

# Metadata and its importance in SO/PHI's on-board data processing K. Albert,<sup>1</sup> J. Hirzberger,<sup>1</sup> D. Busse,<sup>1</sup> P. Gutierrez-Marques,<sup>1</sup> and M. Kolleck<sup>1</sup> <sup>1</sup>Max Planck Institute for Solar System Research



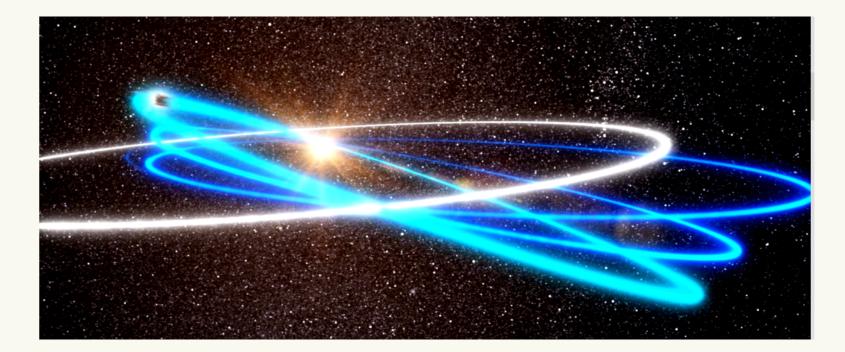
## Solar Orbiter and the Polarimetric and Helioseismic Imager

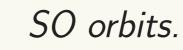
Solar Orbiter: Orbits the Sun between 1 AU and 0.28 AU,

 with an inclination from ecliptic: up to 33° (extended mission).
 SO/PHI: Imaging spectropolarimeter at the Fel 617.3 nm absorption line. Two optical paths: FDT (2°) and HRT (0.28°, 100 km/pix at 0.28AU). Extensive on-board processing: science data reduction, instrument characterisation and operational calibration. See [3].

## Full on-board data reduction:

24 raw images  $(6 \times \lambda, 4 \times \text{Pol}) \rightarrow 5$  physical quantities  $(\vec{B}, v_{\text{LOS}}, T)$ , by applying the on-board created calibration data and inverting the RTE.







SO/PHI flight model O-unit.

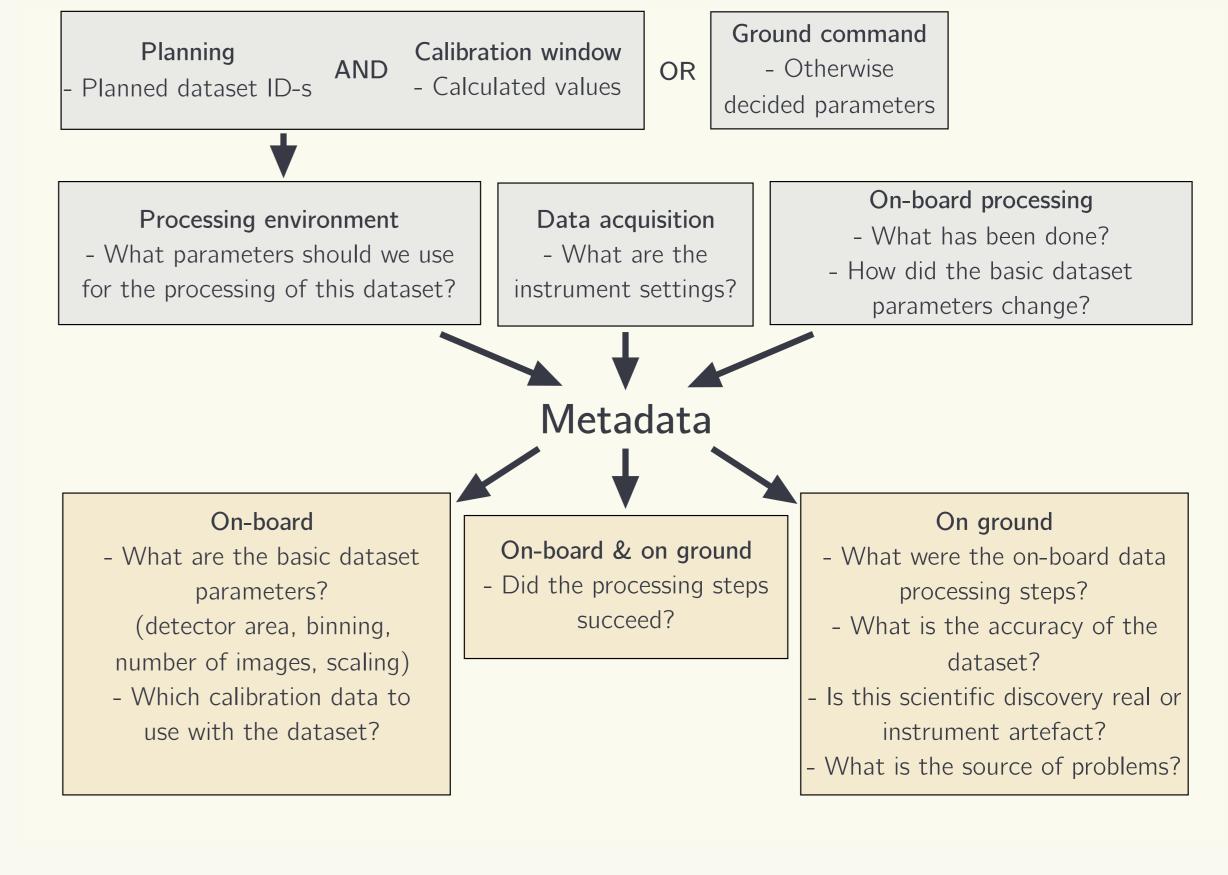
## Data processing pipelines

- Functions: science data reduction, instrument characterisation and operational parameter calculation.
- Autnomy: little interaction with pipeline due to long command-response turnaround and limited TM/TC volume.
- Available hardware: 2 reconfigurable FPGAs to accelerate image processing, 1 System Controller GPU for control and back-up implementation.
- Requirements: science ready datasets as result, flexible pipelines, fixed point arithmetics (where possible).

Image Acquisition	
	Data processing pipeline
Dark Field Correction	Data pre-processing pipeline
Flat Field Correction	
Impaired pixels detection -	Binning Cropping Primary processing
Correction of PSF	Correction for interference fringes Deconvolution
Polarisation demodulation	
Cross-talk correction	
Classical estimates and RTE inversion	
Compression	Basic steps Optional steps

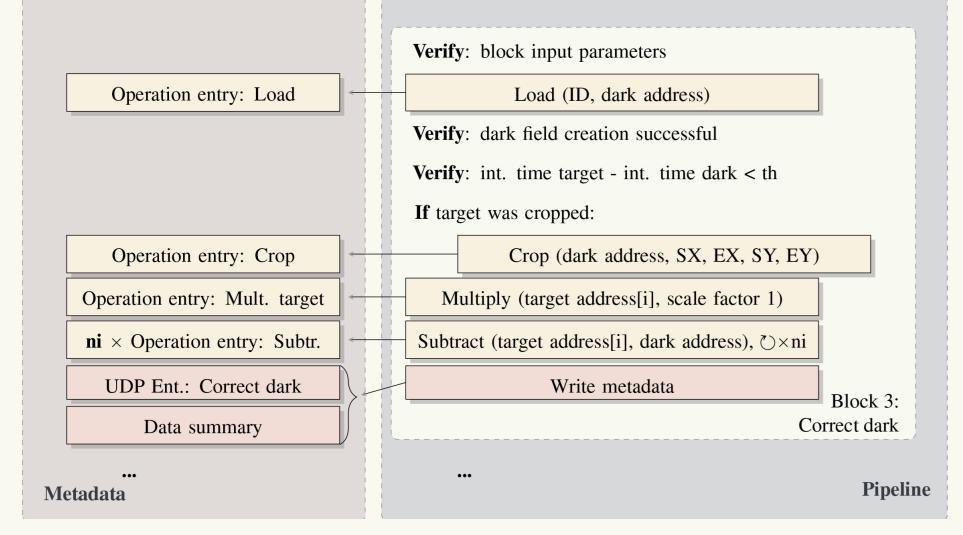
Science data processing of SO/PHI.

### Metadata System



Metadata sources and usage.

# Example metadata collection

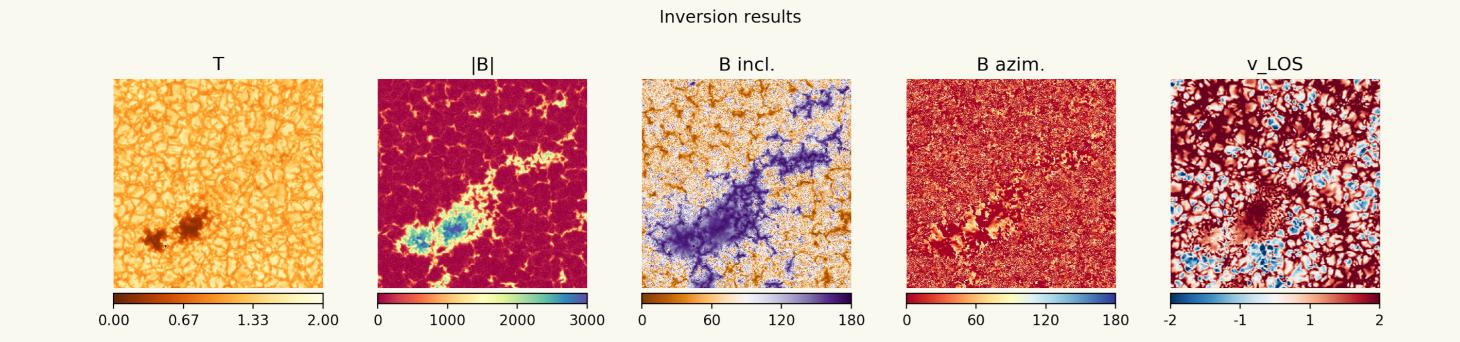


Select	Record Time A24	OperationID A13	OperationReturn A4	MemAddress1 A10	MemAddress2 A10	MemAddress3 A10	Rows A5	Columns A5	Scalar1 A11	Scalar2 A11
All	Time									
Invert	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify
5	2019-09-25 12:50:44.0000	PROC_LOAD	0	90170	2621440	0	512	512	0	0
6	2019-09-25 12:50:44.0000	PROC_F_MUL_S	0	26214400	0	26214400	512	512	131072	0
7	2019-09-25 12:50:44.0000	PROC_F_SUB_I	0	0	26214400	0	512	512	0	0
8	2019-09-25 12:50:44.0000	PROC_F_SUB_I	0	1048576	26214400	1048576	512	512	0	0
9	2019-09-25 12:50:44.0000	PROC_F_SUB_I	0	2097152	26214400	2097152	512	512	0	0
10										
11	2019-09-25 12:50:45.0000	PROC_F_SUB_I	0	22020096	26214400	22020096	512	512	0	0
12	2019-09-25 12:50:45.0000	PROC_F_SUB_I	0	23068672	26214400	23068672	512	512	0	0
13	2019-09-25 12:50:45.0000	PROC_F_SUB_I	0	24117248	26214400	24117248	512	512	0	0

Implementation details of dark field correction module, one of the pipeline blocks executed during science data processing.

Operation entries in the metadata, collected during the run of dark field correction. (Excerpt.)

#### Example metadata based error search



Select	Record Time A24	BlockReturn A4	BlockName A5	OperandID A10	FreeParameter1 A11	FreeParameter2 A11	ImageEndIndex A3	RowEnd A5	ColumnEnd A5
Ali Invert	Time Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify
III¥CI (	Mounty	Moarry	Mouny	Mourry	Mounty	Mounty	Mounty	Mounty	I WOUT Y
1	2019-09-25 12:50:43.0000	0	LOAD	90240	512	512	24	511	511
2	2019-09-25 12:50:44.0000	0	DARK	90270	8388608	0	24	511	511
3	2019-09-25 12:51:22.0000	0	FLAT	90280	4	0	24	511	511
4	2019-09-25 12:51:23.0000	0	PIPE1	90240	0x7F	0	24	511	511
5	2019-09-25 12:51:24.0000	0	LOAD	90240	0	0	24	511	511
6	2019-09-25 12:52:00.0000	NANS	DEMOD	90260	0	0	24	511	511
7	2019-10-01 12:10:55.0000	0	NORM	92240	49868192	0	24	511	511
8	2019-10-01 12:12:26.0000	0	NANS	92240	0	2048	24	511	511
9	2019-10-01 12:12:30.0000	0	REOR1	92240	0x1FF	1	25	511	511
10	2019-10-01 12:12:30.0000	0	REOR1	92240	5	0	25	511	511
11	2019-10-01 12:18:26.0000	0	INVER	92240	1	0	6	511	511
12	2019-10-01 12:19:09.0000	0	REOR2	92240	0x1FF	1	5	511	511
13	2019-10-01 12:19:16.0000	0	PIPE2	92240	0x7F	0	5	511	511

	RecordTime	BlockReturn	BlockName	OperandID	📕 Free Parameter 1	📕 FreeParameter2	📕 ImageEndIndex	RowEnd	ColumnEnd	
Select	A24	A4	A5	A10	A11	A11	A3	A5	A5	

0.0000 0.0033 0.0067 0.0100	0 1000	2000 3000	0 60	120 180	0	60 120	180	-2 -1	1	2

All 📕	Time								
Invert	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify
1	2019-09-25 12:50:43.0000	0	LOAD	90240	512	512	24	511	511
2	2019-09-25 12:50:44.0000	0	DARK	90270	8388608	0	24	511	511
3	2019-09-25 12:51:22.0000	0	FLAT	90280	4	0	24	511	511
4	2019-09-25 12:51:23.0000	0	PIPE1	90240	0x7F	0	24	511	511
5	2019-09-25 12:51:24.0000	0	LOAD	90240	0	0	24	511	511
6	2019-09-25 12:52:00.0000	WFSM	DEMOD	90261	0	0	24	511	511
7	2019-10-01 12:10:55.0000	0	NORM	92240	49868192	0	24	511	511
8	2019-10-01 12:12:26.0000	0	NANS	92240	0	2048	24	511	511
9	2019-10-01 12:12:30.0000	0	REOR1	92240	0x1FF	1	25	511	511
10	2019-10-01 12:12:30.0000	0	REOR1	92240	5	0	25	511	511
11	2019-10-01 12:18:26.0000	0	INVER	92240	1	0	6	511	511
12	2019-10-01 12:19:09.0000	0	REOR2	92240	0x1FF	1	5	511	511
13	2019-10-01 12:19:16.0000	0	PIPE2	92240	0x7F	0	5	511	511

Top: expected, usual results for the pipeline. Bottom: obtained final results, clearly wrong at the first look. An incorrect demodulation matrix has been used on the dataset (can happen due to planning or operator error).

UDP entries during the pipeline run. (Excerpt.) The highlighted return values are warnings for NaN-s produced in the dataset during the operation (a usual case), and for demodulation matrix mismatch due to different feed select mechanism positions (i.e. it is for the other optical path).

References	Acknowledgments
<ol> <li>K. Albert, J. Hirzberger, D. Busse, and et al. Autonomous on-board data processing and instrument calibration software for the SO/PHI. Proc. SPIE, 707:10707 – 10707 – 9, 2018.</li> <li>K. Albert, J. Hirzberger, D. Busse, and et al. Performance analysis of the SO/PHI software framework for on-board data reduction. arXiv e-prints, page arXiv:1905.08690, May 2019.</li> <li>S. K. Solanki, J. C. del Toro Iniesta, J. Woch, and et al. The Polarimetric and Helioseismic Imager on Solar Orbiter. arXiv e-prints, page arXiv:1903.11061, Mar 2019.</li> </ol>	MAX-PLANCK-GESELLSCHAFT
	Contact: albert@mps.mpg.de