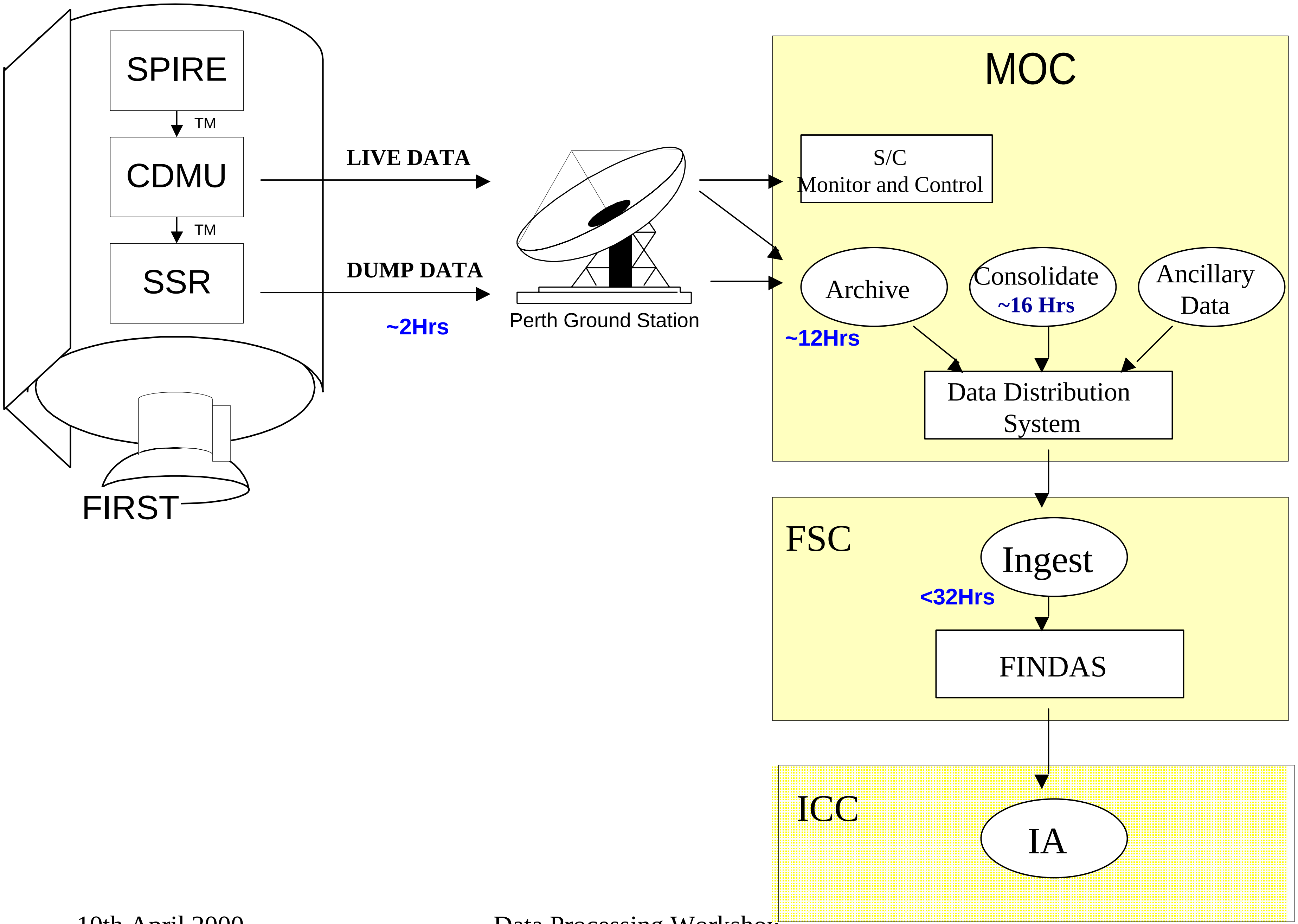
Monday 10 April 9:30 a.m. 2.82 R25 RAL

9:30 Reprise of observing modes - Matt
10:15 Coffee
10:30 How the data gets from the satellite to the ICC and what goes where (Findas etc) - Ken/Sunil
11:00 What is done for ISO - Sunil
11:30 ORAC DR data processing and relevance to SPIRE - Gillian
12:00 Seb's outline processing diagram and definition of common tasks Matt/Bruce
12:30 Discussion of how to proceed for the rest of the day
12:45 Lunch
13:30 Parallel working groups - Photometer and Spectrometer
15:45 Tea
16:00 Reports from working groups and continuation or plenary discussion/conversion to WPs
16:30 Assignment of actions/tasks
17:00 Conclusions and close.


SPIRE
TM
CDMU
TM
SSR
FIRST
LIVE DATA
DUMP DATA
~2Hrs
Perth Ground Station
MOC
S/C
Monitor and Control
Archive
Consolidate
~16 Hrs
Ancillary
Data
~12Hrs
Data Distribution
System
FSC
Ingest
<32Hrs
FINDAS
ICC
IA

- Telemetry is available in FINDAS 48hrs after DTCP.
- FINDAS stores TM as objects (probably containing one TM packet)
- Science, hsk, events are separate packets
- Science packets will be indexed by
  - observation type (AOT)
  - time
  - instrument mode, subsystem configuration
  - pointing
- All packets will be linked to
  - proposal, proposer
  - uplink, commands, schedule
- A Common Object Model is being developed for all FIRST Telemetry

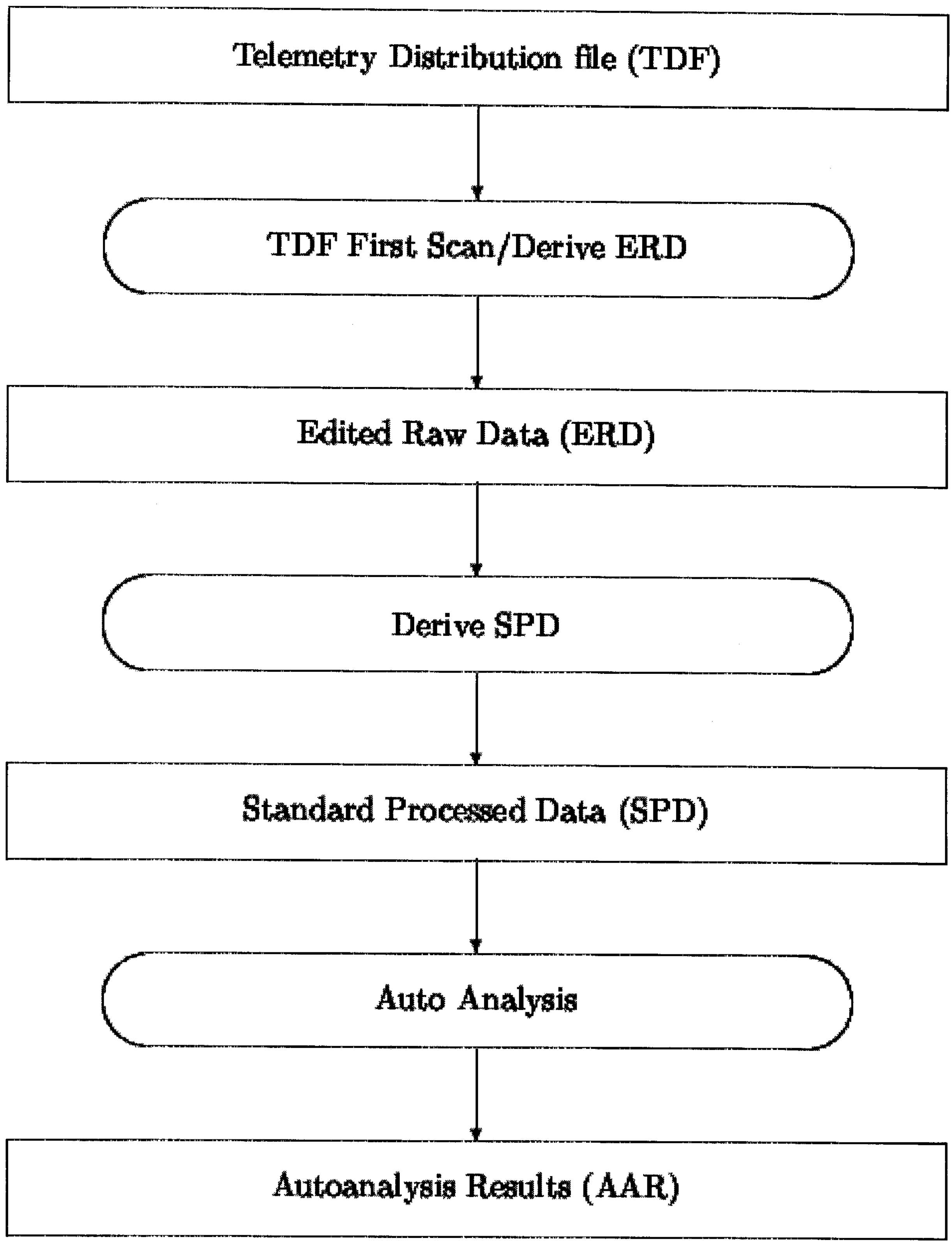
- PHOT Science Packets will contain a single ‘frame’. The frame contains:
  - 1 sample from each detector in the phot arrays, including blank pixels and temperature monitors
    - ~300 data values
  - BSM status
    - commanded position, posn sensor output, current …
  - Calibrator status
    - commanded temperature, current ….
  - Temperatures
  - Observation info
    - observation number, step, mode ……
  - Time info

- SPEC Science Packets will contain 7 or 8 frames. Each frame contains:
  - 1 sample from each detector in the spec arrays, including blank pixels and temperature monitors: ~60 data values
  - BSM status
    - commanded position, posn sensor output, current …
  - Calibrator status
    - commanded temperatures, currents ….
  - Temperatures
  - Observation info
    - observation number, step, mode ……
  - Time info
  - FTS position times, relevant to this frame
- An additional packet containing the complete sequence of FTP position times will also be generated

ISO Data: Key Pipeline Processing Stages

1. TDF_FIRST_SCAN: First pass through raw telemetry (TM) data held in TM Distribution Files (TDF's)
2. DERIVE_ERD: Second pass through TDF's. Produces Edited Raw Data (ERD) files
3. DERIVE_ SPD: First stage of scientific processing. The output files are the Standard Processed Data (SPD) products. The data are in engineering units (e.g. photocurrents (A), grating LVDT positions, etc.)
4. AUTO_ANALYSIS: Second stage of scientific processing. The output files are the final products from the pipeline processing. The data are in astronomical units (e.g. Flux densities (Jy), wavelengths (μm), etc.)

Figure 3.1: *Overview of the ISO data processing.*



1. TDF_FIRST_SCAN:

- Processes data for one revolution at a time
- Determines the boundaries of AOT's and TDT's
- Assigns the time (UTK - Universal Time Key)
- Extracts the transparent data (TDATA) and produces the EOHA and EOHI files
  - EOHA is the Executed Observation History for each AOT
  - EOHI is the Executed Observation History for each Instrument Command Sequence (ICS)
- Produces status history and housekeeping files

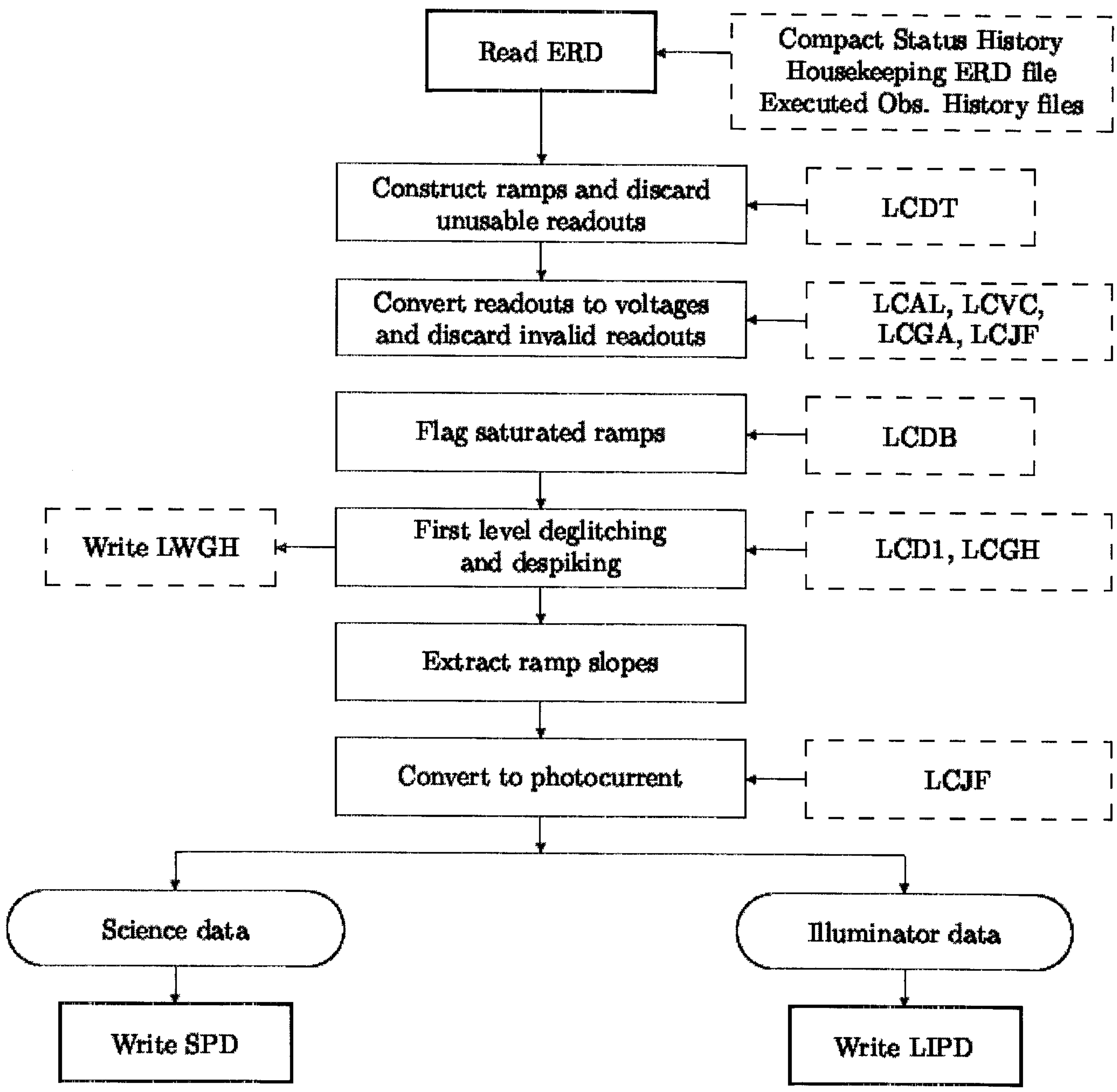
2. DERIVE_ERD:

- Processes data for one revolution at a time
- Produces ERD products for each observing mode. For LWS these products include:
  - LGER: ERD for grating data
  - LLER: ERD for FPL data
  - LSER: ERD for FPS data
  - LIER: ERD for internal illuminator data
  - LXER: ERD for special non-AOT calibration data
  - LWHK: ERD for HK data
  - LSTA: ERD for the instrument status history
- Creates the instrument pointing history files (IRPH & IIPH)

3. DERIVE_SPD:

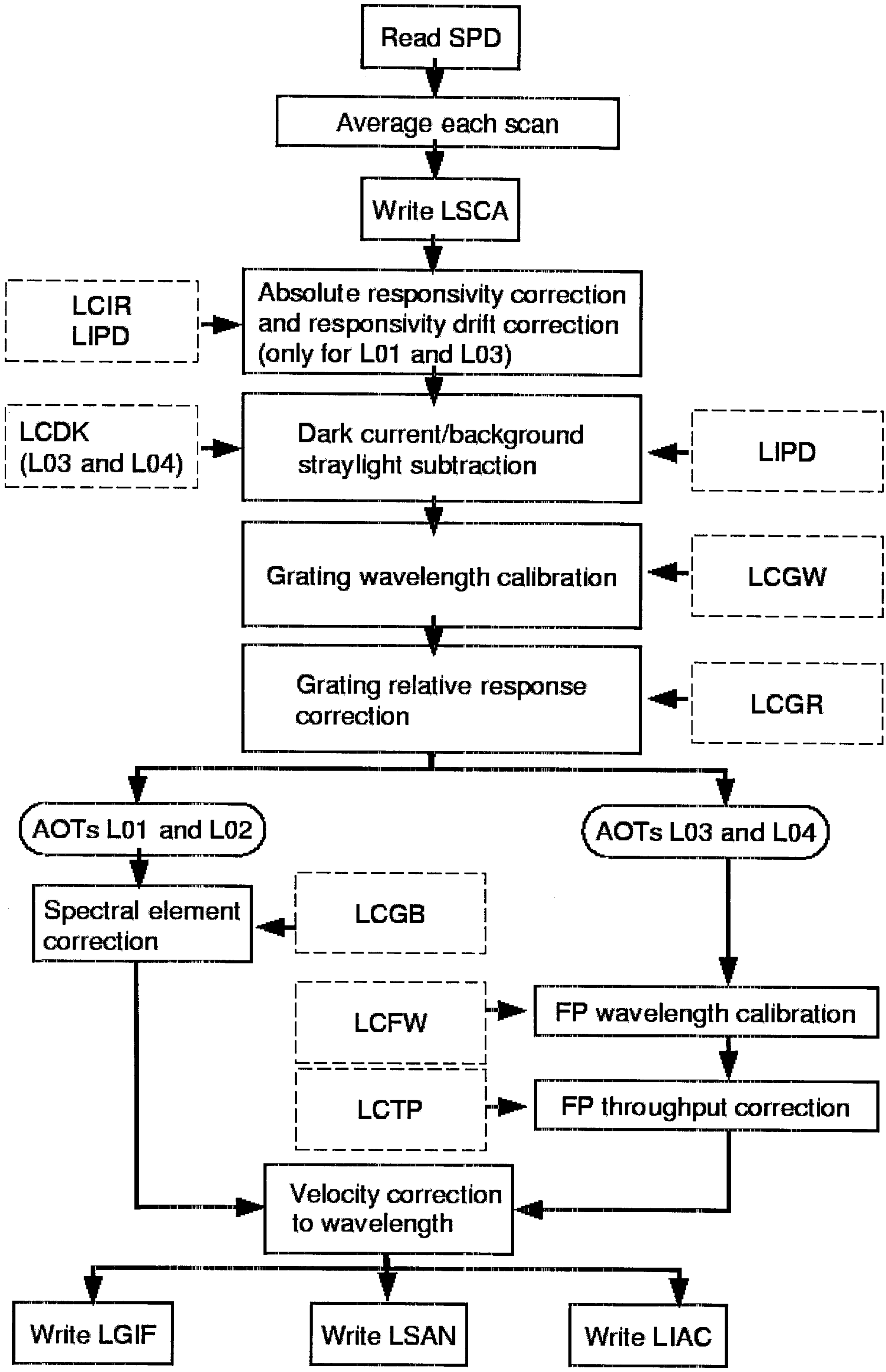
- Processes data for one observation at a time
- Produces the following SPD products for LWS:
  - LSPD: processed data for grating, FPL or FPS
  - LIPD: processed data for internal illuminators
  - LWGH: History file of all the glitches and spikes found in the observation

Figure 3.2: *Schematic overview of Derive–SPD. The names in the dashed boxes indicate auxiliary or calibration files.*



4. AUTO_ANALYSIS (AA):

- Processes data for one observation at a time
- Produces the following AA products for LWS:
  - LSAN: Auto Analysis results file (read by ISAP)
  - LIAC: Illuminator summary file
  - LSCA: Scan summary file
  - LGIF: Group information file


Read SPD
Average each scan
Write LSCA
LCIR
LIPD
Absolute responsivity correction and responsivity drift correction (only for L01 and L03)
LCDK (L03 and L04)
Dark current/background straylight subtraction
LIPD
Grating wavelength calibration
LCGW
Grating relative response correction
LCGR
AOTs L01 and L02
AOTs L03 and L04
Spectral element correction
LCGB
LCFW
FP wavelength calibration
LCTP
FP throughput correction
Velocity correction to wavelength
Write LGIF
Write LSAN
Write LIAC

Product Shapes

3 product shapes are used for ISO data:

- Shape 1: Products which are time independent. Most calibration files fall into this category, e.g. LCDT, LCGR, LCIR etc.
- Shape 2: Products which are unique to a revolution, e.g. EOHA231
- Shape 4: Products which are unique to an observation. The 6 digit Target Dedicated Time (TDT) number and the Observation Sequence (OS) number are concatenated and appended to the product name, e.g. LSAN23102411

Calibration Files

ISO defined 3 types of downlink calibration files:

1. Cal-G: General calibration files for the DERIVE_SPD or AUTO_ANALYSIS stages. Provided by the instrument teams. e.g. LCGR, LCDT, etc.
2. Cal-A: Observation dependent calibration files generated during the DERIVE_SPD process. e.g. LIPD
3. Cal-B: Observation dependent calibration files generated during the AUTO_ANALYSIS process. e.g. LIAC, LGIF and LSCA

ORAC

Observatory Reduction and Acquisition Control

- ORAC-OT : pre-observing preparation using library sequences (i.e. operating modes)
- ORAC-OM : Manages Observing process
- ORAC-OS : Sequences execution of observations
- ***ORAC-DR : Flexible, extensible, on-line automatic data reduction pipeline for all current and future UKIRT instruments***

Automatic DR needed because :

- Queue / Flexible / Service /Starred Programs

  ⇒ Need to assess & guarantee data quality

  ⇒ Need to “keep up” with acquisition & know whether observations need to be repeated by the next night

- “Classical” observing

  ⇒ need to assess data quality while observing, and in the IR that means reducing the data.

  ⇒ Data reduction needs to be fast to keep up with incoming data rate

  ⇒At 14,000 ft people are not good at manually manipulating numbers or data reduction packages

- Monitor instrument and telescope performance

Flexible, Extensible because:

- New Instruments
  - Don’t fully know how to take or reduce data to get best results until you try
  - Several new UKIRT instruments planned. Don’t want to have to write or support DR package for each, do want rapid publication of new results !
- Existing instruments evolve
  - New observing modes/methods developed
  - hardware changes/upgrades or instrument “breaks”
  - better reduction techniques invented

⇒Want to be able to implement changes to reduction algorithms quickly and easily

Other Requirements

- All instrumental artefacts removed, flux and wavelength calibrated.
- Reliable, quantitative, quality assessment possible.
- Publication quality reduction in most cases
  - e.g. post observing reduction should concentrate on analysis steps not repeating the flat fielding or glitch removal.
- Run independently of rest of system and without human intervention.
- Ability to change reduction steps without needing programmer effort.
- Facilitate efficient code re-use.

Modular :

- Separate completely the functions of the pipeline, the reduction steps to carry out, and the code for each step.

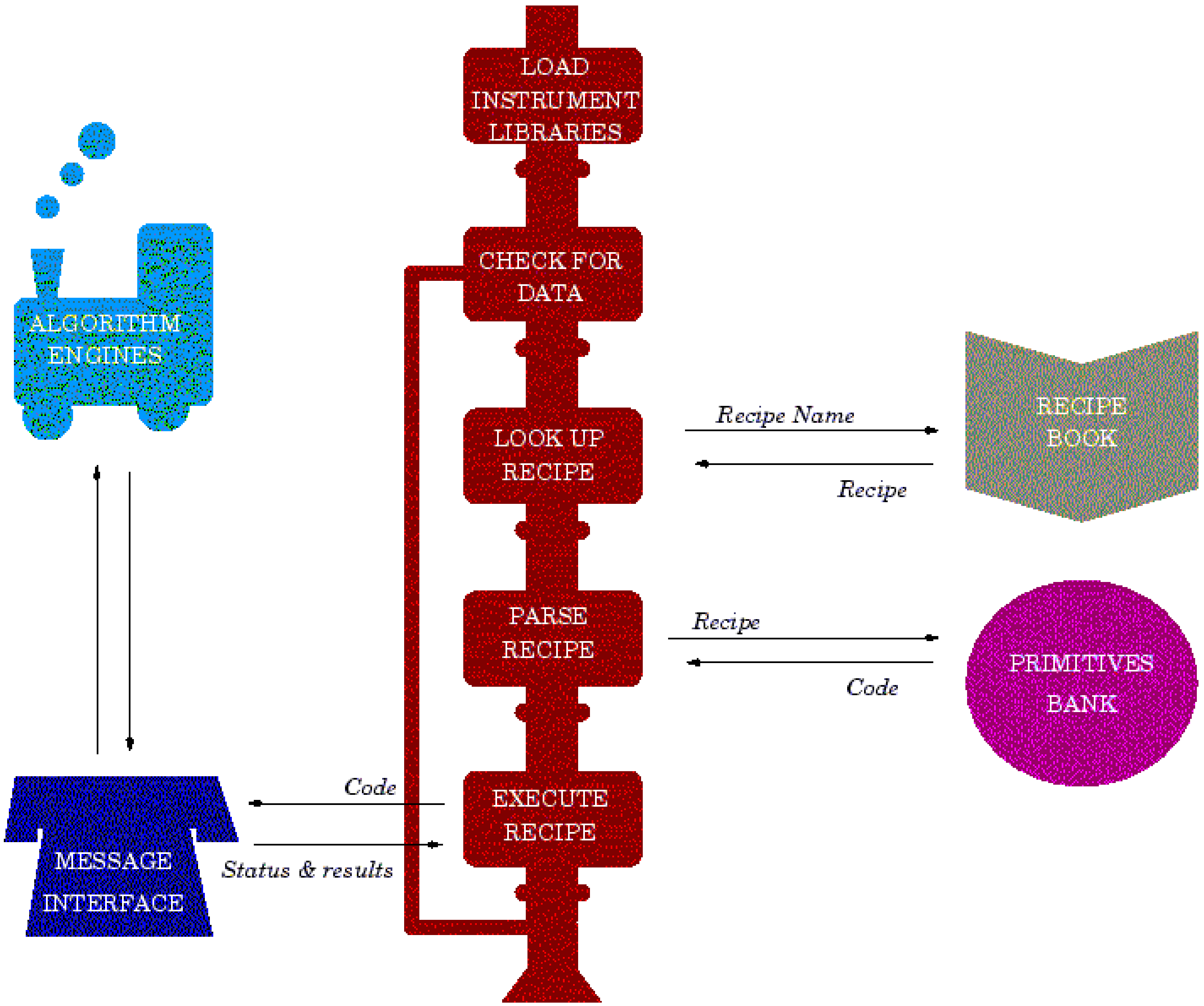
- Pipeline manager, recipes, primitives and algorithm engines

- Object Oriented design using Perl

Modular

- Pipeline manager - detects arrival of data on disk, keeps track of calibration objects, drives reduction packages via a messaging system.

- Recipe - ordered list of individual data reduction steps
- Primitive - code performing an individual data reduction step
- Algorithm engine - data reduction package that performs a certain algorithmic step



UK Astronomy Technology Centre

Robustness

- Data - driven
  - all the information necessary to reduce the data is contained in (or derived from) the data file header
- Use of message bus
  - full control of what the applications do
    - including setting *and getting* of parameters
  - error handling
    - distinguish predictable errors (S/N too low for certain step) from catastrophic (someone deleted the data files …) and decide what to do.
- In operational use at UKIRT for ~1.5yrs - extremely low fault rate

Flexibility

- Modularity of recipes and primitives

  ⇒ many components can be shared amongst instruments
- New observing technique - needs new recipe ?
  - Scientist can write new recipe using existing primitives
- Easy to re-order primitives to get better reduction
- Radically new reduction step needed ?
  - write new primitive / adapt an existing one
- Need to be more careful about calibration?
  - Modify the calibration rules for that instrument
- New recipe for old data ? Re-run pipeline and over-ride recipe name in header.

UK Astronomy Technology Centre

ORAC

Flexibility

- New Instrument ?
  - Add knowledge (new instrument class) to pipeline
  - write any new primitives and use to make recipes
  - infrastructure is all there - concentrate on getting details of reduction right
- Designed for UKIRT , in use at :
  - JCMT (Scuba data)
  - CADC (reduction of archive data)
  - AAO (IRIS-2 data reduction)
  - possibly others
- JCMT /Scuba data is fundamentally different from UKIRT instruments

Groups, Calibration

- Concept of a “group” used by pipeline to link related observations together (e.g. in maps)
  - UKIRT uses “hard” allocation of group membership, implicit specification at preparation stage of ORAC
  - JCMT uses “fuzzier” definition……..

- Calibrations
  - recognized by header
  - pipeline keeps index
  - “rules” for each instrument and calibration type determine which one is used.

Other Features

- Modules can be replaced - future enhancements

- It pipes therefore it is
- Display control available during reduction, & can drive various display engines
- Don’t need recipe name in header - can specify when pipeline invoked instead
- Various ways of detecting arrival of data, & options for off-line use.

- Log kept of everything its done

Algorithm Engines

- Interface requirement is existence of messaging system (can be simple, e.g. sockets)
- UKIRT currently uses Starlink Monoliths and Adam messaging system

- In future :
  - IRAF (when message bus completed)
  - MIDAS (if ESO are still working on message system)
  - IDL

EXAMPLE

_PRE_PROCESS_

_FLAT_FIELD_

_EXTINCTION_CORRECT_

_CLIP_BOLOMETERS_ NSIGMA=3

_REMOVE_SKY_NOISE_JIGGLE_

_CALC_PHOT_RESULT_

_CALIBRATE_PHOTOM_DATA_

_PRINT_RESULTS_PHOTOM_FRAME_

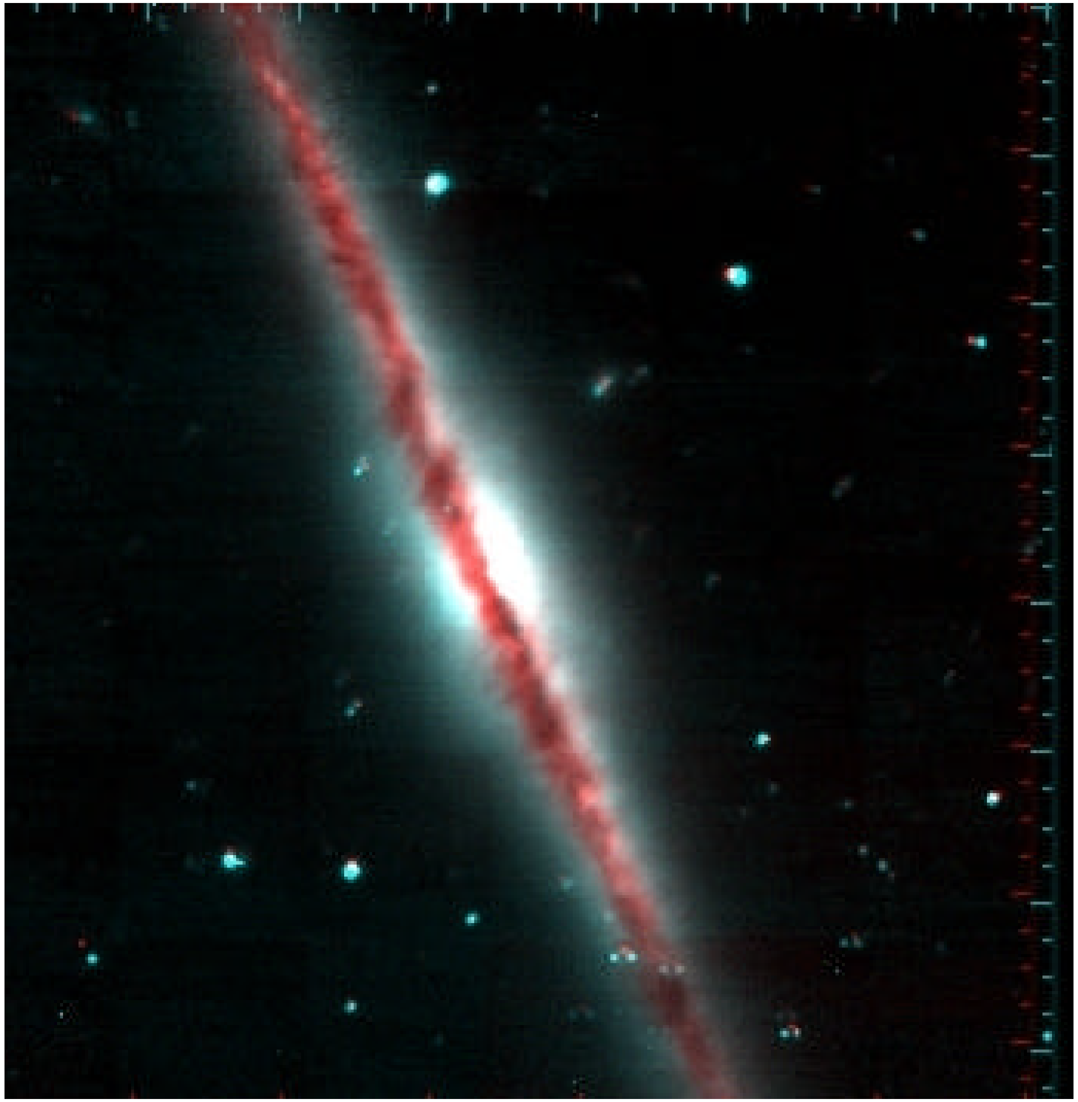
- Primitives are perl code sending commands and parameters to algorithm engine
  - can be as simple or as complex as you like
  - modularity => keep simple

Relevance to SPIRE

- Experience
- Some aspects now proven to work very well:
  - Fully header driven
  - Groups , membership determined when data taken
  - use of message system rather than simple script
    - error handling and modularity easier
  - Modularity itself
    - new instruments are being added easily, and recipes have rapidly evolved
- Many data processing requirements are similar
  - similar solutions, save re-inventing the wheel ?

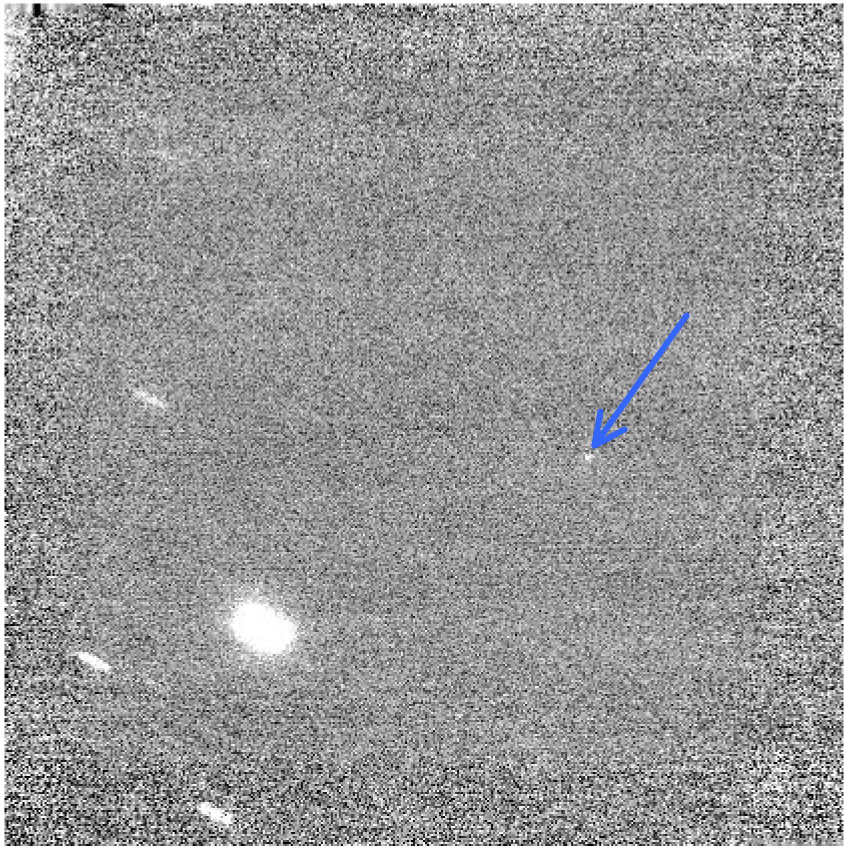
The Final Result

- **Combination of J and K band data taken and reduced at UKIRT on 26 October 1999**
- **5 x 5 mosaic used the ORAC library sequence Extended_5x5. Data reduced in real time by ORAC-DR.**



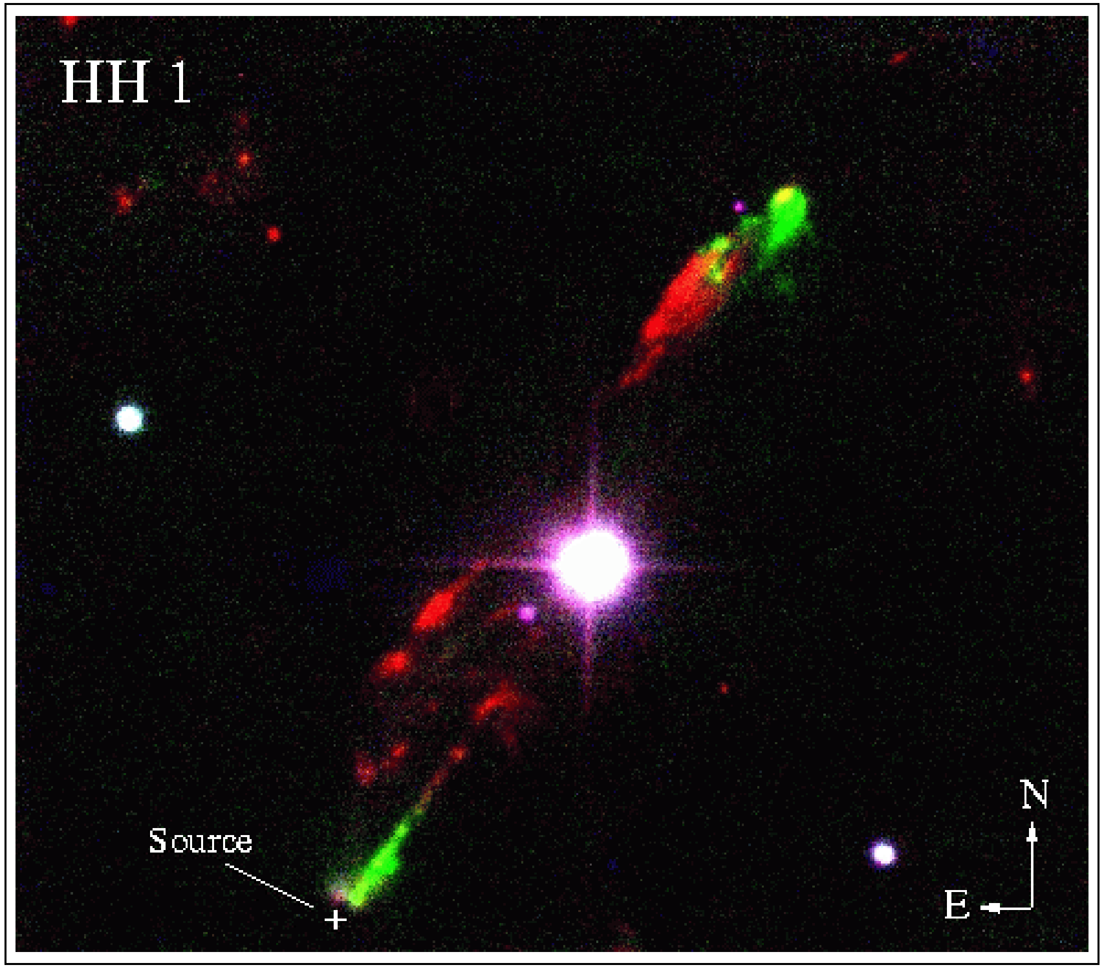
Other Commissioning Images

- **Asteroid 1998SG35 observed by J.K. Davies, 28 October 1999**
- **27 images obtained using ORAC library sequence jitter9_self_flat**
- **Faint moving target data reduction by ORAC-DR. Uses orbital constants for asteroid motion to register the images.**

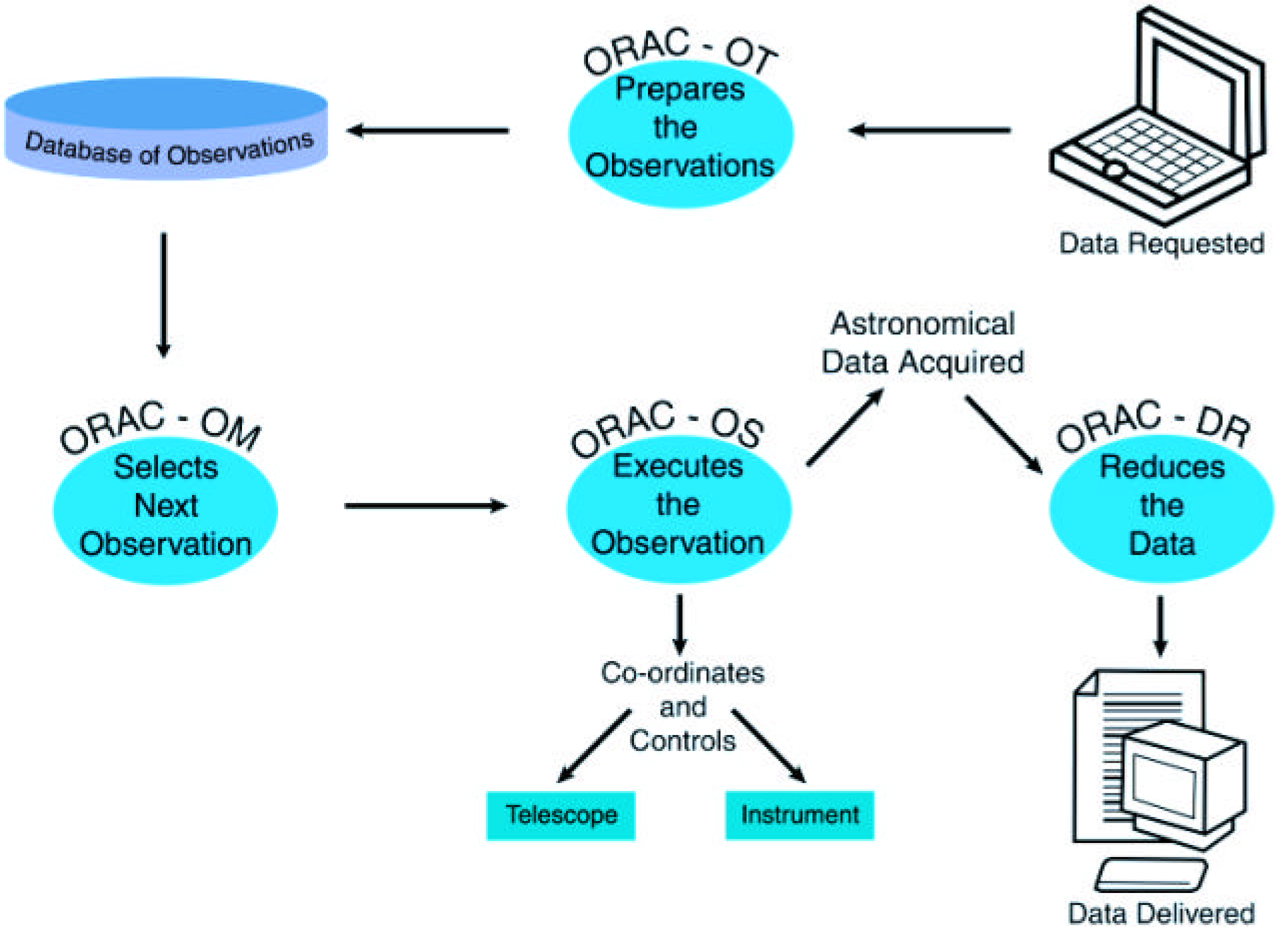


Other Commissioning Images

- **HH1 observed by C.J. Davies, 27 October 1999**
- **Red, H_2 emission, Green, [FeII] emission**
- **Data taken using ORAC library sequence quadrant_jitter**
- **Data reduction in real time by ORACDR**



ORAC in Use



ORAC - OT
Prepares the Observations
Database of Observations
Data Requested
ORAC - OM
Selects Next Observation
ORAC - OS
Executes the Observation
Astronomical Data Acquired
ORAC - DR
Reduces the Data
Co-ordinates and Controls
Telescope
Instrument
Data Delivered

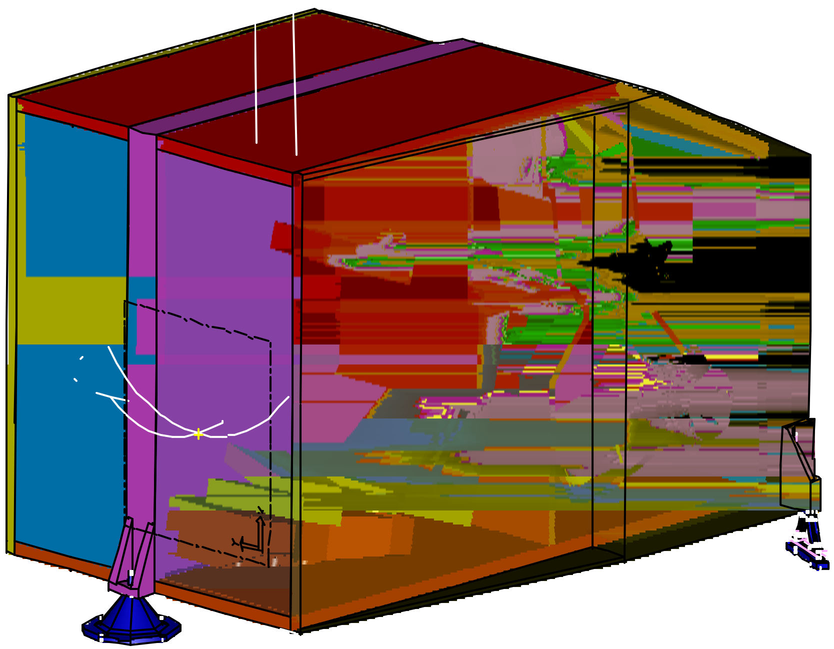
SPIRE

SPIRE Observing Modes

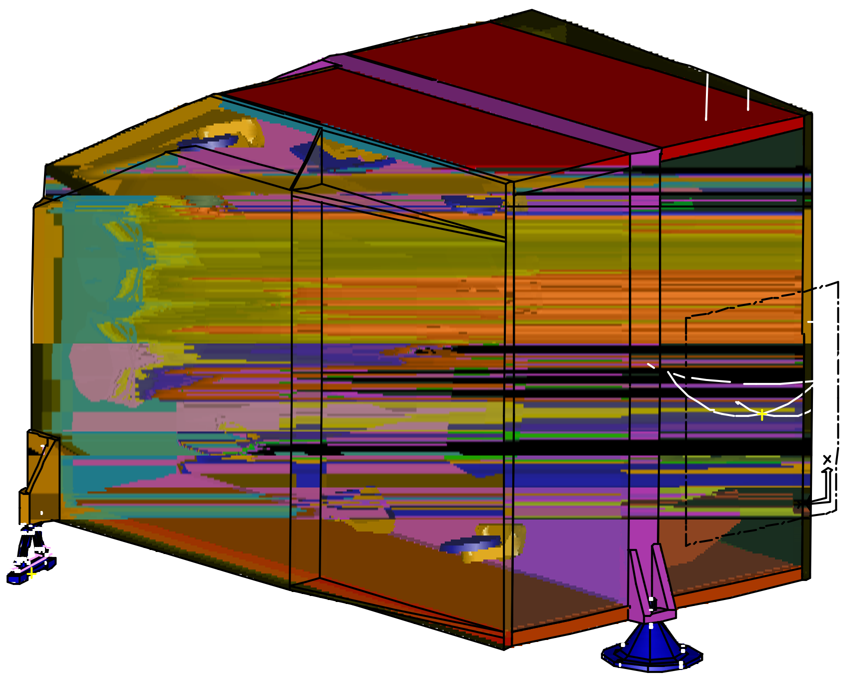
- **Instrument overview**
- **Photometer observing modes**
- **Spectrometer observing modes**
- **Requirements on AOCS**

FPU Internal Layout

Photometer

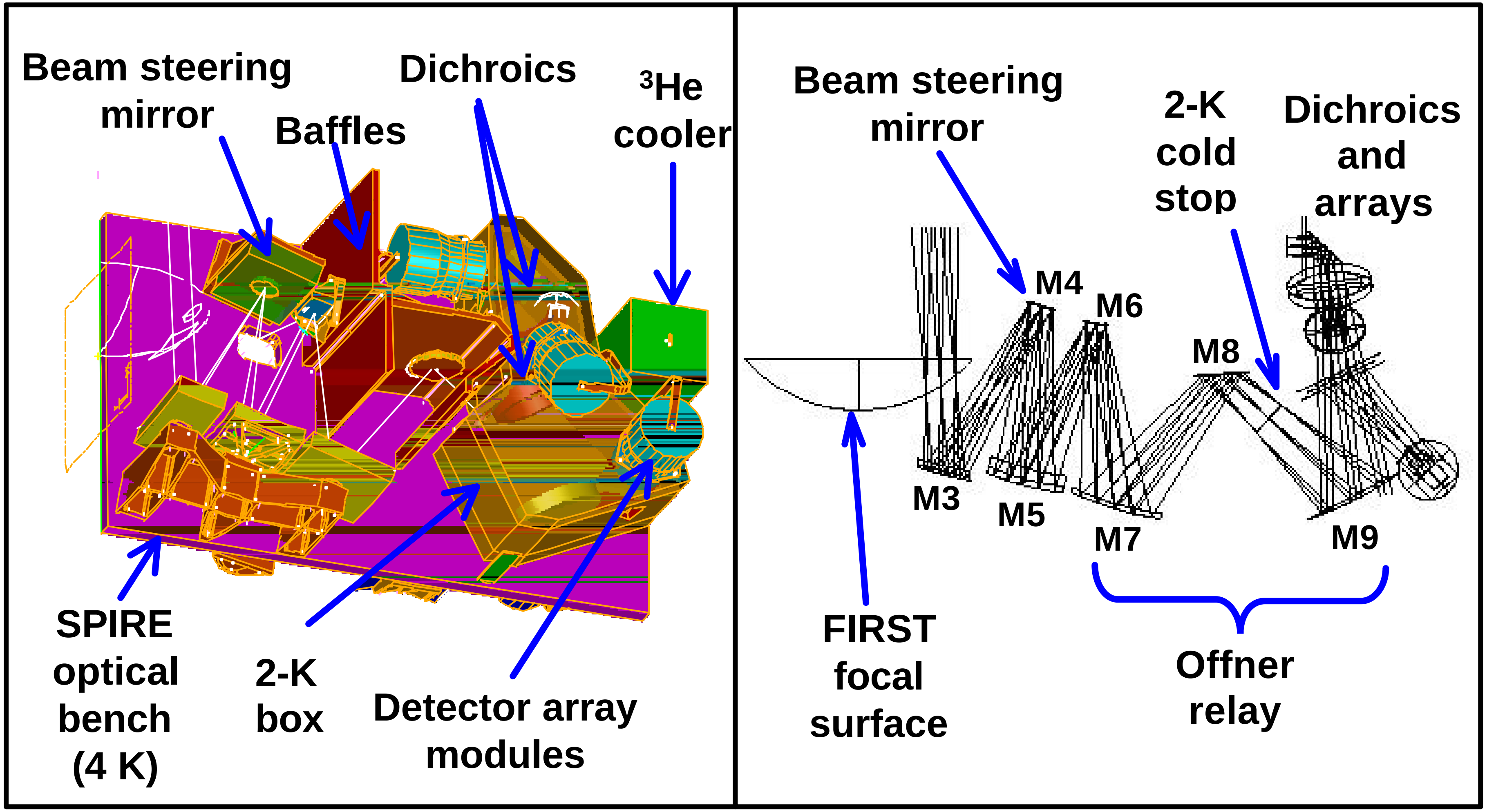


Spectrometer

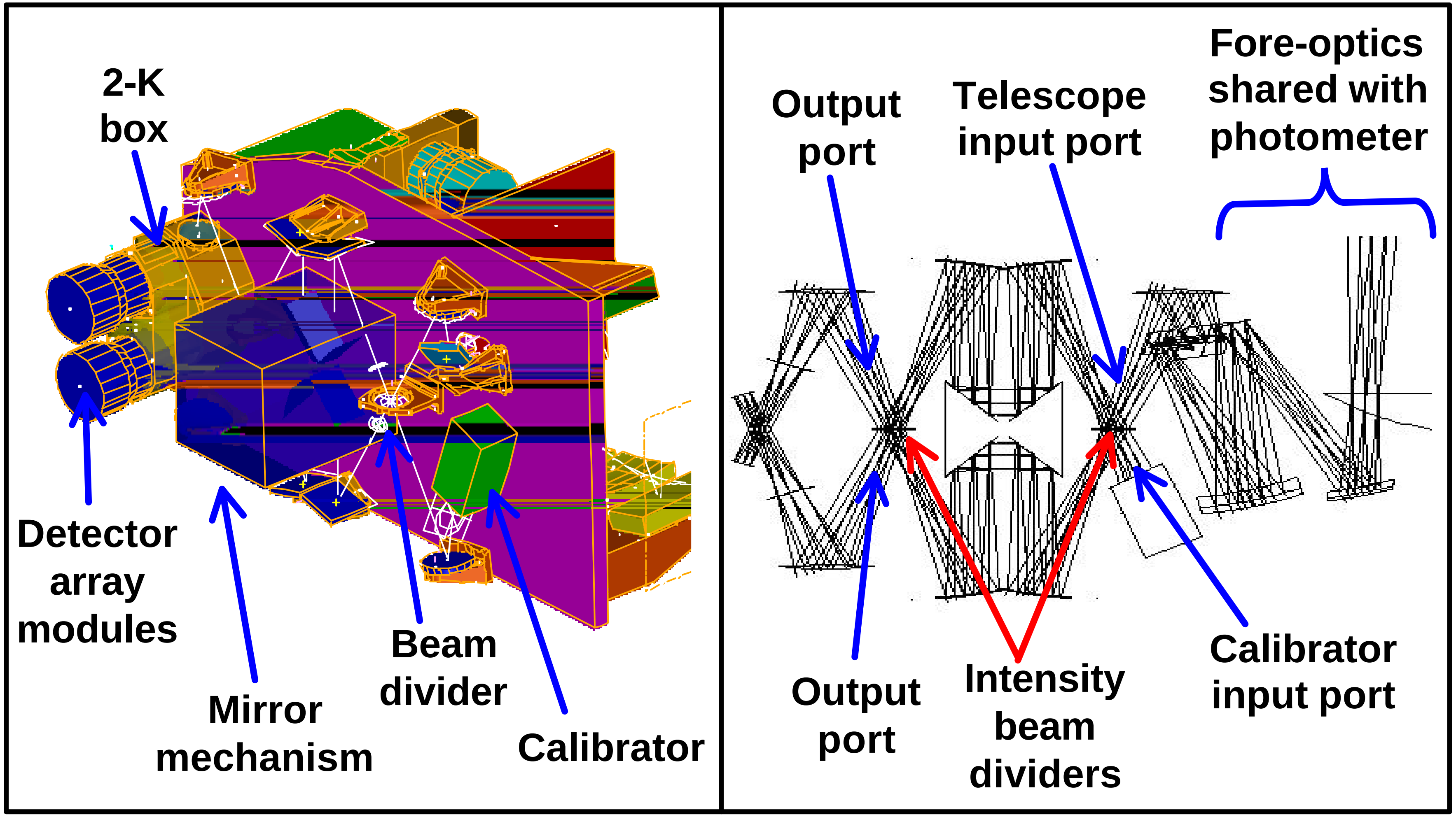


SPIRE

Photometer Layout and Optics

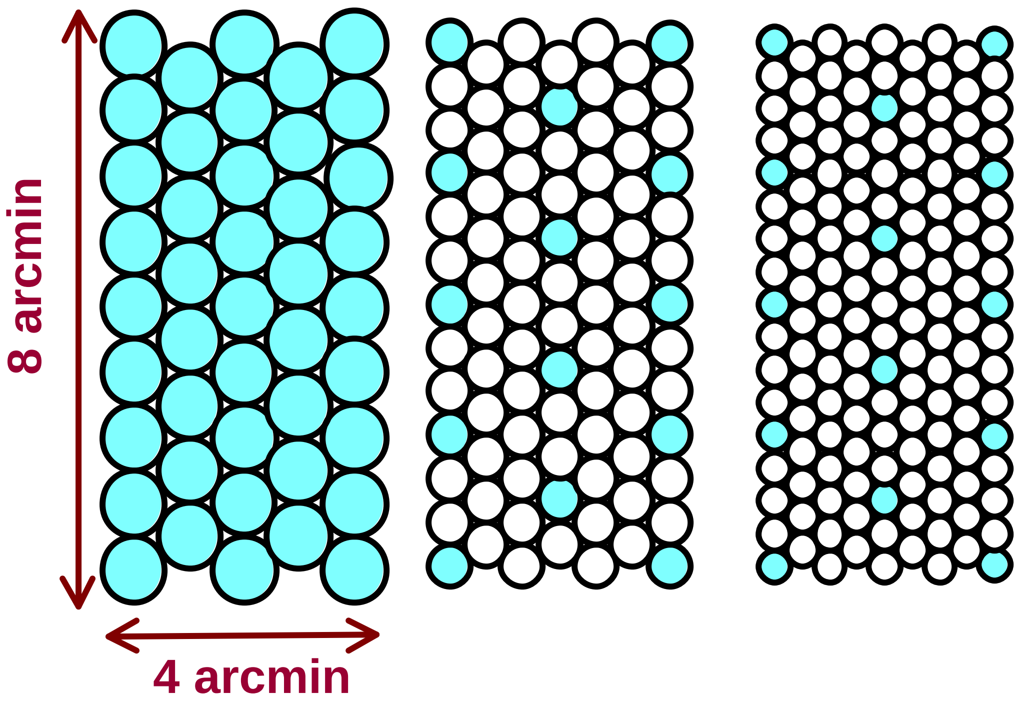


FTS Layout and Optics



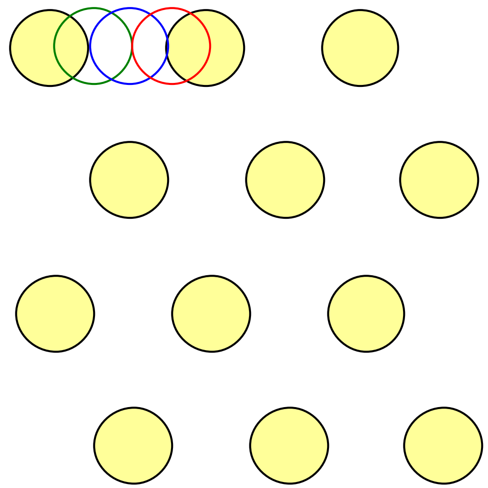
Photometer arrays: focal plane layout

500 mm	350 mm	250 mm
43 detectors	88 detectors	149 detectors



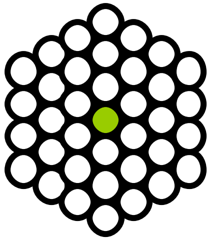
Þ **Sets of detectors with exactly overlapping beams on the sky**

- **Same 4 x 8 arcminute field of view for all three arrays**
- **FWHM beams on the sky do not overlap**
- **Pointing adjustments needed for full sampling (half-beam spacing)**

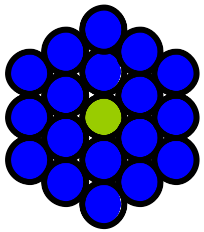


SPIRE Spectrometer arrays: focal plane layout

200-300 μm
37 detectors



300-670 μm
19 detectors



 ⇒ **Overlapping beams**

- **Same ~ 2.6 arcminute field of view for both arrays**
- **AS for photometer, FWHM beams on the sky do not overlap**
- **Pointing adjustments needed for full sampling (half-beam spacing)**

SPIRE

Photometer Observing Modes

Photometer Observatory Functions

FH_POF1	:	Chop Without Jiggling
FH_POF2	:	Seven-Point Jiggle Map
FH_POF3	:	N-Point Jiggle Map
FH_POF4	:	Raster Map
FH_POF5	:	Scan Map Without Chopping
FH_POF6	:	Scan Map With Chopping
FH_POF7	:	Photometer Peak-Up (TBD)
FH_POF8	:	Operate photometer internal calibrator
FH_POF9	:	Special engineering modes (TBD)

SPIRE

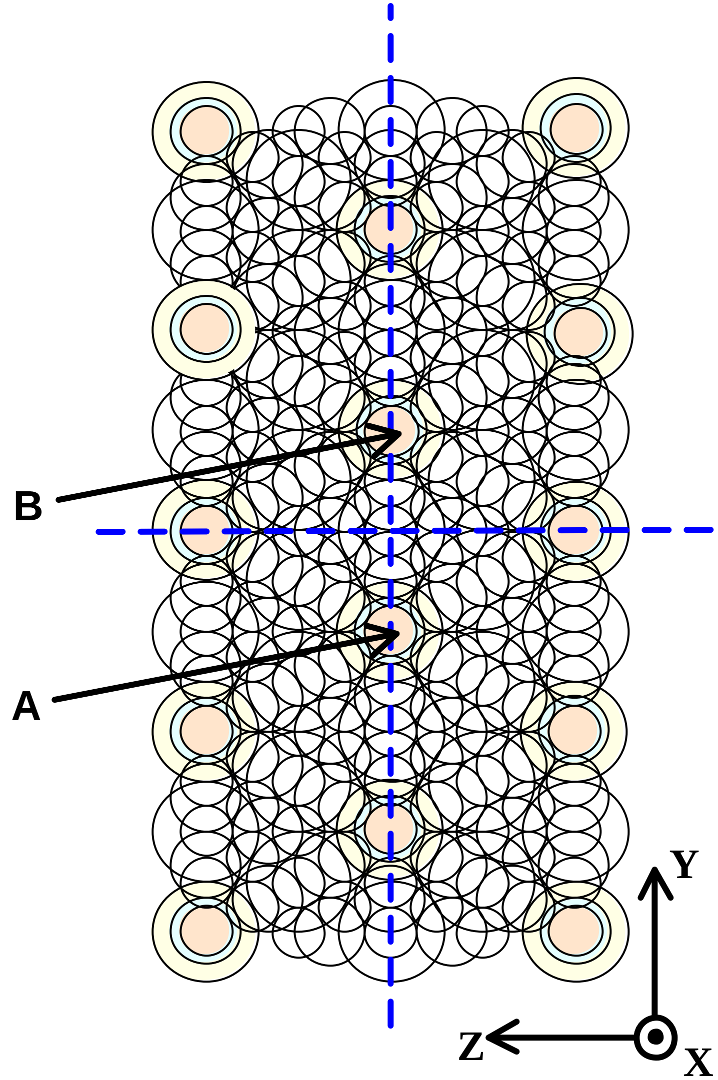
Photometer Observing Modes

- Point source photometry (POF1 or POF2):
  - Telescope pointing fixed
  - Beam steering mirror chops 125” between overlapping sets of detectors
  - Seven-point jiggle can be done if desired using the BSM
  - Nodding may be implemented
- Field mapping of sources of a few arcmin in size (POF3 or POF4):
  - Telescope pointing fixed or raster scanning
  - Beam steering mirror chops up to 4’ and performs 64-point “jiggle” to achieve full spatial sampling
  - Available fov = 4’ x 4’
  - Telescope nodding may be implemented with nod interval ~ a few minutes
- Scan mapping of large areas (POF5 or POF6):
  - Beam steering mirror not operated
  - Telescope line scanning at up to 60”/second
  - Scan angle wrt array axis to give full spatial sampling

SPIRE

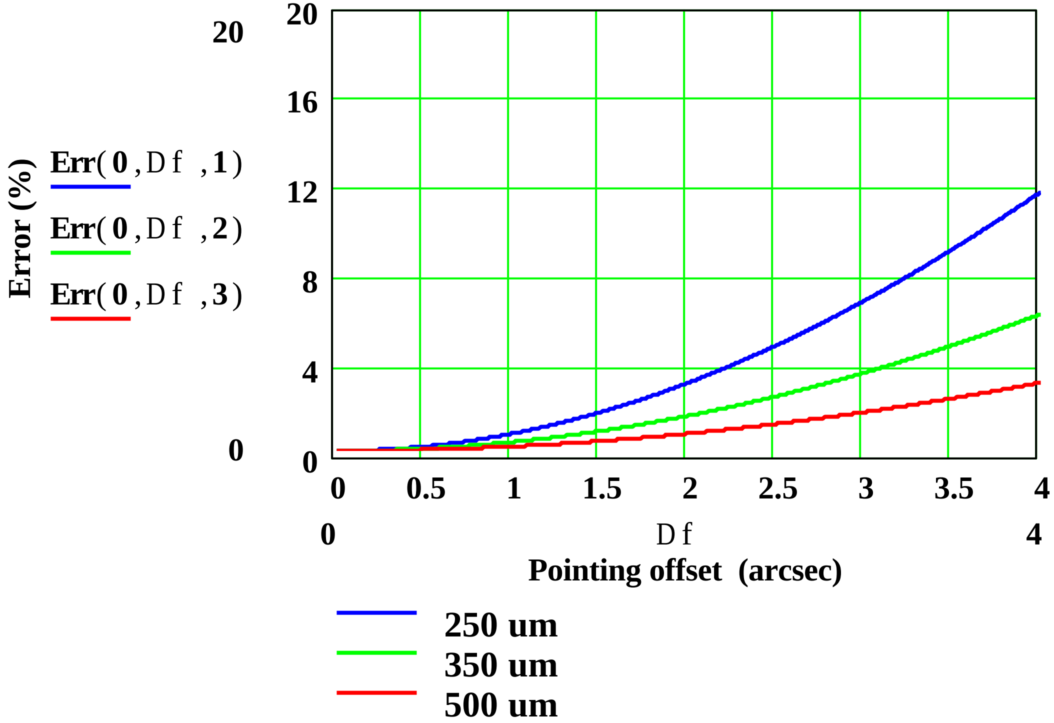
Photometer: point source photometry

- **Telescope pointing fixed**
- **SPIRE BSM chopping in Y-direction between A and B (126 arcsec.)**
- **Nominal f_{chop} = 2 Hz**
- **Nodding is optional (nod interval est. ~ 1 - 3 minutes)**
- **POF1 (Chop without jiggling) is OK if the pointing is accurate enough**



Photometer: point source observation

- **Position error of ~ 2 arcsec. or more can result in unacceptable signal uncertainty**
- **Solutions: (a) BSM does seven-point jiggle (baseline) - POF2**
  (b) Peak up using BSM (POF7), adjust pointing, then chop without jiggle (POF1)
  (c) Improved pointing accuracy

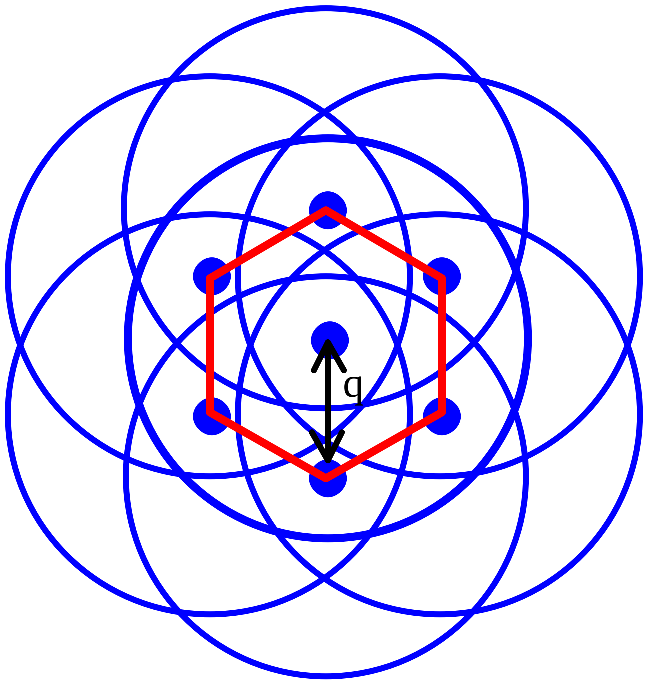


SPIRE Photometer: 7-point jiggle map (POF2)

- **SPIRE BSM chops 126 arcsec as for POF1**
- **BSM also does 7-point pattern**
- **Angular step q ~ 4-6 arcseconds (> APE)**
- **Total flux and position can be fitted**
- **Compared to single accurately pointed observation, the S/N for same total integration time is degraded by**

20%	**at**	**250 mm**
13%	**at**	**350 mm**
6%	**at**	**500 mm**

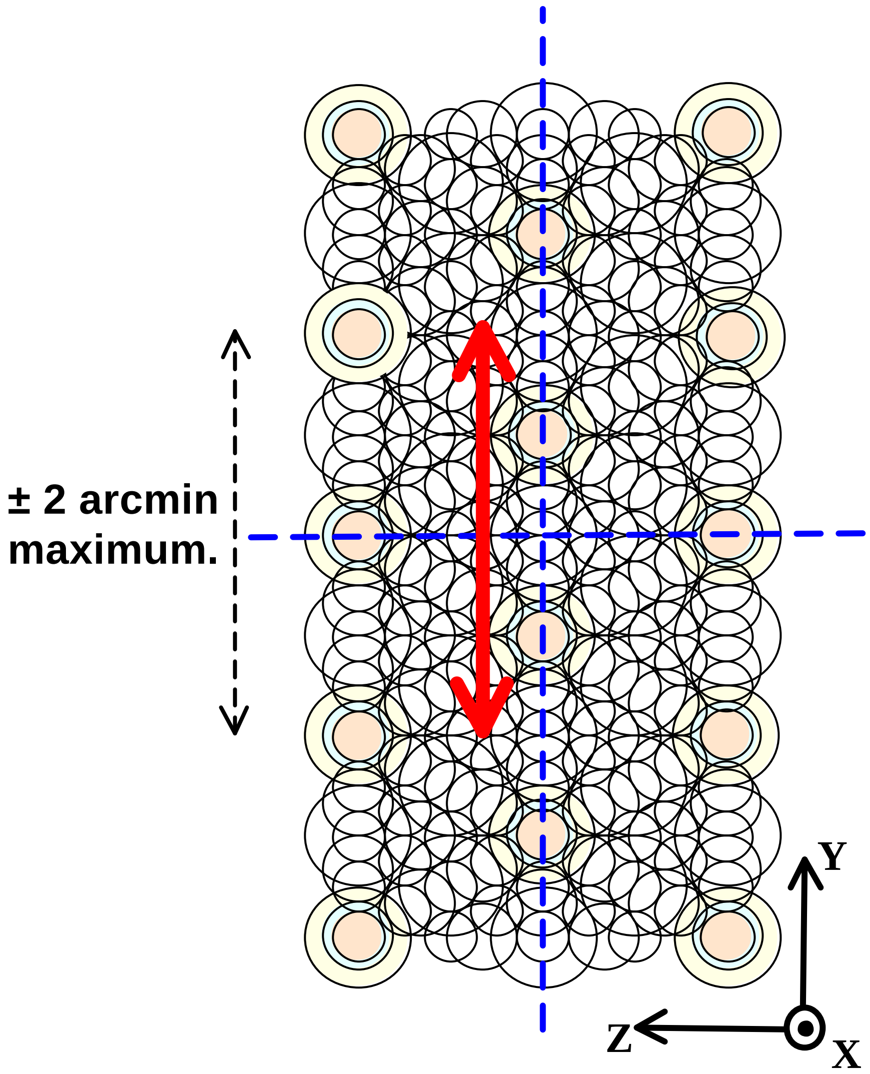
This ignores time needed for peak-up so degradation is actually less



SPIRE

Photometer: field mapping

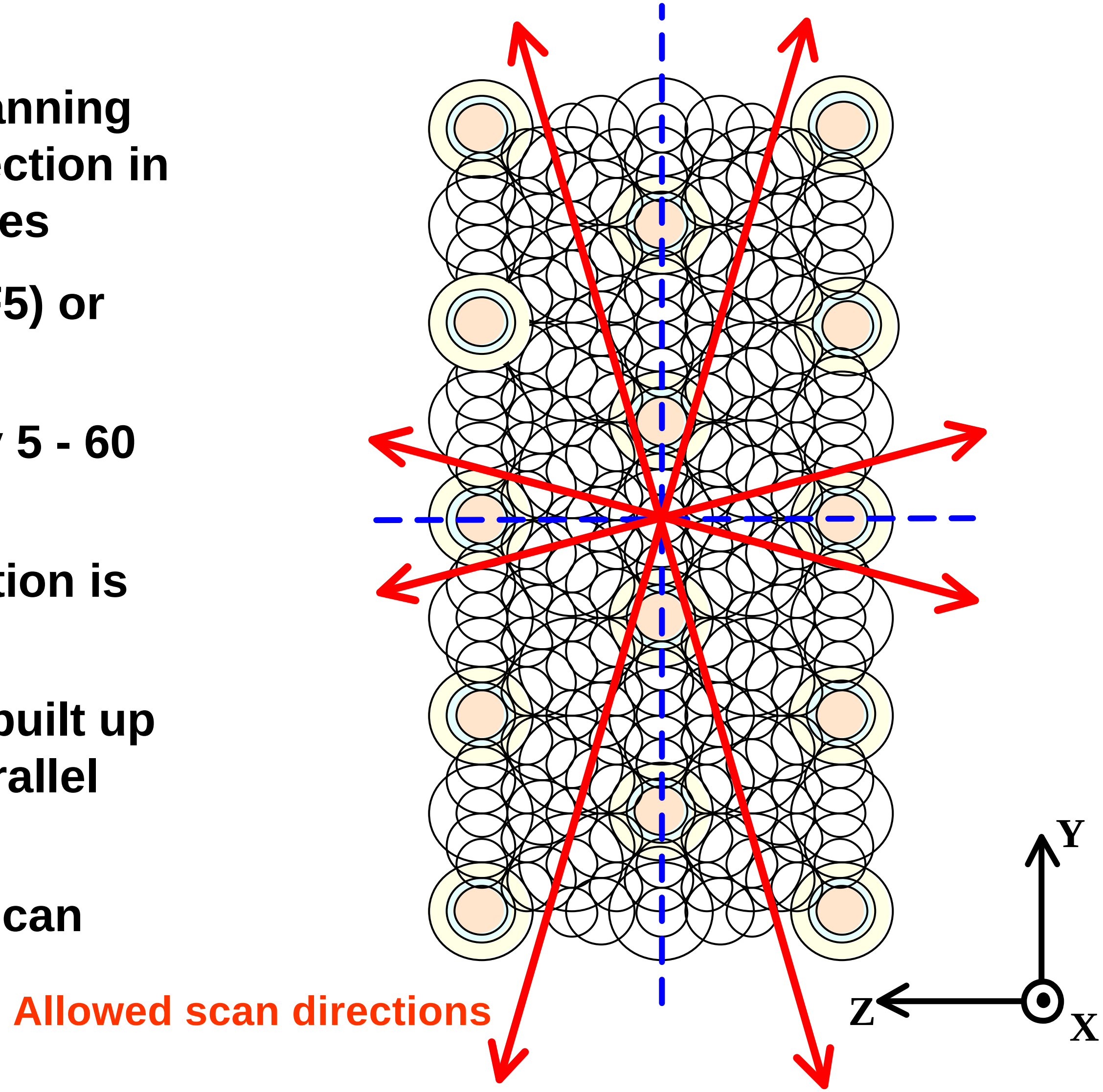
- **N-point jiggle map (POF3) Nominally N=64**
- **Telescope pointing fixed (POF3) or in raster mode (POF4)**
- **Nodding is optional**
- **SPIRE BSM chops up to 4 arcmin amplitude in Y direction at ~ 2 Hz**
- **BSM also executes 64- point "jiggle" pattern at ~ 1 Hz for full spatial sampling**
- **Minimum duration ~ 1 min.**
- **Telescope pointing accuracy is not a problem**



SPIRE

Photometer: scan mapping

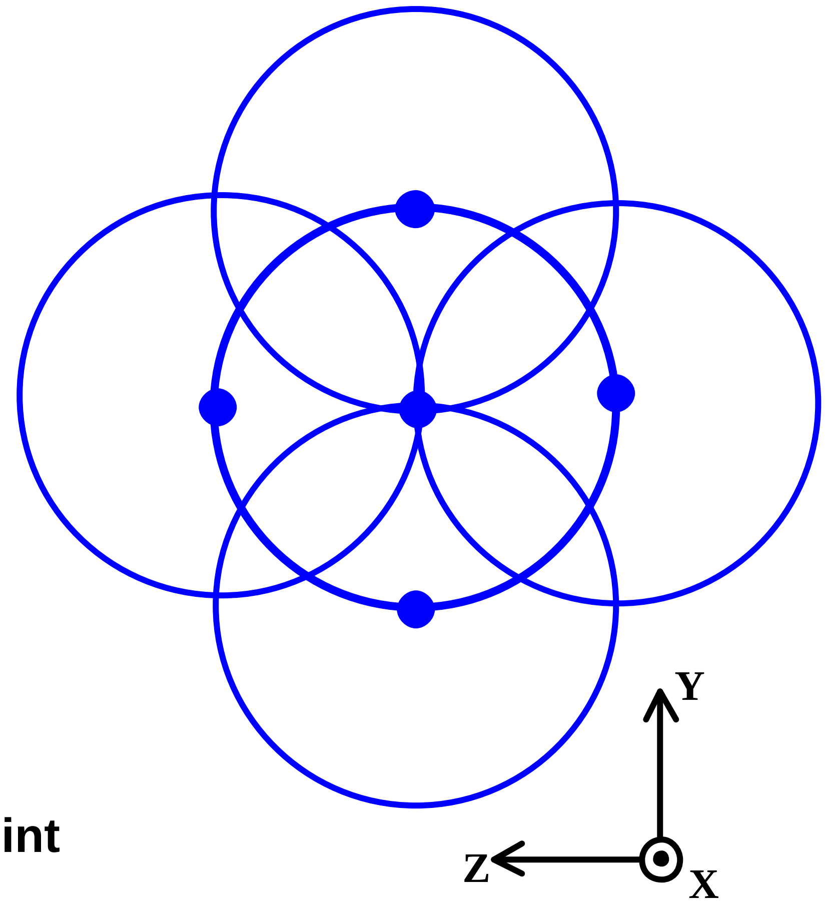
- **Telescope in line scanning mode, with scan direction in spacecraft coordinates**
- **BSM can be off (POF5) or chopping (POF6)**
- **Scan rate TBD (likely 5 - 60 arcsec/sec.)**
- **Optimum scan direction is at 14.5º to array axis**
- **Map of large area is built up from overlapping parallel scans**
- **Question: RPE and scan jitter?**



SPIRE

Photometer peak-up (POF7)

- **BSM chops and executes 5-point or 7-point cross**
- **Angular step q ~ 9 arcseconds (FWHM at 250 mm)**
- **SPIRE fits 2-D Gaussian and computes required Dy and Dz**
- **Duration of 5-point ~ 1 - 3 minutes**
- **Pointing corrections transmitted to AOCS and executed**
- **Point source observation with no jiggle then executed**
- **Likely to be less efficient than 7-point in most cases**



SPIRE

FTS observing modes

Spectrometer Observatory Functions

FH_POF 20: **Point Source Spectrum – Low or Medium Resolution**

FH_POF 21: **Point Source Spectrum – High Resolution**

FH_POF 22: **Fully Sampled Spectral Map – Low/Medium Resolution**

- **Nodding is not required for any FTS modes**

SPIRE FTS: point source observation (POF20/21)

- Telescope already accurately pointed with the source on the central pixel
- FTS mirror is scanning
- Duration of individual observation at least 1 minute
- If telescope pointing accuracy not adequate, then:

  - POF20/21 must be preceded by photometer peak-up (POF7)

    or

  - POF22 must be implemented

SPIRE

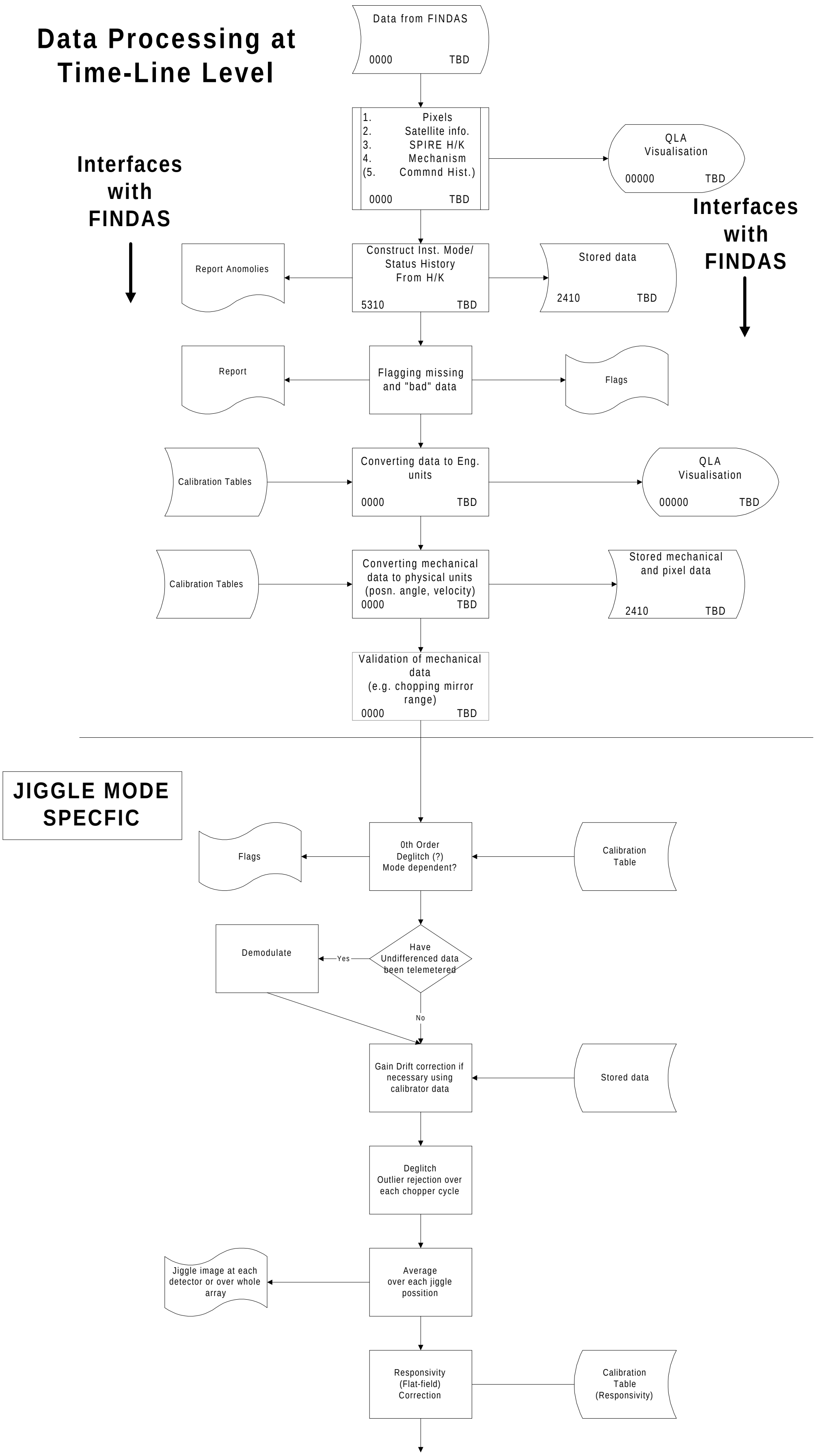
FTS: map (POF22)

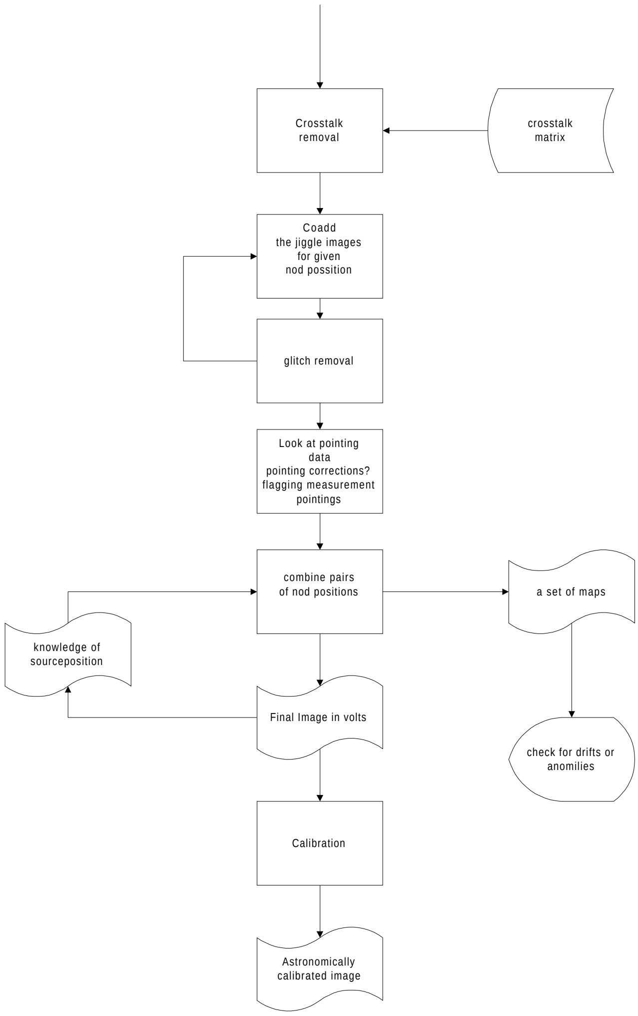
- **Telescope pointing fixed**
- **Spectral scans taken at a number of positions**
- **Positions selected by commanding the BSM to implement required angular offset and hold while FTS scans are made**
- **Point source : BSM pattern is 5- or 7-point to allow for pointing error**
- **Extended source: BSM pattern is as for N-point jiggle to provide full sampling over the 2.6- arcminute field**
- **Option**
  - **Spacecraft could execute the re-pointings rather than the BSM**
    - **Possible advantages: (i) Greater pointing stability?**
      (ii) Allows observation in the event of BSM failure

SPIRE

Requirements on the AOCS

- **Raster and line scanning must be in spacecraft coordinates**
- **Baseline:**
  - **Peak-up (if used) is carried out internally using SPIRE BSM)**
  - **BSM can implement required offset, so no interaction with the AOCS is needed**
- **Backup:**
  - **Peak-up carried out by moving the spacecraft pointing**
  - **SPIRE computes offset, so communication with the AOCS is needed**
  - **Could be needed if BSM jiggle-axis fails**
- **SPIRE surveys will involve long telescope drift scans**
  - **What are pointing jitter and drift specifications during a line scan?**
  - **Do they vary with the scan rate?**


Data Processing at Time-Line Level
Data from FINDAS
0000 TBD
1. Pixels
2. Satellite info.
3. SPIRE H/K
4. Mechanism
(5. Commnd Hist.)
0000 TBD
QLA Visualisation
00000 TBD
Interfaces with FINDAS
Interfaces with FINDAS
Report Anomolies
Construct Inst. Mode/ Status History From H/K
5310 TBD
Stored data
2410 TBD
Report
Flagging missing and "bad" data
Flags
Calibration Tables
Converting data to Eng. units
0000 TBD
QLA Visualisation
00000 TBD
Calibration Tables
Converting mechanical data to physical units (posn. angle, velocity)
0000 TBD
Stored mechanical and pixel data
2410 TBD
Validation of mechanical data (e.g. chopping mirror range)
0000 TBD
JIGGLE MODE SPECFIC
Flags
0th Order Deglitch (?) Mode dependent?
Calibration Table
Demodulate
Yes
Have Undifferenced data been telemetered
No
Gain Drift correction if necessary using calibrator data
Stored data
Deglitch Outlier rejection over each chopper cycle
Jiggle image at each detector or over whole array
Average over each jiggle possition
Responsivity (Flat-field) Correction
Calibration Table (Responsivity)


Crosstalk removal
crosstalk matrix
Coadd the jiggle images for given nod possition
glitch removal
Look at pointing data pointing corrections? flagging measurement pointings
combine pairs of nod positions
a set of maps
knowledge of sourceposition
Final Image in volts
check for drifts or anomilies
Calibration
Astronomically calibrated image

Data Reduction Pipe-Line for SPIRE data

Overview of pipe-line

This document is a first cut attempt to define the data reduction pipe-lines for SPIRE. It is not intended to provide an optimal data reduction which will only be possible after much in-flight experience, but a workable software solution that can be implemented pre-flight. Currently it only describes one operating mode, but will be extended to include all modes in the Operation mode document.

Flow-Chart

The pipe-line is guided by the flow-chart. There are currently 6 different box symbols used in the flow chart.

1. Rectangular boxes: These indicate software processes that have to be run
2. Wavy boxes: These indicate data output by the processes
3. Curved vertical line boxes: These indicate data required by the processes
4. Bullet shaped boxes: These indicate visualisation or interactive processes
5. Diamond boxes: These indicate decisions or different possible paths
6. Half-wavy boxes: These indicate documentation produced

Description of Boxes: Generic to all modes

Data from FINDAS

Includes all SPIRE relevant data

Injection into SPIRE pipeline

1., 3.,4. are obvious, 5., may not be required, 2 may include real astrometric information as a function of UT but may require a software module which can interpret or reinterpret satellite pointing data as the reconstruction models are improved (these modules could be implemented at any stage in the pipe-line)

Construct Inst. Mode/Status history from H/K

Self explanatory. May be checked against requested mode?

Flagging missing and Bad data

Self explanatory

Converting mechanical data to Physical Units

Physical units would be Volts, x,y, positions in mm, angles in degrees, etc.

Validation of mechanical data

Checking e.g. that the position of the chopper mirror is appropriate (dependent on mode?). This includes checks which would not have been trapped by the usual out of limits (hard or soft).

Calibration Tables

Required as input to the two conversion processes. Presumably these are likely to be look-up tables or parameters for simple algorithms

Reports

Reports are required to indicate where the mode is non-standard in some way, or if there is an anomalously high rate of bad pixels

Stored data

There are two points at which data is stored. In general data should be stored at a point in the pipe-line that one may wish to return to (to run new procedures) without having to go further back. So it is likely that data should be stored after time-consuming or stable processes.
The two points indicated here for storage are not cast in stone, but appear after what are presumed to be reasonable stable processes

Visualisation

Two points are indicated where QLA visualisation routines would be required. I.e. we would like to be able to examine the most raw of data products, before any real processing has occurred, and we would like to be able to visualise the data in physical units

Description of Boxes: Jiggle mode specific

0^{th} Order Deglitching

Filtering out very high significance, short time-scale spikes in the time-line

Demodulation

Differencing on-off chop position

Gain Drift correction

Probably requires sensitivity measurements as a function of time and interpolates between

Deglitch 2

Filtering out outliers from "average" of chopped signals at a single jiggle pointing

Average over jiggle position

Average together all chop cycles at a single jiggle pointing. I think pointing is a better word than position here since we return to this jiggle position later. SHOULD ACTUALLY BE ITTERATIVE WITH PREVIOUS STEP

Responsivity

Taking out the differing responsivity of the different detectors

Cross-talk

Self explanatory if hard.

Coadd Jiggle Images

As we return a number of times to each jiggle position within a single nod pointing we need to average the signals within the nod pointing

Glitch removal

Deviations between signals from sequential returns to the same jiggle position can be filtered out, iterative with previous step

Look at pointing data

Assign astrometric positions to co-added detector images

Combine pairs of nod positions

Combine images which are taken at genuinely different telescope pointings, i.e. not different because of the jiggle and chop movements of the mirror

Calibration

Self-explanatory