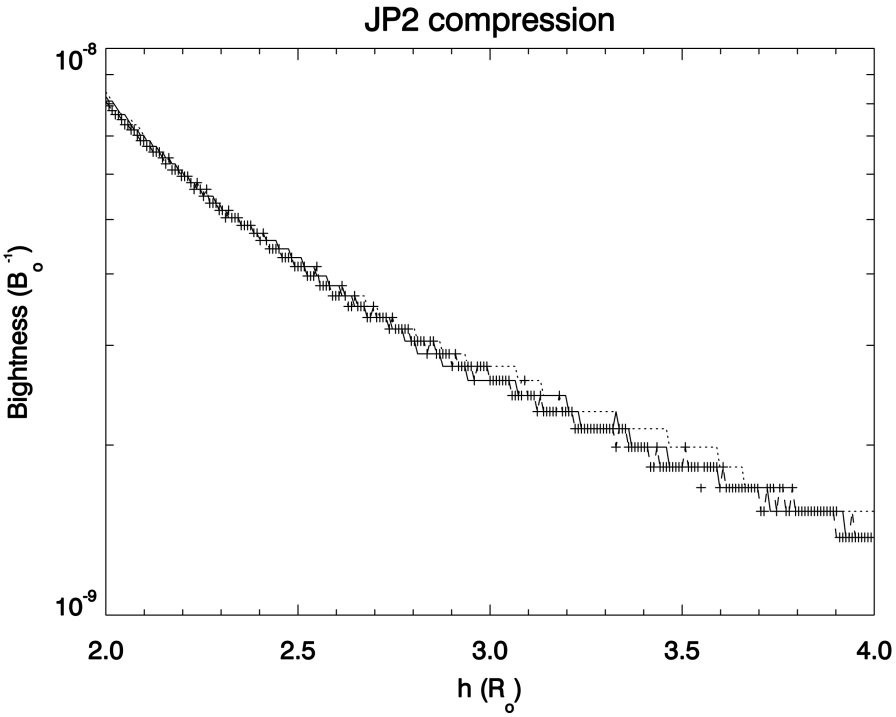

Figure 2: comparison between original data (plus symbols) and data resulting from JPEG-2000 compression with a compression factor by 5 (dashed), 10 (solid) and 15 (dotted line).

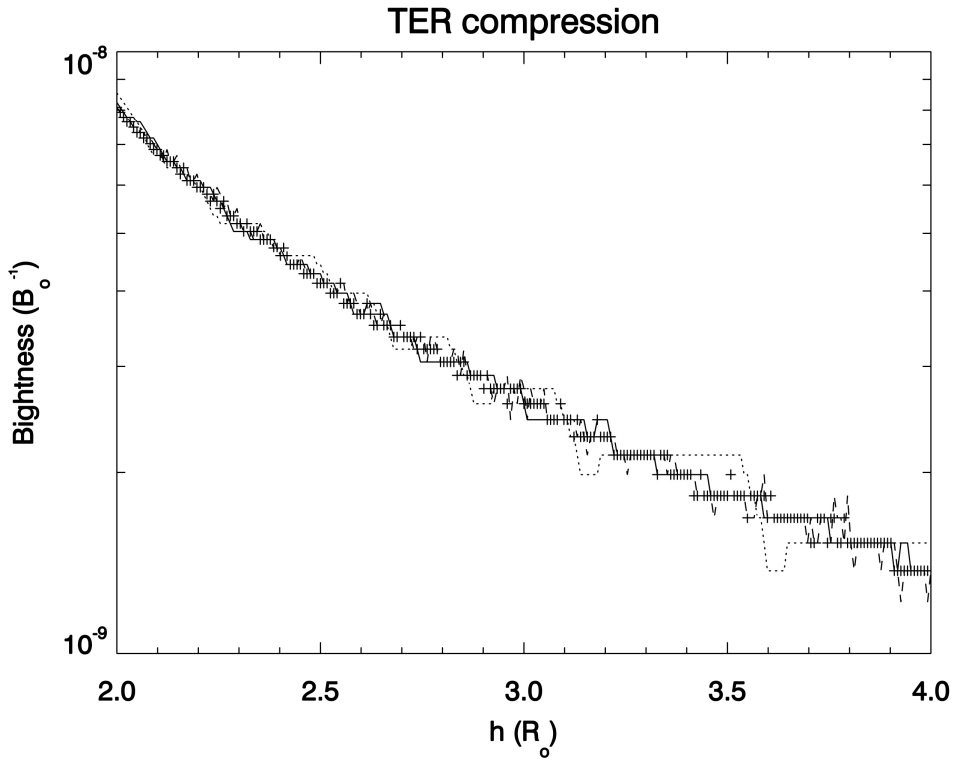

Figure 3: comparison between original data (plus symbols) and data resulting from TER compression with a compression factor by 5 (dashed), 10 (solid) and 15 (dotted line).

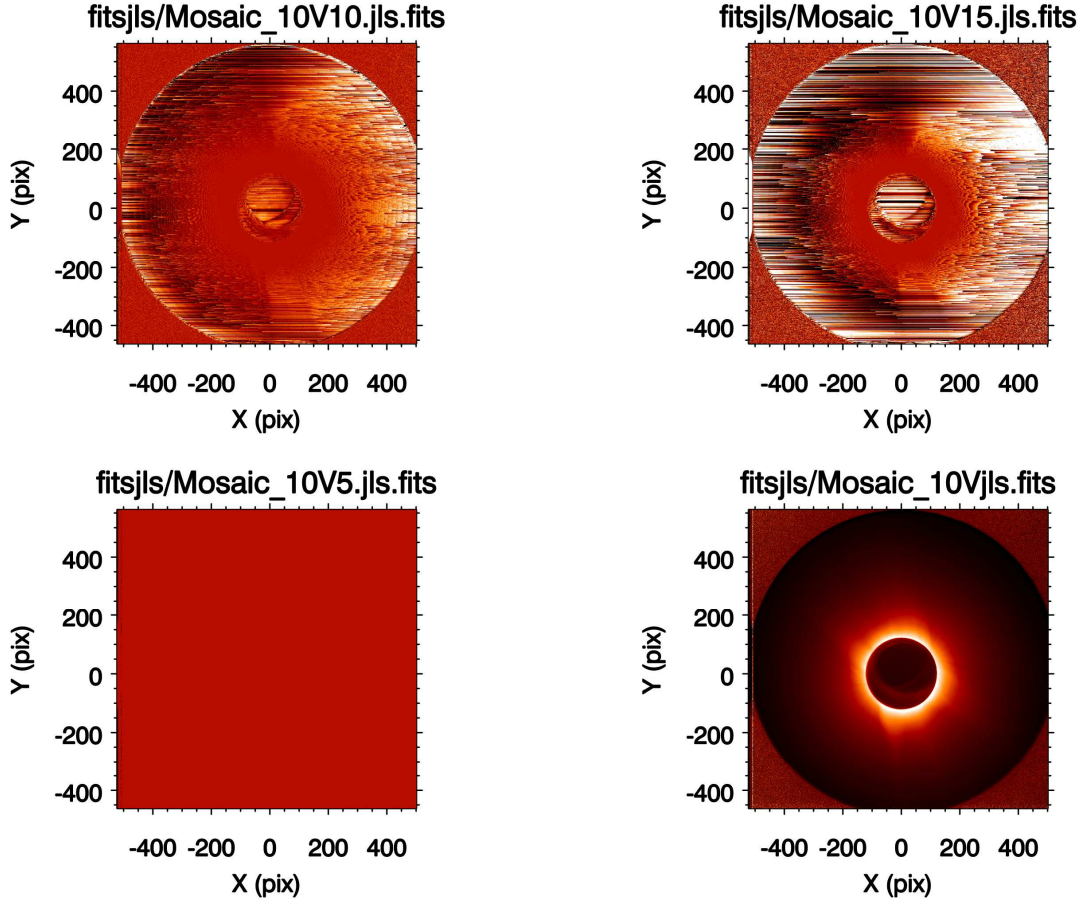

Figure 4: relative differences D_i (0%-40%) for JPEG-LS compression with factors 5 (bottom left, 10 (top left),and 15 (top right) with respect to the original polarized image (bottom right).

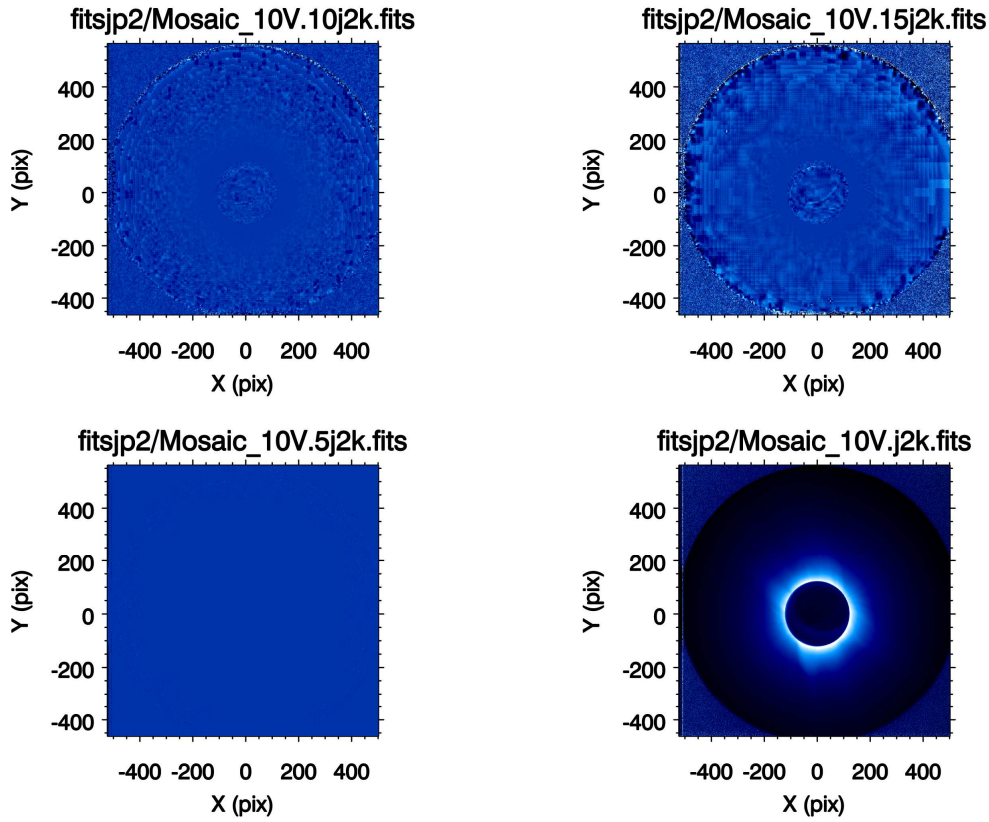

Figure 5: relative differences D_i (0%-40%) for JPEG-2000 compression with factors 5 (bottom left, 10 (top left),and 15 (top right) with respect to the original polarized image (bottom right).

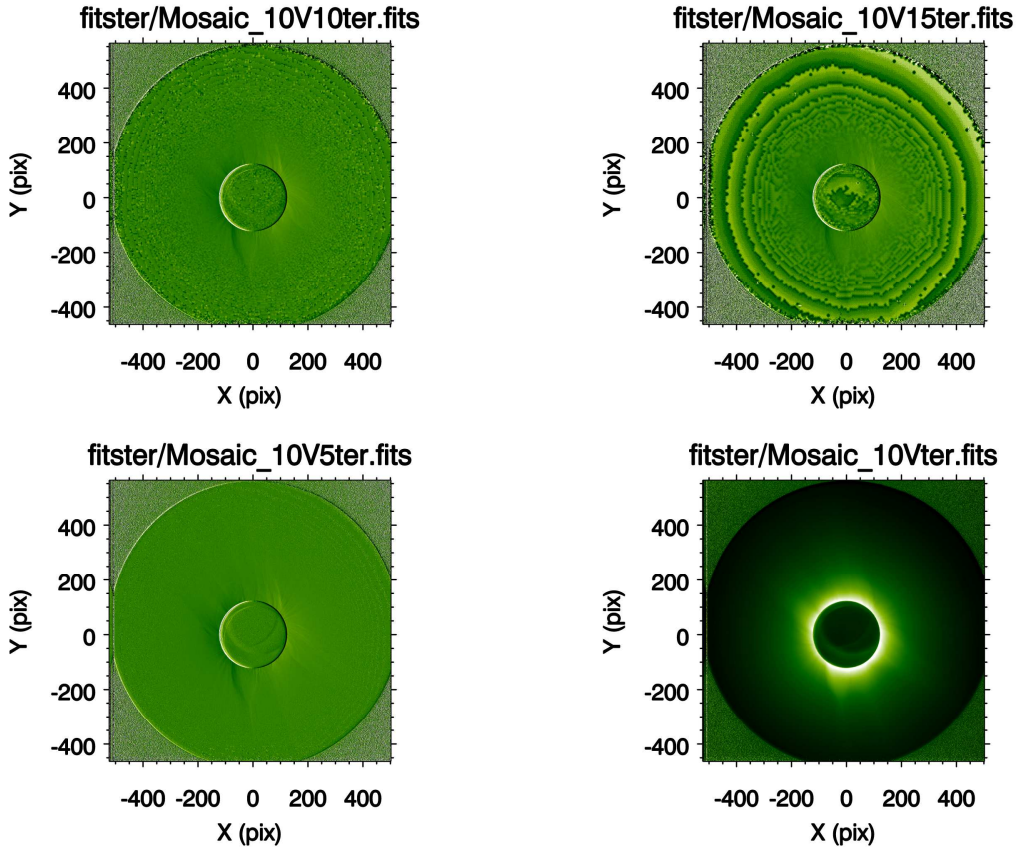

Figure 6: relative differences D_i (0%-40%) for TER compression with factors 5 (bottom left, 10 (top left),and 15 (top right) with respect to the original polarized image (bottom right).

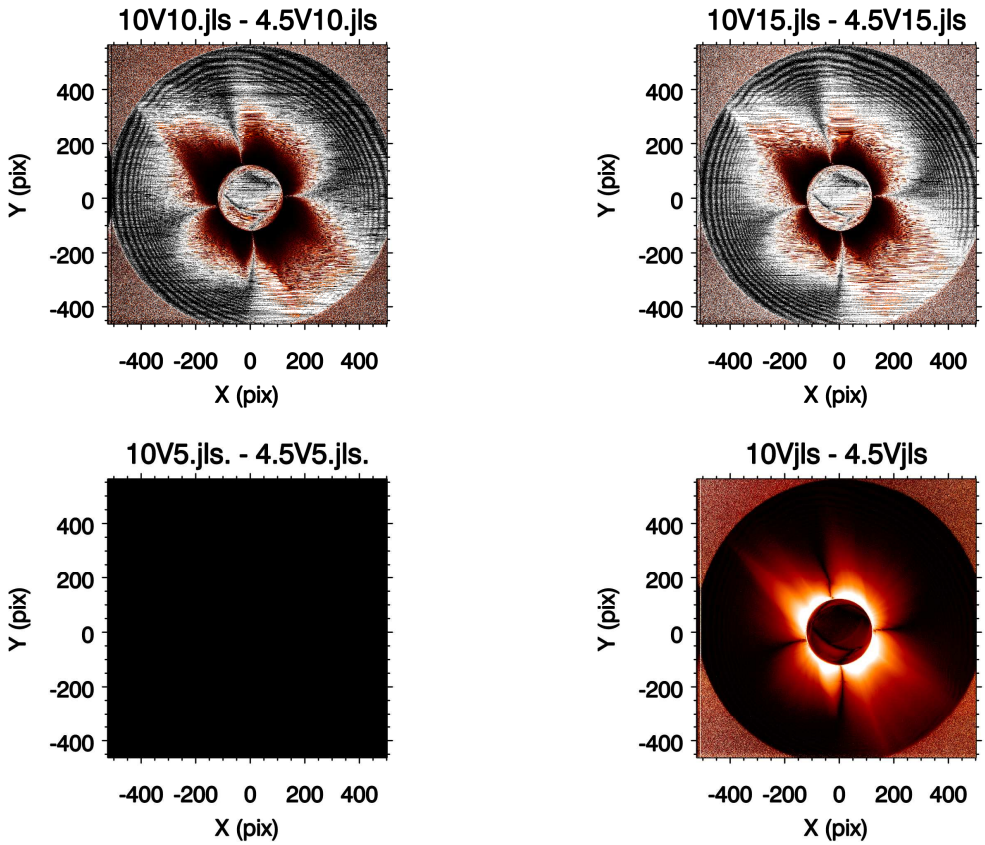

Figure 7: relative differences DD_i (0%-50%) for JPEG-LS compression with factors 5 (bottom left, 10 (top left),and 15 (top right) with respect to the original polarization difference image (bottom right).

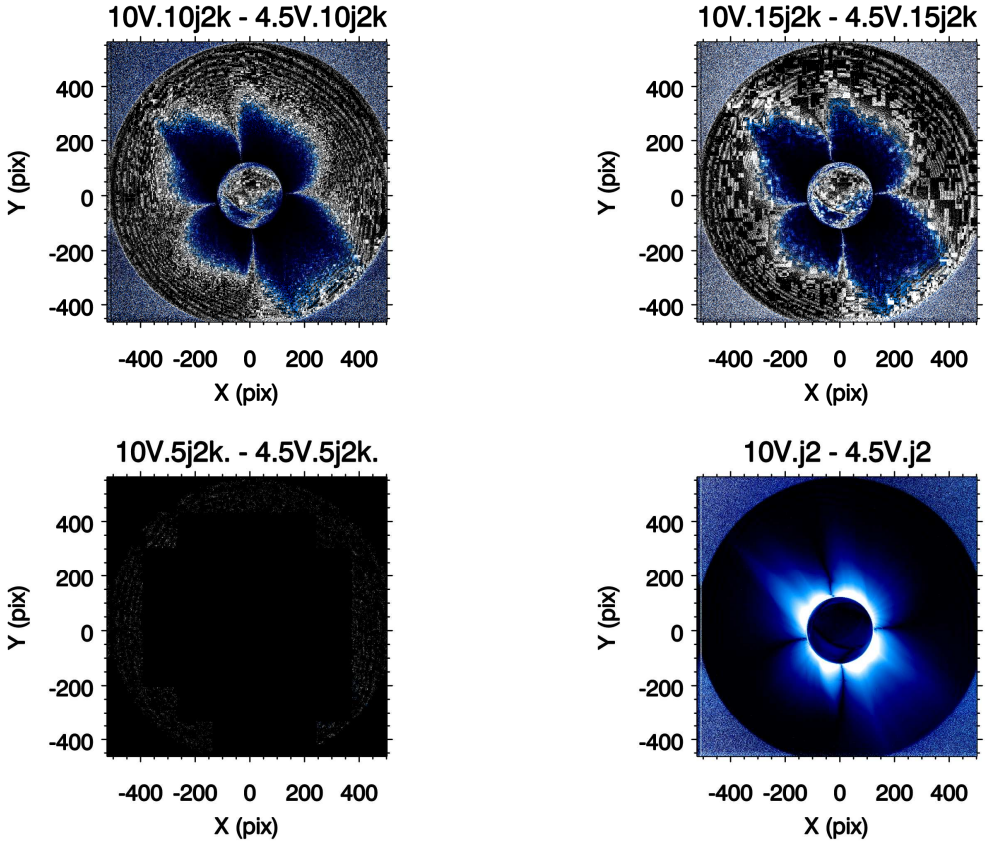

Figure 8: relative differences DD_i (0%-50%) for JPEG-2000 compression with factors 5 (bottom left, 10 (top left),and 15 (top right) with respect to the original polarization difference image (bottom right).

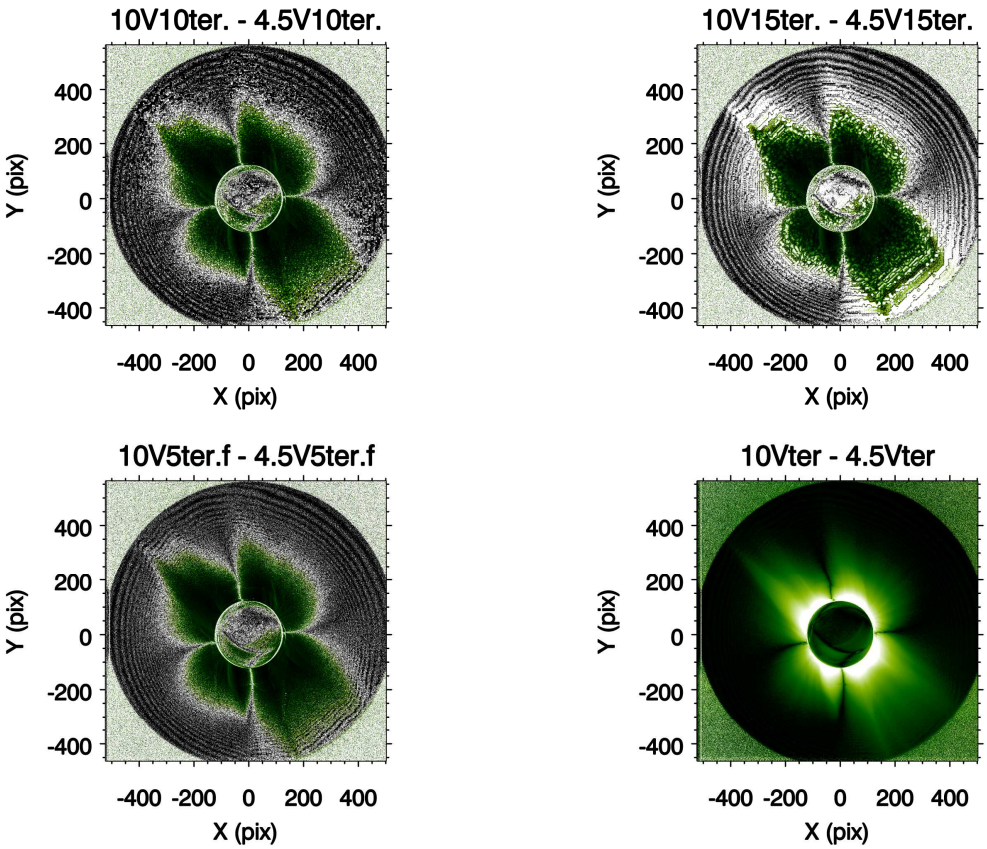

Figure 9: relative differences DD_i (0%-50%) for TER compression with factors 5 (bottom left, 10 (top left),and 15 (top right) with respect to the original polarization difference image (bottom right).

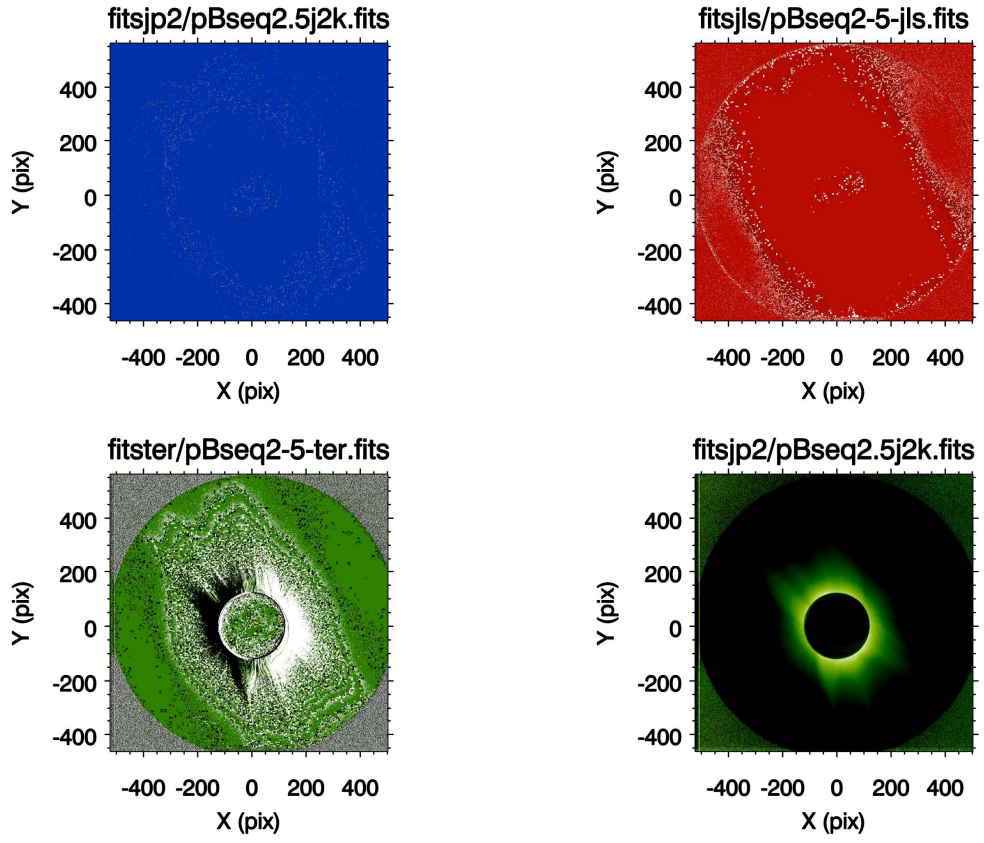

Figure 10: comparison between JPEG-2000 (top left), JPEG-LS (top right) and TER (bottom left) relative difference images D_i (color scale up to 1%) for a pB image (bottom right).

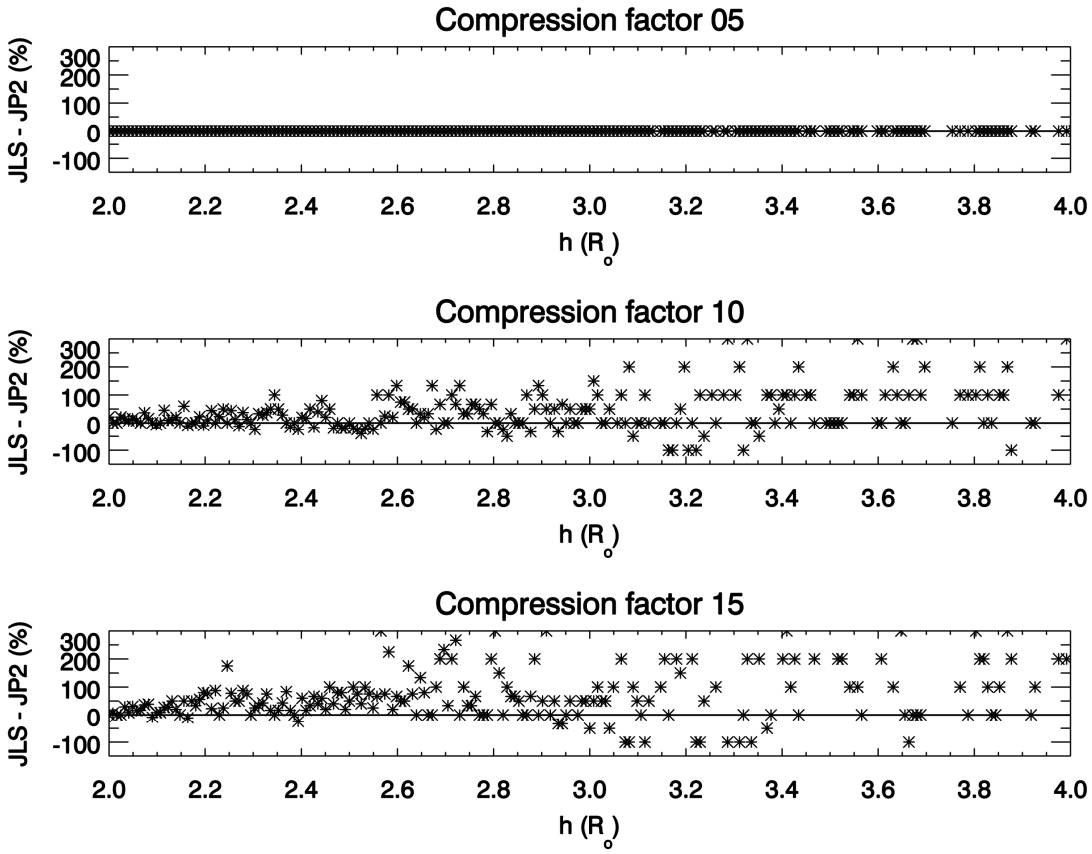

Figure 11: comparison between relative errors (%) introduced by JPEG-LS and JPEG-2000 compressions in the polarization differences for compression factors by 5 (top), 10 (middle) and 15 (bottom).