Calibration

CU6 Workshop, Royal Observatory Belgium, 12/13 October 2006

Calibration: overview

- The RVS calibration occurs at two main levels:
  1. CCD level – bias, gain, cosmetic defects *etc*.
  2. astronomical – photometric throughput, wavelength scale *etc.*
- The *Gaia*3 design provides visibility of data from each CCD individually: not combined on board (better)

Calibration: overview (ctd)

- *Gaia*3 design has the concept of
  - nominal $\lambda/\Delta\lambda\sim11500$ resolving power
  - low $\lambda/\Delta\lambda\sim5000$ resolving power
- Also many different window overlap settings with mixed/partial windows
- This means that calibrations will need to examine the subtle effects of these different configurations

also

- Across-scan binning prevents 2-D information from CCDs being obtained except for Bright Star Mode including Calibration Faint Stars.
- This means that some CCD parameters (eg flat field determinations, cosmetics etc) will need to be determined using BS mode windows, or if not sufficient, via detailed analysis of normal windows.

Calibration: CCD level

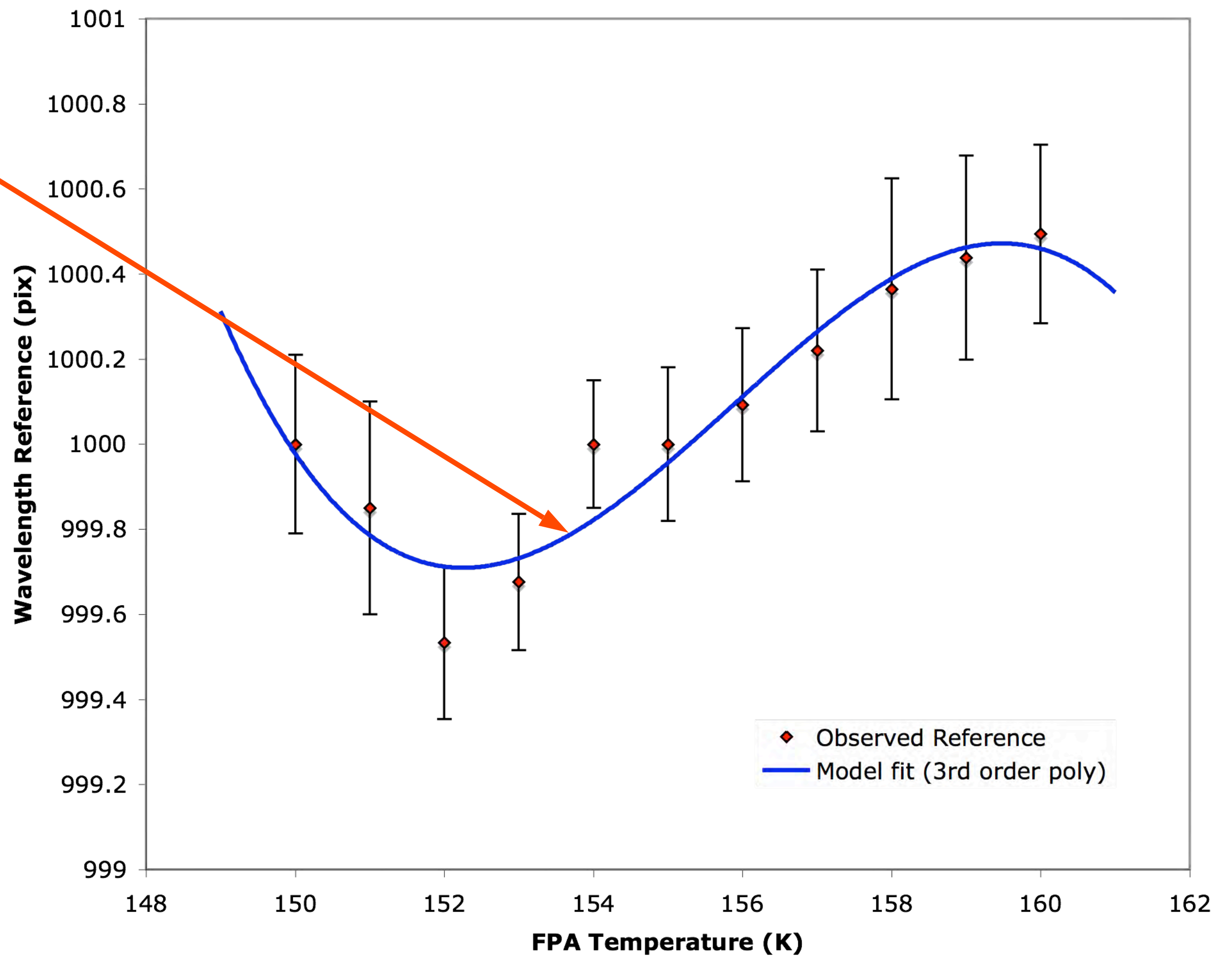
- Calibration at CCD level includes
  - CCD bias as f(CCD#)
  - CCD gain as f(CCD#) [charge conversion at the readout node]
  - CCD readout and dark noise as f(CCD#,y)
  - CCD TDI flat field as f(CCD#,y,λ)
  - CCD blemishes as f(CCD#,y)
  - signal linearity as f(CCD#)
  - saturation level as f(CCD#)
- also, if fixed in the CCD frame:
  - scattered light/ghosts as f(CCD#,y)

Calibration: normal calibrations

- The set of calibration stars is made up of
  - external standards (flux standards, radial velocity standards *etc.*)
  - an internal set of stars with consistent characteristics from scan to scan, and appropriate spectra
- Have in the calibration database
  - observations of the set of calibration stars
  - the calibration model
- The set of calibration stars is continually updated by eliminating unsuitable stars (outliers) as calibration improves
- A model fit is made to the set of calibration stars as a function of the parameters of interest (eg temperature, Sun angle *etc*.)
- The model is updated in the daily calibration cycle.
- New observations are then calibrated with the most recent model.

Calibration: Modelling

- Example of wavelength reference dependence on the temperature of the FPA
- In general the model will be multi-dimensional f(T_i,CCD#,y...)
- Need to identify all important parameters in order to reduce calibration residuals



Calibration: SGIS

- The SGIS (Spectroscopic Global Iterative Solution) occurs in an outer loop, where the calibration parameters from the instrument are re-derived by refining both
  - the calibration applied to the calibration star observations (from a reanalysis of the observations) and
  - the model

  at the same time, iteratively
- Past work at Meudon (Guerrier & Katz) has simulated this and checked for convergence (*c.f.* next talk)
- The size of the sample to be used for SGIS will affect the frequency with which it is possible to re-run SGIS (6 months nominally?).
- It will in any case be necessary to have observations separated by a sufficient duration in order to correct for/model all significant systematic effects using SGIS.
  - to get sufficient sampling of the parameter space
  - to determine evolution with time

Calibrations: SGIS (ctd)

- SGIS will determine the main instrument calibration
  - wavelength scale and zero reference as f(y,λ,T)
  - photometric throughput as f(CCD#,y,λ)
  - AC line spread function as f(CCD#,y,λ,scan_law)
  - AL line spread function as f(CCD#,y,λ,T)
  - distortion map as f(CCD#,y,λ,T)
  - scattered light/ghosts as f(CCD#,y)

- For scattered light/ghosts analysis have to learn how to reconstruct the focal plane imaging in absence of 2-d imaging

Work Plan - Calibration

- Phase 1 (Oct06-Jan07) – mostly WP 630-01000
  - familiarisation with CU6 infrastructure
  - familiarisation with CU1 methodologies
  - set up management interfaces with CU6 and CU5 (PPARC)
  - contribute to continuing functional analysis at CU6 level
  - detailed definition of external interfaces and protocols to routines based on functional analysis
- Phase 2 (Dec06-Mar07) – mostly WP 630-02000
  - refine the requirements for the extraction workpackage tasks
  - perform detailed functional analysis for extraction tasks
  - specify internal interfaces
  - consider and devise test frameworks
- Phase 3 (Feb07-May07) – other WP 630-0x000
  - prototype code
  - generate test harnesses
  - iterate

Workpackage 630

The top level WBS is given in GAIA-C6-SP-OPM-DK-003-1

GWP-S-630 Calibration of the spectroscopic instrument

- 630-01000 Management, configuration management & interfaces
- 630-02000 Detailed functional analysis of the calibrations
- 630-03000 Interface with Quick Look group
- 630-05000 Detailed First Look & validation: raw data
- 630-06000 Implementation of SGIS
- 630-07000 CCD bias, CCD readout and dark noises, CCD blemishes
- 630-08000 Phot. throughput, CCD flat f., linearity, satur. lev.
- 630-09000 Along scan & across scan line spread functions
- 630-10000 Wavelength scale, Distortion map
- 630-11000 Scattered light & ghosts
- 630-12000 Detailed first look & validation: calibration
- 630-13000 Detailed First Look: faint stars

630-01000

Title: Management, configuration management and interfaces		
Provider: MSSL	**Manager**: Simon Rosen	
Start: 01/10/2006	**End**: 01/03/2012	**Effort**: 0.1 MY/year

Objective:
To manage the calibration workpackages to ensure that the software development is produced to specification and on time.

Tasks:

1. Communicate with ESA, Meudon (CU6 lead institute) and where necessary, oth er GAIA CUs, for all CU6-specific and general GAIA software and other project is sues (e.g. calibration, archiving, interfacing, scheduling, planning etc.), to e nsure timely delivery and quality control of required software.
2. Act as point of contact (POC) for information flow, SPR/SCRs, and CU6/proj ect decisions. Respond to problems/issues.
3. Oversee internal manpower assignments, resourcing, scheduling and budget c ontrol.
4. Oversee all design, prototyping, coding, testing and validation/quality co ntrol of the calibration workpackages for which MSSL is responsible.
5. Ensure documentation is written, maintained and appropriately organised.
6. Ensure local staff are fully familiar with project documentation and proce dures.
7. Interface with PPARC (via the Vega consortium) with regard to financial re porting and related issues. Maintain close liaison with Cambridge/Vega consortiu m relating to UK involvement with the GAIA project.

630-02000

Title: Detailed functional analysis of calibration tasks		
Provider: MSSL	**Manager**: Simon Rosen	
Start: 01/10/2006	**End**: 01/10/2007	**Effort**: 0.1 MY/year
Objective: To produce a detailed functional analysis of the calibration tasks.		
Tasks: This workpackage defines the calibration of the spectroscopic instrument. This refers to the *determination* of the calibrations: these calibrations are *applied* in GWP-S-620-04000. 1. consider and design the workflow for determining the calibration of the spectroscopic instrument, including the detector characteristics, self-calibration via SGIS and calibration to external standards, i.e. wavelength and spectrophotometric scales; also the quick/first look 2. identify and scope the data storage requirements and transfer rates 3. identify external and auxiliary data required 4. define the timescales for reiteration		

630-03000

Title: Interface with Quick Look group		
Provider: None	**Manager**: Shan MIGNOT	
Start: 06/03/2006	**End**: 2016	**Effort**: 0.1 MY/year
Objective: Follow the Quick Look aspects concerning the RVS and report to CU6.		

Tasks:

1. Follow Quick Look activities conducted by industry (read and summarise the documentation produced).
2. Collaborate with CU3 to understand and appraise the monitoring planned.
3. Report CU6's management and work-packages concerned with the technical status of the instrument and CU6's Quality Assurance.
4. During the operational phase, interface between MOC (or CU3) and CU6 concerning the daily RVS status.

630-06000

Title: Implementation of SGIS		
Provider: MSSL	**Manager**: Simon Rosen	
Start: 01/10/2006	**End**: 01/03/2012	**Effort**: 0.4 MY/year

Objective:
To develop the code to derive the internal RVS wavelength calibration.

Tasks:
This workpackage will produce the code which derives the internal RVS wavelength calibration – both zero point and the dispersion relation – as a function of magnitude, windowing scheme, CCD number and binning, AC position *etc*. This is performed through an iterative method, the SGIS (spectroscopic global iterative solution), operating on a self-selected set of calibration stars which is continually being updated. This allows the wavelength calibration to be tracked for a much larger number of stars than would be available from external standards. A subsequent step (GWP-S-630-10000) aligns the internal SGIS calibration onto an absolute reference wavelength scale.

1. identify the sample characteristics for SGIS stars (sample size, stellar characteristics, magnitude limits *etc*.
2. identify the distribution of observing characteristics required for the application of the SGIS (magnitude, windowing scheme, CCD number and binning, AC position *etc*)
3. develop algorithms to produce a self-selecting SGIS sample of stars with the correct characteristics, including sample updates and outlier rejection
4. identify appropriate parameterisations of the wavelength scale (polynomial, spline *etc*.)
5. identify appropriate convergence criteria
6. develop code to run SGIS and derive parameters, including derivation and propagation of systematic and random errors
7. develop verification code for SGIS
8. verify SGIS code using simulated data

Title: CCD bias, CCD readout and dark noise, CCD blemishes		
Provider: MSSL	**Manager**: Simon Rosen	
Start: 01/10/2006	**End**: 01/03/2012	**Effort**: 0.1 MY/year

Objective:
To develop the code to derive many of the CCD characteristics for calibration

Tasks:
This workpackage will produce the code which identifies and quantifies many of the instrumental signature as imparted by the CCDs. This includes the CCD bias levels, readout noise, dark noise and blemishes. As there will be no dedicated calibration observations, this code will need to draw on data derived during nominal operation.

1. identify how CCD characteristics will be delivered to ground from in-orbit data
2. develop code to determine bias levels including derivation and propagation of systematic and random errors
3. develop code to determine CCD readout noise including derivation and propagation of systematic and random errors
4. develop code to measure CCD dark noise including derivation and propagation of systematic and random errors
5. develop code to recognize and characterize CCD blemishes
6. develop code to incorporate CCD calibration information into calibration files
7. develop verification code
8. verify CCD calibration code using simulated data

630-08000

Title: Photometric throughput, CCD flat field, linearity, saturation levels		
Provider: MSSL	**Manager**: Simon Rosen	
Start: 01/10/2006	**End**: 01/03/2012	**Effort**: 0.2 MY/year

Objective:
To develop the code to derive photometric throughput and CCD intensity scale parameters for calibration

Tasks:
This workpackage will produce the code which identifies the remainder of the instrumental signatures imparted by the CCDs (beyond those in GWP-S-630-07000). This includes the CCD flat field, linearity and saturation levels. It also includes the overall throughput of the instrument. This code will need to draw on information derived during nominal operation.

1. identify external photometric standards for the derivation of throughput
2. identify necessary links to *Gaia* photometric information and establish how to exploit it
3. develop code to determine photometric throughput including derivation and propagation of systematic and random errors
4. identify how CCD characteristics will be delivered to ground from in-orbit data
5. develop code to measure CCD flat fields including derivation and propagation of systematic and random errors
6. develop code to measure CCD linearity function including derivation and propagation of systematic and random errors
7. develop code to establish CCD saturation levels
8. develop code to incorporate throughput calibration information into calibration files
9. develop code to incorporate CCD calibration information into calibration files
10. develop verification code
11. verify throughput calibration code using simulated data
12. verify CCD calibration code using simulated data

Title: AL and AC LSF		
Provider: MSSL	**Manager**: Simon Rosen	
Start: 01/10/2006	**End**: 01/03/2012	**Effort**: 0.2 MY/year

Objective:
To develop the code to derive the AL and AC LSFs for calibration

Tasks:
This workpackage will produce the code which identifies and quantifies the line spread functions (LSFs) in the AL and AC directions as a function of position on the RVS focal plane As there will be no specific calibration observations, this code will need to draw on data derived during nominal operation, and in particular on the 2-D windows available from bright stars.

1. investigate the selection procedures that will need to be executed to recognize and isolate suitable observations for AL LSF determination as a function of magnitude *etc*.
2. investigate the selection procedures that will need to be executed to recognize and isolate suitable observations for AC LSF determination as a function of magnitude *etc*.
3. develop code to construct AL LSFs as a function of magnitude, windowing scheme, CCD number and binning, AC position *etc* including derivation and propagation of systematic and random errors
4. develop code to construct AC LSFs as a function of magnitude, windowing scheme, CCD number and binning, AC position *etc* including derivation and propagation of systematic and random errors
5. develop code to incorporate AL and AC LSF calibration information into calibration files
6. develop verification code
7. verify AL and AC LSF calibration code using simulated data

630-10000

Title: Wavelength scale and AC Distortion map		
Provider: MSSL	**Manager**: Simon Rosen	
Start: 01/10/2006	**End**: 01/03/2012	**Effort**: 0.2 MY/year

Objective:
To develop the code to derive the wavelength scale and AC spatial distortion for calibration

Tasks:
This workpackage will produce the code which identifies and quantifies the wavelength scale and AC spatial distortion as a function of position on the RVS focal plane. This workpackage does not address the AL distortion, as this is mixed with the wavelength zero point. The detailed wavelength scale is determined by the SGIS (GWP-S-630-06000), but it needs to be referenced to external standards (identified in GWP-S-640-x). As there will be no dedicated calibration observations, for the AC spatial distortion this code will need to draw on data derived during nominal operation, and in particular on the 2-D windows available from bright stars.

1. identify algorithms for determining and applying wavelength zeropoints from external standards to the SGIS internal solutions
2. investigate the selection procedures that will be needed to recognize and isolate suitable observations for the AC distortion determination as a function of magnitude *etc*.
3. develop code to construct AL wavelength zero points and absolute wavelength scale from SGIS internal calibration and from external wavelength standards as a function of magnitude, windowing scheme, CCD number and binning, AC position *etc* including derivation and propagation of systematic and random errors
4. develop code to construct AC distortions as a function of magnitude, windowing scheme, CCD number and binning, AC position *etc* including derivation and propagation of systematic and random errors
5. develop code to incorporate wavelength scale calibration information into calibration files
6. develop code to incorporate AC distortion calibration information into calibration files
7. develop verification code
8. verify wavelength scale and wavelength zero-point calibration code using simulated data
9. verify AC distortion calibration code using simulated data

630-11000

Title: Scattered light and ghosts		
Provider: MSSL	**Manager**: Simon Rosen	
Start: 01/10/2006	**End**: 01/03/2012	**Effort**: 0.2 MY/year

Objective:
To develop the code to derive the scattered light and ghost map for calibration

Tasks:
This workpackage will produce the code which identifies and quantifies the ghost images and scattered light as a function of object coordinates and position on the RVS focal plane. As there will be no dedicated calibration observations, this code will need to draw on data derived during nominal operation. It will be necessary to mostly use data from bright stars in 2-D windows.

1. investigate the selection procedures needed to identify and isolate suitable observations for mapping scattered light and ghosts as a function of off-axis angle, magnitude *etc*.
2. develop code to construct ghost images as a function of magnitude, viewing angles, windowing scheme, CCD number and binning, position *etc* including derivation and propagation of systematic and random errors
3. develop code to construct scattered light as a function of magnitude, viewing angles, windowing scheme, CCD number and binning, position *etc* including derivation and propagation of systematic and random errors
4. develop code to incorporate ghost images and scattered light calibration information into calibration files
5. develop verification code
6. verify ghost image and scattered light calibration code using simulated data