# Observing with Future Instruments: *Comprehensive Simulations*

E-ELT DRM & DRSP Workshop

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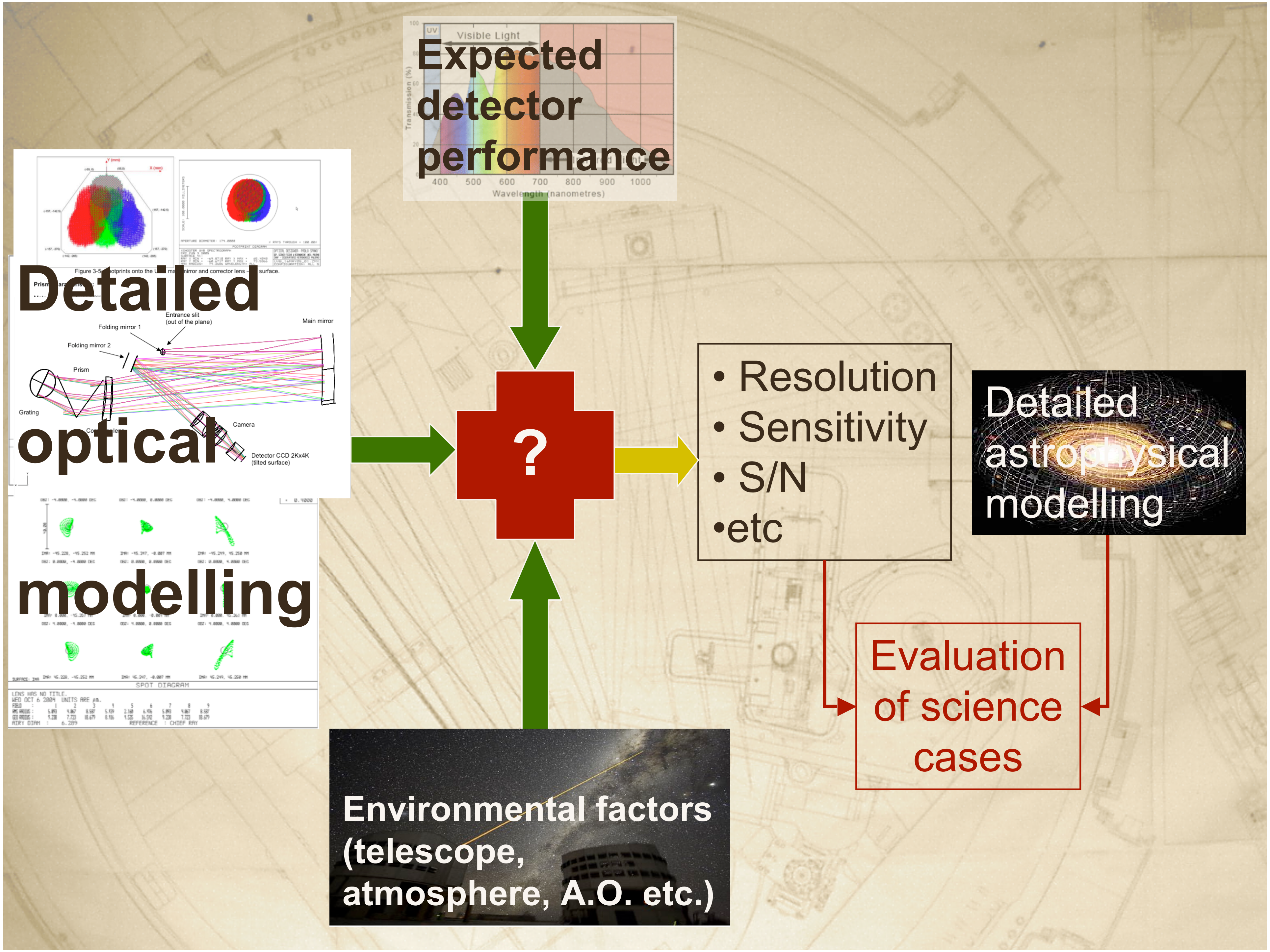
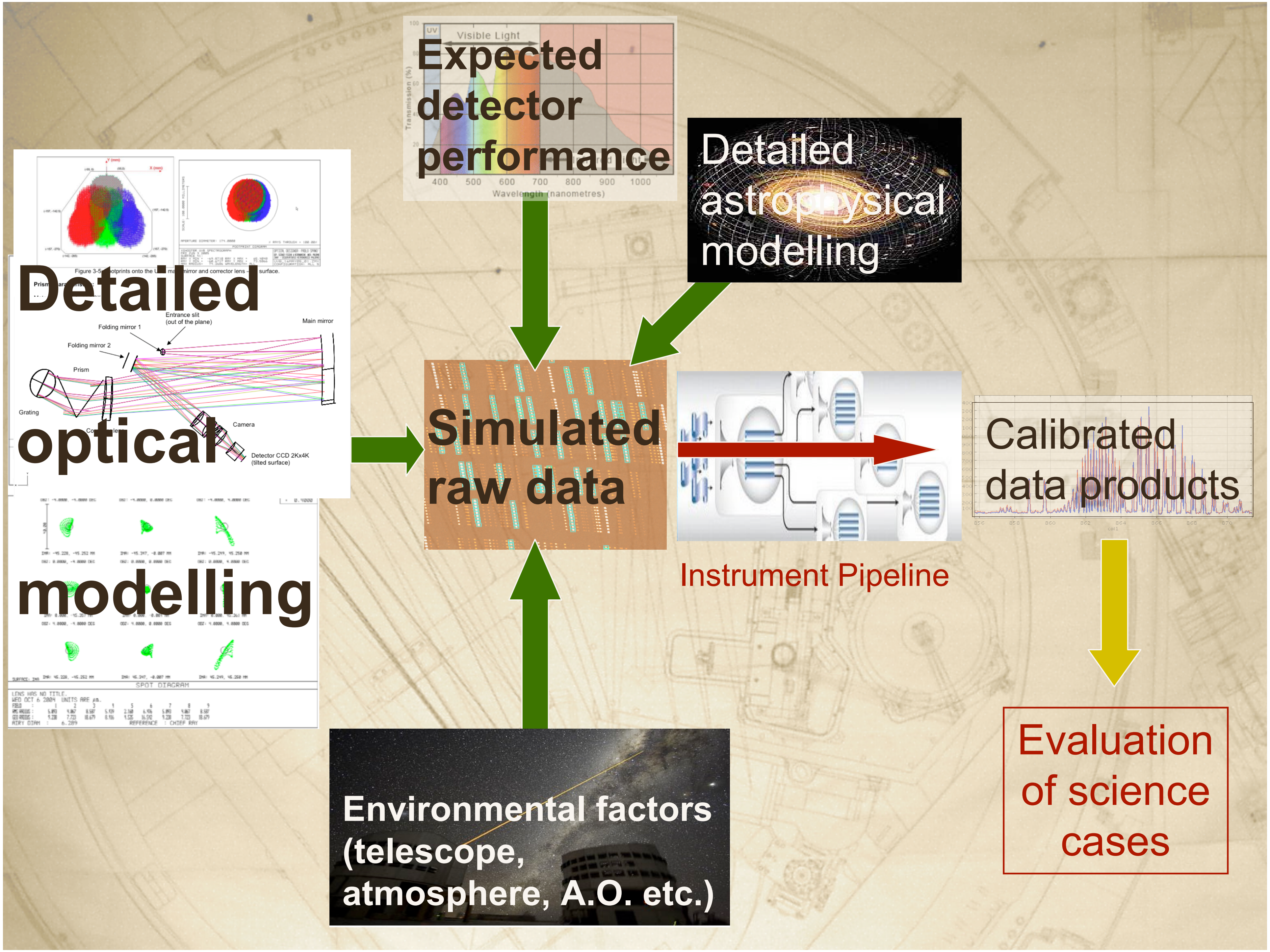
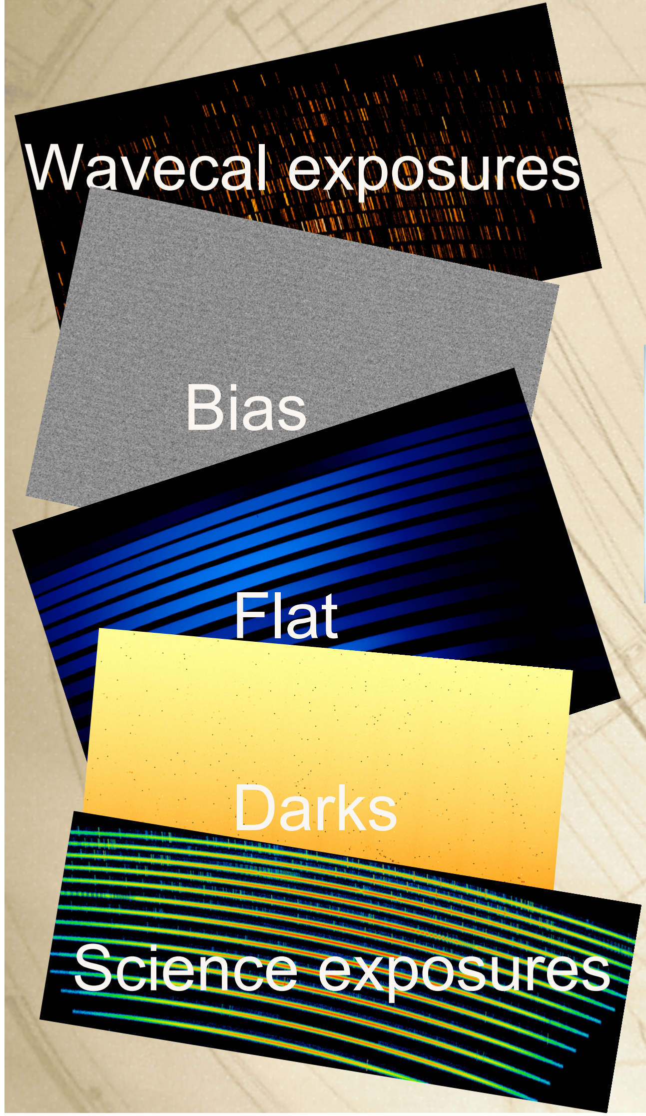
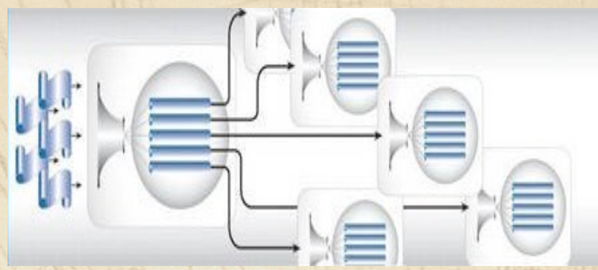

Expected detector performance
Visible Light
UV
Transmission (%)
400 500 600 700 800 900 1000
Wavelength (nanometres)
Detailed optical modelling
Entrance slit (out of the plane)
Folding mirror 1
Folding mirror 2
Main mirror
Prism
Grating
Camera
Detector CCD 2Kx4K (tilted surface)
SPOT DIAGRAM
?
• Resolution
• Sensitivity
• S/N
•etc
Detailed astrophysical modelling
Evaluation of science cases
Environmental factors (telescope, atmosphere, A.O. etc.)

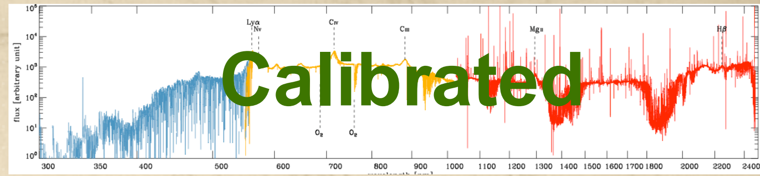

Expected detector performance
Detailed astrophysical modelling
Detailed optical modelling
Simulated raw data
Calibrated data products
Instrument Pipeline
Environmental factors (telescope, atmosphere, A.O. etc.)
Evaluation of science cases

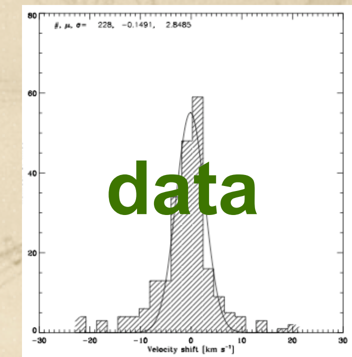
# Comprehensive Simulation



Instrument Pipeline



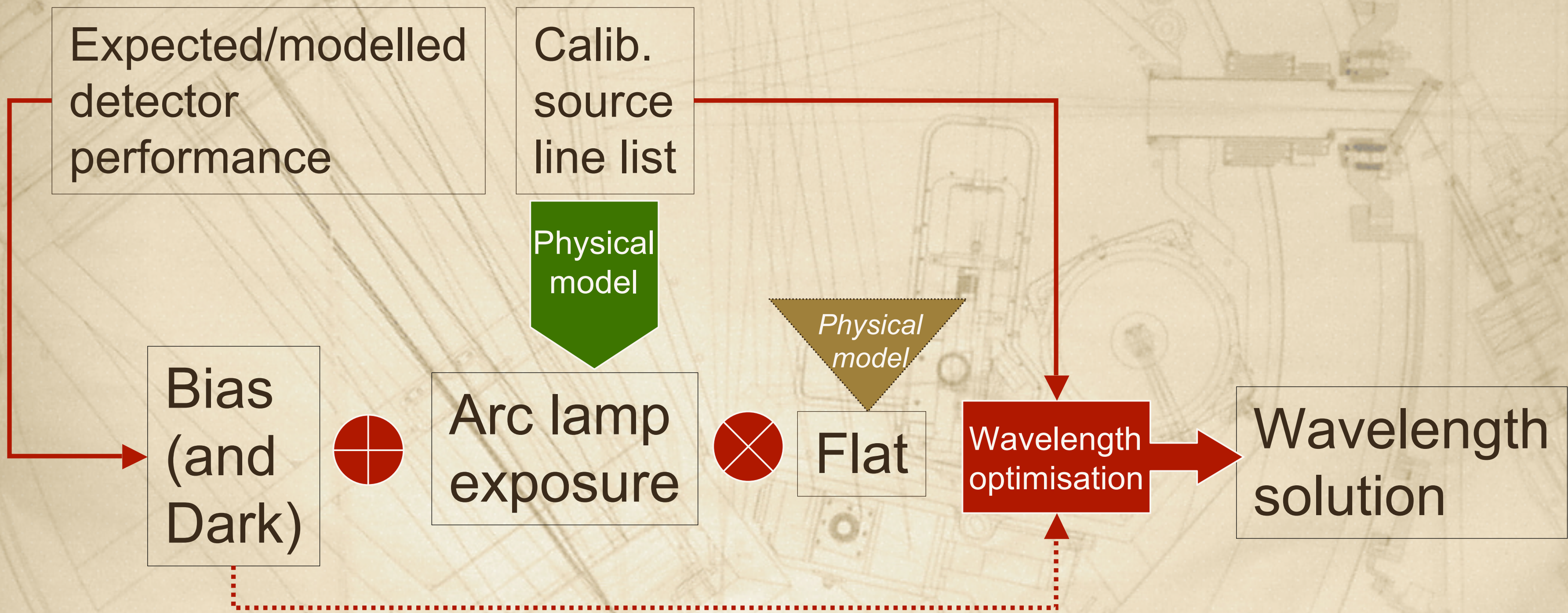

# Our "Physical Model"

- Originally developed by Rosa and Ballester
- Our approach is a simplified ray trace that maps: $p_s, \lambda \mapsto x, y$
  - Based on key physical parameters of the instrument
  - Parameters can be optimised to match actual performance of an operational instrument
  - Supports wavelength calibration in the DRS
  - Enables instrument monitoring
  - Potentially useful for observation planning
- Already implemented for (HST)STIS, CRIRES & X-shooter

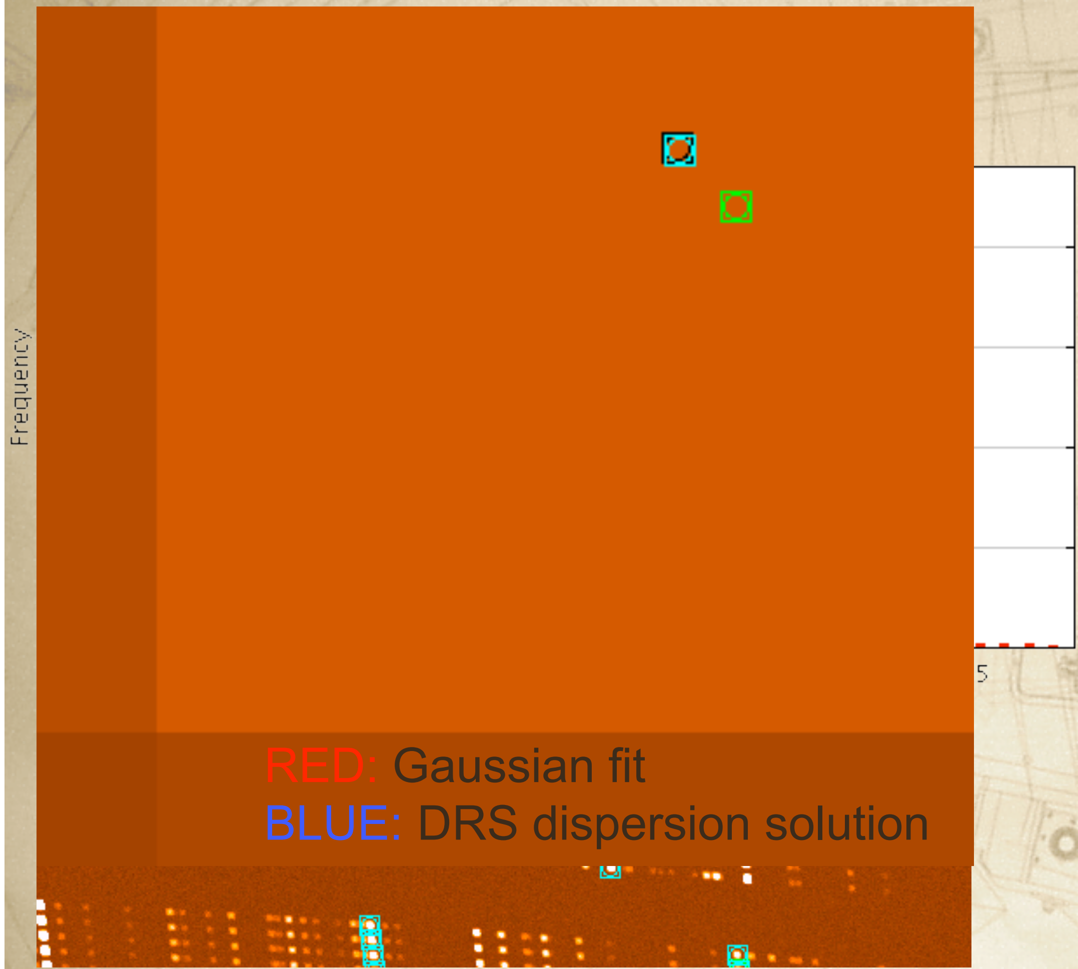
# Physical Model

- Key optical components are represented by:
  - Relative position
  - Relative orientation
  - Dispersive properties (refractive indices, grating constants etc.)
  - Detector properties
- Initially physical parameters taken from detailed optical design (CodeV, Zemax)

# Flowchart of simulations: Calibration data example - dispersion solution



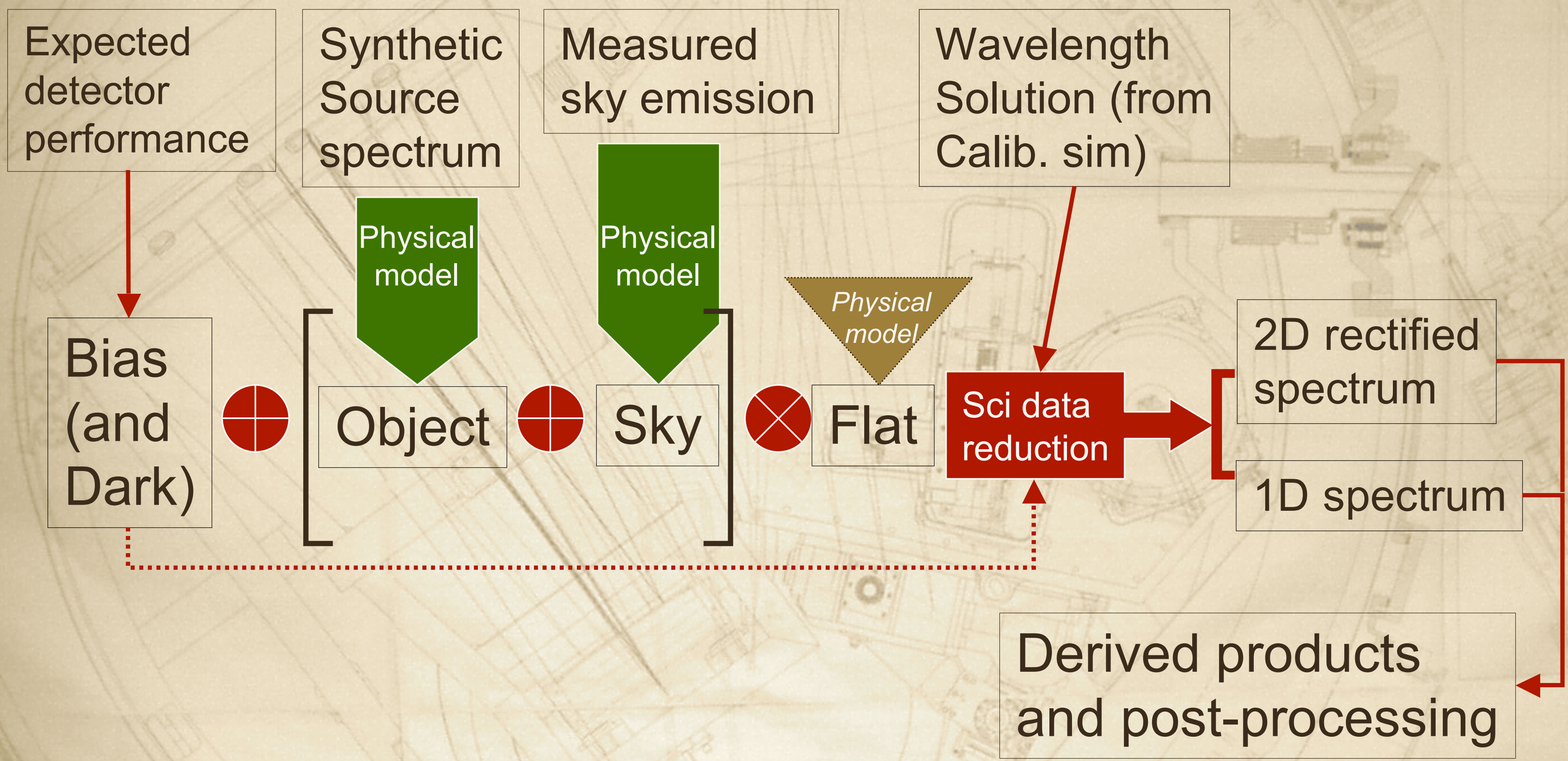
# Simulated Wavecal




X-shooter VIS 9 pinhole mask Th-Ar HCL exposure

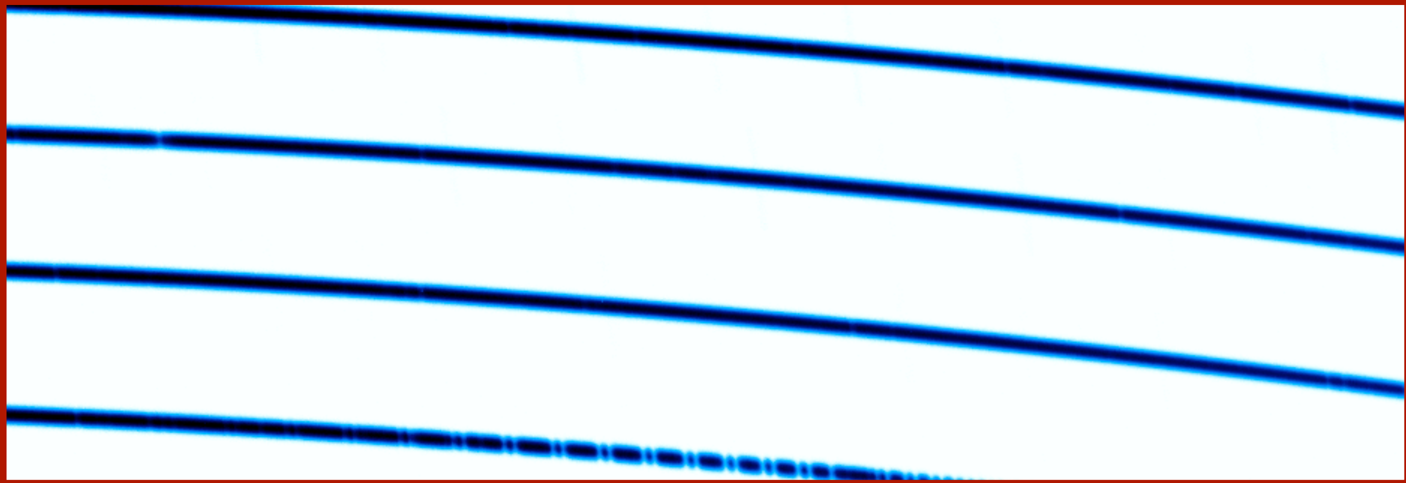
- Simulated data processed by pipeline
- Optimised wavelength solution
  - Compare to *known* solution
  - Choice of source (laser comb?)
  - Density of features
  - Exposure time

# Flowchart of simulations: Science exposure example



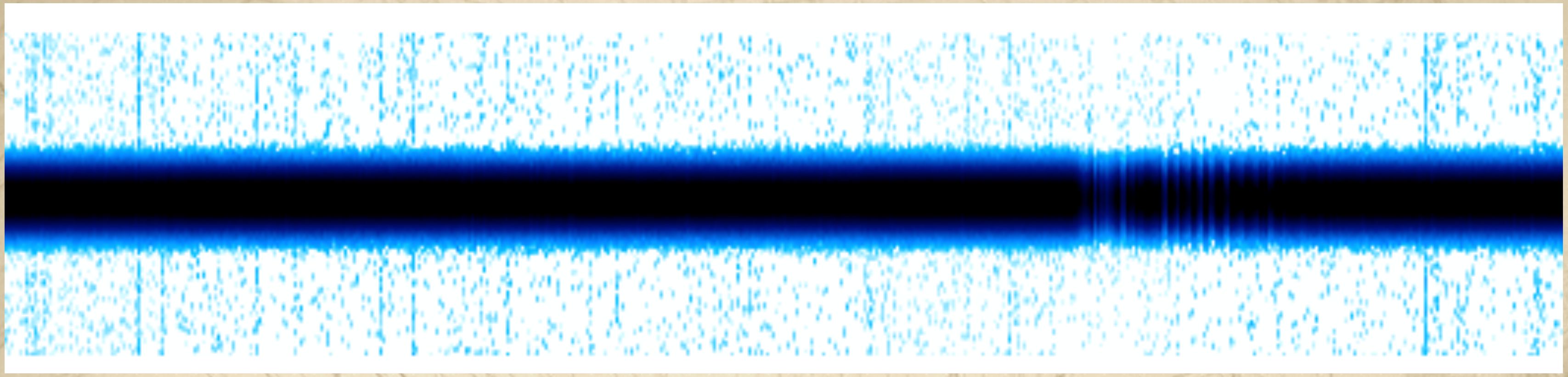
# Simulated science exposure

FITS Header



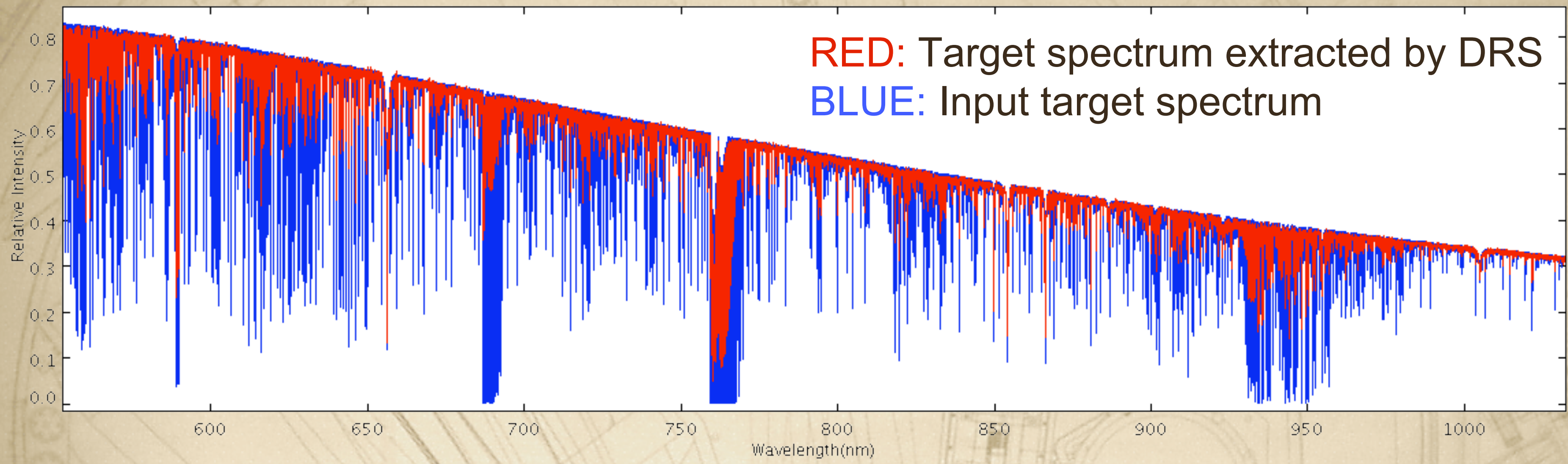
- Simulated sky
- Add object at given position on slit
- (Add specific "*critical*" features)
- Add headers with calibration switches

# Reduced data



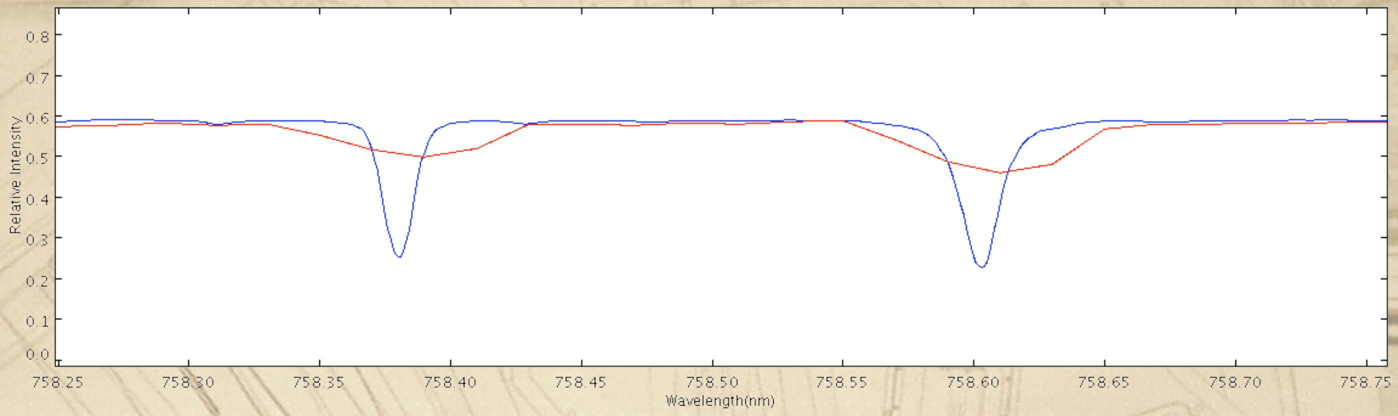
2D rectified spectrum

# Reduced data



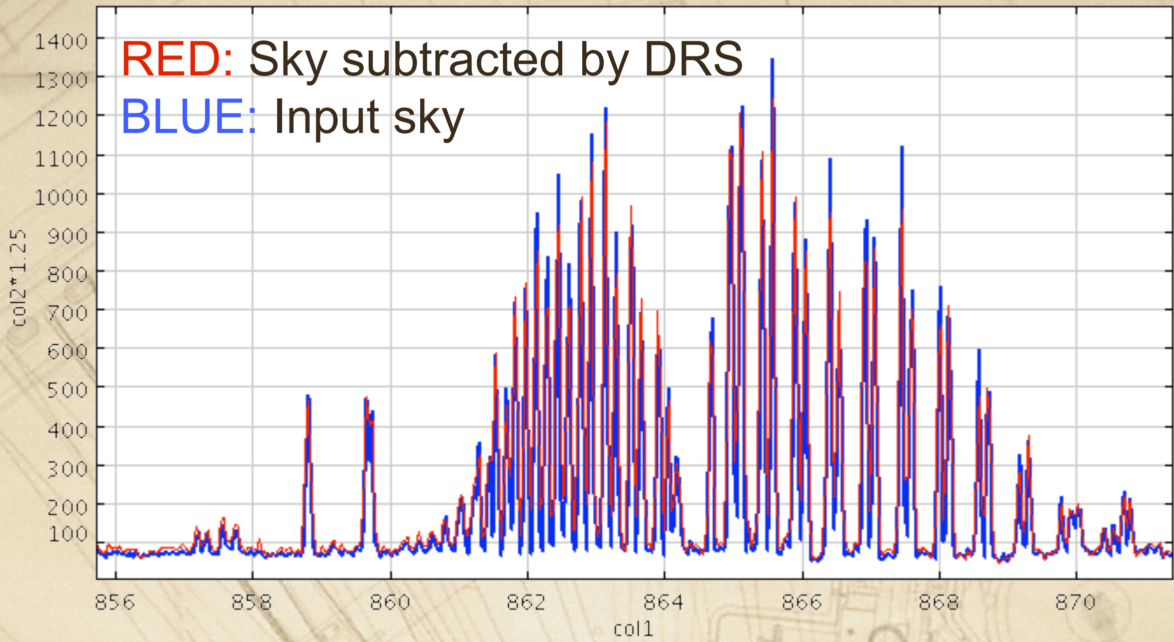

Extracted 1D spectrum of the target

# Specific features




- Investigate line strengths and widths and wavelength accuracy as a function of:
  - *Spectrograph design*
  - Integration time
  - Detector modes (binning, sampling)
  - Data reduction techniques (eg. Sky subtraction strategy, optimal extraction etc.)

# Reduced data




Full set of pipeline output products is available, including for example sky background spectra.

# Availability of DRS

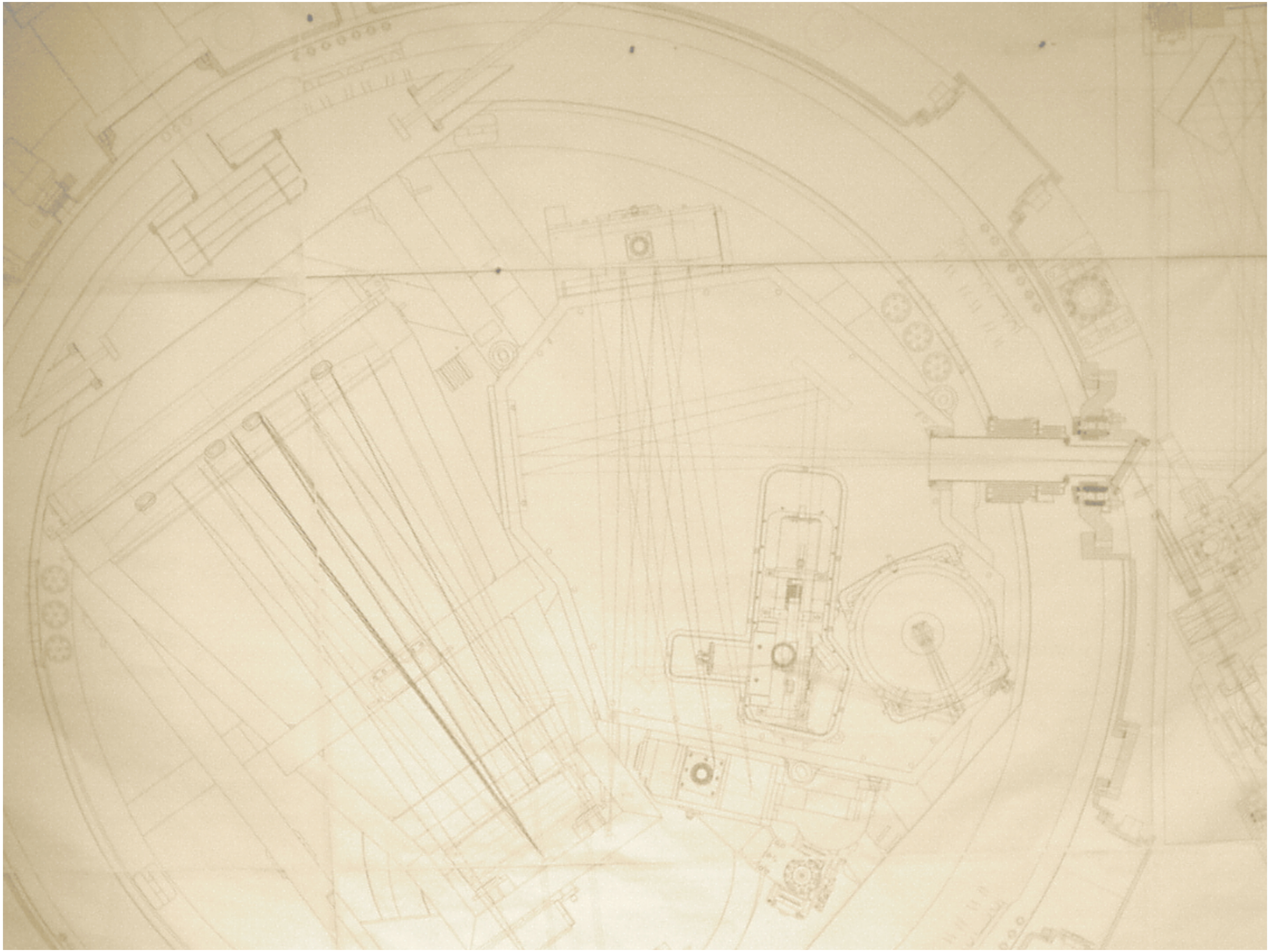
- Typically/traditionally the DRS only becomes available around the time the instrument reaches the telescope (or sometimes later!)
- Evolution from generic spectrograph pipeline to customised high fidelity final version
- Physical model provides simulated data to enable early DRS development *(cf X-shooter)*

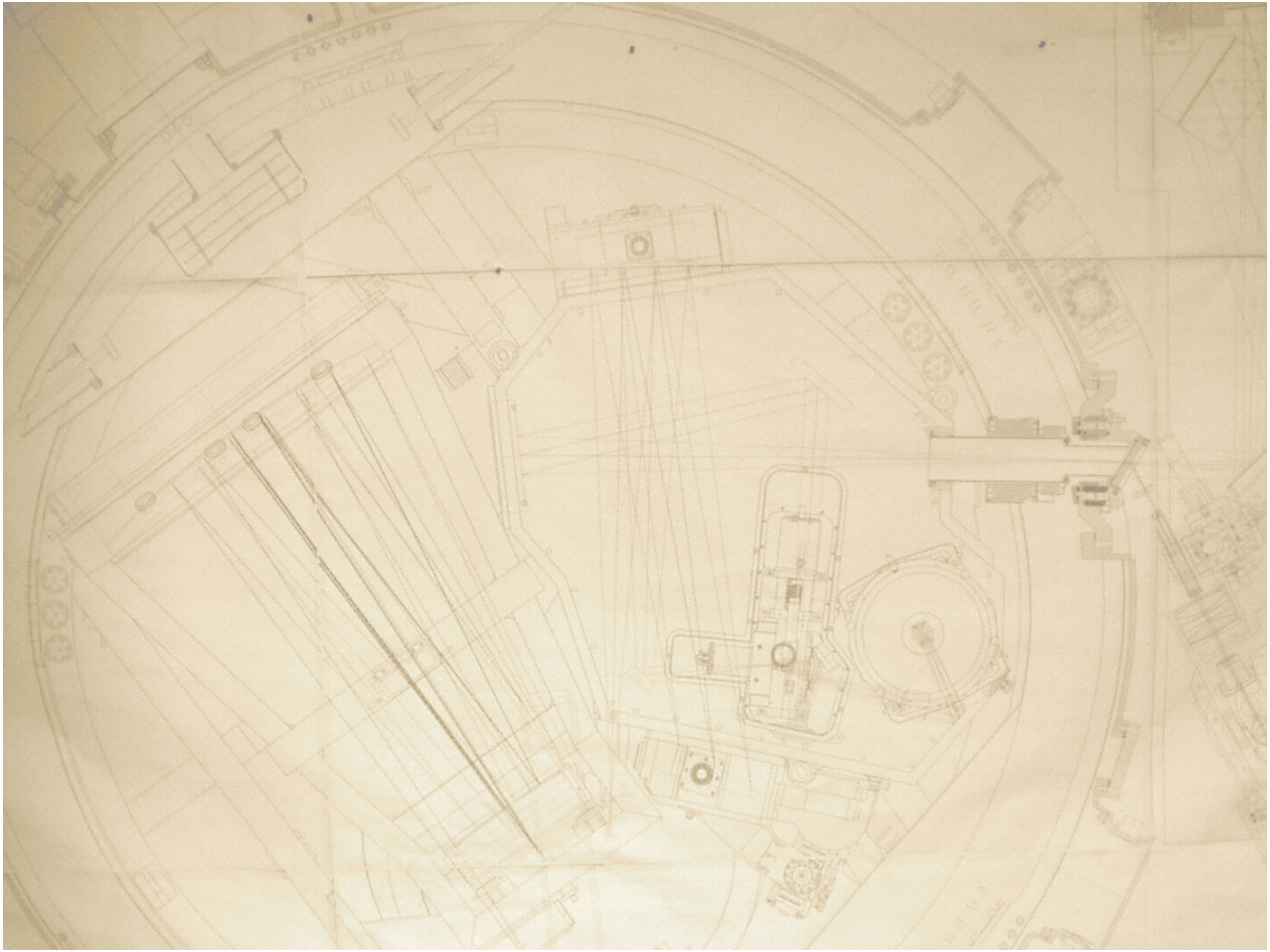
# Applicability throughout the project

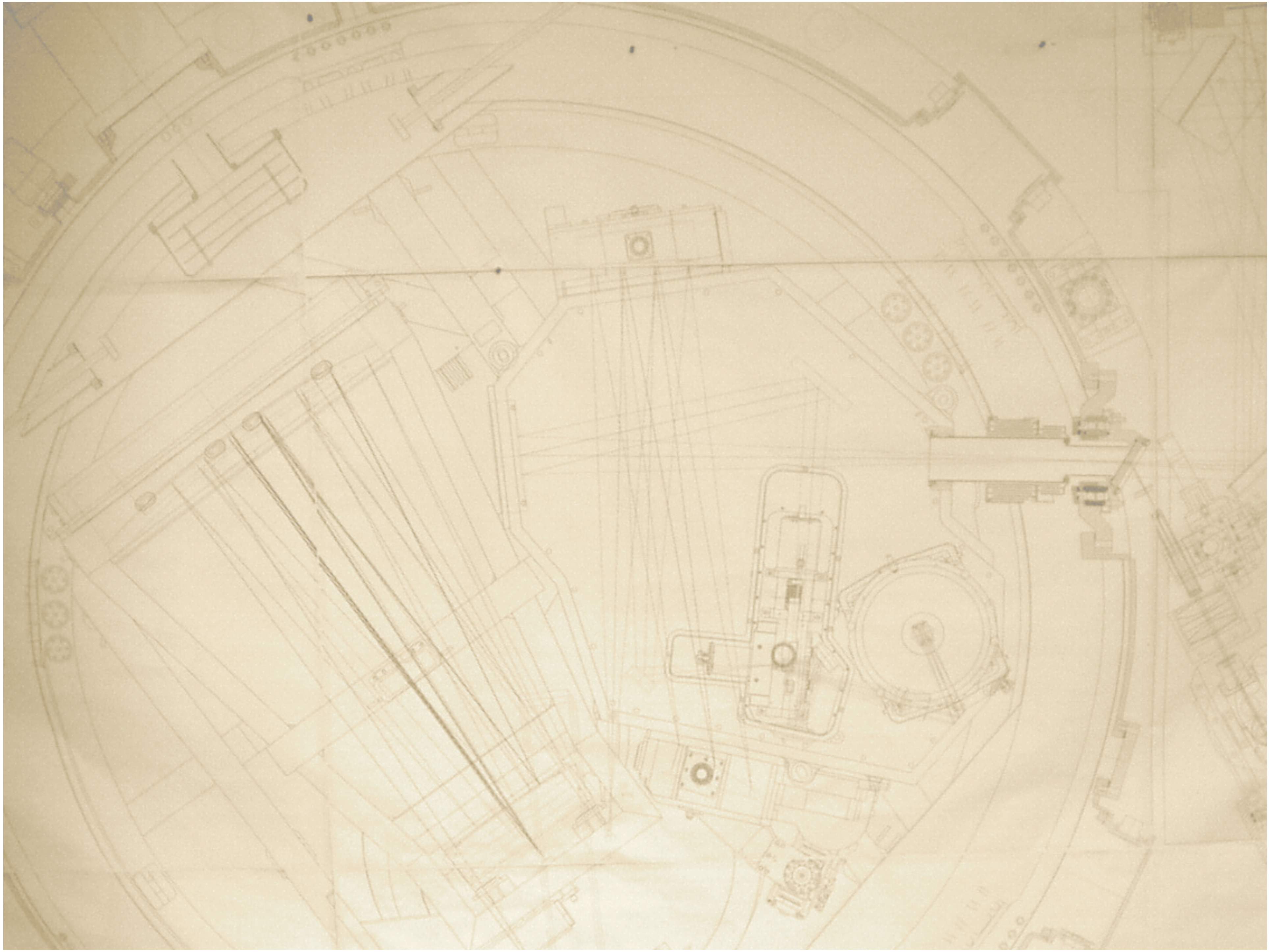
- Design and development:
  - Systems Engineering: Engineering trade-offs linked to data products in a robust way
  - Observation planning: Facilitates virtual realisation of a detailed observing scenario for a proposed instrument
- Data reduction software: Same physical model can drive the DRS wavelength calibration *(we already do this)*
- Operations: Observation planning

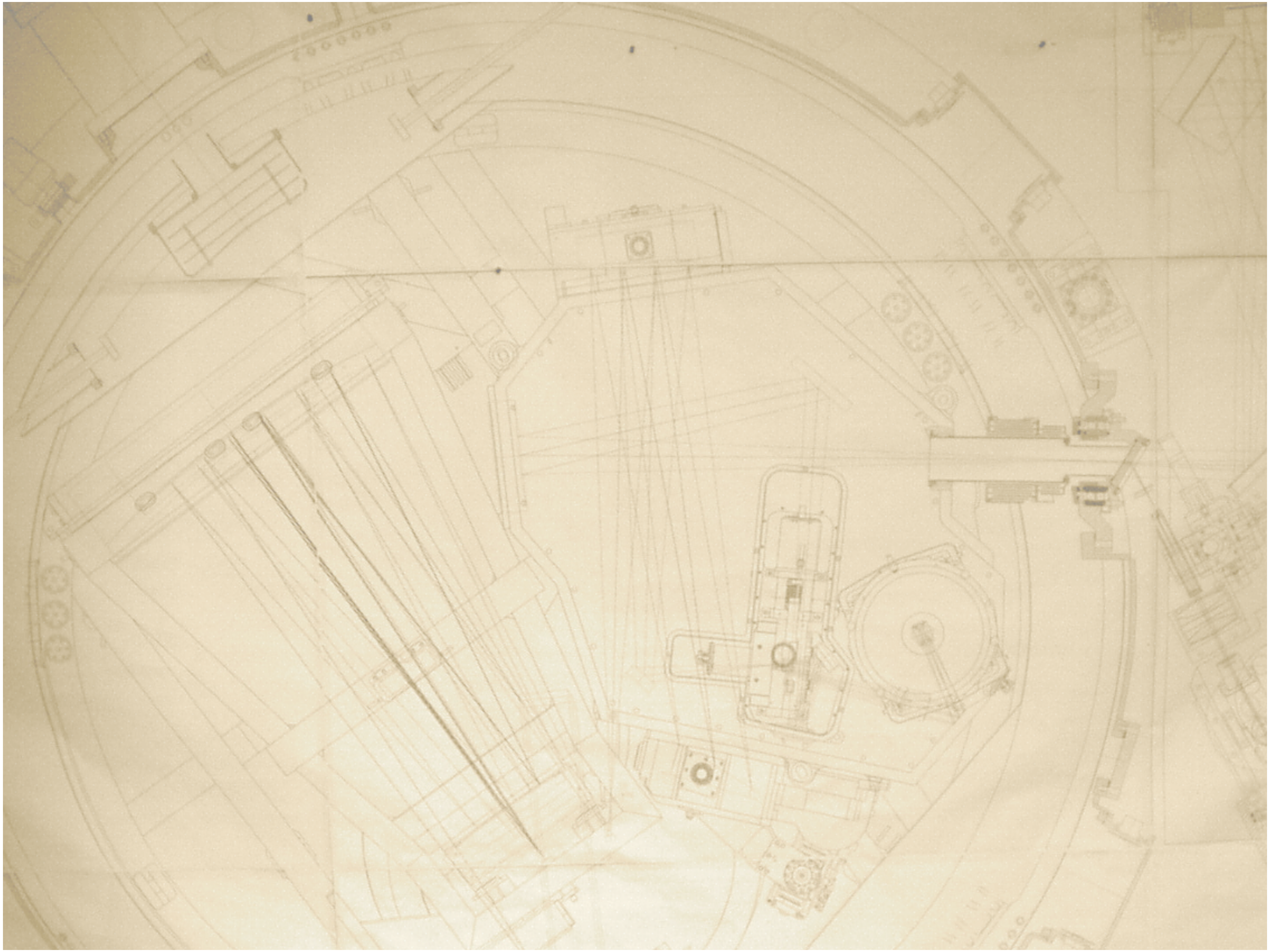
# Conclusions

- Comprehensive simulations of raw exposures
- Processing with instrument DRS pipeline to produce fully calibrated data.
- Science goals evaluated in calibrated data products
- Enables systems engineering analysis of engineering and science trade offs.
- Fully utilises existing high quality modelling
- Re-usable in calibration and observation planning.

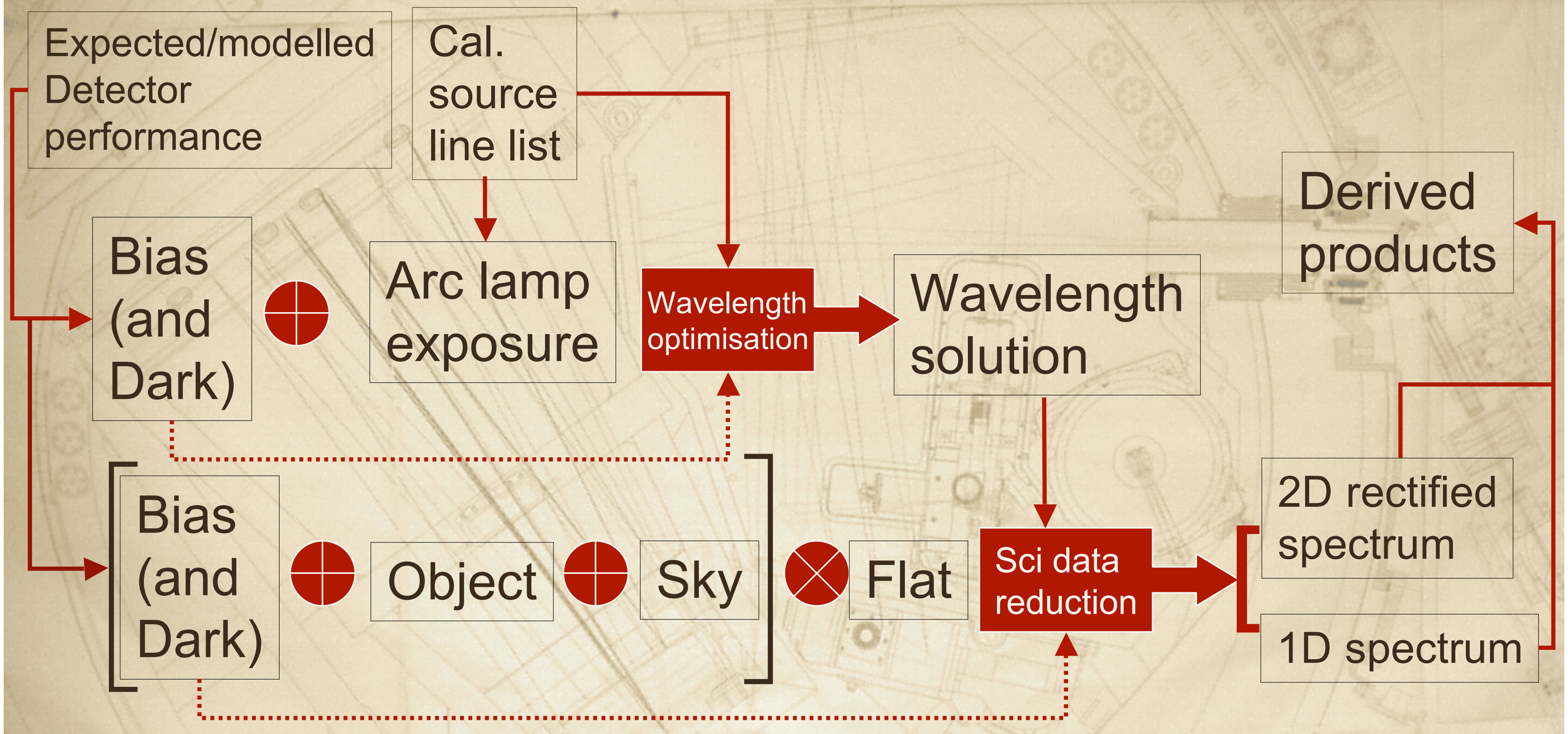








# Flowchart of simulations



# From design to scientific performance

- Detailed Optical Model of spectrograph (CodeV/Zemax)

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- ✦Detailed Optical Model of spectrograph (CodeV/Zemax)
- ✦Accurate PSF, beam footprints, resolution and many more diagnostics

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- ✦ Detailed Optical Model of spectrograph (CodeV/Zemax)
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- ✦ *Combined* with detailed detector Characterisation and high quality environmental data and models

=> Science goals

# Filling in the Gaps

- ✦Physical Model to simulate exposure
- ✦Simulated data processed with early Data Reduction Software
- ✦Full DRS products available for evaluation of science goals

# Other considerations

- ✦Removes any "guesstimation"
- ✦Includes DRS implications
- ✦Modifications are easily incorporated
- ✦Same model and infrastructure can be used later for:
  - ✦Calibration (*we already do this*)
  - ✦Observation planning