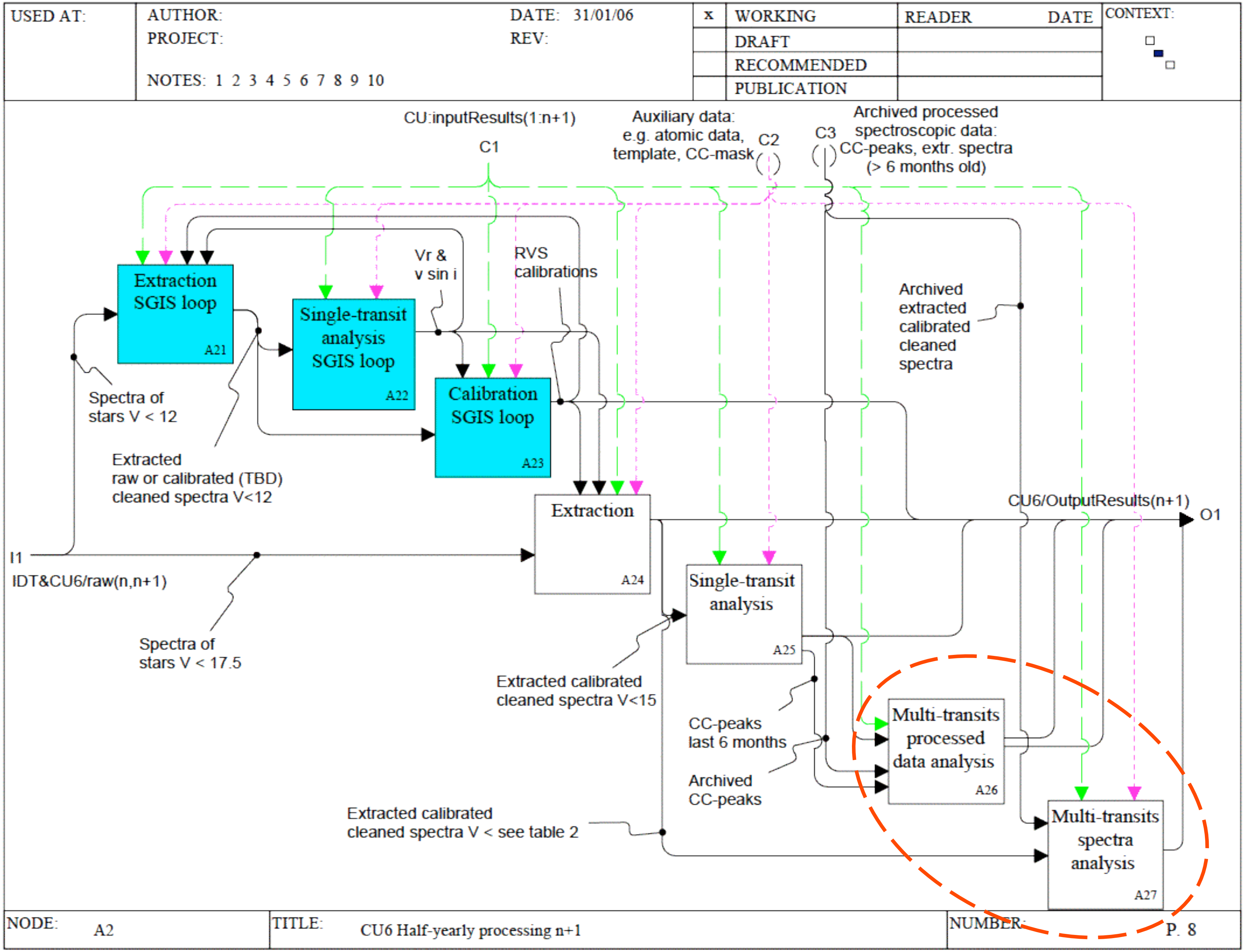
Multi-Transit Analysis

CU6 Workshop, IAP, 6/7 March 2006

Multi-Transit Analysis: overview

- The multi-transit analysis is the analysis on the combined data from more than 1 transit.
- The dataset on which it operates will increase with mission duration.
- The analysis will operate on 6-monthly timescales (TBC) on the total dataset to that point.
- The output of the last multi-transit analysis will be the final parameters determined from the spectroscopic data.
- The multi-transit analysis runs at the end of the half-yearly processing chain and consists of 2 parts:
  - radial velocity cross-correlation domain [processed] data
  - wavelength domain [spectral] data

Half-yearly processing



Workpackages

- The top level WBS is given in GAIA-C6-SP-OPM-DK-002-1

GWP-S-670-00000 Multiple transits analysis: processed data
GWP-C-670-01000 Management, configuration management & interfaces
GWP-D-670-02000 Detailed functional analysis of multiple transits data
GWP-S-670-03000 Overview of existing techniques for radial & rot. velocities
GWP-S-670-04000 Radial velocities from multi-transit data [skew analysis]
GWP-S-670-05000 Assess sources spectroscopic stability/variability

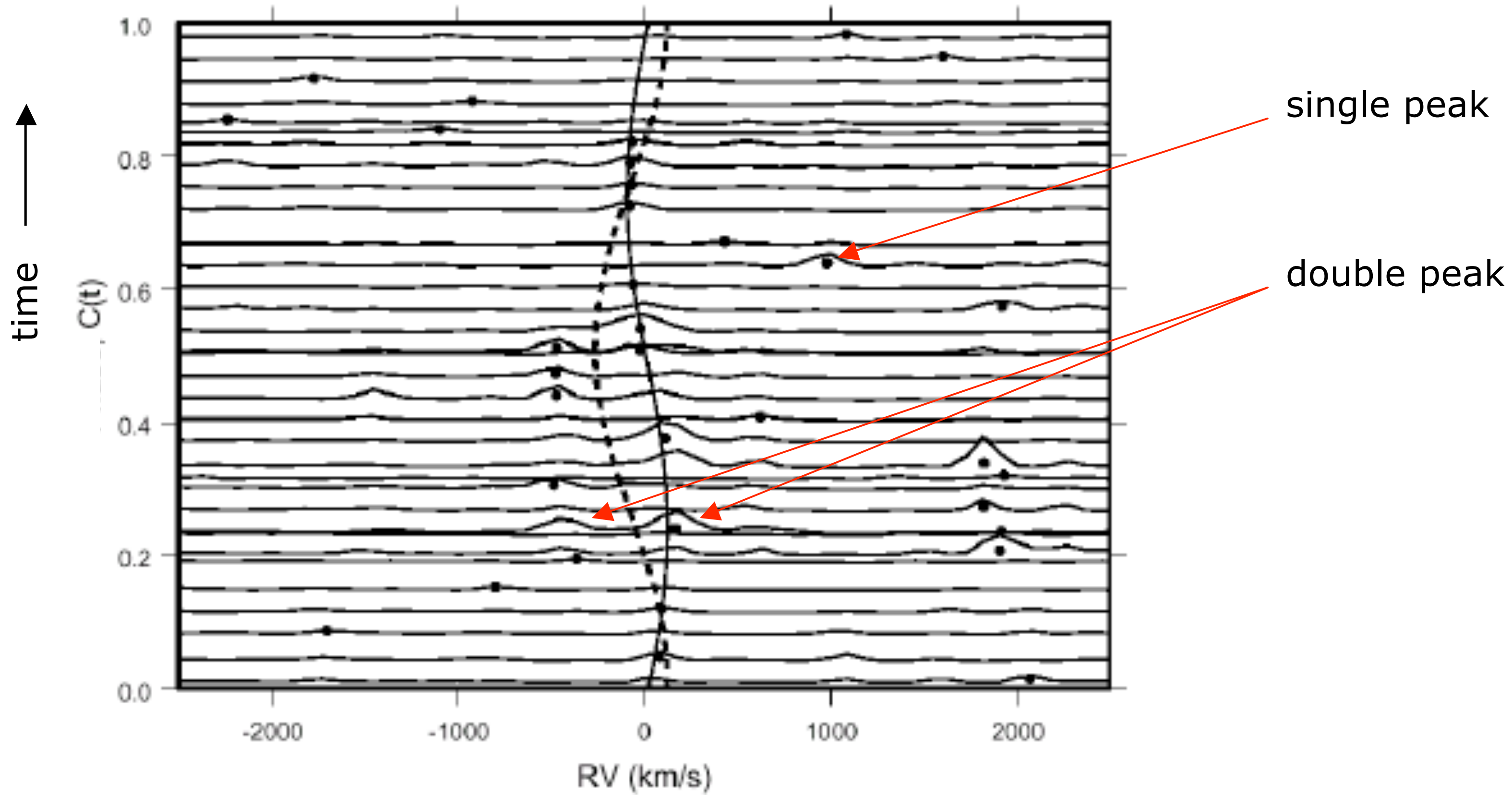
GWP-S-680-00000 Multiple transits analysis: spectra
GWP-C-680-01000 Management, configuration management & interfaces
GWP-D-680-02000 Detailed functional analysis of the combined-transits
GWP-S-680-03000 Optimal combination of spectra
GWP-S-680-04000 Mean radial and rotational velocities

WP-670: Processed Data

- This workpackage uses the results of the single transit analysis directly – *i.e.* the cross-correlations.
- Somehow, a "mean" cross-correlation should be derived from the individual cross-correlation, in order to achieve the mission-averaged radial velocity.
- Individual cross-correlations will be very noisy for stars with V>15, with multiple peaks.
- The analysis must also provide uncertainties and some measure of the robustness (if these are not directly coupled)
- The analysis must be able to deal naturally with variability/binarity *i.e.* without a decision having to be made before the start of the processing
- A technique has been developed to do this - Skew Mapping

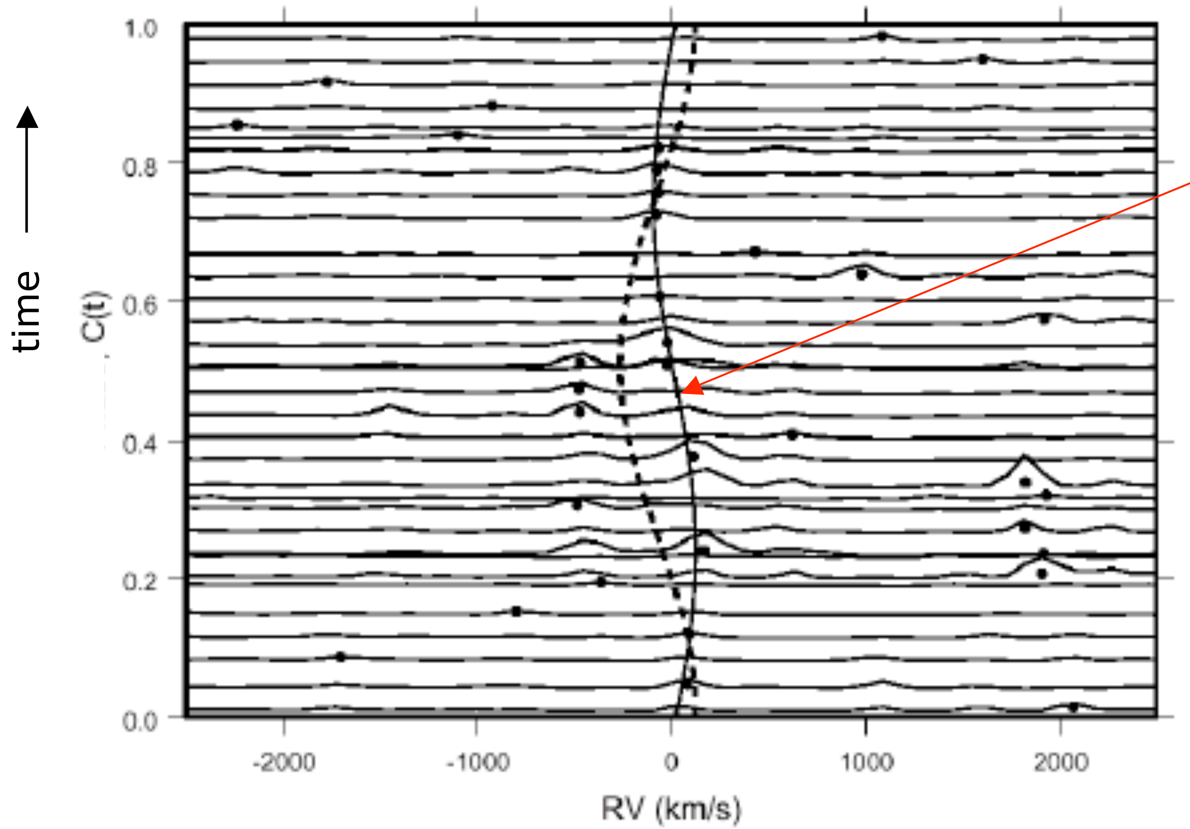
One technique: Skew Mapping

- Start by stacking up radial velocity cross-correlations for each epoch (• shows individual radial velocity):



Skew Mapping (ctd)

- Form line integrals along different paths computed according to some model
  (eg radial velocities of a binary, given a set of input parameters)

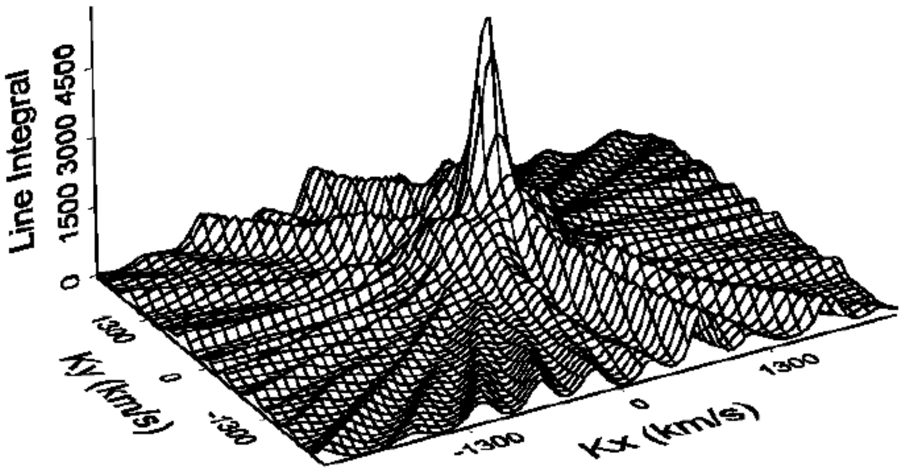


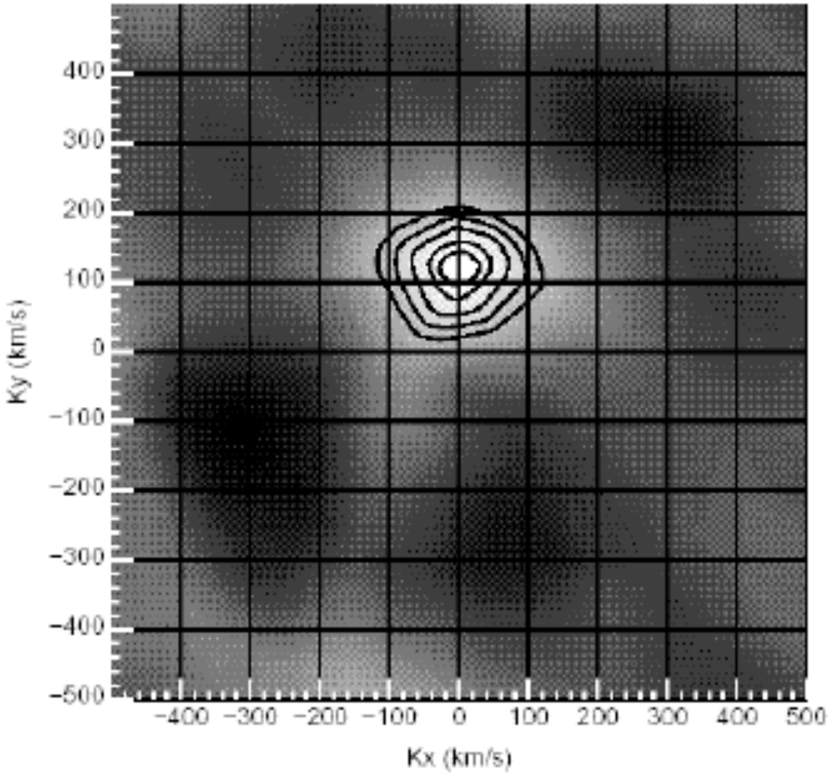
form line integral along this path

i.e. add up the amplitude of the cross-correlation along this path

Skew Mapping (ctd)

- Plot the line integral as a function of parameters describing the path





Skew Mapping (ctd)

- For single-lined spectroscopic binary path is defined by

$$RV = \gamma + K \sin\left(\frac{2\pi t}{P} + \phi_0\right)$$

$\Rightarrow$ Need to fit 4 parameters:

- systemic RV (γ)
- amplitude (K)
- zero phase epoch (ϕ_0)
- period (P)

$\Rightarrow$ 4-dimensional parameter space (resource limitations?)

- For single stars $K \sim \sigma(\gamma)$ so can be treated as for double stars

Skew Mapping (ctd)

- Advantages:
  - For single stars $K \sim \sigma(\gamma)$ so single/double stars can be treated uniformly
  - Extremely robust to outliers
  - Does not require a-priori selection of correct cross-correlation peak
  - naturally self-extending as new data become available

- Development issues (some)
  - derivation of errors on RV from skew map
  - extension to double-line binaries/multiple systems
  - limiting magnitude/total flux for application

- See van der Putte *et al* (2003), MNRAS, 342, 151.

Processed Data (ctd)

- In the end, the individual spectra are shifted in velocity according to the best parameters and then summed to generate the mean spectrum
- There will be different techniques used in the single-transit cross-correlations, probably requiring the skew mapping to be run for each one.

- Skew mapping is one technique that can be used; perhaps there are others $\Rightarrow$ some exploration of appropriate techniques is required

WP-680 Spectral Data

- This workpackage uses the reduced spectra from the single-transit analysis.
- Again, a mean spectrum needs to be generated, together with the associated radial velocities.
- Again, the analysis must also provide uncertainties and some measure of the robustness (if these are not directly coupled)
- The analysis must be able to deal naturally with variability/binarity *i.e.* without a decision having to be made before the start of the processing
- The options need further analysis: the best way forward may be to adopt a variant of the skew mapping, but working with the actual spectra.

Spectral Domain

- In this case the individual spectra are shifted in velocity according to some model (eg a binary star), as in the skew mapping.
- The spectra are then summed $\Rightarrow$ one summed spectrum for each combination of parameters in the model, eg
  - mean velocity
  - amplitude
  - period
  - phase *etc.*
- A cross-correlation is performed for each summed spectrum
- The strength of the cross-correlation is plotted for each summed spectrum (*i.e.* each combination of parameters) – *c.f.* skew map
- The final spectrum is generated from the velocity shifts produced by the set of parameters corresponding to the peak of the cross-correlation plot.
- This set of parameters also are output, together with an estimate of their uncertainties.
- Again if $K \sim \sigma(\gamma)$ then the star can be considered single.

Development

- First year will be dedicated to exploration of the different alternatives and methodologies (scientific algorithms)
- Code prototyping and development will occur after that
- Java will be used to keep in alignment with CU6 standards
- eXtreme Programming methods are being considered (*cf* CU1 AGIS):
  - ⇒ rapid development cycles
  - ⇒ tight control on what is really needed
  - ⇒ concurrent requirements development
- Total effort assigned (PPARC bid):
  - 0.5 FTE in Oct 2006/Oct 2007
  - 5.5 FTE in Oct 2007/Mar 2012 [4.5 yr = 1.2 FTE/yr]
- Staff effort made up of
  - 0.5 Senior Researcher and
  - 0.7 Senior Developer/Developer