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DELIVERABLE D20.2

Survey Document –State of the Existing Pipelines and Procedures– Preliminary Report on Pipelines Guidelines

WP20 Integrated Operation and Exploitation of Solar Physics Facilities and Coordination with other Research Infrastructures

1ST Reporting Period

November 2014

PROJECT GENERAL INFORMATION

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Periodic report: 1st **X** 2nd ☐ 3rd ☐ 4th ☐

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Deliverable 20.2 "Survey document - State of the art of existing pipelines and procedures - Preliminary report on pipeline guidelines"

Reminder of task WP 20.2 - Guidelines for pipeline development.

Description of Work of task 20.2

The object of this task is to complement the technical work that will be undertaken in WP50 in the following actions:

- *to make a survey of existing pipelines for the instruments being part of the WP50 action, to identify duplication and analyze possible merging of processing tools;*
- *to make a survey of existing observing procedures for the instruments being part of the WP50 activity;*
- *to collect the opinion of the community on those aspects that should be integrated in software;*
- *to define and propose standard observing procedures and pipeline for WP50 instruments that do not have one already and propose modifications for those already existing, if considered necessary;*
- *to define documentation guidelines of pipelines;*
- *to define the evaluation of the ergonomics/usability of pipelines;*
- *to follow the evolution of the pipeline development in WP50 and its suitability to the imposed requirements;*
- *to define scientific acceptance tests of the pipelines;*
- *to advertise the output of WP50 work to the community;*

Besides the technical design the software associated to instruments, this task is aimed at reviewing and unifying observing procedures, at the commonality of software tools, at the convergence and exchangeability of data products, and at a shared awareness toward a higher scientific quality. This is a huge leap towards our community integration at European level, and in the perspective of the future European Solar Telescope.

Summary of Deliverable 20.2

A survey of existing pipelines and observing procedures for an approved list of instruments has been performed. The task of reviewing pipelines is relatively easy but this is not the case for observing procedures, which are mostly in non-written form, and considered as a "natural sequel" by most of the instruments reviewed.

Instrument "families", with conceptually equivalent outputs can be defined. Tentative generic flowcharts for 3 pipelines are presented, based on the commonality of analysis needs of all those instrument families. Typical levels of analysis are suggested, together with the indication of what are "science ready data" in each of the cases. Finally, preliminary recommendations are outlined.

Participants

Cauzzi (INAF), Del Moro (UtoV) , Mathioudakis (QUB) , Balthasar (AIP) , Denker (KIS), Collados (IAC), Löfdahl (SU), Kiselman (SU), Lopez (CNRS) , Doerr (KIS), Bello Gonzales (KIS), Kentischer (MPG), Jurcak (AIASCR), Gelly (CNRS)

Survey poll

In order to start the SOLARNET data pipeline activities, we have been conducting a survey of the current situation for the instruments involved in this action, as per WP 20.2 ("guidelines for pipelines development"). The instruments involved and corresponding contact persons were:

- DST/IBIS (Cauzzi, Del Moro)
- DST/ROSA
- (Mathioudakis)
- GREGOR/GFPI (Balthasar, Denker)
- GREGOR/GRIS (Collados)
- GREGOR/BLISS (Balthasar, Denker)
- SST/CRISP (Löfdahl)
- SST/TRIPPEL (Kiselman)
- SST/CHROMIS (Löfdahl)
- THEMIS/MTR (Lopez)
- THEMIS/TUNIS (Lopez)
- VTT/LARS (Doerr)
- VTT/TESOS (Bello Gonzales, Kentischer)

Survey questions:

Please tell me if you think we forgot a significant contributor or if we are mistaken on some contact person. We realise that the data gathered by this survey will be rather heterogeneous, and therefore we ask you to provide information in free format. It would, however, be good if you could look at the few questions below and try to take them into account in your answer. If the surveyed instrument is not on-line or not even existing yet, please state your predictions and plans but be sure to state clearly what is existing at the moment and what is not.

- *Please describe your instrument in a short but comprehensive way.*
- *Is relevant information about this instrument published?*
- *Please describe the output data from your instrument.*
- *Can you provide a typical specimen of reduced and possibly raw data?*
- *What is the current status of the reduction software?*
- *What major reduction steps are performed by the software/pipeline?*
- *What computer language is used?*
- *Do you have a technical documentation for the pipeline?*
- *Do you have a user's manual for this pipeline?*
- *How widespread is the use of the software?*
- *Is it used in one or in several places?*
- *Are there many varieties, or even several different codes (that are actively used), for these data?*
- *Does your pipeline imply to respect a procedure when observing?*
- *Is this observing procedure in written form?*

Survey answers

VTT / LARS (H. Doerr)

(answer is from HPD)

Please describe your instrument in a short but comprehensive way.

LARS (Lars is an Absolute Reference Spectrograph) is an instrument for precision solar spectroscopy in applications that do not require high spatial or temporal resolution but a high signal to noise ratio and an accurate wavelength calibration. It is based on the existing VTT echelle spectrograph (R > 750 000) with a single mode fiber feed (SMFF) and a laser frequency comb (LFC) based wavelength calibration system. The fiber feed picks up light from the VTT focal plane with a field of view of three arcseconds on the sky. With the LFC an absolute wavelength calibration of better than one meter per second is possible. The SMFF enables a high spectral purity with low instrumental straylight and superior flatfielding with a tungsten flatfield lamp.

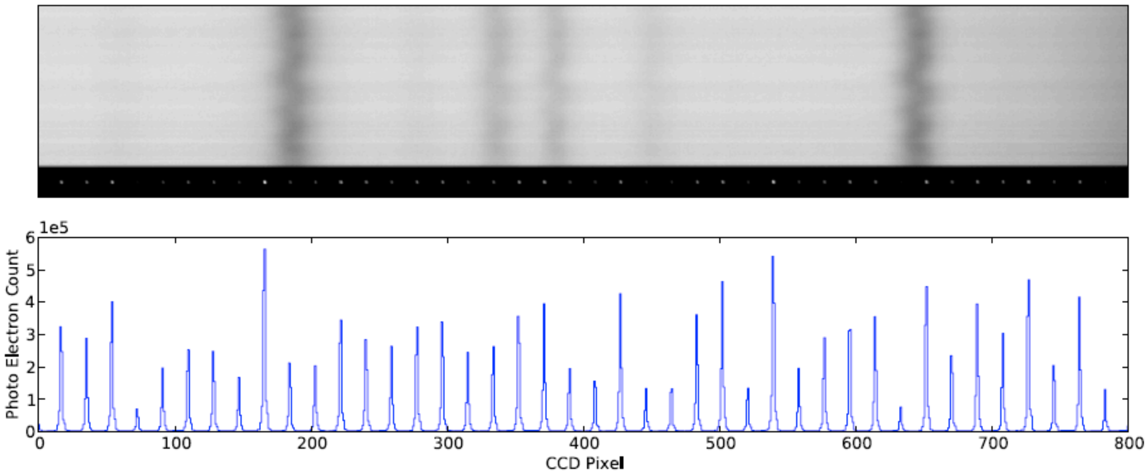
Is relevant information about this instrument published?

- Science 5 September 2008: 1335-1337. [DOI:10.1126/science.1161030] Steinmetz et al., 321 (5894): 1335-1337
- arXiv:1204.0948
- http://dx.doi.org/10.1117/12.926224

Please describe the output data from your instrument:

Level0 data are raw one-dimensional CCD spectra (object, flat field, wavelength calibration) or time-series thereof in FITS format. Some meta-data are recorded in a separate side-car file for each observing sequence. A slitjaw image is recorded for each object exposure.

Level1 and above data will be calibrated spectra in FITS format, including error estimates and probably (optionally) employing the World-Coordinate-System (WCS) Standard for co-ordinate conversion (pixel -> wavelength, pixel -> frequency, spatial co-ordinates).



Can you provide a typical specimen of reduced and possibly raw data?

Not yet. Data format is not yet matured.

What is the current status of the reduction software?

Parts of the pipeline are implemented in prototype-status code for testing and in-house application

What major reduction steps are performed by the software/pipeline?

- flat/dark correction
- Individual wavelength calibration for each object exposure based on the recorded LFC spectra.
- Data can optionally be re-sampled equidistantly in wavelength or frequency.

What computer language is used?

IDL + some C for the prototype. Probably no IDL but C/C++/Python for a public release.

Do you have a technical documentation for the pipeline ?

No

Do you have a user's manual for this pipeline ?

No

How widespread is the use of the software? Is it used in one or in several places?

only inhouse

Are there many varieties, or even several different codes (that are actively used), for these data ?

No

Does your pipeline imply to respect a procedure when observing ?

yes. on-disk data layout, filenames, meta-data etc are completely defined by the operation mode of the instrument which is controlled by the observer with an all-in-one software. Data set definitions are kept as simple as possible and any data could be manually calibrated by experienced observers, though.

Is this observing procedure in written form?

Observer's manual?

Not yet.

VTT / TESOS (N. Bello Gonzales, T. Kentischer)

(Answser from N.B.G.)

Please describe your instrument in a short but comprehensive way.

This project is supported by the European Commission's FP7 Capacities Programme for the period April 2013 - March 2017 under the Grant Agreement number 312495.

The Triple Etalon Solar Spectrometer (TESOS) is a 2D spectrometer at the 70 cm-Vacuum Tower Telescope(VTT) at the Observatorio del Teide, Tenerife. The instrument primarily consists of a combination of three Fabry-Pérot interferometers in a telecentric configuration (FPIs located near the focal plane). TESOS is capable of observing wavelengths between 430-750 nm with a spectral resolution of up to 300 000. It has a pixel scale of 0.086 arcsec/pixel and a field of view of 44 arcsec2. Up to four different wavelength passbandscan be scanned sequentially with a delay of about 1-2 seconds between each. The sampling is usually done at 30-40 wavelength positions in about 25-30 s. TESOS possesses a second channel for the acquisition of simultaneous broad-band images, to allow for the use of speckle reconstruction techniques. The Visible Imaging Polarimeter (VIP) can be used as an extension to TESOS to measure the full polarisation state of the incident light (Stokes I/Q/U/V). It consists of a modulator system composed by two nematic liquid crystals acting as retarders whose retardance can be controlled by applying a given voltage. In this case, the usable wavelength range decreases to 430-700 nm and the field of view to 21x41 arcsec. With 2x2 pixel binning, a polarimetric noise level of about 2x10-3 can be achieved for a typical line scan at 40 wavelength positions, which takes about 60 s.

Instruments that are comparable to TESOS/VIP are the GREGOR Spectro-Polarimeter (GFPI), the Interferometric Bidimensional Spectrometer (IBIS), and the Crisp Imaging Spectro-Polarimeter (CRISP).

Is relevant information about this instrument published?

- Kentischer, T. J.; Schmidt, W.; Sigwarth, M.; Uexkuell, M. V., "TESOS, a double Fabry-Perot instrument for solar spectroscopy", 1998, Astronomy and Astrophysics, Vol. 340, p. 569-578
- Tritschler, A.; Schmidt, W.; Langhans, K.; Kentischer, T., "High-resolution solar spectroscopy with TESOS - Upgrade from a double to a triple system", 2002, Solar Physics, Vol. 211, Issue 1, p. 17-29
- Tritschler, A.; Bellot Rubio, L. R.; Kentischer, T. J., "Towards 2D-Spectropolarimetry with TESOS and Adaptive Optics", 2004, American Astronomical Society Meeting 204, Bulletin of the American Astronomical Society, Vol. 36, p. 794
- Beck, C.; Bellot Rubio, L. R.; Kentischer, T. J.; Tritschler, A.; Del Toro Iniesta, J. C., "Two-dimensional solar spectropolarimetry with the KIS/IAA Visible Imaging Polarimeter", 2010, Astronomy and Astrophysics, Vol. 520, 10 pp.

Please describe the output data from your instrument:

TESOS can be run in 2 observing modes, spectroscopic and spectropolarimetric (VIP) mode.

1. Spectroscopic mode: Narrow-band channel data: It consists of a data cube (x, y, lambda x speckles) with spatial information while scanning along a given spectral range. Typically, 7-8 short-exposure (10 ms) images or speckles are acquired per wavelength position to apply speckle reconstruction techniques. Broad-band channel data: It consists of a data cube (x, y, t) with spatial and temporal information recorded strictly simultaneously and with the same exposure as for the narrow-band data.
2. Spectro-polarimetric (VIP) mode: Narrow-band channel data: It consists of a data cube (x, y, lambda x speckles x 4 polarisation states) with spatial information while scanning along a given spectral range and at 4 different polarisation states (modulated by VIP). Typically, 7-8 short-exposure (10 ms) images or speckles are acquired per wavelength position and polarization state, to apply speckle reconstruction techniques. Broad-band channel data: It consists of a data cube (x, y, t) with spatial and temporal information recorded strictly simultaneously and with the same exposure as for the narrow-band data.

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SEVENTH FRAMEWORK PROGRAMME
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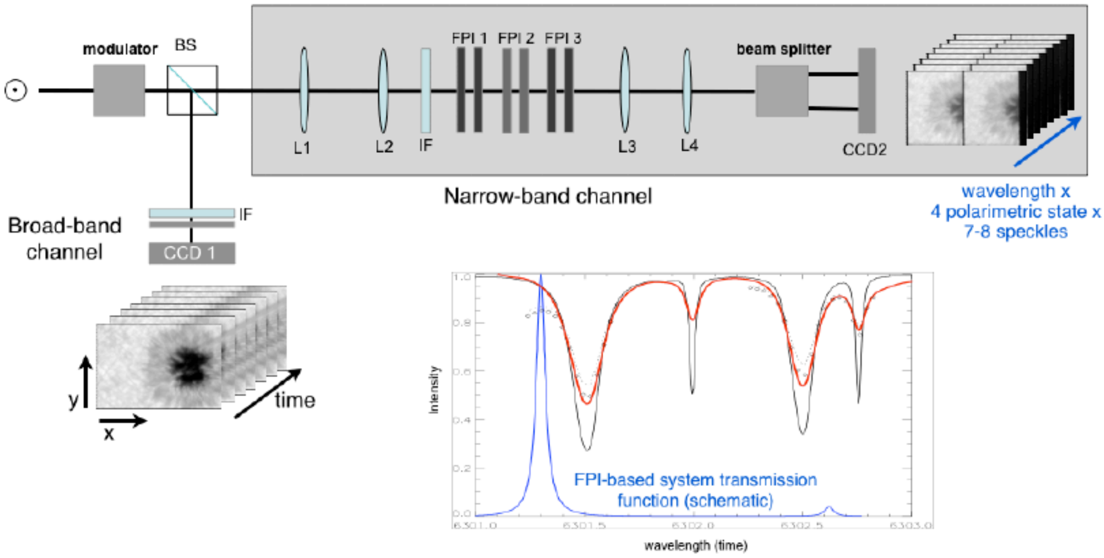


Fig.1: Scheme of the TESOS optical setup, and scanning. BS: beam-splitter, L: lenses, IF: interference filter

Can you provide a typical specimen of reduced and possibly raw data?

Yes, we can provide with raw and calibrated data in FITS format. Yet, the reduced data would be an example of data reduced using specific IDL programs from a given TESOS user, not the output of a "standard datapipeline.

Snapshots on raw and calibrated (non-reconstructed) data can be seen in Fig. (below). They correspond to images in the blue wing, line minimum and red wing of the H-alpha line, respectively. Snapshots of reconstructed data observed at different wavelengths in the H-alpha line can be seen in Fig. 3.

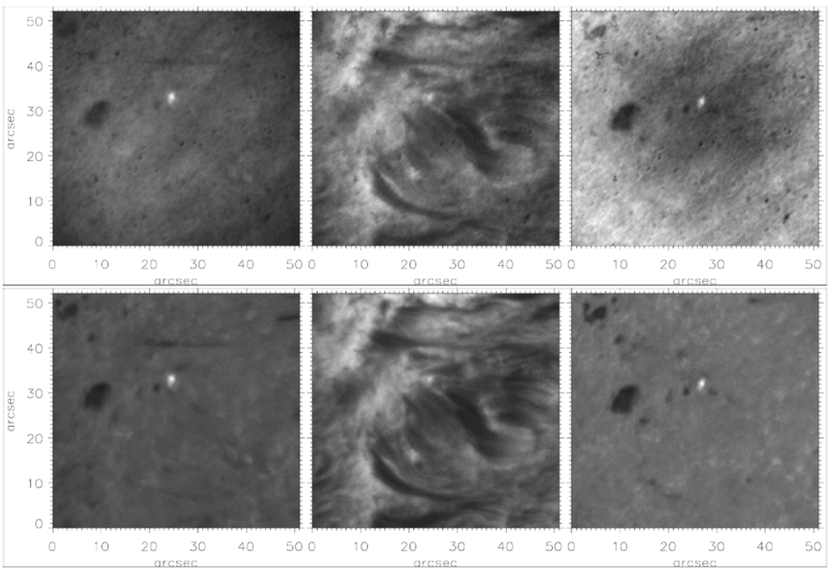


Fig. 2: Snapshots of raw (upper row) and reduced data (lower row), at 3 different wavelengths of the H-alpha line.

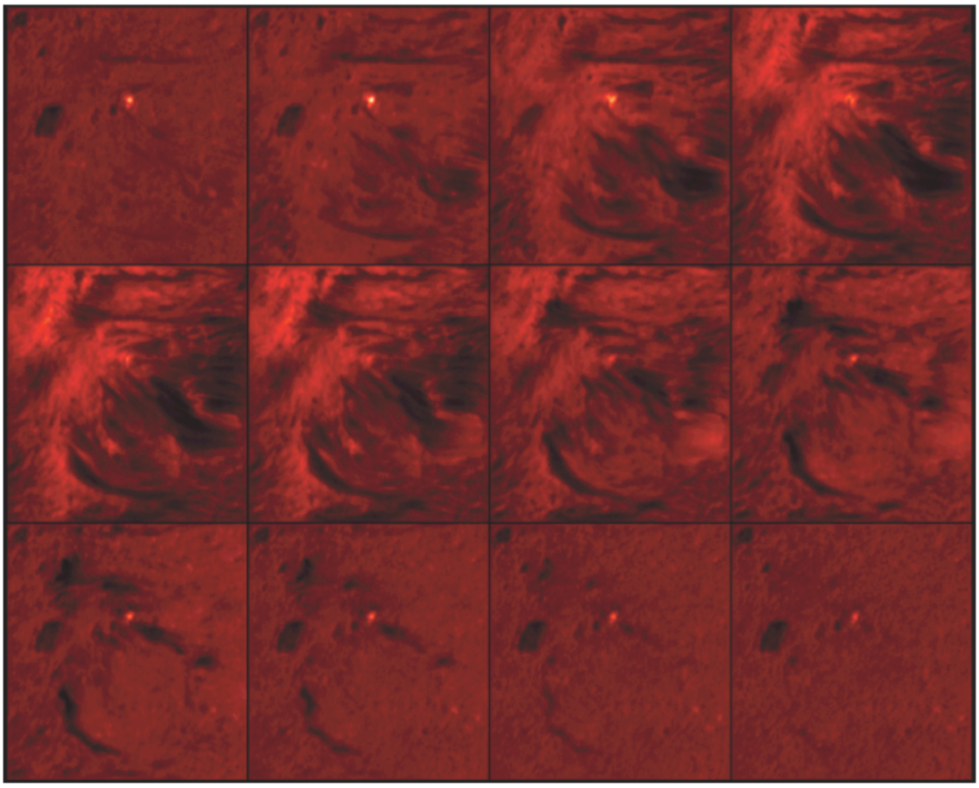


Fig. 3: Snapshots of TESOS reconstructed data scanned along the H-alpha line.

What is the current status of the reduction software?

There is an out-of-date IDL library for TESOS data reduction available at KIS. Otherwise, different TESOS users use their own data reduction procedures.

What major reduction steps are performed by the software/pipeline?

With the outdated library, one can:

- correct from dark and flatfield. However, the wavelength shifts introduced by the difference in roughness of the etalons is not taken into account.
- align and cut the images to the effective region of interest.
- partially analyse the data, e.g., retrieve Dopplermaps from line-minimum intensities.

The KISIP code has been extensively developed at KIS, however it is not implemented as part of the calibration procedures of the outdated IDL TESOS libraries. Otherwise, there exist programs used by given TESOS users which handle with the full data calibration, including wavelength shifts issues and speckle reconstruction techniques. These programs are the starting base of the future TESOS datapipeline

What computer language is used?

Mainly IDL

Do you have a technical documentation for the pipeline ?

The outdated IDL library for TESOS data calibration is documented.

How widespread is the use of the software? Is it used in one or in several places?

The community of TESOS users is small. Nowadays, some former TESOS experts with their own data reduction procedures are working outside KIS.

Are there many varieties, or even several different codes (that are actively used), for these data ?

Yes, this is the case. Nowadays, TESOS users run their own procedures.

Does your pipeline imply to respect a procedure when observing ?

The planned and under development TESOS data pipeline implies, of course, some requirements on calibration data acquisition, data format,...

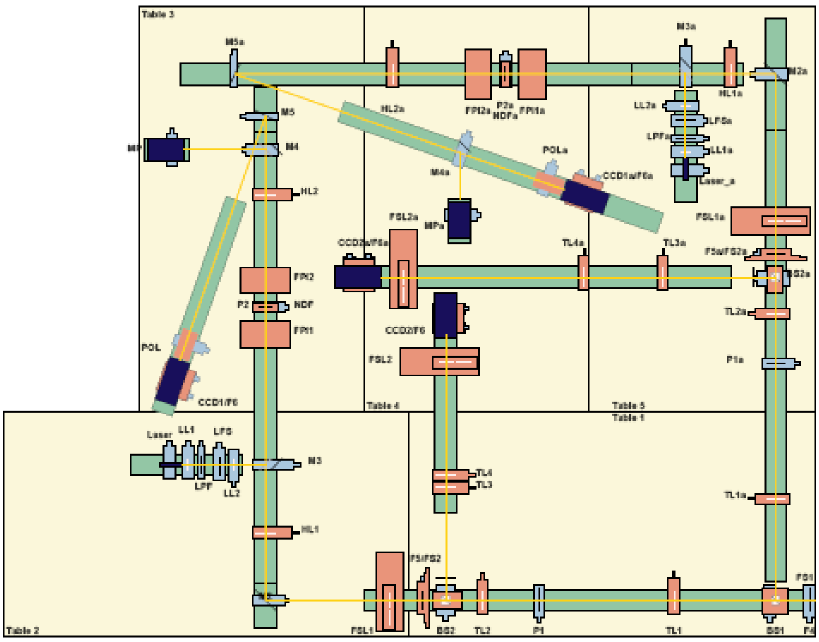
Is this observing procedure in written form ?

There exists an excellent TESOS manual very useful for the observer, explaining carefully also how to use TESOS. However, so far, there is no observing procedure in a written form.

GREGOR / GFPI / BLISS (Puschmann, Denker, Balthasar)

(Answer compiled from litterature)

The GREGOR Fabry-Pérot Interferometer (GFPI) is one of the first-light post-focus instruments for the German 1.5-meter GREGOR solar telescope at the Observatorio del Teide. The GFPI is a tuneable dual-etalon system in collimated mounting that allows fast narrow-band imaging. It is designed for spectrometric and spectropolarimetric observations between 530-860 nm and 580-660 nm, respectively, and has a theoretical spectral resolution of about 250,000. The field-of-view in spectroscopic mode is 50" x 38" (25" x 38" in case of Stokes-vector spectropolarimetry). In combination with post-facto image reconstruction it has the potential for discovery science concerning the dynamic Sun and its magnetic field at spatial scales down to about 50 km. The instrument underwent an extended commissioning in 2011 and careful science verification throughout 2012.



Layout sketch of the GFPI with BLISS (2013)

GFPI shall be completed in a near future by BLISS (BLue Imaging Solar Spectrometer) currently in design phase (2012), a second Fabry-Pérot Interferometer for the wavelength range 380-530 nm. GFPI and BLISS can be used to extend our knowledge on the structure of sunspots and the solar chromosphere.

GFPI (and possibly BLISS) are designed to work in a polarimetric speckle mode, mostly derived from VTT – GPFI experience. In such polarimetric mode, the data acquisition/ reduction process goes through the following steps:

- Acquisition of n(1) narrowband exposures (20ms) per polarimetric state (6 states) and spectral position, the Polarimetric cycle being the fastest of the two.
- The former acquisition is simultaneous with broad band image acquisition
- Dark and flats corrections applied
- Broadband data is reconstructed using speckle code package
- Narrowband data is deconvolved using the former step
- Aligning of individual images
- Polarimetric calibration (Requires the Mueller matrix of the telescope + polarimeter)
- Demodulation, toward Stokes maps

(1) n=7 currently.

GREGOR / GRIS (Collados)

(Answer from M.C.)

GRIS is the spectrograph installed at GREGOR. As such it does not provide any data unless a detector is mounted. The most immediate use is together with TIP. Thus the answers below correspond to the instrument TIP@GREGOR. In a more or less future, ZIMPOL@GREGOR might be available . Preliminary tests have just been carried out a couple of weeks ago. TIP@GREGOR will be probably ready next year for use by the observers.

Please describe your instrument in a short but comprehensive way.

GRIS is the spectrograph installed at GREGOR. As such it does not provide any data unless a detector is mounted. The most immediate use is together with TIP. Thus the answers below correspond to the instrument TIP@GREGOR. In a more or less future, ZIMPOL@GREGOR might be available . Preliminary tests have just been carried out a couple of weeks ago. TIP@GREGOR will be probably ready next year for use by the observers .

Is relevant information about this instrument published?

Yes.

Please describe the output data from your instrument.

Spectropolarimetric data from 1 to 1.8 microns and spectroscopic data from 2 to 2.3 microns. The output is written is single FITS files (or splitted into several sub-files, if the size is large than 2 GB). Data are usually reduced and calibrated on the same day they are taken using standard routines.

Can you provide a typical specimen of reduced and possibly raw data?

I can provide examples of spectropolarimetric data taken with TIP@VTT. For the moment, no regular data from GREGOR exist in polarimetric mode. I attach three spectroscopic images taken at 1083, 1565 and 2230 nm.

What is the current status of the reduction software?

The reduction software for TIP data exists since the year 2000. It corrects for dark current, flat field and performs the automatic alignment of the polarized beams, demodulation of the polarimeter response. The instrumental polarization introduced by the VTT is also evaluated and corrected. The change to include the time-varying Mueller matrix of the telescope at GREGOR is in progress, once its polarimetric behaviour is well measured. Quick-look Stokes profiles are displayed on line while observations are performed

What major reduction steps are performed by the software/pipeline?

- Dark current and flat field correction
- Beam alignment
- Demodulation of the polarimeter response
- Correction of telescope Mueller matrix for VTT

. Gregor telescope will be included soon.

What computer language is used?

IDL for the reduction

Do you have a technical documentation for the pipeline ?

No

Do you have a user's manual for this pipeline ?

No

How widespread is the use of the software?

Is it used in one or in several places? All observers at the VTT are well familiar with the reduction software. This includes most of the expected observers at GREGOR:

Are there many varieties, or even several different codes (that are actively used), for these data ?

Not that I know of.

Does your pipeline imply to respect a procedure when observing ?

Yes. Flat fielding before and after every observation. Each flat requires about five to ten minutes. Flats should not be separated more than 1.5 hours. Calibration files (for polarimetric performance) are only required one in the morning and one in the afternoon at the VTT. At GREGOR, we have no experience yet how often calibration data are required (due to the time-varying Mueller matrix of the telescope)

Is this observing procedure in written form ?

No.

DST / IBIS (Cauzzi, Del Moro)

(Answer is from G.C.)

Please describe your instrument in a short but comprehensive way.

IBIS (Interferometric BIdimensional Spectropolarimeter) is a dual Fabry-Perot system in collimated mount installed at the 76 cm Dunn Solar Telescope of the US National Solar Observatory. It performs solar imaging spectropolarimetry in the range 580-860 nm, on a circular field of view of 95" diameter, sampled at 0.098"/pix (with a 1k x 1k camera). Simultaneous broadband images allow the use of post-facto image reconstruction techniques. IBIS has a spectral resolution over 200,000 at all wavelengths, and can sample over a dozen of relevant solar spectral lines. An observational sequence can combine up to six different spectral lines (prefilters). The sustained maximum cadence for IBIS acquisition is 8 fps when sequentially sampling distinct wavelength points or in spectropolarimetric mode. This increases to 14 fps for bursts of images at a fixed wavelength setting. Typical exposure times range from 10 to 30 ms in spectroscopic mode, and ~50 ms for polarimetry. Dual-beam polarimetry is performed with liquid crystal variable retarders ahead of the instrument, and a polarizing beamsplitter in front of the detector. The two orthogonal states of polarization imaged on the chip each have a FOV of ~40" x 90". Six modulations states are acquired at each wavelength. The instrument has proved very stable and reliable, allowing acquisition of sequences of long duration (e.g. several hours).

Further info at : http://www.arcetri.astro.it/science/solar/IBIS/IBIS_description.html

Is relevant information about this instrument published ?

Yes

Please describe the output data from your instrument.

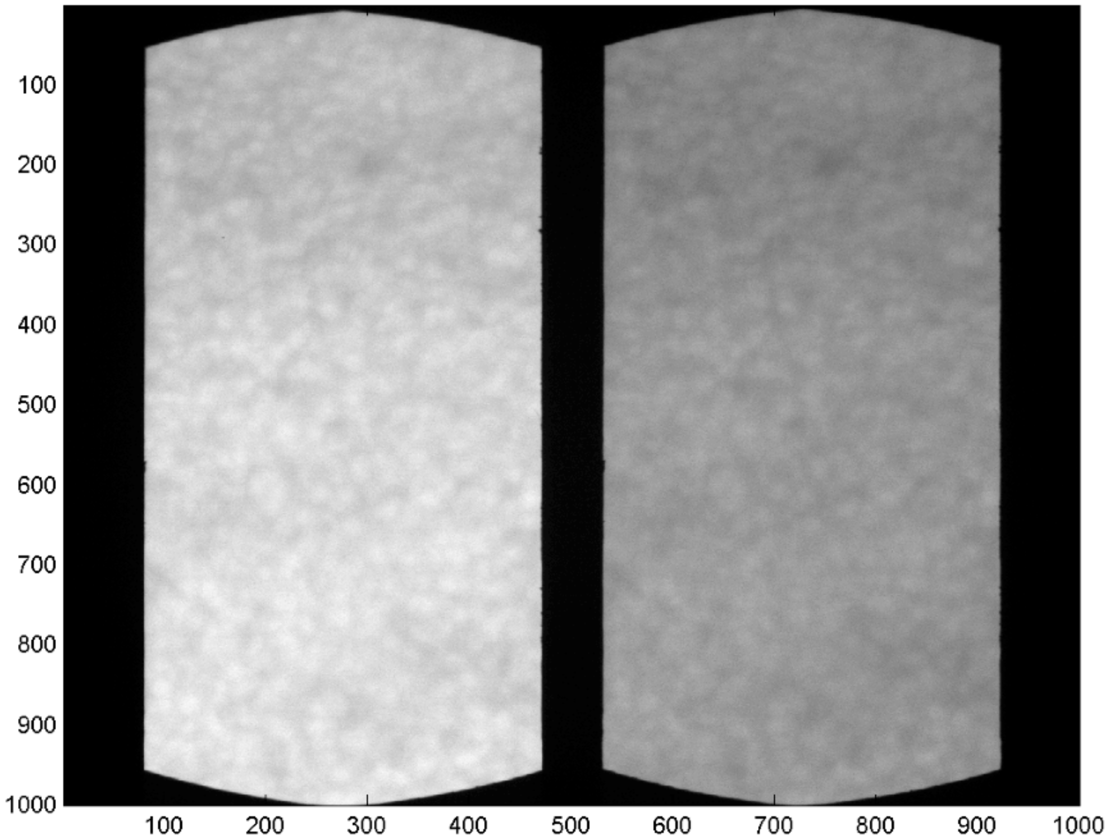
The science data consist of FITS files with each 2-D image in the predefined observing sequence stored as an extension (integer, 2 bytes/pixel). For example, if the sequence consists of a scan of one line in 15 points, a second line in 20 points, and a single wavelength burst with 30 images, the FITS file will include 65 1k x 1k image extensions. Sequences can be highly varied: hence the FITS files can have sizes from 2 MB to 2 GB (1-1000 images). If sequences are repeated in time, the files are saved with a progressively numbered filename in the same directory. Calibration data are similar: flat field sequences are completely analogous to science ones, but on a quiet, blurred and moving disk-center target. The data are automatically sorted into subdirectories based on observing modes.

Can you provide a typical specimen of reduced and possibly raw data?

Yes we can provide a sample. How should we deliver this? (*BG: I shall ask you whenever I am ready)*

We can also point you to a repository of raw data from the recent service-mode observations carried out at the DST: ftp://vso.nso.edu/DST/DST_Service_1/date

(BG: That works as of 2013/10 - FITS are fpack compressed)



What is the current status of the reduction software?

A data reduction software package is under ongoing development in order to deliver as many of the tasks as possible, defined in the IBIS data reduction "recipe". A single command/definition file is used to configure and sequence the data reduction process for a variety of datasets. This allows the software package to automatically carry out many of the spectroscopic calibrations and mitigation of the atmospheric turbulence through destretching or speckle reconstruction techniques. Yet several modules are still needed to produce a more self-consistent and usable data product, the most of important of which might be:

1) correction of the prefilter transmission profile to high accuracy;
2) automatic determination of parameters (shift, scale, rotation, distortions) among different detectors or spectral lines;
3) providing proper alignment and correction of extended image sequences;

4) more automated polarimetric calibration, which includes correction for telescope and instrumental polarization characteristics.

Steps are still to be taken to produce datasets that are fully documented for inclusion in an archive and that can be easily overlaid on data from other instruments, in particular space ones (e.g. SDO, IRIS, etc.).

What major reduction steps are performed by the software/pipeline?

1. Dark and flat corrections. Here it is worth noting that the definition of the flat-field for the spectral channel is a complicated but well understood step - the instrumental blueshift (due to the collimated mount) produces a mix of spectral and system response variations when scanning a spectral line. Proper disentangling in thus necessary before one can apply standard dark+flat corrections.
2. Alignment of the spectral and broadband channel images, and in polarimetric mode, alignment of the images in the two beams.
3. Removal of atmospheric distortions in the spectral channel through destretching or speckle reconstruction, informed by the broadband channel.
4. Measurement of the atmospheric transmission; assignment of proper (quasi-absolute) wavelength scale.
5. Determination of the instrumental polarimetric matrix from daily calibrations, and optionally application to the data, together with a stored telescope polarization matrix.

What computer language is used?

Mostly IDL, will external calls to C procedures for the speckle reconstruction phase. Do you have a technical documentation for the pipeline ?

A formal documentation does not exist. Some technical reports, memos, and paper drafts exist but nothing in homogeneous format.

Do you have a user's manual for this pipeline ?

No

How widespread is the use of the software? Is it used in one or in several places?

The code is used in many European and US institutes, as well as possibly some Institutes in India

Are there many varieties, or even several different codes (that are actively used), for these data ?

Yes. The main repository is currently at NSO (Ali Tritschler is the person mainly behind the putting together the package), but people/institutes are running their own forked version pf the software.

Does your pipeline imply to respect a procedure when observing ? Only in the sense of defining an observational sequence which must then be described in the master command file for the automatic reduction. Some of the more complicated or exotic observing sequences are not amenable to the automated processing.

Is this observing procedure in written form ? No

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DST / ROSA (Mathioudakis)

(answers by MM)

Please describe your instrument in a short but comprehensive way.

ROSA is a six camera imaging system optimized for optical wavelengths. Can/has acquired observations in the 3500 – 8500A wavelength range. The six cameras are synchronized through a precision control unit. Cameras are controlled through a GUI interface (running on DELL servers).

Is relevant information about this instrument published?

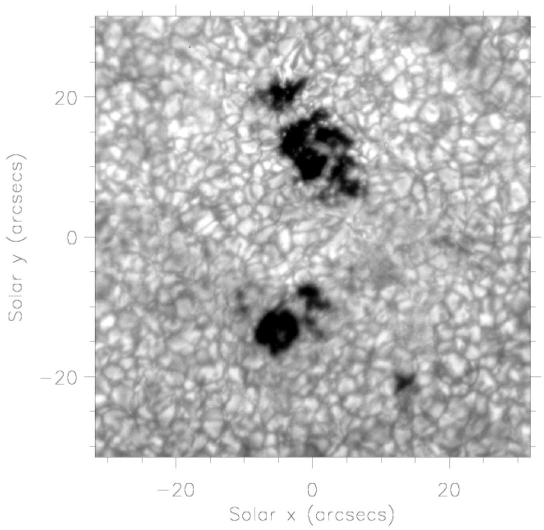
Solar Physics 261, 363-373, 2010)

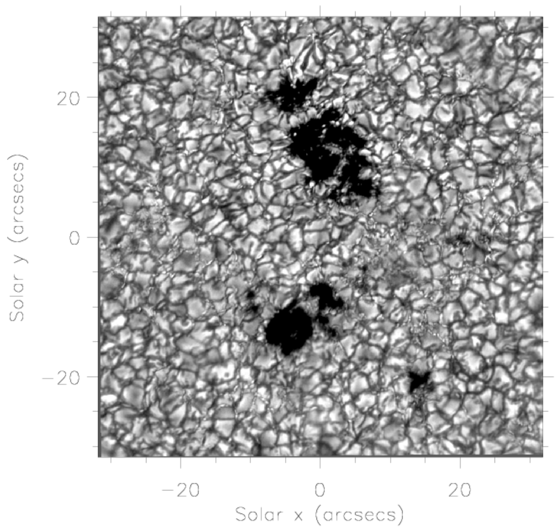
Please describe the output data from your instrument.

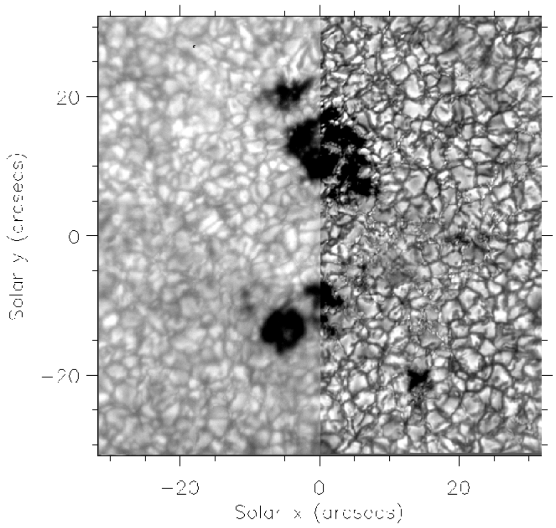
Compressed version of FITS (FTS). 256 images in each file.

Can you provide a typical specimen of reduced and possibly raw data?

See attached images for the wavelength of 4170A (continuum)







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Before and after reconstruction. Additional wavelengths may be sent on request.

What is the current status of the reduction software?

The reduction software is complete. Can be streamlined to work more efficiently/faster.

What major reduction steps are performed by the software/pipeline?

- Flat-fielding
- Dark subtraction
- KISIP reconstruction
- Alignment
- Destretching

Due to the high sensitivity of the ROSA system, it is imperative to accompany data imaging sequences with a range of additional observations. It is these supplementary observations which allow accurately processed images to be produced via the ROSA-specific data reduction pipeline. To compensate for dark current and read-out noise, sufficient dark images (> 250) with exposure times equal to the data acquisition must be obtained and subtracted from the science images. Many flat-field images (> 500) should also be taken through an un-flat telescope mirror coupled to a random guider to allow an accurate gain table to be created for each ROSA camera. These key calibration procedures will enable science data to be corrected for camera inconsistencies as well as for variable light levels across the incident beam.

At this stage, PFIR techniques such as speckle (Weigelt & Wirnitzer, 1983) or multi-object multi-frame blind deconvolution (van Noort, Rouppe van der Voort and Löfdahl, 2005) may be implemented. Indeed, Wöger, von der Lühe and Reardon (2008) have shown how modern PFIR techniques can produce reconstructed images which are photometrically accurate, allowing reliable studies of solar structures to be undertaken. However, image reconstruction processes are extremely CPU intensive and this must be taken into consideration before attempting to reduce the data. For example, during the commissioning run a single ROSA camera obtained over 105,000 raw G-band filtergrams in only one hour of observing. With excellent seeing conditions, an image reconstruction of 16/1 was deemed suitable, providing a reconstructed cadence of 0.5 s. Thus, over 6500 separate reconstructions were required, with each individual process taking approximately 30 CPU minutes to complete on a modern Intel Xeon processor. If access to only one computer is possible (e.g. preparing the data solely on the user's desktop PC), then reconstructing all 6500 images would take in excess of 135 days, with additional time being required to process the data from the remaining five ROSA cameras. As telescope schedules often grant individuals in excess of seven days observing time, and each day commonly provides 2 − 3 hours of good seeing conditions, it is imperative to consider how and where the acquired observations will be reduced so excessive time delays are not experienced. In order to co-align each ROSA camera, additional calibration images should be acquired. Images of an Air-Force target will allow compensation for general rotation and image mirroring, while acquiring a burst of grid images will enable small-scale inter-camera image rotation to be evaluated and removed. With these camera positioning artifacts removed, image destretching can be accomplished through use of the ROSA data reduction pipeline. Under normal circumstances, a 40 × 40 grid, equating to a 1.700 separation between spatial samples (for diffraction-limited resolution at 4170 °A), is used to evaluate local offsets between successive images, allowing compensation for spatial distortions caused by atmospheric turbulence and/or air bubbles crossing the entrance aperture of the telescope. The fine destretching grid implemented in this process allows compensation for small-scale seeing conditions of 100 to 200 in size.

To help facilitate and expedite data preparation, QUB have developed a parallel processing cluster dedicated to ROSA data reduction. This cluster consists of 25 Intel Xeon quad-core CPUs providing 100 processing nodes on a dedicated private network. Users of the ROSA instrument may opt for all data reduction to be carried out on the QUB cluster, or may avail of the freely distributed ROSA pipeline for use on their own reduction cluster. The accurate reconstruction, co-alignment and destretching of multiple atmospheric heights will promote the use of multi-wavelength studies, whereby the cause of dynamic phenomena can be probed and analysed,"

What computer language is used?

IDL except KISIP which is done through a GUI interface

Do you have a technical documentation for the pipeline ?

No

Do you have a user's manual for this pipeline ?

No

How widespread is the use of the software? Is it used in one or in several places?

Used at QUB & Armagh (KISIP used in many institutes)

Are there many varieties, or even several different codes (that are actively used), for these data ?

No – Just the pipeline mentioned above

Does your pipeline imply to respect a procedure when observing ?

There are no special observing procedure for this pipeline.

Is this observing procedure in written form ?

Not applicable

SST / CRISP (Löfdahl)

(Answer is a tentative compilation of the SST website (BG))

Please describe your instrument in a short but comprehensive way

"During April 2008, the CRisp Imaging SpectroPolarimeter (CRISP) was installed at the SST on La Palma. The tunable filter part of this system is a dual Fabry-Pérot Interferometer (FPI) system, usable from 510 to 860 nm with 0.3-0.9 nm wide pre-filters. It has a compact telecentric optical design with a minimum number of optical surfaces and high overall transmission. Polarization measurements are made by liquid crystal (LC) modulation and a polarizing beam splitter, located close to the final focal plane and feeding two 1k×1k-pixel Sarnoff CCD cameras.

MOMFBD image restoration is aided with a third CCD providing broad-band images synchronized with the two narrowband images and recorded through the pre-filter of the FPI system. The optimization of the FPI system is described by Göran Scharmer (2006, A&A 447, 1111), the overall design and details of CRISP will be described in a forthcoming publication and also provided on our web site"

Publications

Many, although none really dedicated to the full polarimetric instrument

0806.1638v2 for general considerations

0902.4150v1 for polarimetry

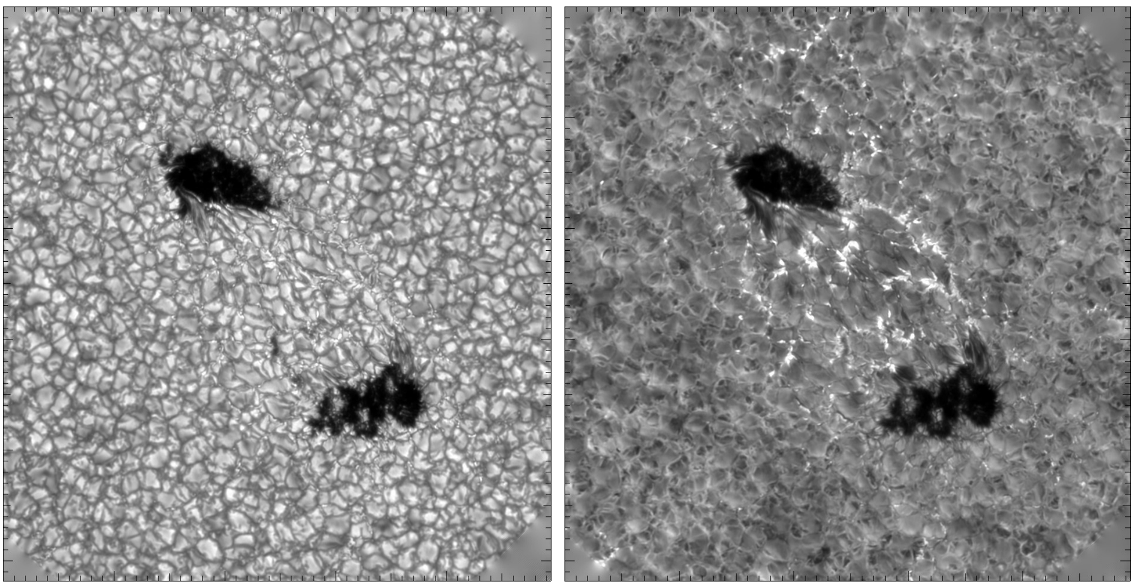
Please describe the output data from your instrument.

"[...]The two CRISP narrowband images shown (below) (jpeg by clicking on the thumbnails, 1000 km tickmarks; in FITS format below, 0.071 arcsec pixels) are recorded at -5 pm from the line core and in the nearby continuum, resp., of the Zeeman-sensitive Fe I line at 630.2 nm. The filter passband is about 6.5 pm at this wavelength. The CRISP tuning sequence used scanned the line in 11 wavelength positions plus one continuum wavelength during < 11 s, while cycling through 4 polarization states. Such data, consisting of a total of 338 images from the broadband camera and 334 polarimetric images each from the two CRISP narrowband cameras, was processed as a single MOMFBD data set by Mats Löfdahl. The restored polarimetric images, each based on 7 exposures, demonstrate impressive spatial resolution at or near the diffraction limit of the telescope (0.16 arcsec at this wavelength) and very high polarimetric sensitivity. "

NB: 1pm =10 mA . Filter is 65 mA wide. NB: Fe line is 600 mA from continuum to continuum. 10 non overlapping filtergram would cover the full line...

Can you provide a typical specimen of reduced and possibly raw data?

Processed (MOMFBD) images from CRISP (No polarisation)



What is the current status of the reduction software?

What major reduction steps are performed by the software/pipeline?

Website has some relevant notes about data processing:

Data processing notes

Description of some polarimetric data reduction:

The data displayed here were recorded on June 12, 2008 as part of a campaign during June 2008. The target was a pore (AR 10998) located at S09E24 (ì=0.79). The field of view was 70″×70″. The images recorded correspond to complete Stokes measurements at 15 line positions in steps of 48 mA, from − 336m̊A to +336m̊ A, in each of the FeI lines, 6301.5 and 6302.5 A. In addition, images were recorded at one continuum wavelength. Each camera operated at 35 Hz frame rate. For each wavelength and LC state, 7 images were so recorded per camera. Each sequence for subsequent MOMFBD processing consists of about 870 images per CCD (2600 in total), recorded during 30 s. The images were divided into overlapping 64×64 pixel subfields sampling different isoplanatic patches with overlaps. All images from each subfield were then processed as a single MOMFBD set. They were demodulated with respect to the polarimeter and a detailed telescope polarization model. In addition, the resulting Stokes images were corrected for remaining I to Q , U and V crosstalk by subtraction of the Stokes continuum images. Figure 1 shows an example of the resulting Stokes images.

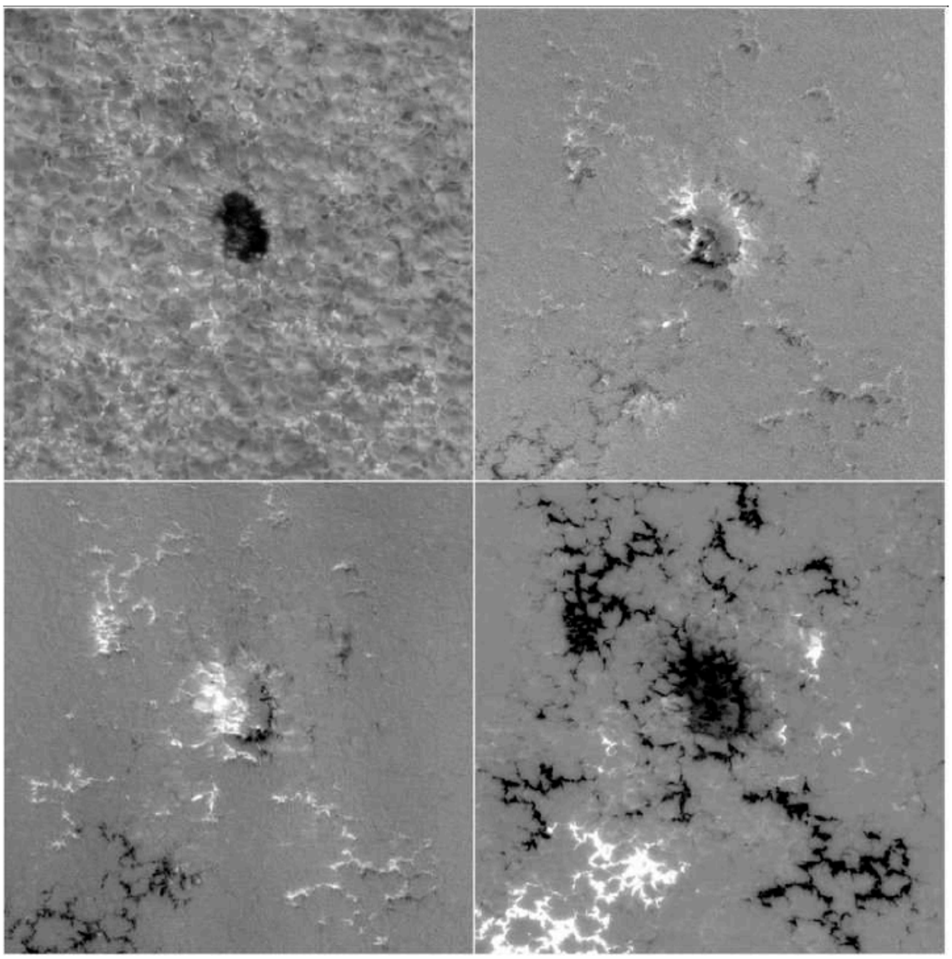


Fig. 1. Clockwise: Stokes I, Q, V and U images taken in the blue wing of Fe I 6302.5 Å at $\Delta\lambda = -48$ mÅ, on June 12, 2008.

To derive the atmospheric parameters from the observed Stokes images we use a least-square inversion code, LILIA (Socas-Navarro 2001), based on LTE atmospheres.We assume a one component, laterally homogeneous atmosphere together with stray light contamination. The inversions returns 9 free param- eters as a function of optical depth, including the three components of the magnetic field vector (strength, inclination and azimut), LOS velocity and temperature among others.

What computer language is used?

- [IDL]

Do you have a technical documentation for the pipeline ?

-

Do you have a user's manual for this pipeline ?

-

How widespread is the use of the software?

Is it used in one or in several places?

Are there many varieties, or even several different codes (that are actively used), for these data ?

Does your pipeline imply to respect a procedure when observing ?

Is this observing procedure in written form ?

SST / TRIPPEL (Kiselman)

(Answer from DK)

Please describe your instrument in a short but comprehensive way

Tri-Port Polarimetric Echelle-Littrow Spectrograph, TRIPPEL, is a grating spectrograph with three exit ports allowing simultaneous observations of three different wavelength regions. Order selection is made with interference filters placed in front of the cameras.

There exists a polarimeter for TRIPPEL. It has not been used much and was essentially moth-balled when Hinode started its successful observations. The problem with the polarimeter is that it is built around a camera that is no longer supported (manufacturer bankrupt) and is thus stuck with a very old computer and control software.

*Is relevant information about this instrument published?*yes

2011A&A...535A..14K (See Sec.2)

Please describe the output data from your instrument.

Spectrograms (up to three different) "Slit-jaw" images where the observer has large freedom to set up cameras and filters.

Can you provide a typical specimen of reduced and possibly raw data?

Please see Let me return with this. I can do it.

What is the current status of the reduction software?

It exists in a repository in Stockholm, but there was some time since I looked at it last.

It is rather simple and not well-written nor documented, but more advanced features are foreseen and could be added without many complications. (More advanced stray light-modelling is an obvious such improvement.)

If it has a name, it is "redspec".

What major reduction steps are performed by the software/pipeline?

- Mapping of, and subsequent correction for, geometrical distortion of the spectrograms.
- Dark-subtracting Construction of flat fields
- Wavelength calibration (from comparing flat-field exposures to a solar atlas)
- Simple estimation of and correction for straylight and correction for large-scale deviations by comparing mean spectra with a solar atlas.
- Simple intensity calibration correcting for airmass changes, odd-even shutter effects etc during observations.
- Simple reduction of any slit-jaw images, but here different observers always use different setups so these procedures can never be very general.

What computer language is used?

IDL, making use of some more or less standard DLMs for reading raw images.

Do you have a technical documentation for the pipeline ?

No.

Do you have a user's manual for this pipeline ?

Not really.

How widespread is the use of the software? Is it used in one or in several places?

It has been copied by two or three users, and what they do to it, I don't know.

Are there many varieties, or even several different codes (that are actively used), for these data ?

I suspect that some of those who copied this made their own changes, but there can't be any dramatic changes or improvements.

In Oslo they have their own software, probably written by Langangen. I don't know if that is actively maintained.

Other observers may have done their own independent efforts (Bellot Rubio? Schlichenmaier? Sancez Almeida? Berger?)

This project is supported by the European Commission's FP7 Capacities Programme for the period April 2013 - March 2017 under the Grant Agreement number 312495.

Does your pipeline imply to respect a procedure when observing ?

It assumes that flatfields and darks are taken as well as exposures with a grid in front of the slit to aid the mapping of geometrical distortions.

Is this observing procedure in written form ?

The SST wiki http://dubshen.astro.su.se/wiki /contains some advice on setup and observations, but does not impose any specific procedure.

SST / CHROMIS (Löfdahl)

(Tentative answer from Mats Lofdahl)

Please describe your instrument in a short but comprehensive way:

CHROMIS will be a CaII H&K spectral imaging device similar to CRISP in design (e.g. FP based)

No data on polarimetric capabilities

Current status at the time of this poll is: Just starting

THEMIS / MTR (Lopez)

(answer from A. Lopez)

Please describe your instrument in a short but comprehensive way.

MTR stands for "MulTIRaie". It is a multiline double pass spectrograph instrument able of observing up to 6 simultaneous spectral domains from 400 through 1300nm. By default it includes polarimetry

Is relevant information about this instrument published?

Yes

Please describe the output data from your instrument.

A FITS3 file. Each file contains one single header and a cube of data with dimensions 512x512xN where N is the number of polarimetric modulation states (usually 6) times the number of scan steps or time series

Can you provide a typical specimen of reduced and possibly raw data?

Yes (how?)

What is the current status of the reduction software?

Two data reduction packages are available to the observer. One of them (SQUV) is freely downloadable, the second one (DeepStokes) upon request. SQUV also runs automatically on the telescope so that a standard data reduction is performed online and in almost real time.

What major reduction steps are performed by the software/pipeline?

Dark current, flat fielding, geometry corrections (field limits, spectral line redressing, wavelength calibration), polarimetric demodulation

What computer language is used?

IDL

Do you have a technical documentation for the pipeline?

Yes

Do you have a user's manual for this pipeline?

Yes

How widespread is the use of the software? Is it used in one or in several places?

SQUV is used by about half the users of MTR and installed in their computers. DeepStokes is used by just 3 teams.

Are there many varieties, or even several different codes (that are actively used), for these data ?

As said above, there are two different pipelines provided for this instrument. They are called SQUV and DeepStokes

Does your pipeline imply to respect a procedure when observing ?

Both codes assume the presence of one Dark Current and one Flat Field per Data File

Is this observing procedure in written form ?

Observation with this instrument comes with a HowTo document that prones observing in a manner that both ensures the quality of the data and the ability of the two pipelines to correctly work with it

THEMIS / TUNIS (Lopez)

(answer from A. L.A. & B.G.)

Please describe your instrument in a short but comprehensive way.

TUNIS stands for "Tunable Universal Narrowband Imaging Spectrograph". It is a subtractive double pass imaging spectrograph that images 2x2 arcmin at any wavelength between 400 and 1300nm with 20mA bandwidth. Spatial resolution is 0.2arcsec. It uses spectral multiplexing to cover 63 wavelength bins quasi simultaneously over the image.

Is relevant information about this instrument published?

HD-TUNIS (with wavelength multiplexing)

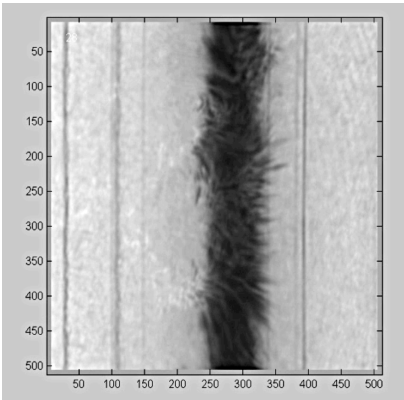
TUNIS without multiplexing

Please describe the output data from your instrument.

A series of FITS files. Each FITS file contains 63 images 1024x1024 in size that correspond to a multiplexing cycle. There are as many files as required by the scan or the time series

Can you provide a typical specimen of reduced and possibly raw data?

Below is an example of one TUNIS raw spectroimage, taken in the Ha domain over the quiet Sun. The spectroimage is the superimposition of an image (mostly coming from the continuum) and of the the familiar Ha profile. No wavelength multiplexing was done on this spectroimage.



What is the current status of the reduction software?

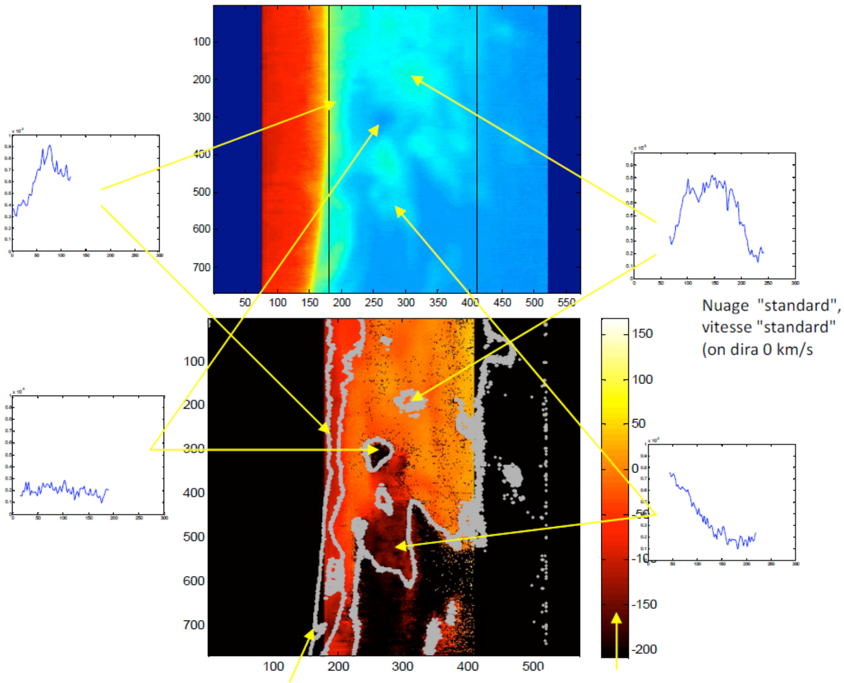
A data reduction package is available

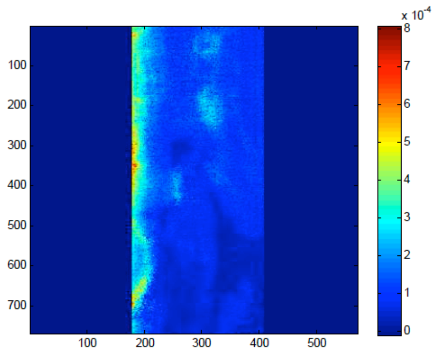
What major reduction steps are performed by the software/pipeline?

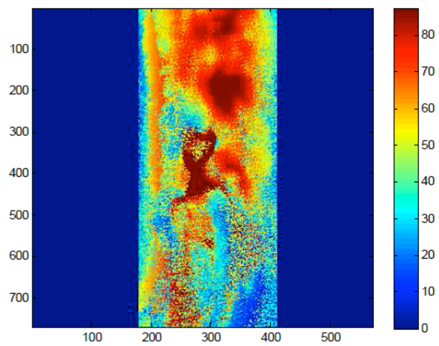
- Dark current, flat fielding
- wavelength calibration and demultiplexing.
- Mapping of spectral line parameters (Intensity, velocity, and linewidths maps are available)

Below is an example of what is currently achievable with HD-TUNIS:

Top frame is the intensity average over a prominence observed in the Ha line. Middle frame is the velocity mapping of the same field. (Some field restriction is unavoidable between intensity and other parameters due to wavelength scanning). Bottom frames are line amplitude and FWHM. For each field point, a *partial* Ha line profile is available. Inserted plots show how this profile reflects physics changes across the field.







What computer language is used?

IDL / MATLAB

Do you have a technical documentation for the pipeline?

No

Do you have a user's manual for this pipeline?

No

How widespread is the use of the software? Is it used in one or in several places?

TUNIS is just commissioned. There have been no open observations with this instrument yet

Are there many varieties, or even several different codes (that are actively used), for these data?

No

This project is supported by the European Commission's FP7 Capacities Programme for the period April 2013 - March 2017 under the Grant Agreement number 312495.

Does your pipeline imply to respect a procedure when observing?

Yes

Is this observing procedure in written form ?

No

Survey Summary of replies

Tel.	Instrument		Polar	Has pipeline	Computer language	Tech Doc	User's manual	Observing procedure
VTT	LARS	Fiber-fed spectrograph with laser frequency comb reference	N	ongoing	IDL / C	N	N	Y / no doc
	TESOS	Vis triple FP etalon (+ visible imaging polarimeter)	Y	Y (outdated)	IDL	N	Y	Y (instrument manual)
GREGOR	GRIS-TIP	1d IR polarimeter (TIP) / long slit spectrograph	Y	Y since VTT	IDL	N	N	Y / no doc
	BLISS	Vis/Blue double FP (+ Gregor polarimeter)	Y	?	?	?	?	?
	GFPI	Vis/Red double FP (+ Gregor polarimeter)	Y	Y	IDL / C	?	?	?
SST	CHROMIS	Vis/Blue Dual FP	?/Y	?	?	?	?	?
	TRIPPEL	Tri-port echelle Littrow spectrograph (+ polarimeter)	Y	Y	IDL	N	Some ?	Y in wiki
	CRISP	VIS double FP (+ own LCVR polarimeter)	Y	Y	IDL / C / C++	Some	wiki	Y in wiki
DST	ROSA	High frequency broad band (filter) multichannel imaging	N	Y	IDL / C	N	N	N (but ?)
	IBIS	Double FP (+ own polarimeter)	Y	Y	IDL / C	some	N	Y (seq. definition) /no doc
THEMIS	TUNIS	Subtractive double pass spectroimager	N	Y	IDL	N	N	Y /no doc
	MTR	1d Vis/Nir multiline spectropolarimeter	Y	since 2006	IDL	N	Y	Y/ w. howto doc

Instrument families

The panel of 12 surveyed instrument included 8 typical imagers or spectroimagers, and 4 spectrograph-based instruments

Among the imagers,

- 6 are double or triple Fabry-Perot narrow band tunable imagers (TESOS, BLISS, GPFI, CHROMIS, CRISP, IBIS)
- 1 is a subtractive double pass spectroimager (TUNIS)
- 1 multichannel BB imager (ROSA)

Among the spectrographs,

- 2 are visible or near infrared spectropolarimeters (MTR, TRIPPEL)
- 1 is an infrared spectropolarimeter (with visible capability) GRIS-TIP
- 1 is high precision radial velocity device, based on laser-comb user (LARS)

Polarimetry:

Polarimetric (usually full-Stokes) is either permanent or on-demand on 9 instruments:

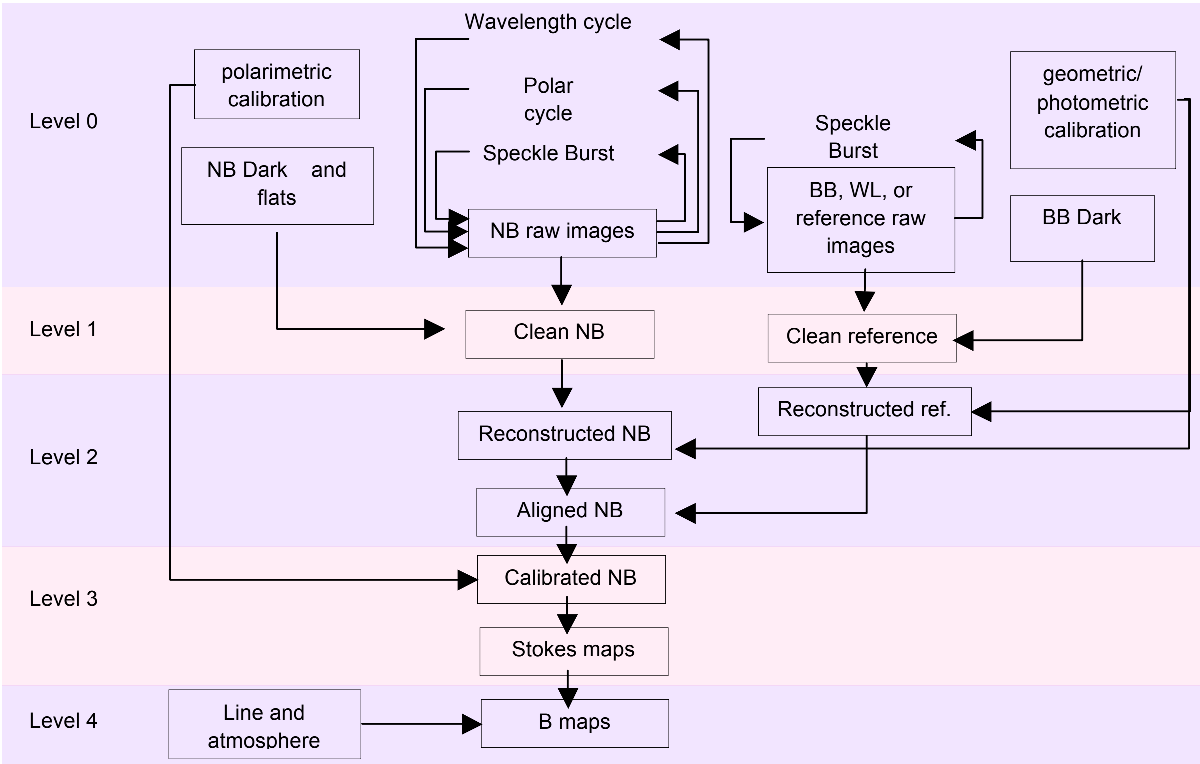
- TESOS, GRIS-TIP, BLISS, GPFI, CHROMIS TRIPPEL, CRISP, IBIS, MTR

3 Instruments are not polarimeters, or have not been using polarimetric analysis so far.

- LARS, ROSA, TUNIS

Data Processing levels

Imaging instruments in polarimetric mode:



Typical pipeline flow for imaging instruments running in polarimetric mode.

Following is a tentative referencing of data products coming out of this mode, broken down into levels of analysis. We indicate also a degree of complexity of which the data may depend on:

Typical parameters:

- *x, y* field position or image pixel
- λ wavelength
- *S* Stokes parameter
- *nburst* burst index number
- *t* time of the day
- *TBD* To be defined dependance

Level 0.

IP 0 .1	Burst of polarimetric narrowband images	$I_n(x, y, \lambda, S, nburst)$
IP 0 .2	Dark images for narrowband cameras	$X_n(x, y, nburst)$
IP 0 .3	Flat images for narrowband cameras	$Y_n(x, y, nburst)$
IP 0 .4	Burst of broadband or white light images	$I_b(x, y, \lambda, S, nburst)$
IP 0 .5	Dark images for broadband cameras	$X_b(x, y, nburst)$

IP 0 .6 Flat images for broadband cameras Y_b(*x, y, nburst*)
IP 0 .7 Any other geometrical calibration image (e.g. pinhole, …) C_g(*x, y, TBD*)
IP 0 .8 Any other photometric calibration image C_p(*TBD*)
IP 0 .9 Polarimetric calibration data (Telescope and instrument Mueller matrix) *CP(t, S, TBD)*

Level 1.

IP 1 .1 Clean narrowband images I_n (*x, y, λ, S, nburst*)
IP 1 .2 Clean reference imag I_b (*x, y, λ, S, nburst*)

Level 2.

IP 2 .1 Reconstructed narrowband images I_n (*x, y, λ, S*)
IP 2 .2 Reconstructed reference images I_b (*x, y*)
IP 2 .3 Aligned narrowband images I_n (*x, y, λ, S*)

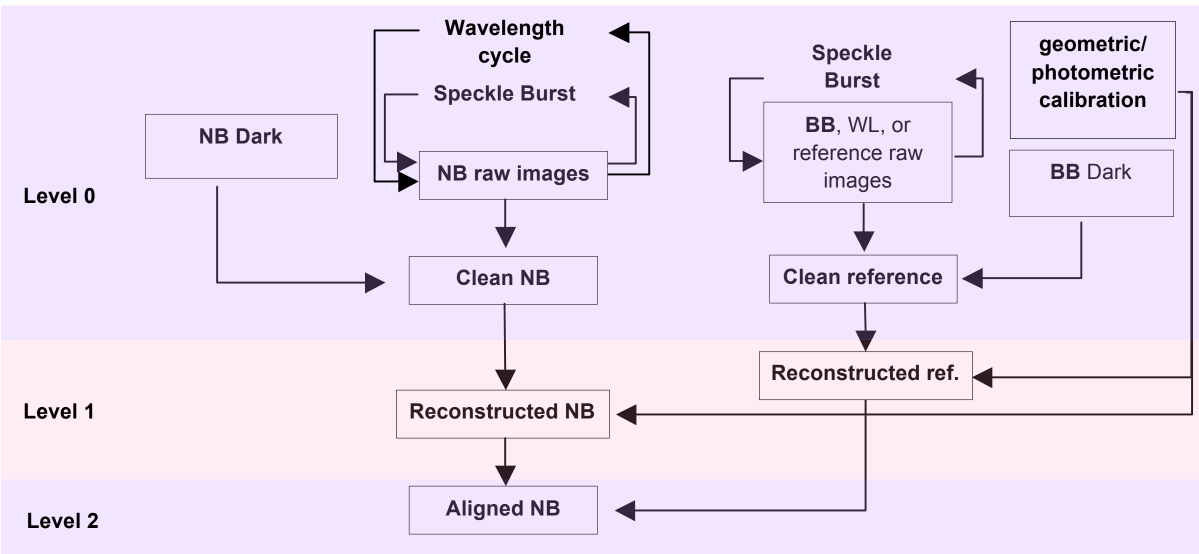
Level 3.

IP 3 .1 Polarimetry calibrated narrowband images I_n (*x, y, λ, S*)
IP 3 .2 Stokes maps S_{ns} (*x, y, λ*)

Level 4.

IP 4 .1 Magnetic field maps B (x, y, *TBD*)
IP 4 .2 Filling factor maps
IP 4 .3 TBD scientific analysis

Imaging instruments FP based in non polarimetric mode



Typical pipeline flow for imaging instruments in non-polarimetric (only imaging) mode

This project is supported by the European Commission's FP7 Capacities Programme for the period April 2013 - March 2017 under the Grant Agreement number 312495.

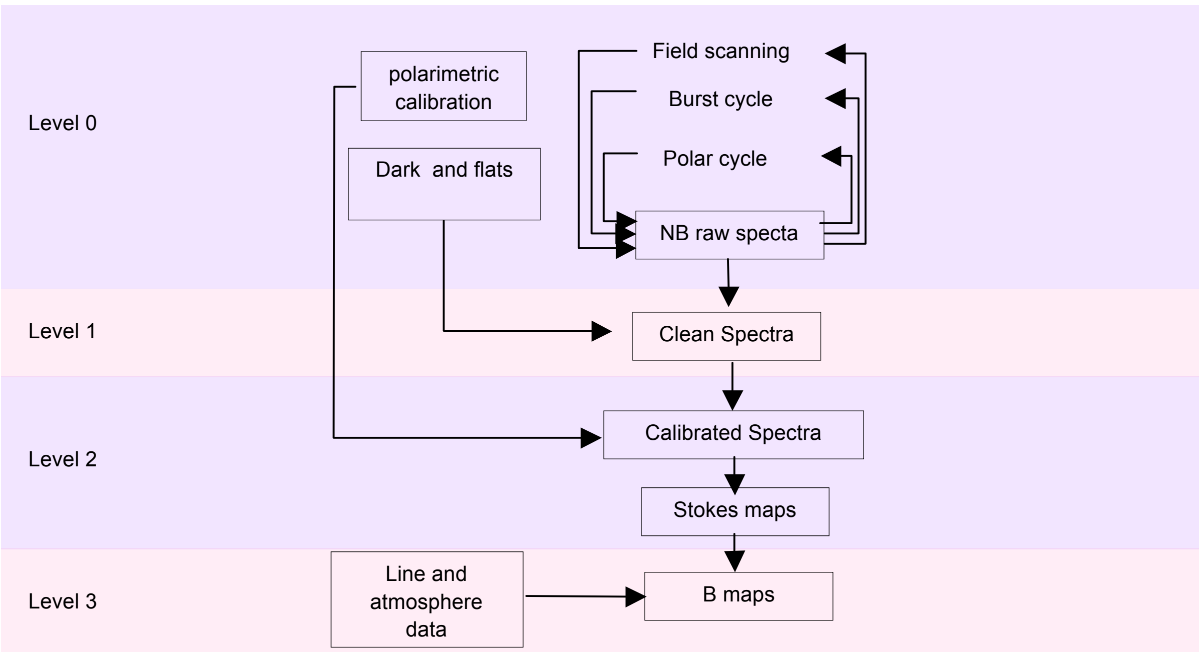
This is a simpler version of the former analysis, in which, the polarimetric cycle basically disappear from the acquisition loop. Therefore, no demodulation is needed or possible, and the analysis stops at former level 2. Following is a tentative referencing of data products broken down into levels of analysis.

Level 0. data products
- INP 0.1. Burst of narrowband images
- INP 0.2. Dark images for narrowband cameras
- INP 0.3. Flat images for narrowband cameras
- INP 0.4. Burst of broadband or white light images
- INP 0.5. Dark images for broadband cameras
- INP 0.6. Flat images for broadband cameras
- INP 0.7. Any other geometrical calibration image (e.g. pinhole, …)
- INP 0.8. Any other photometric calibration image

Level 1. data products
- INP 1.1. Clean narrowband images
- INP 1.2. Clean reference image

Level 2. data products
- INP 2.1. Reconstructed narrowband images
- INP 2.2. Reconstructed reference images
- INP 2.3. Aligned narrowband images

Spectropolarimetric instruments (Long Slit Scanning Spectrographs)



Typical pipeline flow for imaging instruments in non-polarimetric mode (only imaging)

Following is a tentative referencing of data products coming out of this mode, broken down into levels of analysis. We indicate also a degree of complexity of which the data may depend on:

Typical parameters:

- *x, y* field position (or image pixel)
- λ wavelength
- *S* Stokes parameter
- *nbusrt* burst index number
- *t* time of the day
- *TBD* To be defined dependance

Level 0.

SP 0.1	Burst of polarized spectra	I_n(*x*, λ, *S*, *nburst, nscan*)
SP 0.2	Dark referenc	X_n(*x*, λ, *nburst*)
SP 0.3	Flat reference	Y_n(*x*, λ, *nburst*)
SP 0.4	Polarimetric calibration data (Telescope and instrument Mueller matrix)	C*P(t, S, TBD)*

Level 1.

SP 1.1	Clean spectra	I_n(*x*, λ, *S*, *nburst, nscan*)

Level 2.

SP 2.1	Polarimetry calibrated spectra	I_n(*x*, λ, *S, nscan*)
SP 2.2	Stokes maps	S_{ns}(*x*, *y*, λ)

Level 3.

SP 3.1	Magnetic field maps	B (x, y, *TBD*)
SP 3.2	Filling factor maps	
SP 3.3	TBD scientific analysis	

Pipeline considerations

It is obvious from the above tables that data products *decrease in complexity and number* with the analysis level.

An end-to-end pipeline to reduce narrowband imaging data in polarimetric mode (IP flowchart) can hence be decomposed in 4 "big chunks", corresponding to the laps between the 5 data levels we have identified. These chunks can be roughly described as follow:

- Chunk 1: from raw to clean data, for NB and reference (white light) channels. This basic step requires a large amount of additional calibration data that have to obey certain strict logic procedures during the acquisition process to exist. Failure to do so would result in uncleanable data and full-stop of the pipelines.
- Chunk 2: from clean to reconstructed co-aligned NB images. This is the **"reconstruction"** or **"deconvolution"** step. While this was truly a research area in recent years (and without any presumption that it will stop being the case), it is now a relatively mature process that has been automated in many places.
- Chunk 3: from reconstructed co-aligned NB images to Stokes maps. This is a **demodulation** process that relies on the specific polarimetric modulation that has been used during the acquisition.

- Chunk 4: from Stokes maps to $\vec{B}$ (magnetic field) maps and other science products (filling factors, etc ...). This is the **"inversion"** process which relies on a numerical inversion algorithm (several flavours available) , and the theoretical knowledge of the polarized radiation transfer for the spectral line used. While there are very little line choices for a full formal treatment, approximations and proxies can provide some of the relevant information in a larger number of cases.
-

		Difficulty in pipelining
Chunk 1	Cleaning	Availability of all required annex and calibration products. Critically relies on an observing protocol
Chunk 2	Reconstruction	Straightforward
Chunk 3	Demodulation	Availability of calibration data
Chunk 4	Inversion	Availability of scientific knowledge

IP pipeline chunks

We do not discuss the INP pipeline as it would be the same than above, only simpler as it would stop at chunk #2.

Below is the same for the SP pipeline.

		Difficulty in pipelining
Chunk 1	Cleaning	Availability of all required annex and calibration products. Critically relies on an observing protocol
Chunk 2	Demodulation	Availability of calibration data where needed
Chunk 3	Inversion	Availability of scientific knowledge

SP pipeline chunks

So given the data levels above that are shared by the instruments families we defined, we are now able to identify (rather precisely) some pipelines chunks that are right now implemented and exploited, of course differently depending on the instrument and the team considered. Having common analysis tools is not a matter of the present work but may be of interest if looking at the future EST.

"Science ready" data:

"Science ready data" are level 0 data that have been processed to some point that make them suitable:

- for archiving for future needs, saving the trouble to reprocess the raw data each time.
- to represent the starting point of higher levels of processing, more dedicated to the scientific exploitation.

There is a fundamental difference between the initial processing to produce the "science ready data" and the further processing steps, mostly because the initial processing requires an extensive knowledge of the instrumental design and setup, or calibration procedures, which is typically with the instrument maker or the telescope operator. Inversely, the further analysis of science ready data shall be independent of this instrumental knowledge, making this processing possible by a scientist only concerned by some specific science case, possibly without any other additional information than the data themselves.

While we have been formerly dealing with several data level, we can now simplify this scheme, there is a lower processing segment (level 0 data to science ready data), and a higher processing segment (from science ready data to infinity and beyond).

Science ready data are obviously more than just clean level 1 data. They include more processing depending on the pipeline considered. In our opinion, science ready data are the following:

IP case

- IP 3.1 Polarimetry calibrated NB images
- IP 3.2 Stokes maps

INP case

- INP 2.3 Aligned NB images

SP case

- SP 2.1 Polarimetry calibrated spectra
- SP 2.2 Stokes maps

In both cases, we assume that the reconstruction/alignment process is part of the lower level processing, with little or no options during this part that could impact the further scientific exploitation. In the polarimetric case, we assume that polarimetric calibration shall be also part of the lower level.

Polarimetric NB images, or polarimetric spectra are the very basic products that can be qualified as science ready. There is a discussion to have as if the demodulation process producing the Stokes maps shall be or not included in the lower level processing.

File formats

FITS files are used by many operators from the lowest level, and by everybody in this survey at higher processing levels. Raw camera format can be more convenient for rapid data streaming in some cases, but their use is by now restricted to level 0 data.

FITS is an open standard that defines "a digital file format useful for storage, transmission and processing of scientific and other images. FITS is the most commonly used digital file format in astronomy." It is mostly supported by NASA and other large size astronomy agencies. We foresee no problem in recommending the use of FITS as it is today the case, and see no advantage in changing to other suitable formats (CDFS of HDFS) that exists.

We detect however that there is so far no convergence in the survey on how FITS metadata are used, from simple datacube container to complex headers trying to say something of/to the related pipelining process. Too little sample data have been provided to explore further in this direction, and that is something worth to be done during the next months.

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Preliminary tentative recommendations / future actions

1. Implement a data level reference standard within the pipelines makers, possibly using the proposed levels defined in this document. Doing this, pipelines development can stay independent, but inputs and outputs products reference can be shared across institutions.

2. Also try to better define these products (next report) .

3. Regarding the future interoperability of pipelines and programming staff, most of the efforts shall be put on the "lower level processing " (from level 0 data to science ready data for a given instrument family).

4. Get an agreement on the science ready data definition proposed in this document.

5. Within the "lower level processing", the pipeline step from level 0 to level 1 (clean) shall have an unlimited guaranty of robustness. We think that only or the instrument maker or the telescope operator should build and tune this part of the pipeline. We stress the fact that this step must obviously include the knowledge of the observing procedure, plus the knowledge of all the unexpected / undocumented events that may have affected this procedure and the observations (weather, failures…) , and that **must** be considered by the program without any (or as little as possible) human operator intervention. We recognize this to be possibly the most difficult step to perform among all the processing levels.

6. The former point shall not be taken in the meaning of maximizing the data output, but of maximizing the robustness of the cleaning process.

7. Archiving / data diffusion (recommendations subject to individual telescopes policies)

    - keep level 0 data at the telescope archive **and only there**. No level0 data should ever be distributed to an end user.
    - archiving/diffusion of level 1 and science ready levels are high priority duties of the community.
    - Possible archiving diffusion of some higher level data products may be relevant but would require an agreement on which products can interest a larger community than the Solarnet partners, and an agreement on higher level scientific processing to get to these products. We see this as a lower priority possibility.

Coming next RP:

- Observing procedure documentation
- Data level referencing acceptance
- Data documentation (fits metadata)
- Data quality index and scientific acceptance tests
- Processing documentation (fits metadata and user's guides).