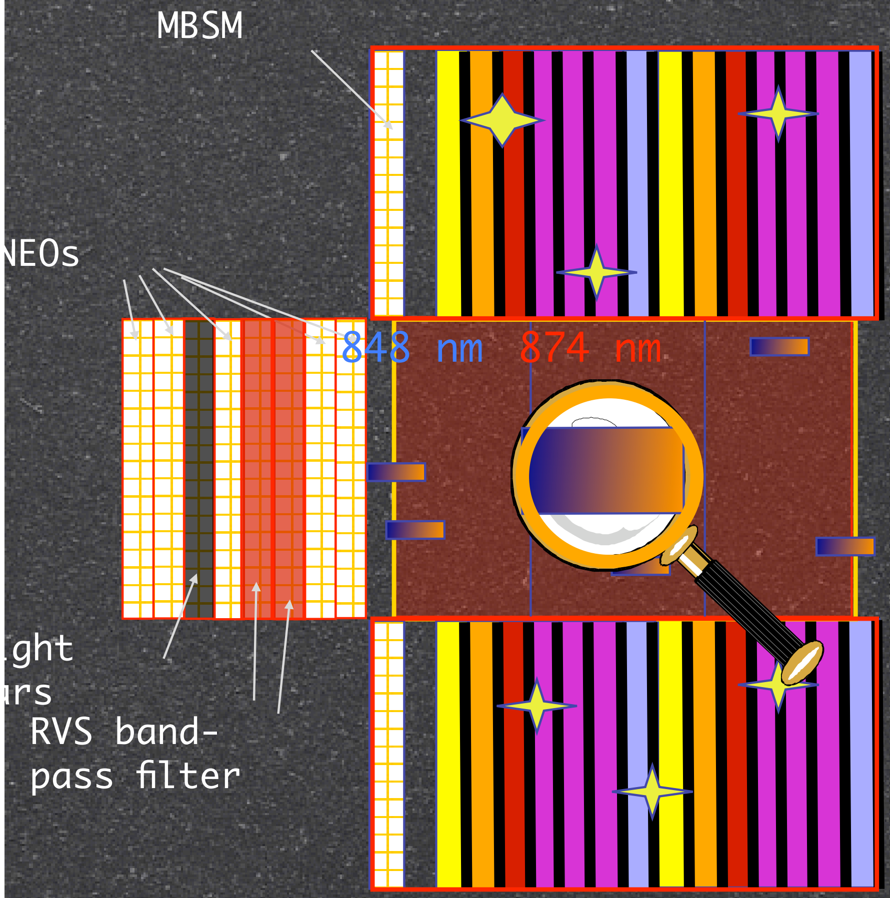
Detection, design, Payload Data Handling Electronics and RVSM

F. Arenou & S. Mignot

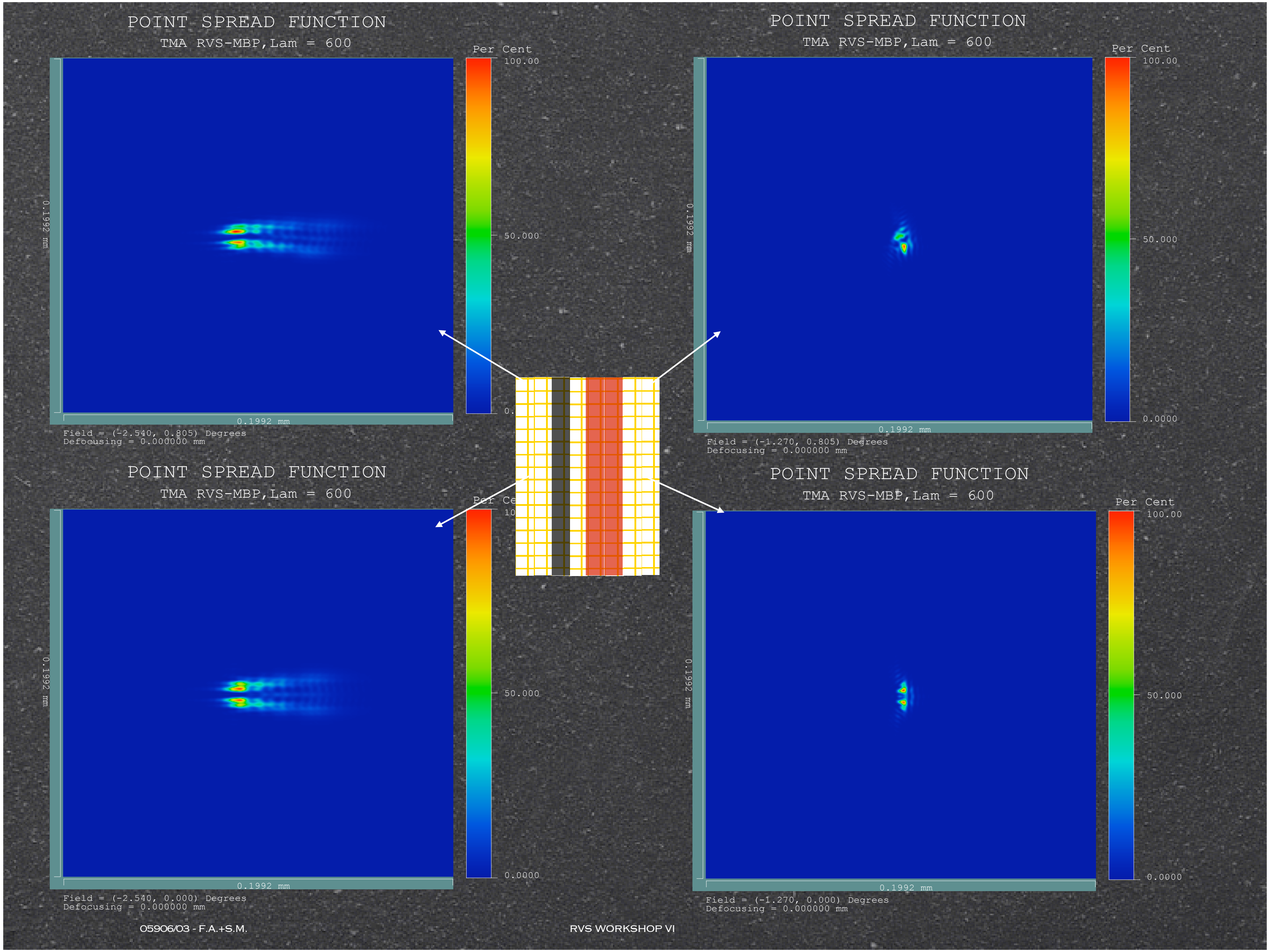
The instrument

based on CUO-117 proposal

Spectro field



- Objects:
  - Stars
  - NEOs
  - Saturated objects
- Detection of moving objects
  - ~50s between RVSM1 and RVSM8
  - Assumption @G>20: σ(8-1)>4mas/s
  - MBO: σ=10mas/s AL, 15 AC
  - NEO: σ=30 mas/s AL, 40 AC
  - But what about the PSF effect?


POINT SPREAD FUNCTION
TMA RVS-MBP,Lam = 600
Per Cent
100.00
50.000
0.1992 mm
Field = (-2.540, 0.805) Degrees
Defocusing = 0.000000 mm
POINT SPREAD FUNCTION
TMA RVS-MBP,Lam = 600
Per Cent
100.00
50.000
0.0000
0.1992 mm
Field = (-1.270, 0.805) Degrees
Defocusing = 0.000000 mm
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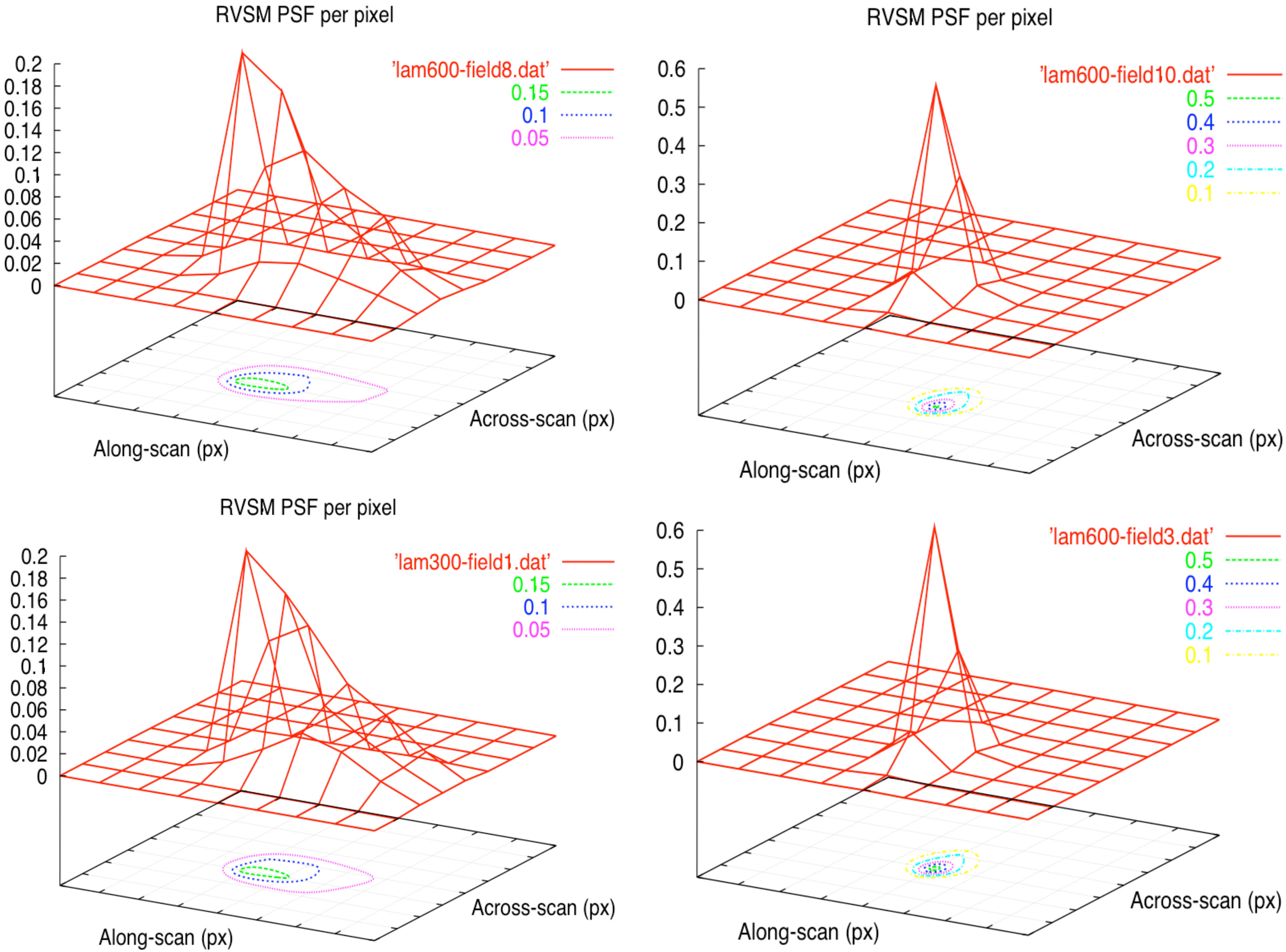
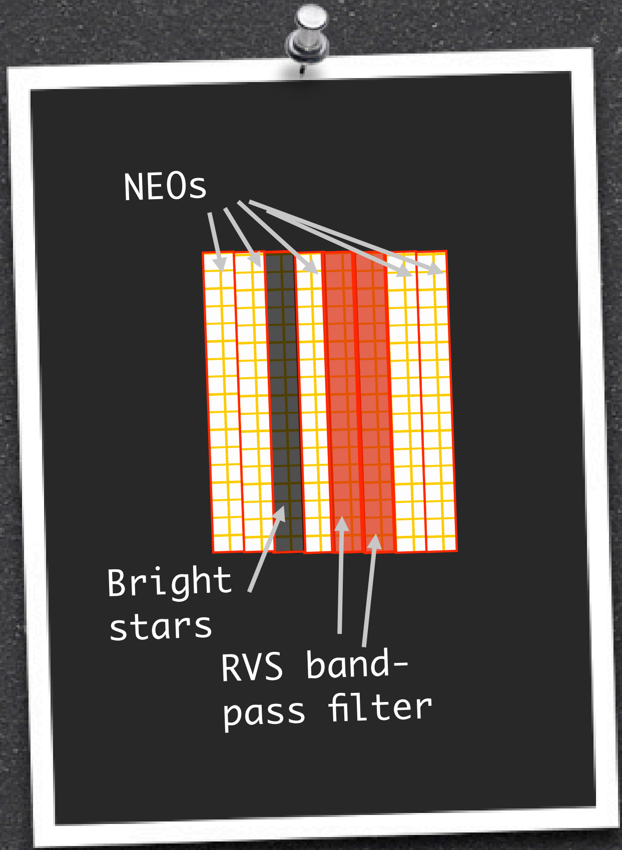
05906/03 - F.A.+S.M.
RVS WORKSHOP VI


RVSM PSF per pixel
'lam600-field8.dat'
0.15
0.1
0.05
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Along-scan (px)
Across-scan (px)
RVSM PSF per pixel
'lam600-field10.dat'
0.5
0.4
0.3
0.2
0.1
0.6
0.5
0.4
0.3
0.2
0.1
0
Along-scan (px)
Across-scan (px)
RVSM PSF per pixel
'lam300-field1.dat'
0.15
0.1
0.05
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Along-scan (px)
Across-scan (px)
'lam600-field3.dat'
0.5
0.4
0.3
0.2
0.1
0.6
0.5
0.4
0.3
0.2
0.1
0
Along-scan (px)
Across-scan (px)

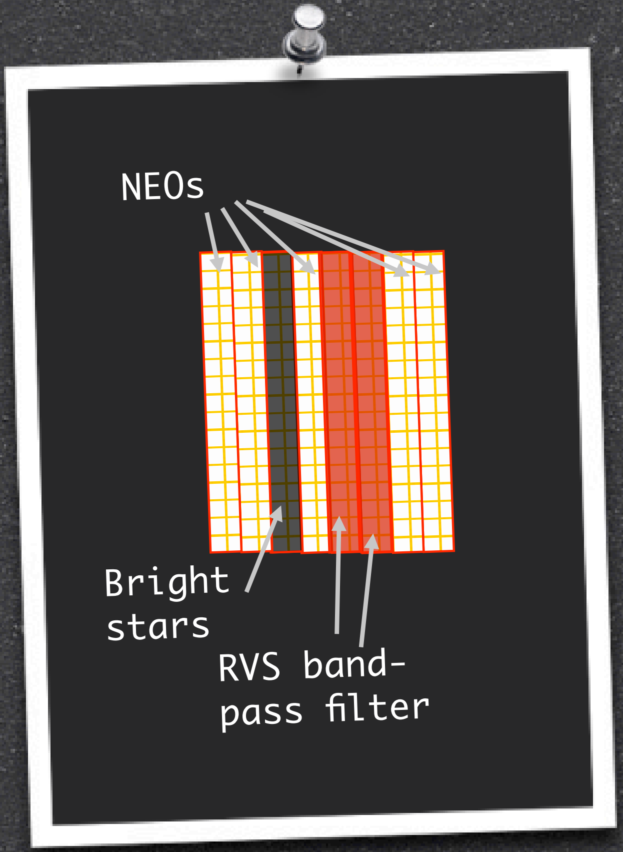
Function of RVSM

- Read all pixels of all CCDs
- Run detection in all CCDs
  - <3000 obj/s assumed (80000 max)
- Cross-correlate detections
  - high computational complexity
- Transmit position and flux
  - of all objects brighter than G=20 (pollution of spectra)
- Transmit background map #5&#6
  - Computed in a 32x32 px^2 mesh
- Determine NEO
  - Transmit position, motion and flux.
- Astrium: bright star for ASM
  - Activation of gates 38mn later



Application of RVSM

- RVSM #3:
  - improved centroiding for saturated objects (wavelength calibration)
  - is optical quality good enough?
- RVSM #5 and #6:
  - red filters: 848 to 874 nm
  - calibrate the RVS sky background (download specific data)
  - demix the stacked spectra in high stellar density areas (predict precise RVS content).
- RVSM #1 (#2), #4, #7 (#8)
  - normal objects
  - detect as faint as possible



Detection

Detection: Algorithmic drivers

- Simplicity:
  - Real-time constraints
  - Limited computing power
- Efficiency:
  - Telemetry & computing resources (false detections)
  - Crowding of spectra (completeness) > G=20
  - Completeness of telemetered information (calibration)
- Robustness:
  - Instrument deterioration (detectors and geometry)
  - Diversity of observed objects & associated tasks (stars, saturated objects, NEOs, cosmic rays, extended objects, etc.)
  - Modes of operation

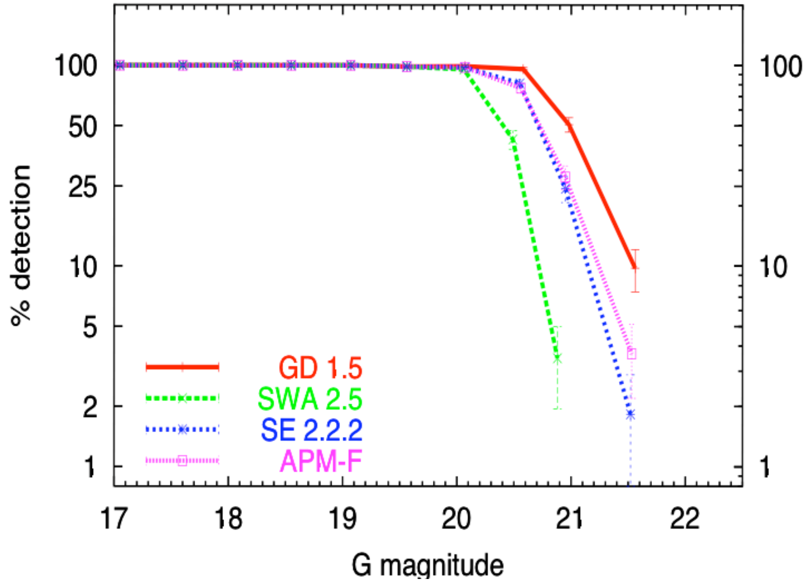
Two approaches

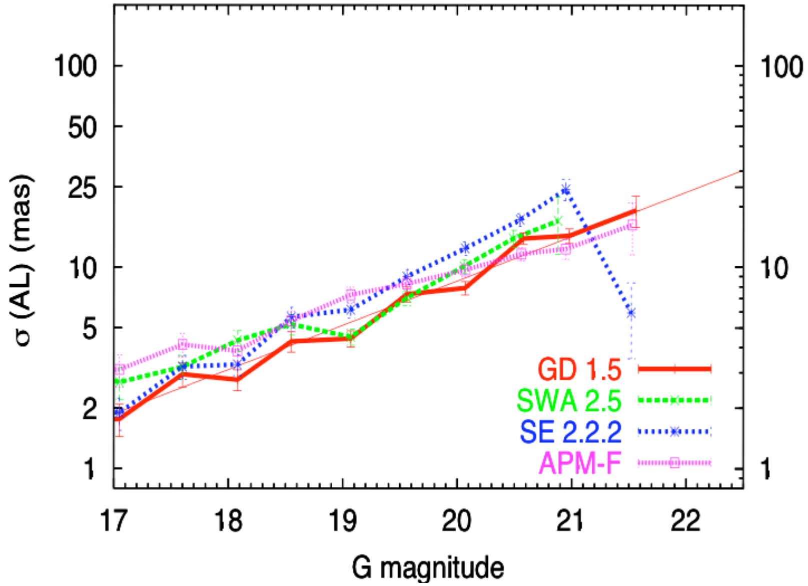
Algorithm	SWA	GD
Origin	E. Hoeg C. Babusiaux	APM, M. Irwin F. Chéreau + S. Mignot
Development	1999	2002
Method	Peak-finding	Segmentation
Buffering	Local approach	Region
Denoising	Convolution 3x3 kernel	Convolution 3x3 kernel
Background	Between PSF spikes	hyperpixels of 32x32 samples
Detection	8-connectivity, χ^2 test 1 max = 1 object	pixel SNR-threshold above interpolated background
Data collection	Background object SNR filtering	Connected components object SNR filtering
measurements	Local centroid (barycenter), flux, background	Object centroid (LSF-fitting AL) flux, background, shape, object classification
Other processing		Remove false detection on spikes, Double/Multiple stars deblending
Advantages	fast	Extended objects: galaxies, asteroids (spatial extension+motion)

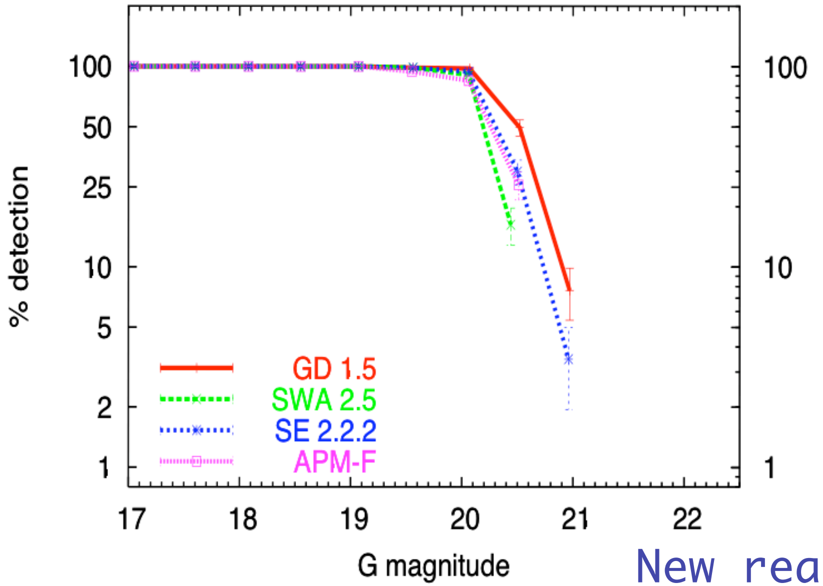
ASM detection performances

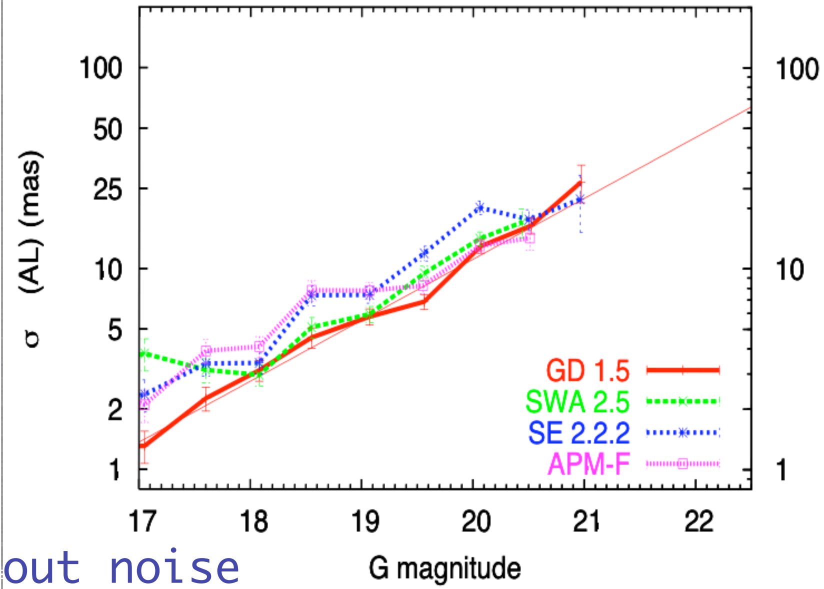
- Comparison between different algorithms in ASM
  - GD, SWA, APM (M. Irwin), SExtractor (E. Bertin)
- Thresholds fixed such as:
  - Less than 1 false detection per million of pixels (~ 1 per 200 stars)
  - maximum number of detections
- Former RON was too optimistic
  - 8.7 e- instead of 14 in ASM
  - Completeness at G=20?
  - 0.5 mag will be lost at faint end
  - Loss of precision for faint objects

Former read-out noise





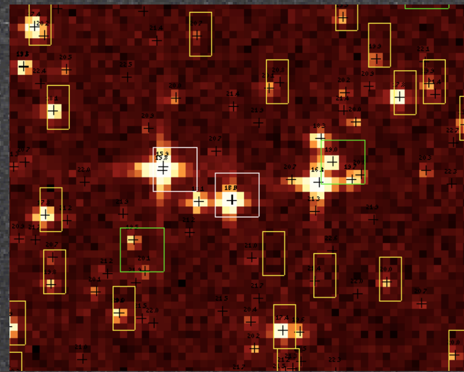




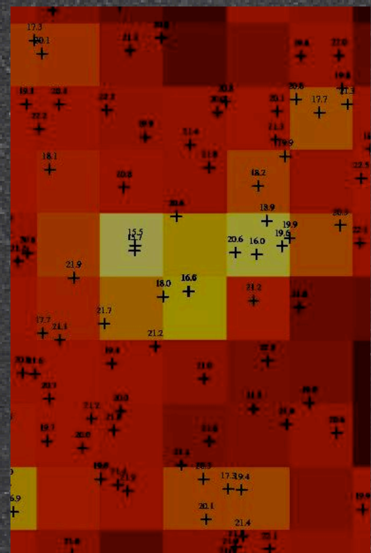
New read-out noise

Development drivers

- Adapt the Astro methodology to RVSMs
  - Specific PSFs & high level of variability
  - red filter, noise, vignetting (pixel distribution)
- Specific requirements
  - background
  - moving objects
  - extensive cross-matching
  - redundancy scheme & instrument modes
  - error tolerance (acquisition, pre-processing, calibration)



ASM / RVSM



Observing strategy

Extraction of spectra

- Localisation of spectra
  - Depending on spectrum geometry and object motion across the RVS
    - straight spectrum and AL displacement only: simple formula
    - crooked spectrum and mixed AL & AC displacements: use a look-up table
- PDHE's VPU considers the output of the RPPU as a virtual CCD (needs to be defined precisely)
- Selection
  - All pixels are read in RVS: possibility to form packets for all detected objects (limited by the processing power in very dense regions)
  - Telemetry-imposed selection: define subsets of consistent data for ground reduction (demixing constraints)

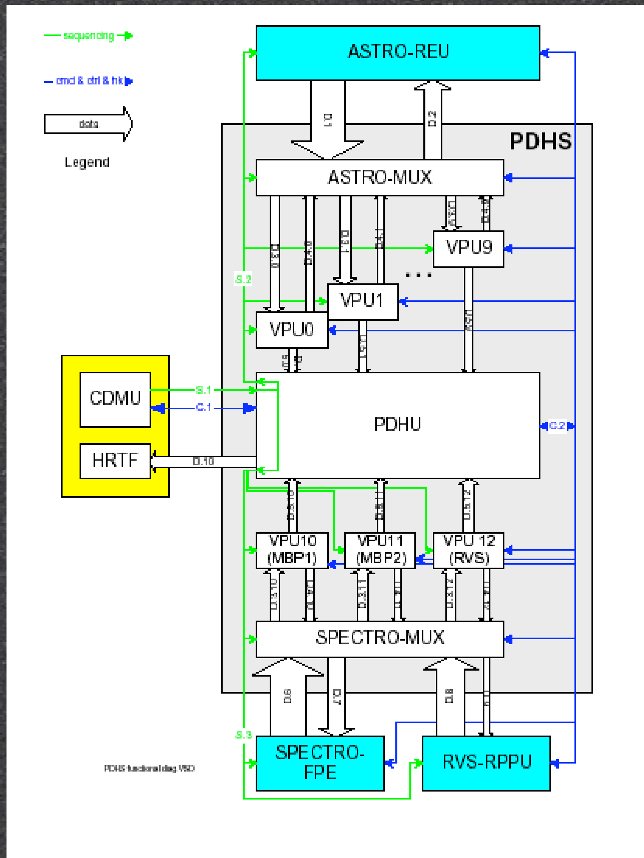
PDHE contract

PDHE contract status

- Phases
  - requirement study and consolidation
  - architectural design of the breadboard.
- Sizing the electronics:
  - handle maximum object density in continuous mode.
  - Pixel-based / object-based task separation for analogical / digital electronic separation:
    - implies very limited complexity on the pixel side and ensuring that the data flows on the object side are considerably reduced.
- Started February, end of phase 1 planned around September
  - Priority to pixel-wise operations (hardware design) / software specification (architecture independent)

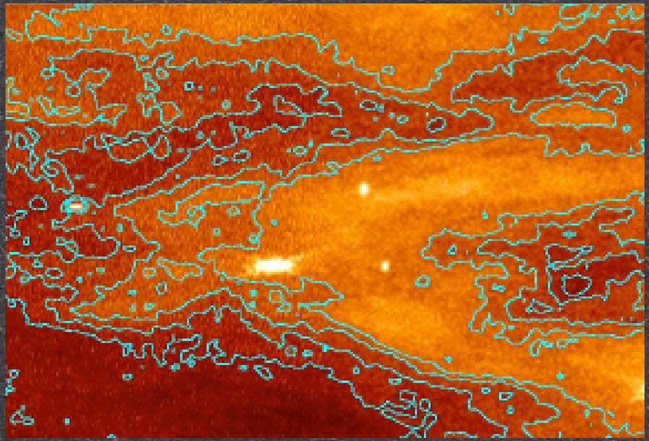
First PDHE progress meeting

- A large work has been done for the on-board electronics
- Algorithm implementation significantly different from what we proposed
  - A sequential algorithm
  - Separating pixel-based and object-based operations
  - Based on a FFT processor



Sky background

- Computing background is needed before validating the detection
- Represents probably most of “pixel” operations
- Flux level
  - Low in astro (1e-/ASM sample)... except in interesting areas
  - High in MBSM/RVSM (>60e-/px)
- Statistical estimate
  - Mean really biased (σ~0.5e-)
  - Median not convergent (& slow)
  - Mode may be preferable (faster)



HST in Orion: ASM (contours at 20,22,24,26e-)

RVSM (contours at 4000,5000,6000,7000 e-)

On-going work (general)

- Baseline (GD & pixel-based operations)
  - Migrating towards the hardware way of thinking for tasks relying on complex logic in software implementation:
    - pre-detection background estimation,
    - connected component search & data strip processing
  - Adaptation of the processing architecture.
  - implementation aspects & possible trade-offs:
- Provide a decision tree for the selection / telemetry
- Evaluation of the alternative approach proposed by the contractor (exploiting pre-existing technology)

Work to be done (RVS)

- Cross-correlation between CCDs' detections
  - important data rates for detection = complexity for cross-correlation
  - on-going study (may-august)
- RVSM performances (current unknowns: PSF + cosmic rays)
- Specific RVS tasks: spectrum localisation & background
- PDHE / RVS consortium interface
  - Definition of the interface between the RVS Pre-Processing Unit and VPUs
  - Specific packets definition (overlapping spectra) for PDHE+GDAAS
- Detailed study of the bright star detection in RVSM
  - Performances of the detection and associated measurements in RVSM
  - Predicting the time and location in Astro 1 and 2
- RVS modes
  - especially in very high density fields: run background computation only?
  - calibration mode

Future developments

- Robustness / full range of possible objects
  - moving objects, asteroids,
  - extended objects,
  - high and varying background,
  - realistic cosmic rays
- Provide a complete and accurate model of object displacement on the focal planes (Astro & Spectro)
  - With the required precision levels: precision on velocities and on their variations, non linear effects etc.
- RVSM Data reduction
  - GDAAS 2 : april 2004