

# CASA-ASAP

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# CASA Requirements

- ALMA OFFLINE subsystem requirements
  - <http://almasw.hq.eso.org/almasw/pub/SSR/SoftwareSubsystemsDetailedRequirements/offline.rqmts.ALMA-70.10.00.00-006-B-SPE.pdf>
- Priorities
  - 1: essential
  - 2: highly desirable
  - 3: desirable, but not critical

# General

- *OL-1.1-R2 All standard observing modes supported by ALMA must be processable by the package: Priority 1*
- cf. Single-dish observing modes
  - OTF mapping
    - with OFF, without OFF (use edge as OFF)
    - position switch, nutating, frequency switch
  - Position switch, beam switch using nutator
  - Frequency switch
- *OL-1.2-R3 There shall be session logging, including the following features:*
  - *OL-1.2-R3.2 logging of tool results such as success or error, files written, time of completion shall be provided: Priority 1*
  - *OL-1.2-R3.3 logging of tool output such as summaries of results shall be provided: Priority 2*

# UIs, Helps, and Documentations

- OL-2.2-R4 *GUI-based tools shall be available* for reduction of data taken in all standard ALMA observing modes: Priority 2
- OL-2.2-R6 *The look and feel of the GUI will be uniform* throughout the entire package: Priority 2
- OL-2.5-R1 *There shall be a variety of help levels and documentation formats accessible from the UI and over the Internet, applicable to novices, experts, and technical users. These shall include:*
  - OL-2.5-R1.1 *user cookbooks* with extensive examples: Priority 1
  - OL-2.5-R1.2 *application descriptions and reference manual* (with all inputs to functions and tools): Priority 1
  - OL-2.5-R1.3 online help, FAQ, email contacts: Priority 1
  - OL-2.5-R1.4 release history, bug reports and tracking, patch descriptions: Priority 1
  - OL-2.5-R1.5 programmer references and guides: Priority 2
  - OL-2.5-R1.6 *data format descriptions*: Priority 2
  - OL-2.5-R1.7 algorithm descriptions: Priority 2
  - OL-2.5-R1.8 newsletters, email exploders, notes series: Priority 3

# Data Format

- *OL-3.1-R2 The Package shall be able to handle the integrated data objects corresponding to the observational programs carried out by ALMA. These objects may be implemented in any manner appropriate, though relations between the components of the object must be maintained through some mechanism. These include:*
  - *OL-3.1-R2.1 Program header information: Priority 1*
  - *OL-3.1-R2.2 Observation status information (and schedules themselves): Priority 1*
  - *OL-3.1-R2.3 Field information: Priority 1*
  - *OL-3.1-R2.4 Data from interferometer and single-dish organized by:*
    - *OL-3.1-R.2.4.1 position: Priority 1*
    - *OL-3.1-R2.4.2 subreflector state: Priority 1*
    - *OL-3.1-R2.4.3 polarization products: Priority 1*
    - *OL-3.1-R2.4.4 spectral channels: Priority 1*
    - *OL-3.1-R2.4.5 frequency bands: Priority 1*
    - *OL-3.1-R2.4.6 IFs: Priority 1*
    - *OL-3.1-R2.4.7 subarray including those of ACA systems (the TP Array and the 7m Array): Priority 1*

# Data Format (Continue)

- *OL-3.1-R2.6 Total power (autocorrelation) data from antennas in single-dish mode : Priority 1*
- *OL-3.1-R2.7 Weights and/or data uncertainties: Priority 1*
- *OL-3.1-R2.8 States indicating special modes (such as ON/OFF positions), for:*
  - *OL-3.1-R2.8.1 OTF scanning: Priority 1*
  - *OL-3.1-R2.8.2 subreflector switching: Priority 1*
  - *OL-3.1-R2.8.3 frequency switching: Priority 1*
- *OL-3.1-R2.9 Flagging data or masks: Priority 1*
- *OL-3.1-R2.14 Processing history: Priority 1*

# Data Selection

- *OL-3.1-R25 Data selection and handling issues specifically related to single dish processing: ...The user will want to be able to quickly flip from considering one spectra to another and,... To do this, the following capabilities are needed:*
  - OL-3.1-R25.1 **Spectra selection**: The software needs an easy-to-use mechanism to select either individual or multiple spectra for viewing, parallel processing, etc.: *Priority 1*
  - OL-3.1-R25.2 **Polarization/IF selection**: *An easy-to-use mechanism to select individual IFs or polarizations is needed: Priority 1*
  - OL-3.1-R25.3 **Interactive channel selection**: *The range of spectral points to use for, e.g., baseline removal, statistical calculations, RFI editing or analysis must be easily set by the user from both the CLI and GUI. ...: Priority 1*



# Data Selection (Continue)

- OL-3.1-R25.4 *Auto-identify reference spectra*: When performing sky subtraction on many spectra simultaneously, the software should have a mechanism for identifying “on” and “off” spectra and automatically selecting the signal and reference spectra based on header information. The algorithm needs to cope with on/off/on/off sequence as well as off/on/off/on sequences. *User specified preference* such as “closest in time” to “first reference before source” should be accommodated.: Priority 1
- OL-3.1-R25.5 *Select source* via header values: The software should be able to select sets of sources based on simple regular expression type filtering (wild cards) on a range of header values: Priority 1
- OL-3.1-R25.6 *Single dish Meta-data*: A comprehensive set of header data should be read from the input data files. The user may wish to enter some specific values by hand.
  - OL-3.1-R25.6.1 *View and edit header data*: All header data (except the processing history) should be viewable and editable by the user. This includes changes such as scaling the given Tsys values.: Priority 1
  - OL-3.1-R25.6.2 *User add missing header data*: The user must be able to add missing header data. It must be possible to add the same header data to multiple scans simultaneously.: Priority 2

# Data Import/Export

- OL-3.2-R1 A variety of data formats must be supported by the Package:
  - OL-3.2-R1.1 The ALMA standard archival data format must be supported for input **without loss of functionality or information** (includes both interferometric and ACA single-dish data format): Priority 1
  - OL-3.2-R1.2 Other standard formats as designated by the ALMA Project shall also be supported for both input and output without loss of functionality or information.
    - OL-3.2-R1.2.3 Single dish FITSs: Priority 2
- OL-3.2-R3 The Package must **be able to handle**, efficiently and gracefully, **datasets larger than main memory of the host system**: Priority 1
- OL-3.2-R7 Coordinate frames and units for single dish data export
  - OL-3.2-R7.1 Position Reference frames: **The user should be able to specify the reference frame (e.g. epoch, equinox) used for exporting data and simple mapping output.** The default should be the frame in which the data was recorded. The following reference frames should be supported, e.g.:
    - OL-3.2-R7.1.1 **Equatorial coordinates at J2000 and B1950**: Priority 1
    - OL-3.2-R7.1.2 **Galactic coordinates** (Blaauw et al. 1960): Priority 1
    - OL-3.2-R7.1.3 **Ecliptic coordinates** at an assigned epoch: Priority 1
  - OL-3.2-R7.2 Non-conformist positional reference frames: **Non-conformist positional frames such as Az-El** should be supported: Priority 2

# Data Import/Export (Continue)

- OL-3.2-R7.3 Standard projections: *The user should be able to specify the projection with the assigned reference position used for exporting data and simple mapping output.* The default should be the projection for which the data was recorded. The following projections should be supported:
  - OL-3.2-R7.3.1 Sine Projection (*SIN*): Priority 1
  - OL-3.2-R7.3.2 Flamsteed (Global sinusoidal, *GLS*) projection: Priority 1
  - OL-3.2-R7.3.3 tangent or gnomonic projection (*TAN*): Priority 2
  - OL-3.2-R7.3.4 Stereographic projection: Priority 2
  - OL-3.2-R7.3.5 Equidistant cylindrical projection: Priority 2
  - OL-3.2-R7.3.6 Mercator's projection: Priority 2
  - OL-3.2-R7.3.7 Hammer's projection: Priority 2
  - OL-3.2-R7.3.8 Aitoff's projection: Priority 2
  - OL-3.2-R7.3.9 Homographic projection: Priority 2
- OL-3.2-R7.4 Any coordinate and projection defined by the World Coordinate System (WCS) and supported by FITS format should be supported: Priority 3
- OL-3.4-R1 Data produced by other interferometers and single dishes in similar observing modes shall be importable and processable if provided in ALMA standard archival data format or an ALMA supported data format: Priority 2

# General Calibration and Editing

# Single-Dish Data Reduction

- OL-4.4-R1 *Straightforward and **flexible fitting of spectral bandpass** from calibration source observations is required. Spectral bandpass fitting, or baseline removal, is needed to correct for imperfections in the sky subtractions in the sky subtraction. Depending on the stability of the system, the residual spectral baseline errors can be small or quite large...: Priority 1*
  - OL-4.4-R1.1 *Standing wave ripples: Removal of standing wave ripples should be done by **fitting a Sine function** to the line-free channels: Priority 3*
  - OL-4.4-R1.2 *Robust fitting: “Robust” fitting functions should be available, which are more tolerant to RFI: Priority 3*
- OL-4.4-R2 **De-stripping and adjustment of scan normalization factors must be available for single-dish OTF observations with overlapping and crossing scans.: Priority 1**
- OL-4.4-R3 Calibration of system parameters such as temperature controlled loads and noise sources from observations of celestial sources shall be supported.: Priority 3
- OL-4.4-R4 Processing for pointing, focus, tipping, or beam-fitting data must be available for both single-scan calibration observations and for multiple datasets.: Priority 3



# Single-Dish Data Reduction (Cont.)

- *OL-4.4-R6 Sky subtraction: To remove the effects of the passband filter shape and atmospheric fluctuations across the band, sky subtraction must be performed on the data....*
  - *OL-4.4-R6.1 Arbitrary reference: The user should be able to specify an arbitrary complex reference/source order (which repeats), which can be used to perform multiple sky subtractions in parallel: Priority 2*
  - *OL-4.4-R6.2 **Position switching**: Position switched sky subtractions should be supported: Priority 1*
  - *OL-4.4-R6.3 **Nutator switching**: Nutator switched sky subtractions should be supported: Priority 1*
  - *OL-4.4-R6.4 **Frequency switching**: Frequency switched sky subtractions should be supported: Priority 2*
  - *OL-4.4-R6.5 Tsys variation with frequency: The software should handle all basic system temperature (Tsys) and gain calibration as well as opacity corrections where relevant...For wideband observations, **the software should have the option to handle Tsys which varies across the band....**: Priority 3*
- *OL-4.4-R7 ACA Total Power Calibration: **Sky subtraction methods (position switching, frequency switching and nutator switching) combined with slow OTF** should be supported in order to make the residual sky brightness sufficiently low: Priority 1*

# Single-Dish Data Reduction (Cont.)

- *OL-4.4-R8 Support polarimetry for single dish: All functions on the data (e.g. calibration, sky subtraction) must support polarization.*
  - *OL-4.4-R8.1 **Polarization leakage**: The software should be able to calculate leakage terms from a calibrator source and correct the data either before or after conversion to Stokes (Johnston 2002): Priority 2*
  - *OL-4.4-R8.2 **Calibrate position angle**: The software should be able to determine absolute position angle from a calibrator source and correct the data either before or after conversion to Stokes: Priority 2*
- *OL-4.4-R9 Single dish-specific editing: In a data set with many observations, individual spectra may be corrupted or the data may be affected by RFI and “birdies”. The user needs to be able to easily **flag individual spectra or channels**....*
  - *OL-4.4-R9.1 **Spectra flagging**: The user must be able to set an entire spectra or thereof (e.g. individual polarization, IF) as being invalid: Priority 1*
  - *OL-4.4-R9.2 **Channel flagging**: The user must be able to indicate an individual spectral point or range of spectral points are invalid. This should be applied to an individual spectrum, or set of spectra: Priority 1*
  - *OL-4.4-R9.3 Flagged channel interpolation: When plotting or processing single dish data (e.g. quotient spectra), the user should be able to request that the **values for flagged data are obtained by interpolation from good data on either side of the flagged points**: Priority 2*

# Single-Dish Data Reduction (Cont.)

- *OL-5.3-R4* **Scaling and de-stripping of scans on image-plane combination and of OTF cubes shall be available.** The latter is needed if calibration errors exist.: Priority 1
  - *OL-5.3-R4.1* Initial de-stripping using spatial baselines created from map regions without emission must be available.: Priority 1
  - *OL-5.3-R4.2* Defining and implementing algorithms to get out residual striping shall also be available.: Priority 1
- *OL-5.3-R5* The Package must be able to produce an image by combining data observed on different rasters, possibly taken with different (regular or irregular) spacings and image centers.: Priority 2
- *OL-5.3-R6* Pointing corrections (e.g. as determined by optical cameras or through monitoring data) shall be applicable to the data during imaging: Priority 2
- *OL-5.3-R7* The imaging tools shall allow the option for the mitigation of the effects of noncoplanar baselines and sky curvature.: Priority 2
- *OL-5.3-R8* *Simple single dish imaging: It should be possible to grid single dish data into a cube if desired. Analysis of this cube would be done using CASA functionality: Priority 1*



# Single-Dish Data Analysis

- *OL-6.1-R2 Spectral and scanning baseline removal facility is required:*
  - *OL-6.1-R2.1 Polynomial baseline fitting shall be supported: Priority 1*
  - *OL-6.1-R2.2 Fourier analysis of standing waves and their removal from spectra shall be available: Priority 2*
- *OL-6.2-R1 Automatic and user-controlled measurement of line parameters shall be available.: Priority 1*
- *OL-6.2-R2 It shall be possible for the user to specify a velocity or frequency windowing region for line fitting.: Priority 1*
- *OL-6.2-R3 Available line fitting parameters and profiled shall include:*
  - *OL-6.2-R3.1 Gaussian line parameters (central and integrated intensity, line width, line center) for single or multiple lines: Priority 1*
  - *OL-6.2-R3.2 Damping profiles (Lorentzian): Priority 2*
- *OL-6.2-R4 A set of ALMA standard line catalogs shall be made available by the project and distributed with the Package, with updates available for download when appropriate.: Priority 1*
- *OL-6.2-R5 User importable line catalogs shall be supported by the Package as an ASCII table and in the ALMA standard format.: Priority 2*
- *OL-6.2-R6 Setting of fit constraints (e.g. spacing for multiple lines) shall be available and flexible (i.e. by GUI or by parameter list): Priority 2*
- *OL-6.2-R7 Export of fit results in ASCII-format is desirable: Priority 3*

# Single-Dish Data Analysis (Cont.)

- *OL-6.4-R1 Average spectra with velocity shift: If the velocity of the spectra to be averaged is different, the data should be aligned in velocity.* The user should be able to turn this feature on or off.: Priority 1
- *OL-6.4-R2 Robust averaging: Various robust averaging possibilities (e.g. median averaging, clipped means)* should be possible: Priority 2
- *OL-6.4-R3 Line flux: It must be possible to calculate the flux integral over a range of channels.* The units should be Jy.km/s (or Kelvin.km/s). *The channel range for the calculation should be specified via the GUI or CLI.:* Priority 2
- *OL-6.4-R4 Line width: It must be possible to calculate the numerical “width” of a line (fullwidth-at-half-maximum type of measurement)...*If the profile shape is complex (e.g. double arch) with multiple crossing points of the fraction value, the minimum and maximum width values should be calculated. There should be the option of using a user specified “maximum value.”: Priority 2
- *OL-6.4-R5 FFT filtering: FFT filtering for high- and low-pass filtering and tapering should be available: Priority 3*
- *OL-6.4-R6 FFT to/from autocorrelation function: It should be possible to FFT the data to and from power spectra to the autocorrelation function: Priority 3*
- *OL-6.4-R7 Cross correlation: The user may wish to compute the cross correlation function of two spectra. The result should be a standard “spectra” which can be displayed and analysed using other functions: Priority 3*

# Single-Dish Data Analysis (Cont.)

- OL-6.4-R8 *Spectral calculator*: Complex experiment-specific processing can often be done using a series of simple basic functions. A spectral calculator option should be added to the CLI to **perform a series of manipulations on a set of spectra**: Priority 1
- OL-6.4-R9 *Split into separate spectra*: ...
  - OL-6.4-R9.1 *Slice data*: It must be possible to take multi-IF or polarization data and split out the splice of individual spectral portions to form self-contained spectra: Priority 1
  - OL-6.4-R9.2 **Slice spectral channels**: It must be possible to select a range of spectral channels to form self-contained spectra. The channel selection may be different for different IFs: Priority 1
  - OL-6.4-R9.3 *Merge scan-tables*: It must be possible to append rows from one scan-table to another: Priority 1
- OL-6.4-R10 **Zeeman splitting**: Zeeman splitting factors should be derived from (previous) profile fitting and the left and right circular polarizations...: Priority 3
- OL-6.4-R11 **Plugins**: The package should support “plugins”. These are user definable functions for specific processing. The plugin code must have full access (read/write) to the spectral data and headers: Priority 1
- OL-6.4-R12 *Plugins can reduce dimensions*: Plugins need to be able to create “derived “ spectra with reduced dimensions (e.g. fewer IFs, polarizations, or spectral channels): Priority 2
- OL-6.4-R13 *Position fitting*: The software should be able to take a simple “grid” of observations (normally a set of observations in a cross pattern on the sky) and, for a subset of channels, **fit the position of the emission**...: Priority 2

# Single-Dish Data Analysis (Cont.)

- *OL-6.4-R14 Kinematic distance:* The kinematic distance of a source should be calculated using basic Galactic rotation models. Multiple Galactic rotation models should be supported and a mechanism for easily adding more should be available.: Priority 3
- *OL-6.4-R15 Plot sigma errors on spectra:* The software should be able to compute the RMS as a function of frequency across the spectra from the off-pulse data and then be able to plot nsigma error bars on the spectra.: Priority 3
- *OL-6.4-R16 Pretty print formula:* The molecular formula should be stored with embedded superscripted and subscripted symbols for “pretty” printing on plots, but printed in plain text on the CLI or in ASCII output.: Priority 3
- *OL-6.4-R17 **Multiple rest frequencies per IF**:* The software should optionally support multiple lines per IF by sorting a set of rest frequencies per IF rather than a single value. A simple mechanism must be possible to change the currently “active” rest frequency: Priority 2



# Visualization

- OL-7.1-R5 *Identification of cursor position* shall be available for interactive plots. Where appropriate, this information shall be recordable and exportable. If you -see-it- you should be able to figure out where it came from: Priority 1
- OL-7.2 R5 *Basic axis transformations* shall be built in to plotting, such as:
  - OL-7.2-R5.1 *Logarithmic* amplitude and intensity scale: Priority 1
  - OL-7.2-R5.2 *Different time and coordinate units and formats* (e.g. hours, hhmmss, radians, ddmms.s): Priority 1
- OL-7.4-R1 The Package shall be able to plot standard ALMA-format ancillary data, including:
  - OL-7.4-R1.1 amplitude or single-dish power *versus AZ and EL*: Priority 1
  - OL-7.4-R1.2 focus data and curves: Priority 2
  - OL-7.4-R1.3 pointing data and offset vectors: Priority 2
  - OL-7.4-R1.4 WVR output data: Priority 3
  - OL-7.4-R1.5 holography and beam map data: Priority 3
  - OL-7.4-R1.6 monitor point values (e.g. temperatures): Priority 3

# Visualization (Continue)

- OL-7.6-R1 *Line and histogram plots of spectra should be possible: Priority 1*
- OL-7.6-R2 *User plot choices: The user must be able to specify:*
  - OL-7.6-R2.1 Line thickness: Priority 1
  - OL-7.6-R2.2 Line style: Priority 1
  - OL-7.6-R2.3 Character size: Priority 1
  - OL-7.6-R2.4 Colors: Priority 1
- OL-7.6-R3 *Non-interactive hard copies: It must be possible to produce hard copies without an interactive plotter starting (e.g. X11): Priority 1*
- OL-7.6-R4 *Arbitrary plots: It must be possible to flexibly select the data to plot (e.g. Tsys vs. time; amplitude vs. channel number or velocity). Preferable any of the header values for a selection of scans could be plotted on a scatter plot (e.g. Tsys vs. elevation).: Priority 3*
- OL-7.6-R5 *Auto-average integrations for plotting: It should be possible to optionally auto-average integrations of a scan for plotting (for data that has not already been scan averaged): Priority 2*
- OL-7.6-R6 *Step between plots: If more spectra than can fit on the plot matrix are to be plotted, then it must be possible to step back and forth between the viewable spectra (e.g. “multipage” plots)...: Priority 2*

# Visualization (Continue)

- *OL-7.6-R7 Multi-panel: change # panels: When using multi-paneling, the plotter should automatically update the plot when the plot matrix dimensions are changed: Priority 2*
- *OL-7.6-R8 Zoomed subplot: On a single plot, it should be possible to plot the full spectrum and a zoomed copy of the data (using a different line style) ...: Priority 2*
- *OL-7.6-R9 Offset plots: Optionally when stacking multiple spectral plots in one sub-window, a (user definable) offset in the “Y” direction should be added to each subsequent spectra.: Priority 2*
- *OL-7.6-R10 Plotter auto-update: The plotter should automatically update to reflect user processing, either from the CLI or GUI. The user should have the option to turn this feature off if they so wish.: Priority 3*
- *OL-7.6-R11 Waterfall plot: It should be possible to plot individual integrations (possibly from multiple scans) in a “waterfall” plot...: Priority 3*
- *OL-7.6-R12 Waterfall editing: When plotting “waterfall” plots, it should be possible to interactively select regions or points and mark them as invalid...: Priority 3*
- *OL-7.6-R13 Export waterfall to fits: It should be possible to export the “waterfall” plot images as a FITs file: Priority 3*

# Visualization (Continue)

- *OL-7.6-R14 Plot line catalog overlays*: Line markers overlays, read from a catalogue should be optionally available. This would include the full Lovas catalog, the JPL catalog and radio recombination lines...The lines should be Doppler-corrected to a specified velocity...: Priority 1 (2 for ALMA combined catalog)
  - *OL-7.6-R14.1 Plot user catalog overlays*: Priority 2
  - *OL-7.6-R14.2 Spectral line identifications*: It should be possible to automatically identify emission features in a spectrum that correspond to spectral lines in a line catalog if the features are above some specified detection limit...: Priority 3
- *OL-7.6-R15 Plot residual data*: It should be possible to plot the residual data with or without subtraction of fit functions.: Priority 1
- *OL-7.6-R16 Plot header data: Basic header data (e.g. source name, molecule name, observation time, Tsys, elevation, parallactic angle) should be optionally shown, either on the plot or next to it....*: Priority 2
  - *OL-7.6-R16.1 User defined header plot positions*: The user should be able to define where on the plot the header info would appear.: Priority 3
- *OL-7.6-R17 Plot annotations*: The user should be able to define simple annotations. This would include text overlay and simple graphics (e.g. lines, arrows, symbols): Priority 2



# Simulation

- *OL-8.1-R1* The Package shall inherit the basic simulation capability of the ALMA Online Data Processing Pipeline (Levels 1 and 2) as outlined in ALMA-70.10.00.00-002-A-SPE
  - *OL-8.1-R1.1 Offline simulation capabilities*: The Package shall also provide a simulation capability that allows the user to take an input image, component model list, or a model description (e.g. flux & Gaussian properties) and simulate visibilities, a point spread function (PSF) and create a resultant image. User-specified simulated observing parameters shall include: e.g. frequency setup; observing times and duration; antenna configurations).: Priority 1
- *OL-8.1-R2 Single dish-specific simulation*: The user should be able to create new spectra which the software treats the same as the original data. This includes full specification of the header items.: Priority 3

# Integrating ASAP into CASA

- `asap_init()`
  - In CASA, the user must run `asap_init()` to access single-dish functionalities
  - `import asap as sd`
  - ASAP is imported as module and is referred as 'sd' tool
  - Also import single dish tasks
- `libatnf (reader/writer)`
  - We don't use codes in `asap/external` directory
  - Instead, we use codes in CASA (we usually update CASA side)
- `casacore`
  - CASA contains its own `casacore` libraries in the distribution
  - CASA-ASAP depends on them
  - independent of `pyrap`

# Architectural View of CASA



user

depends on tb tool  
and casalogger

CLI (IPython)

Python

Tasks

GUI  
matplotlib

GUI  
Qt

Tools

ASAP Python (sd)

aatm (ATM library)

CASA C++ library

ASAP C++ library

CASACORE C++ library

depends on libatnf  
(data filler)

# CASA-ASAP Specific Functionalities

- The developments (almost) follows CASA requirements for single-dish functionalities
- Various fields
  - Data Format
  - Logger
  - Data Reader
  - Calibration
  - Data Reduction and Analysis (fitting, flagging, ...)
  - Plotter

# Data Format

- Added FLAGROW column (MAIN table)
  - Stores flag information for spectrum itself (uint)
  - FLAGTRA is channel-based, FLAGROW is row-based
  - See *OL-4.4-R9.1*
- Updated RESTFREQUENCY column (MOLECULES table)
  - Allows to store multiple rest frequencies
  - See *OL-6.4R17*
- Updated SRCTYPE column (MAIN table)
  - Use an identifier of scan intents (ON, OFF, PS, WOB, FREQ)
- Not reflected Scantable v3?

# Logger

- Logging system of CASA-ASAP is integrated into CASA logging system (casalogger)
  - Logs from both C++ and Python layers are accumulated in asaplog (Logger)
  - Logs accumulated in asaplog is flushed to casalogger, not `sys.stdout` (see `print_log()`)
- Merits of casalogger
  - Processed time is automatically added to the message
  - Logs are saved in the text file (`casapy.log`)
  - See *OL-1.2-R3*

# Data Reader

- Reader for NRO data
  - NRO 45m and ASTE
  - Specific format for OTF observation
  - NEWSTAR format (FITS without main table)
- Reader for GBT SDFITS data (In progress)
  - Different from ATNF SDFITS
  - Must support multiple binary table input

# Calibration

- Extending calibration
  - calibration using loads with known temperature
    - $T_a^* = T_{sys} * (ON-OFF)/OFF$
  - OTF position switch calibration
  - Folding for frequency switch calibration
  - See *OL-4.4-R1, R6, R7*
- Comprehensive method for calibration
  - `asapmath.calibrate()`
  - The user should specify calibration mode (should automate in the future)
  - Calls appropriate methods depending on antenna name



# Data Reduction and Analysis: Fitting

- Lorentzian fitting
  - Defined fitting class for Lorentzian (similar to Gaussian1D in casacore)
  - May be included in casacore?
  - See *OL-6.2-R3.2*
- Sine function fitting (in progress)
  - Fitting function for baseline with standing wave
  - See *OL-4.4-R1.1*

# Data Reduction and Analysis: Flagging

- Row-based flagging
  - `scantable.flag_row()`
  - Connected with FLAGROW column
  - See *OL-4.4-R9.1*
- Y-axis flagging
  - `scantable.clip()`
  - Flag all channels that have spectral value inside/outside of user-specified range
- Interactive flagging (in progress)
  - GUI-based flagging
  - See *OL-2.2-R4*

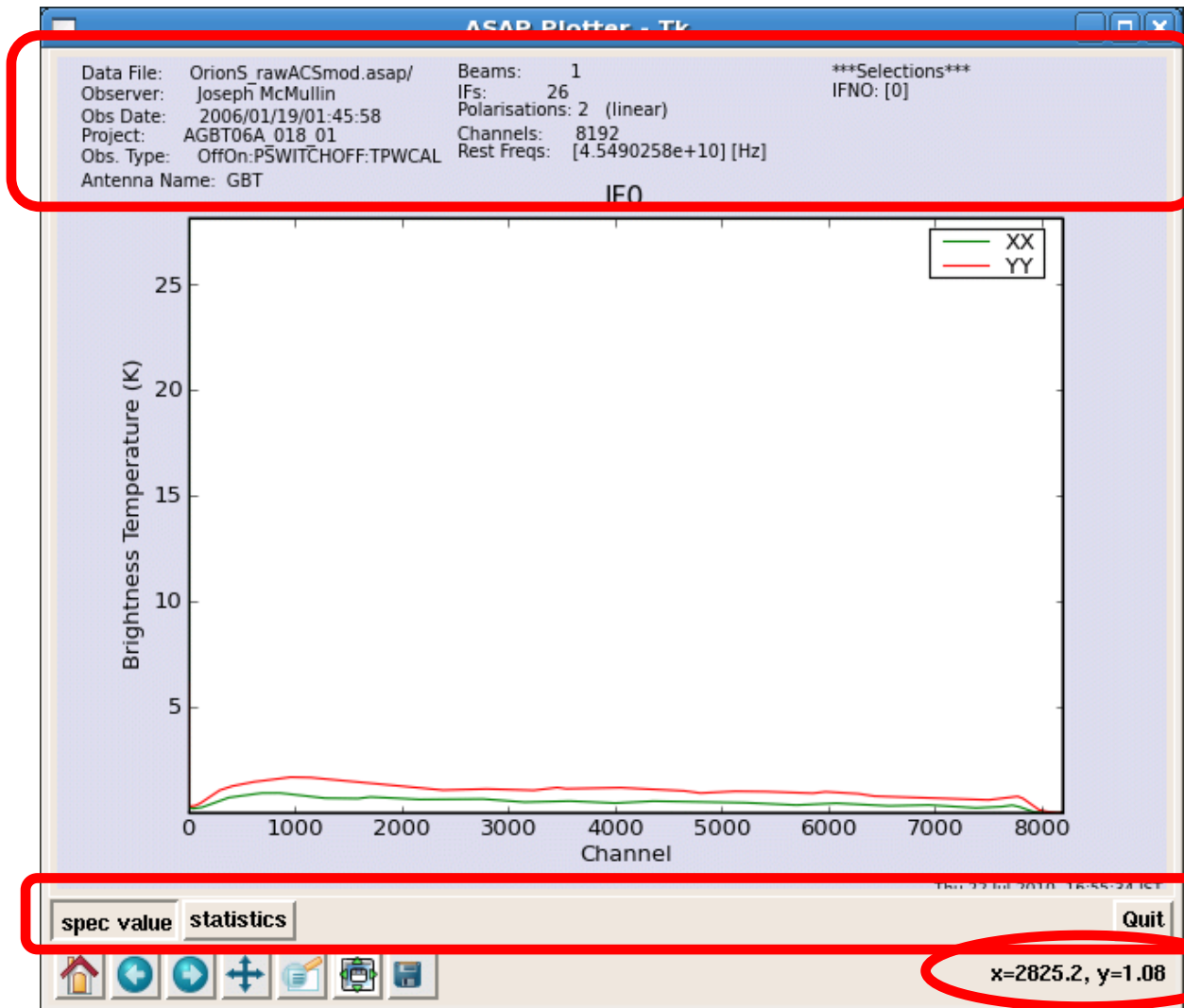
# Data Reduction and Analysis: Others

- Extension of Scantable mathematics
  - Scantable with array that have consistent shape
- Trimming spectra
  - Trim spectra along with user-specified channel range
  - `Scantable::reshapeSpectrum()`
  - See *OL-6.4-R9.2*
- Averaging spectra with different spectral resolution (experimental)
  - Average spectra with different IF settings if there are any overwrapped regions
  - ‘compel’ option for `asapmath.average_time()`

# Plotter

- Plot header information
  - filename, observer, date, project,...
  - `plotter.print_header()`
  - See *OL-7.6-R1.6*
- Added toolbar and control buttons
  - `casatoolbar.py` (`CustomToolbarCommon`, `CustumToolbarTkAgg`)
- Display spectral intensity value and horizontal position
  - Displayed on toolbar
  - See *OL-7.1-R5*
- Interactive masking
  - `interactivemask` class
  - baseline fitting, line fitting, evaluating statistics
  - See *OL-3.1-R25.3*
- Plotter annotation (in progress)
  - Text overlay first
  - See *OL-7.6-R17*

# Plotter: View

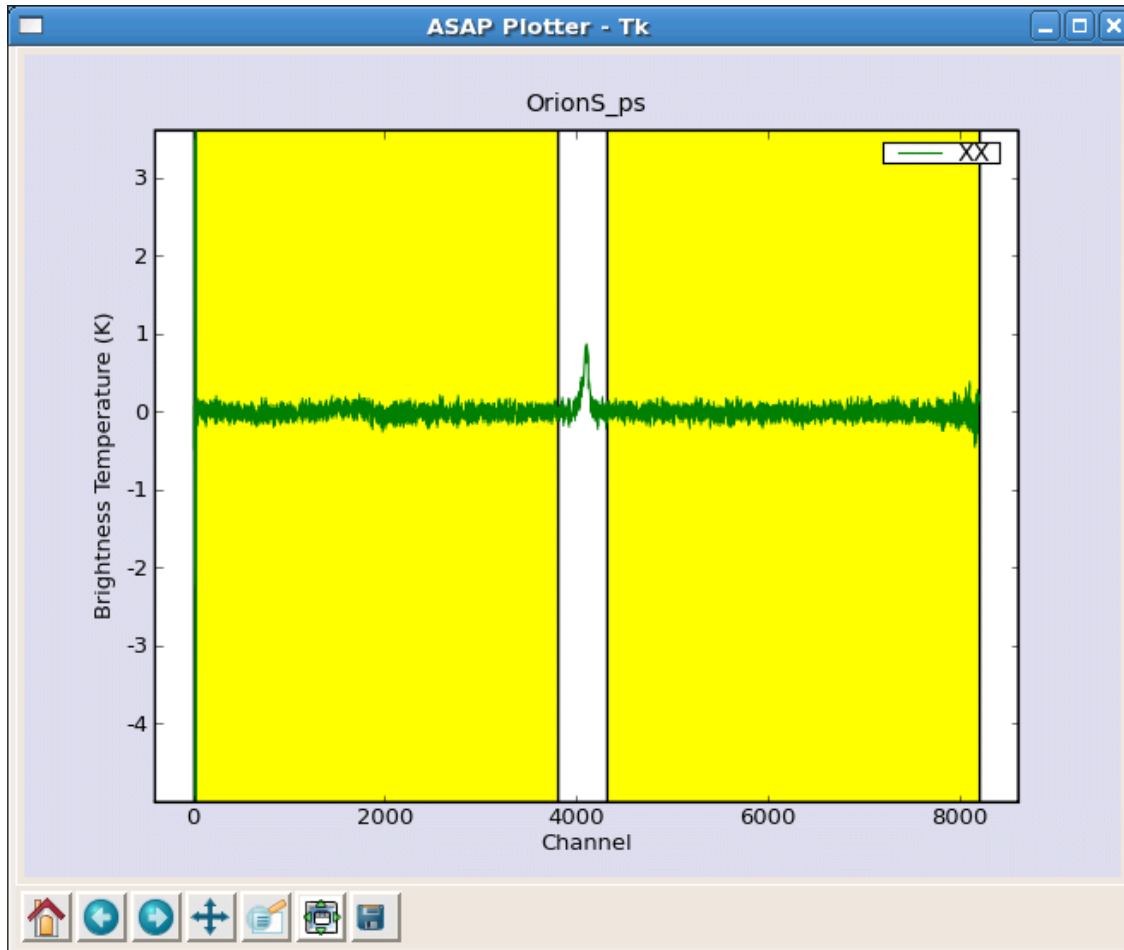


Header informations

Toolbar and buttons

Spectral value  
horizontal position

# Plotter: Interactive Masking



- Left click and drag to include regions
- Right click and drag to exclude regions

# Discussion: Data Format

- Defalut for rcParams['scantable.storage']
  - Should be 'disk'
  - 'memory' may be problematic for large dataset
  - See *OL-3.2-R3*
- Data format
  - Scantable may be updated or replaced other format to be able to store ALMA data without loss of informations
  - Will be discussed at discussion session (6 or 7 Aug.)
  - See *OL-3.2-R1*

# Summary

- Reviewed CASA requirements that are associated with our developments for CASA-ASAP
- Described specific functionalities of CASA-ASAP that we have developed and we are currently working on
  - Developments almost follows ALMA requirements
  - There are also developments independent of ALMA requirements
- Data format may be updated or replaced



# Score Sheet of CASA Requirement

| ID          | Priority | Category | Description                              | Status            |
|-------------|----------|----------|--|-------------------|
| OL-1.1-R2   | 1        | General  | Support all ALMA observing mode          | Partly Available  |
| OL-1.2-R3.2 | 1        | General  | Logging tool results                     | Available         |
| OL-1.2-R3.3 | 2        | General  | Logging tool outputs                     | Available         |
| OL-2.2-R4   | 2        | UI, Help | GUI-based tools                          | Partly Available  |
| OL-2.2-R6   | 2        | UI, Help | Uniform look and feel of GUI             | Not Available     |
| OL-2.5-R1.1 | 1        | UI, Help | Cookbook                                 | Available, But... |
| OL-2.5-R1.2 | 1        | UI, Help | Reference manual                         | Not Available     |
| OL-2.5-R1.3 | 1        | UI, Help | Online manual, FAQ, email contact        | Partly Available  |
| OL-2.5-R1.4 | 1        | UI, Help | Release history, bug report, patch desc. | Available         |
| OL-2.5-R1.5 | 2        | UI, Help | Programmer reference and guide           | Available         |
| OL-2.5-R1.6 | 2        | UI, Help | Data format descriptions                 | Not Available     |
| OL-2.5-R1.7 | 2        | UI, Help | Algorithm descriptions                   | Not Available     |
| OL-2.5-R1.8 | 3        | UI, Help | Newsletters, email exploders, ...        | Available         |

# Score Sheet of CASA Requirement

| ID            | Priority | Category | Description                | Status            |
|---------------|----------|----------|----------------------------|-------------------|
| OL-3.1-R2.1   | 1        | Data     | Program header information | Partly Available  |
| OL-3.1-R2.2   | 1        | Data     | Observation status         | Partly Available  |
| OL-3.1-R2.3   | 1        | Data     | Field information          | Available?        |
| OL-3.1-R2.4.1 | 1        | Data     | Position                   | Available         |
| OL-3.1-R2.4.2 | 1        | Data     | Subreflector state         | Available, But... |
| OL-3.1-R2.4.3 | 1        | Data     | Polarization products      | Available, But... |
| OL-3.1-R2.4.4 | 1        | Data     | Spectral channels          | Available         |
| OL-3.1-R2.4.5 | 1        | Data     | Frequency bands            | Available?        |
| OL-3.1-R2.4.6 | 1        | Data     | IFs                        | Available?        |
| OL-3.1-R2.4.7 | 1        | Data     | Subarray information       | Not Available     |
| OL-3.1-R2.6   | 1        | Data     | Total power data           | Available         |
| OL-3.1-R2.7   | 1        | Data     | Weights/uncertainties      | Not Available     |
| OL-3.1-R2.8.1 | 1        | Data     | OTF scanning state         | Available         |

# Score Sheet of CASA Requirement

| ID             | Priority | Category  | Description                          | Status            |
|----------------|----------|-----------|--------------------------------------|-------------------|
| OL-3.1-R2.8.2  | 1        | Data      | Subreflector switching state         | Available         |
| OL-3.1-R2.8.3  | 1        | Data      | Frequency switching state            | Available         |
| OL-3.1-R2.9    | 1        | Data      | Flagging information                 | Available         |
| OL-3.1-R2.14   | 1        | Data      | Processing history                   | Available, But... |
| OL-3.1-R25.1   | 1        | Selection | Spectral selection                   | Available         |
| OL-3.1-R25.2   | 1        | Selection | Polarization/IF selection            | Available         |
| OL-3.1-R25.3   | 1        | Selection | Interactive channel selection        | Available         |
| OL-3.1-R25.4   | 1        | Selection | Auto-identify reference, user option | Partly Available  |
| OL-3.1-R25.5   | 1        | Selection | Source selection                     | Available         |
| OL-3.1-R25.6.1 | 1        | Selection | View/edit header data                | Available         |
| OL-3.1-R25.6.2 | 2        | Selection | Add missing header data              | Available         |
| OL-3.2-R1.1    | 1        | Data I/E  | Import ALMA data without loss        | Not Available     |
| OL-3.2-R1.2.3  | 2        | Data I/E  | Import/export SDFITS without loss    | Partly Available  |

# Score Sheet of CASA Requirement

| ID            | Priority | Category | Description                             | Status           |
|---------------|----------|----------|---|------------------|
| OL-3.2-R3     | 1        | Data I/E | Handle larger data than main memory     | Available?       |
| OL-3.2-R7.1.1 | 1        | Data I/E | Support Equatorial coordinate           | Partly Available |
| OL-3.2-R7.1.2 | 1        | Data I/E | Support Galactic coordinate             | Partly Available |
| OL-3.2-R7.1.3 | 1        | Data I/E | Support Ecliptic coordinate             | Available?       |
| OL-3.2-R7.2   | 2        | Data I/E | Support non-conformist coordinate       | Available?       |
| OL-3.2-R7.3.1 | 1        | Data I/E | Support SIN projection                  | ?                |
| OL-3.2-R7.3.2 | 1        | Data I/E | Support GLS projection                  | ?                |
| OL-3.2-R7.3.3 | 2        | Data I/E | Support TAN projection                  | ?                |
| OL-3.2-R7.3.4 | 2        | Data I/E | Support stereographic projection        | ?                |
| OL-3.2-R7.3.5 | 2        | Data I/E | Support equidistant cylinder projection | ?                |
| OL-3.2-R7.3.6 | 2        | Data I/E | Support Mercator's projection           | ?                |
| OL-3.2-R7.3.7 | 2        | Data I/E | Support Hammer's projection             | ?                |
| OL-3.2-R7.3.8 | 2        | Data I/E | Support Aitoff's projection             | ?                |

# Score Sheet of CASA Requirement

| ID            | Priority | Category    | Description                        | Status           |
|---------------|----------|-------------|------------------------------------|------------------|
| OL-3.2-R7.3.9 | 2        | Data I/E    | Support homolographic projection   | ?                |
| OL-3.2-R7.4   | 3        | Data I/E    | Support WCS and FITS coord./proj.  | ?                |
| OL-3.4-R1     | 2        | Data I/E    | Importable other telescope's data  | Partly Available |
| OL-4.1-R1     | 1        | Calibration | Support all ALMA calibration modes | Partly Available |
| OL-4.1-R4.1   | 1        | Calibration | Flag by pointing data              | Not Available    |
| OL-4.1-R4.2   | 1        | Calibration | Flag by encoder data               | Not Available    |
| OL-4.1-R4.3   | 1        | Calibration | Flag by weather data               | Not Available    |
| OL-4.1-R4.4   | 1        | Calibration | Flag by Tsys                       | Not Available    |
| OL-4.1-R4.5   | 1        | Calibration | Flag by WVR data                   | Not Available    |
| OL-4.1-R4.6   | 2        | Calibration | Flag by RFI monitoring data        | Not Available    |
| OL-4.1-R4.8   | 3        | Calibration | Flag by array monitoring data      | Not Available    |
| OL-4.1-R4.9   | 3        | Calibration | Flag by other site data            | Not Available    |
| OL-4.4-R1     | 1        | Reduction   | Flexible bandpass fitting          | Partly Available |

# Score Sheet of CASA Requirement

| ID          | Priority | Category  | Description                                | Status           |
|-------------|----------|-----------|--|------------------|
| OL-4.4-R1.1 | 3        | Reduction | Sine function fitting                      | Not Available    |
| OL-4.4-R1.2 | 3        | Reduction | Robust fitting                             | Not Available    |
| OL-4.4-R2   | 1        | Reduction | Basket-Weaving                             | Partly Available |
| OL-4.4-R3   | 3        | Reduction | System calibration using calibrator        | Not Available    |
| OL-4.4-R4   | 3        | Reduction | Pointing, focus, tipping, beam-fitting,... | Not Available    |
| OL-4.4-R6.1 | 2        | Reduction | Support arbitrary sig/ref sequence         | Available?       |
| OL-4.4-R6.2 | 1        | Reduction | Support position switching                 | Available        |
| OL-4.4-R6.3 | 1        | Reduction | Support nutator switching                  | Available?       |
| OL-4.4-R6.4 | 2        | Reduction | Support frequency switching                | Available?       |
| OL-4.4-R6.5 | 3        | Reduction | Frequency dependent Tsys                   | Available        |
| OL-4.4-R7   | 1        | Reduction | ACA Total Power calibration                | Partly Available |
| OL-4.4-R8.1 | 2        | Reduction | Polarization leakage calibration           | Not Available    |
| OL-4.4-R8.2 | 2        | Reduction | Polarization position angle calibration    | Not Available    |

# Score Sheet of CASA Requirement

| ID          | Priority | Category  | Description                           | Status           |
|-------------|----------|-----------|---------------------------------------|------------------|
| OL-4.4-R9.1 | 1        | Reduction | Spectral flagging                     | Available        |
| OL-4.4-R9.2 | 1        | Reduction | Channel flagging                      | Available        |
| OL-4.4-R9.3 | 2        | Reduction | Flagged channel interpolation         | Not Available    |
| OL-5.3-R4   | 1        | Reduction | Scaling/de-stripping (Basket-Weaving) | Partly Available |
| OL-5.3-R4.1 | 1        | Reduction | De-stripping using line-free region   | Not Available    |
| OL-5.3-R4.2 | 1        | Reduction | Residual stripping                    | Not Available    |
| OL-5.3-R5   | 2        | Reduction | Imaging from different grid/center    | Available?       |
| OL-5.3-R6   | 2        | Reduction | Apply pointing correction in imaging  | Not Available    |
| OL-5.3-R7   | 2        | Reduction | Consider sky curvature                | Available?       |
| OL-5.3-R8   | 1        | Reduction | Single dish imaging                   | Available        |
| OL-6.1-R2.1 | 1        | Analysis  | Polynomial baseline fitting           | Available        |
| OL-6.1-R2.2 | 2        | Analysis  | Fourier analysis of standing waves    | Not Available    |
| OL-6.2-R1   | 1        | Analysis  | Line parameter measurement            | Available        |

# Score Sheet of CASA Requirement

| ID          | Priority | Category | Description                             | Status                  |
|-------------|----------|----------|---|-------------------------|
| OL-6.2-R2   | 1        | Analysis | Region selection for line fitting       | <b>Available</b>        |
| OL-6.2-R3.1 | 1        | Analysis | Gaussian line fitting (single/multiple) | <b>Available</b>        |
| OL-6.2-R3.2 | 2        | Analysis | Lorentzian line fitting                 | <b>Available</b>        |
| OL-6.2-R4   | 1        | Analysis | ALMA standard line catalog available    | <b>Not Available</b>    |
| OL-6.2-R5   | 2        | Analysis | User-importable line catalog available  | <b>Available</b>        |
| OL-6.2-R6   | 2        | Analysis | Flexible fit constraints                | <b>Not Available</b>    |
| OL-6.2-R7   | 3        | Analysis | Export fit result in ASCII text         | <b>Available</b>        |
| OL-6.4-R1   | 1        | Analysis | Average spectra with velocity shift     | <b>Not Available</b>    |
| OL-6.4-R2   | 2        | Analysis | Robust averaging (median, etc.)         | <b>Partly Available</b> |
| OL-6.4-R3   | 2        | Analysis | Calculate integrated line flux          | <b>Available</b>        |
| OL-6.4-R4   | 2        | Analysis | Calculate line width                    | <b>Available</b>        |
| OL-6.4-R5   | 3        | Analysis | FFT filtering                           | <b>Not Available</b>    |
| OL-6.4-R6   | 3        | Analysis | FFT to/from autocorrelation             | <b>Not Available</b>    |



# Score Sheet of CASA Requirement

| ID          | Priority | Category | Description                      | Status                  |
|-------------|----------|----------|----------------------------------|-------------------------|
| OL-6.4-R7   | 3        | Analysis | Cross-correlation of spectra     | <b>Not Available</b>    |
| OL-6.4-R8   | 1        | Analysis | Spectral calculator              | <b>Available</b>        |
| OL-6.4-R9.1 | 1        | Analysis | Split data by IF/polarization    | <b>Available</b>        |
| OL-6.4-R9.2 | 1        | Analysis | Slice spectral channels          | <b>Available</b>        |
| OL-6.4-R9.3 | 1        | Analysis | Merge data                       | <b>Available</b>        |
| OL-6.4-R10  | 3        | Analysis | Zeeman splitting                 | <b>Not Available</b>    |
| OL-6.4-R11  | 1        | Analysis | User plugins                     | <b>Available</b>        |
| OL-6.4-R12  | 2        | Analysis | User plugins reduce spectra      | <b>Available</b>        |
| OL-6.4-R13  | 2        | Analysis | Fit the position of the emission | <b>Not Available</b>    |
| OL-6.4-R14  | 3        | Analysis | Kinematic distance determination | <b>Not Available</b>    |
| OL-6.4-R15  | 3        | Analysis | Plot sigma error on spectra      | <b>Not Available</b>    |
| OL-6.4-R16  | 3        | Analysis | Pretty print formula             | <b>Not Available</b>    |
| OL-6.4-R17  | 2        | Analysis | Multiple rest frequencies per IF | <b>Partly Available</b> |

# Score Sheet of CASA Requirement

| ID          | Priority | Category | Description                            | Status               |
|-------------|----------|----------|--|----------------------|
| OL-7.1-R5   | 1        | Visual   | Cursor position                        | <b>Available</b>     |
| OL-7.2-R5.1 | 1        | Visual   | Logarithmic axis                       | <b>Available?</b>    |
| OL-7.2-R5.2 | 1        | Visual   | Various time/coordinate axes label     | <b>Not Available</b> |
| OL-7.4-R1.1 | 1        | Visual   | Plot intensity vs. AL/EL               | <b>Not Available</b> |
| OL-7.4-R1.2 | 2        | Visual   | Plot focus curve                       | <b>Not Available</b> |
| OL-7.4-R1.3 | 2        | Visual   | Plot pointing offset vector            | <b>Not Available</b> |
| OL-7.4-R1.4 | 3        | Visual   | Plot WVR data                          | <b>Not Available</b> |
| OL-7.4-R1.5 | 3        | Visual   | Plot holography and beam map           | <b>Not Available</b> |
| OL-7.4-R1.6 | 3        | Visual   | Plot monitor point data                | <b>Not Available</b> |
| OL-7.6-R1   | 1        | Visual   | Line and histogram plot                | <b>Available</b>     |
| OL-7.6-R2.1 | 1        | Visual   | User is able to specify line thickness | <b>Available</b>     |
| OL-7.6-R2.2 | 1        | Visual   | User is able to specify line style     | <b>Available</b>     |
| OL-7.6-R2.3 | 1        | Visual   | User is able to specify character size | <b>Available</b>     |

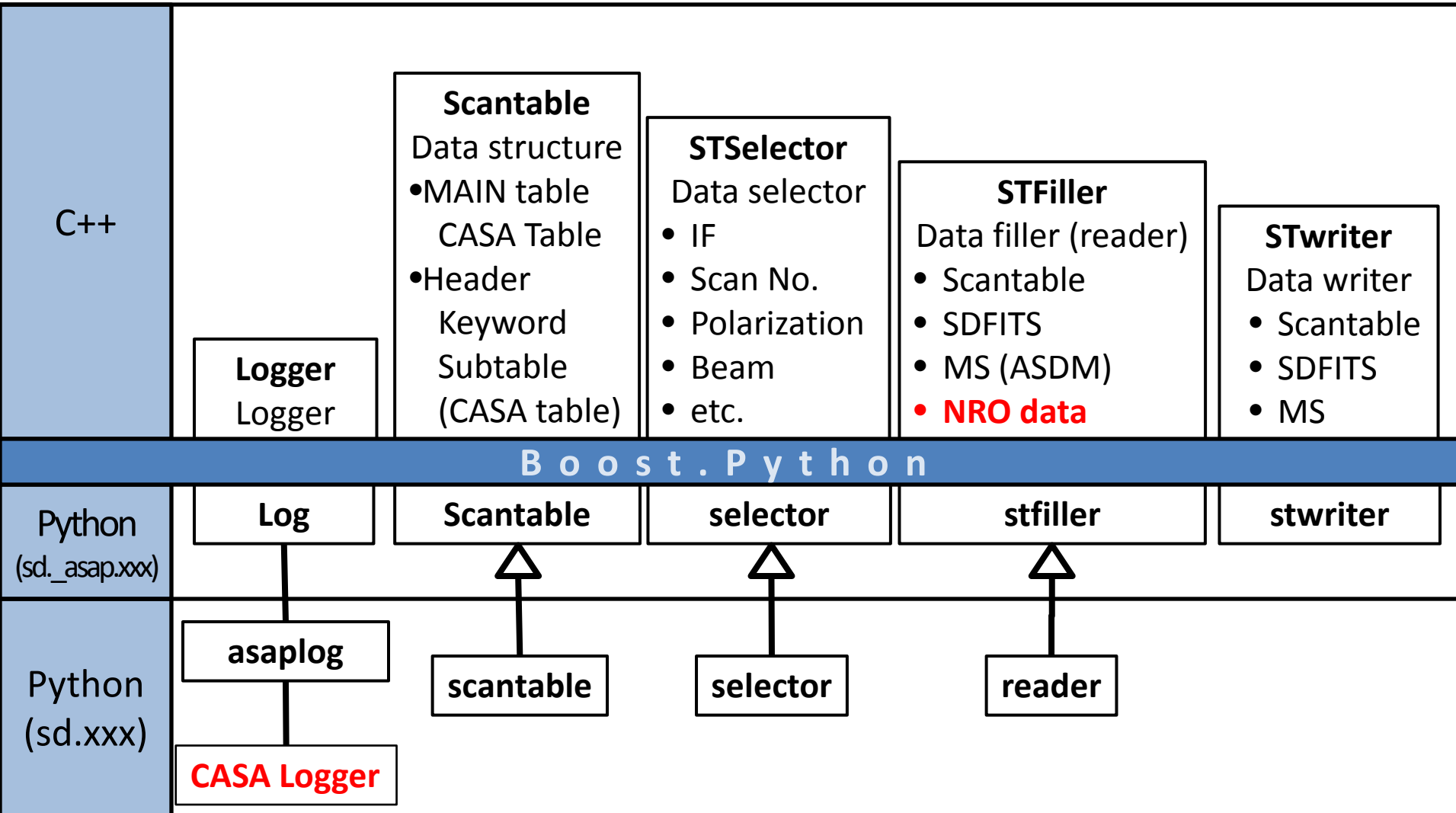
# Score Sheet of CASA Requirement

| ID          | Priority | Category | Description                         | Status                  |
|-------------|----------|----------|-------------------------------------|-------------------------|
| OL-7.6-R2.4 | 1        | Visual   | User is able to specify color       | <b>Available</b>        |
| OL-7.6-R3   | 1        | Visual   | Hard copy without plotter panel     | <b>Available</b>        |
| OL-7.6-R4   | 3        | Visual   | Flexible choice of plot variables   | <b>Partly Available</b> |
| OL-7.6-R5   | 2        | Visual   | Auto-averaging during plot          | <b>Not Available</b>    |
| OL-7.6-R6   | 2        | Visual   | Multi-page plot                     | <b>Not Available</b>    |
| OL-7.6-R7   | 2        | Visual   | Multi-panel plot/auto-update        | <b>Partly Available</b> |
| OL-7.6-R8   | 2        | Visual   | Zoomed subplot                      | <b>Not Available</b>    |
| OL-7.6-R9   | 2        | Visual   | Y offset in stacking                | <b>Not Available</b>    |
| OL-7.6-R10  | 3        | Visual   | Plotter auto-update when processing | <b>Not Available</b>    |
| OL-7.6-R11  | 3        | Visual   | Waterfall plot                      | <b>Available</b>        |
| OL-7.6-R12  | 3        | Visual   | Waterfall editing                   | <b>Available</b>        |
| OL-7.6-R13  | 3        | Visual   | Export waterfall to (image) FITS    | <b>?</b>                |
| OL-7.6-R14  | 1/2      | Visual   | Plot line catalog overlays          | <b>Partly Available</b> |

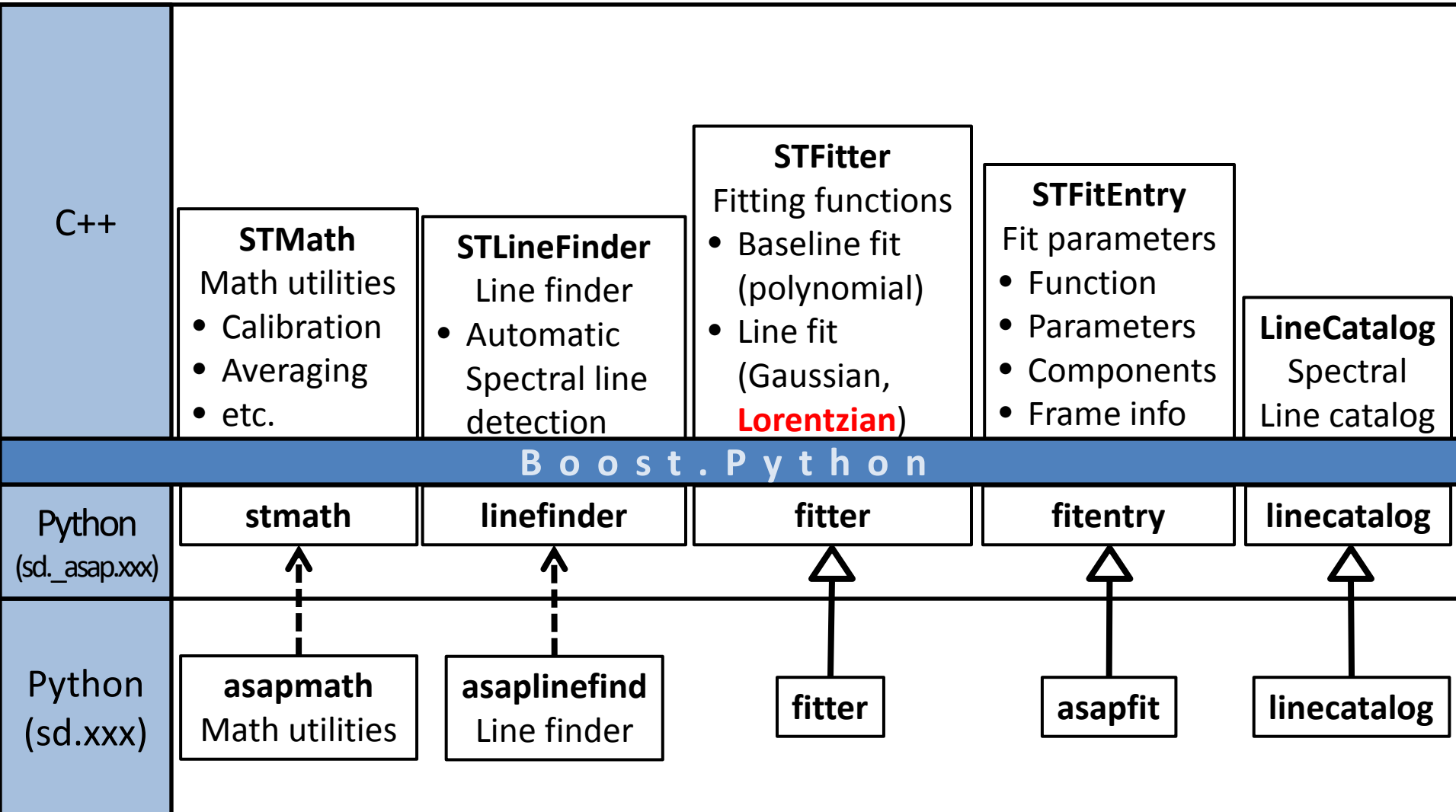
# Score Sheet of CASA Requirement

| ID           | Priority | Category   | Description                           | Status                  |
|--------------|----------|------------|---------------------------------------|-------------------------|
| OL-7.6-R14.1 | 2        | Visual     | Plot user catalog overlays            | <b>Available</b>        |
| OL-7.6-R14.2 | 3        | Visual     | Auto-line identification              | <b>Not Available</b>    |
| OL-7.6-R15   | 1        | Visual     | Plot residual data                    | <b>Available</b>        |
| OL-7.6-R16   | 2        | Visual     | Plot basic header data                | <b>Available</b>        |
| OL-7.6-R16.1 | 3        | Visual     | User-defined plot position for header | <b>Not Available</b>    |
| OL-7.6-R17   | 2        | Visual     | Plot annotation                       | <b>Partly Available</b> |
| OL-8.1-R1.1  | 1        | Simulation | Simulation capabilities               | <b>Available</b>        |
| OL-8.1-R2    | 3        | Simulation | Single-dish simulation                | <b>Available</b>        |

# CASA-ASAP



# CASA-ASAP



# CASA-ASAP

## ■ GUI classes (Python)

