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JP3D compression of solar data-cubes: photospheric imaging and spectropolarimetry

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SOLAR PHYSICS UTOV

Abstract:

Hyperspectral imaging is an ubiquitous technique in solar physics observations and the recent advances in solar instrumentation enabled us to acquire and record data at an unprecedented rate. The **huge amount of data** which will be archived in the upcoming solar observatories press us to compress the data in order to reduce the storage space and transfer times. The correlation present over all dimensions, spatial, temporal and spectral, of solar data-sets suggests the use of a **3D base wavelet decomposition**, to achieve higher compression rates. In this work, we evaluate the performance of the recent JPEG2000 Part 10 standard, known as JP3D, for the **compression of several types of solar data-cubes**.

INTRO:

The new instrumentation at the foci of the 4m class solar telescopes will stream data at a ~1GB/s rate. This rate and the typical 9h duration of the observation runs will very probably exceed the storage and the transmission capacity of even the largest science facilities. This **amount of data should be compressed and made available** to download within the next observation run at the observatories. Then the data will be downloaded and decompressed by the users around the world.

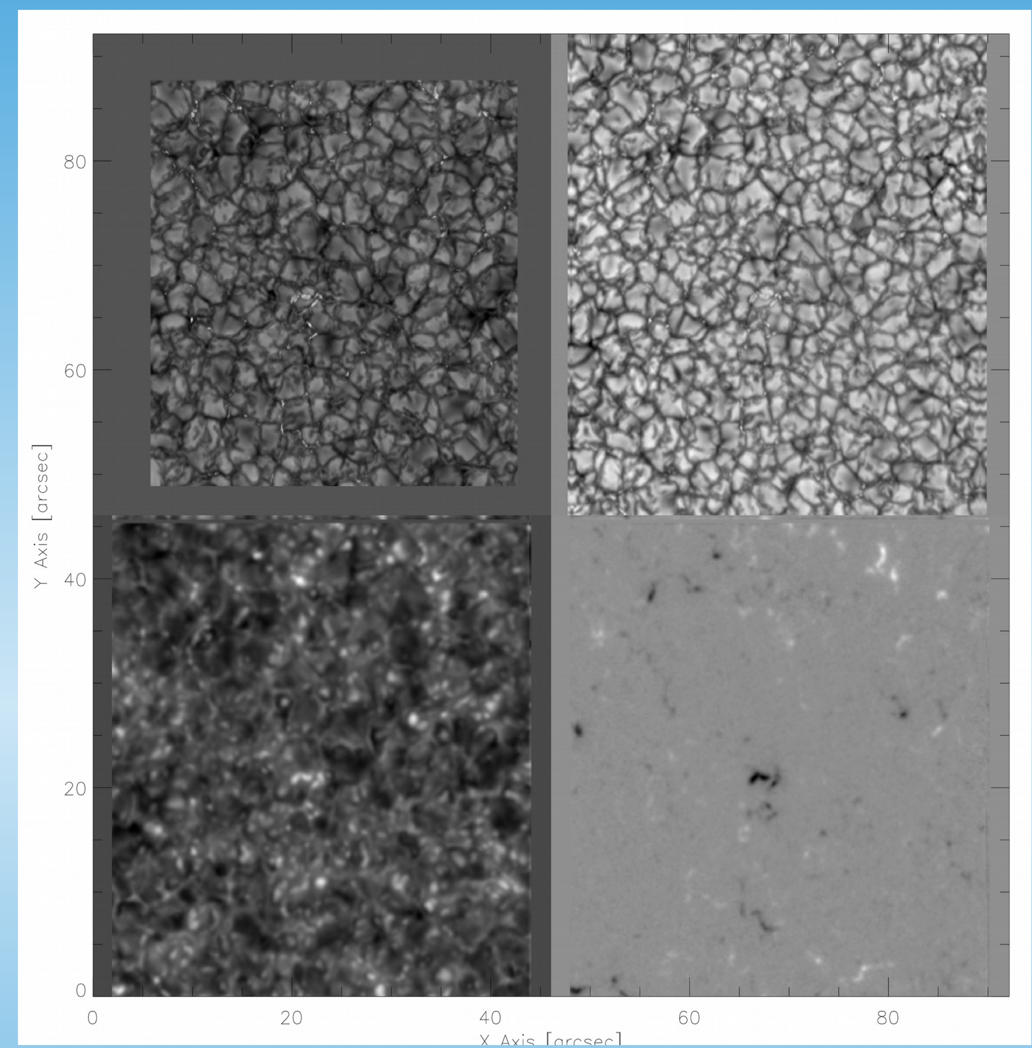
We choose the **OpenJPEG JP3D** compression for this analysis because it is efficient, open-source and well documented.

OpenJPEG is an **open-source** JPEG2000 codec written in **C language**.

It has been developed in order to promote the use of JPEG2000, a still-image compression standard from the Joint Photographic Experts Group (JPEG).

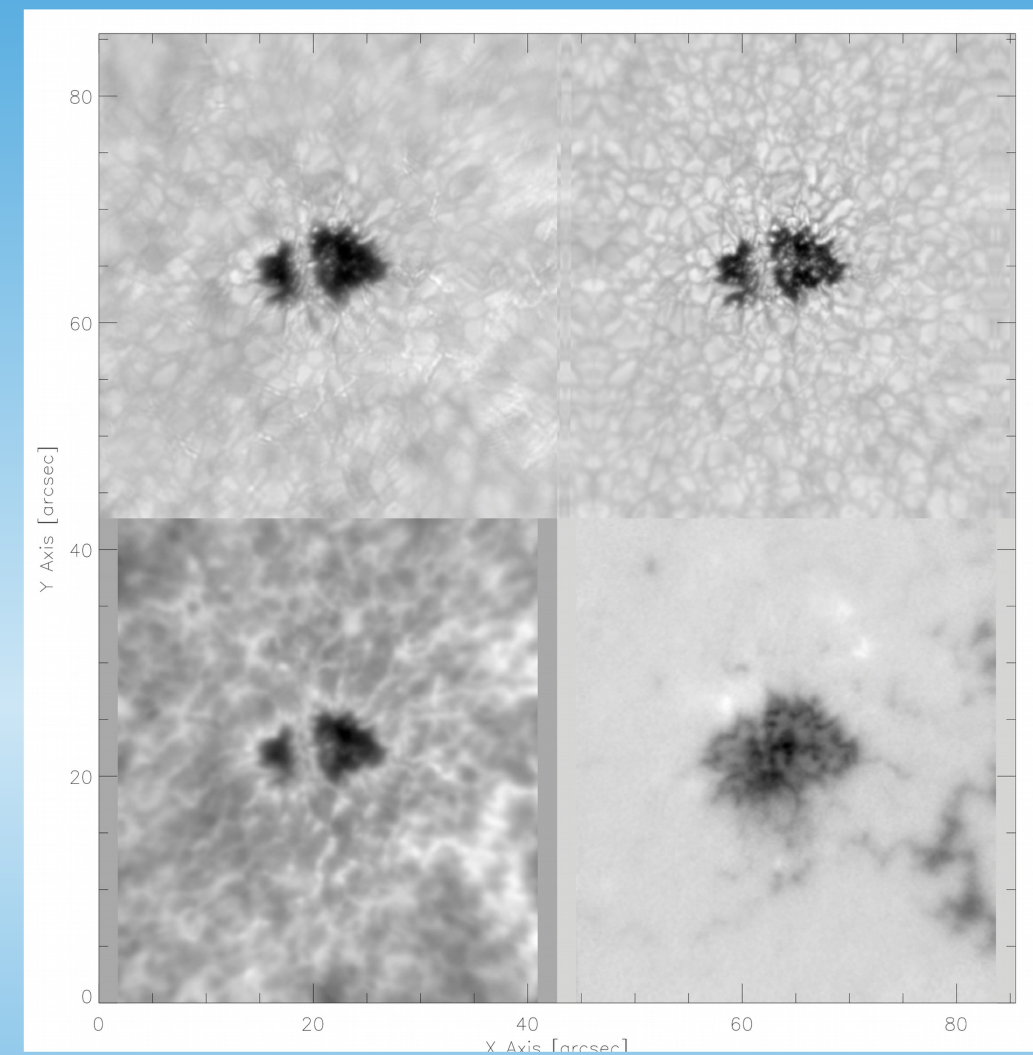
Since May 2015, it is officially recognized by ISO/IEC and ITU-T as a JPEG2000 Reference Software.

The data-sets:



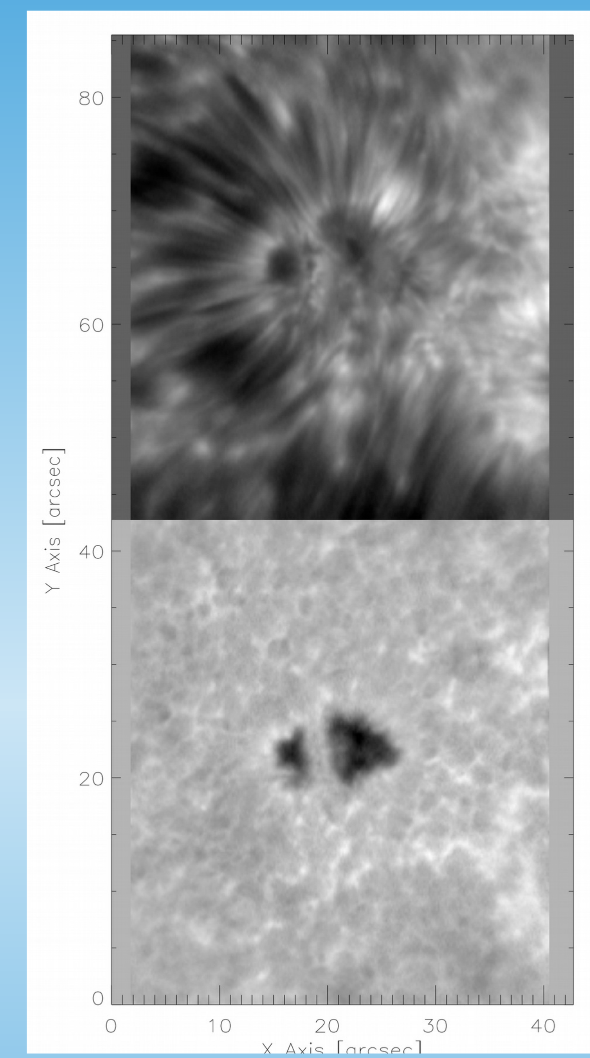
Sample images from the Quiet Sun data-set data-cubes. Upper-left: G-band image; Upper-right: Broad-band image; Lower-left: Stokes-I image near the core of the FeI 630.2 nm line; Lower-right: Stokes-V image near the wing of the FeI 630.2 nm line.

Type	Image Size	N. of frames	Repetitions	Spatial Resolution	Pixel Scale
G-BAND	1024×1024	18	50	0.16 "	0.05 "
BROAD-BAND	256×256	270	50	0.40 "	0.18 "
Fe STOKES I	256×256	45	50	0.40 "	0.18 "
Fe STOKES V	256×256	45	50	0.40 "	0.18 "



Sample images from the Pore data-set data-cubes. Upper-left: G-band image; Upper-right: Broad-band image; Lower-left: Stokes-I image near the core of the FeI 617.3 nm line; Lower-right: Stokes-V image near the wing of the FeI 617.3 nm line.

Type	Image Size	N. of frames	Repetitions	Spatial Resolution	Pixel Scale
G-BAND	1024×1024	3	80	0.10 "	0.04 "
BROAD-BAND	256×256	21	80	0.33 "	0.167 "
Fe STOKES I	256×256	21	80	0.36 "	0.167 '
Fe STOKES V	256×256	21	80	0.36 "	0.167 "
Ca STOKES I	256×512	21	80	Varying	0.167'



Sample images from the Pore data-set data-cubes. Upper: Stokes-I image near the core of the CaII 854.2 nm line; Lower: Stokes-I image near the wing of the CaII 854.2 nm line.

For the sake of visualization, we only show the central part of all the images and their values have been separately linearly scaled to saturate the greyscale palette.

The compression and decompression testshave been performed on an AMD Athlon 64 X2 Dual Core Processor 4400+ with 8GB RAM, 750GB Hitachi Deskstar 7K1000 hard drive and 64bit Linux Fedora 23 Operating System.

The Results:

To summarize the results of our analysis:

a) The performance of the 3D compression varies with the data-type: **G-band** are the most **compressible** (3 BPV-bits per voxel), while **Stokes I** are the **less compressible** (7 BPV);

b) The **CR** (compression ratio) is about **twice** as large as in the case of the 2D JPEG2000 compression;

c) The gain in ordering data in [x,y,λ,t] or [x,y,t,λ] is apparently negligible;

d) The **algorithm** seems to be **efficient** in handling **large files**, with little differences in compressing a single large data-cube or several smaller data-cubes;

e) The spatial correlation present in data which are super-sampled with respect to the telescope cutoff frequency leads to a +33% in compression rate. Obviously, that super-sampling required 4 times the number of voxel, leading to 4x the initial data volume.

We also note that, even considering an enhancement of the data processing capabilities in the foreseeable future, the **compression time** will be a crucial factor.

In fact, the acquisition rates are likely to increase up to ~100 1024x1024 pixel images per second and real time compression of the data-sets may not be feasible. This has to be taken in consideration in the observatory daily schedule.

Description	Size [MB]	CR AVE	CR min	CR MAX	**BPV AVE**	t Comp [s]	t Decomp [s]
Quiet Sun Data							
Broad-band x,y,t [256,256,270]	68.0	5.7	5.2	9.9	**5.7**	25.0	32.0
16bit Broad-band x,y,t [256,256,270]	34.0	2.7	2.6	3.0	**6.0**	26.4	33.4
G-band x,y,t [1024,1024,18]	72.0	10.3	9.1	14.9	**3.2**	23.0	35.0
G-band x,y,t **BIG** [1024,1024,288]	1200.0	9.5	//	//	**3.3**	370.0	568.0
G-band x,y,t **REBIN** [512,512,18]	18.0	6.7	6.5	7.5	**4.8**	7.3	10.6
STOKES I x,y,λ [256,256,45]	11.2	4.4	4.1	6.0	**7.3**	5.7	7.2
STOKES I x,y,t [256,256,50]	12.5	4.3	4.1	5.1	**7.3**	6.3	8.2
STOKES V x,y,λ [256,256,45]	11.2	5.8	5.5	6.1	**5.6**	4.1	5.6
STOKES V x,y,t [256,256,50]	12.5	5.8	5.5	6.5	**5.5**	5.0	6.9
STOKES I±V x,y,λ [512,256,45]	23.0	4.2	4.1	4.3	**7.7**	11.2	14.0
Pore Data							
Broad-band x,y,t [256,512,21]	10.5	8.5	6.9	10.6	**3.8**	3.1	4.4
16bit Broad-band x,y,t [256,512,21]	5.2	4.6	3.9	5.3	**3.5**	3.1	4.4
G-band x,y,t [1024,1024,3]	12.0	12.0	9.7	14.7	**2.7**	2.7	3.9
G-band x,y,t **BIG** [1024,1024,240]	960.0	10.3	//	//	**3.1**	268.0	376.0
STOKES I x,y,λ [256,512,21]	10.5	7.1	6.4	8.2	**4.5**	4.2	6.5
STOKES I x,y,t [256,512,80]	40.0	7.1	6.5	7.6	**4.5**	16.0	25.0
STOKES V x,y,λ [256,512,21]	10.5	7.8	7.2	8.7	**4.1**	3.9	5.8
STOKES V x,y,t [256,512,80]	40.0	7.8	6.9	8.4	**4.1**	13.9	21.8
STOKES I±V x,y,λ [512,512,21]	21.0	6.6	6.2	7.0	**4.9**	8.7	13.0
STOKES I x,y,λ [256,512,21] Chromosphere	10.5	6.4	5.9	7.1	5.0	4.4	6.7
STOKES I x,y,t [256,512,80] Chromosphere	40.0	6.4	5.8	7.3	5.0	16.8	25.4

Biblio:

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