Development of Techniques for Data Interpretation

(CoRoT + Gaia heritage)

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for the Leuven MOST, CoRoT & Gaia Teams

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Kepler and variable stars

- Kepler will discover many new pulsators (many in close binaries...)
- Kepler has dedicated list of targets for asteroseismology (to be composed)

BOTH DESERVE TO BE ANALYSED PROPERLY ... situation just as seismic and exoplanet targets of CoRoT: the majority of pulsators are in the exofields!

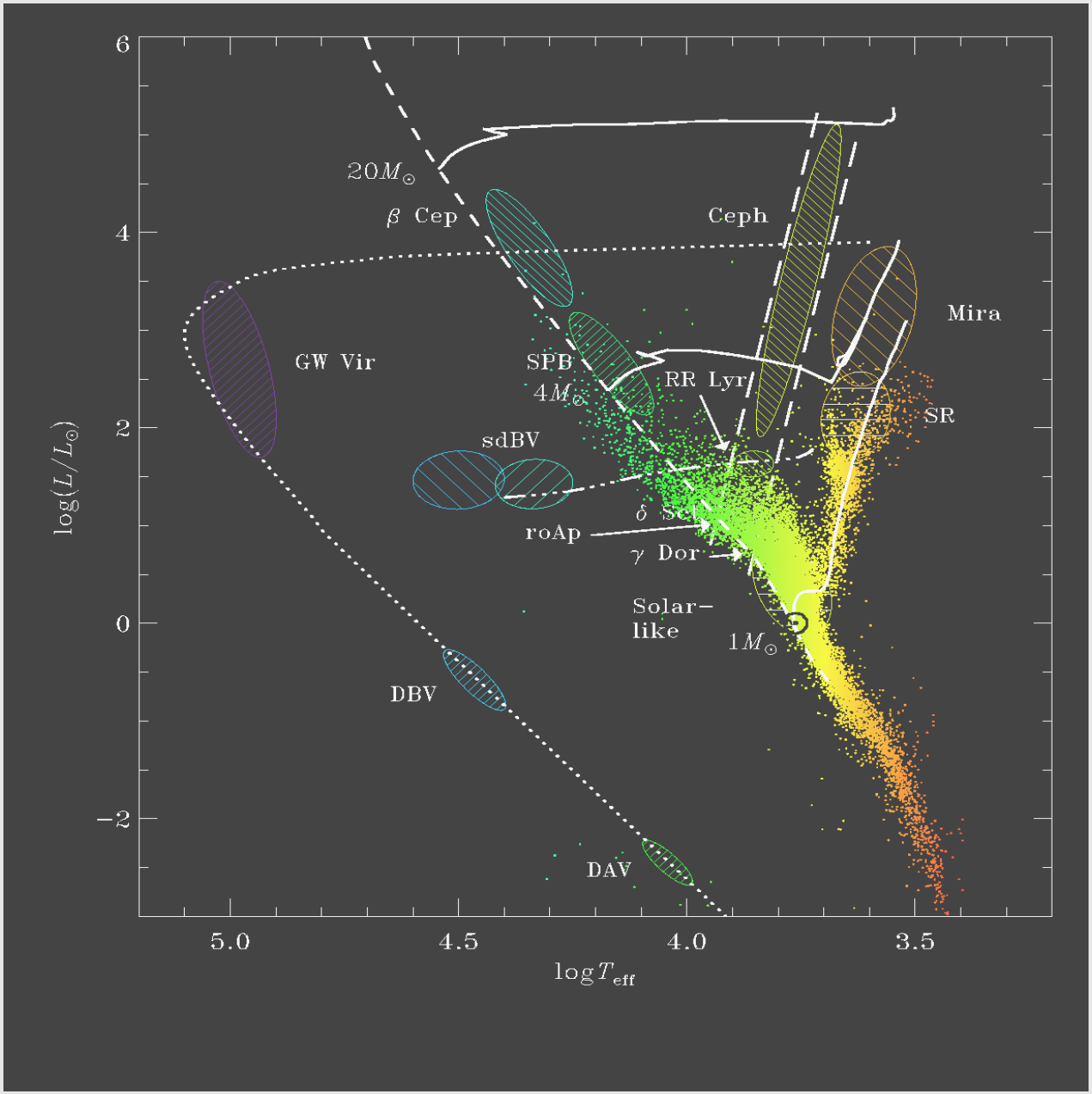
The majority of pulsating stars to be studied with Kepler will NOT be those selected by the KASC....

This talk thus focuses on all pulsators in the Kepler FOV

Different levels of data interpretaton

- Variability characterization for all Kepler stars:
  - Automated frequency search + prewhitening
  - Automated variability parameter estimation
- Automated supervised variability classification:
  - Based on known properties of definition stars
  - Gaussian Mixture model and hierarchical Neural Network (Debosscher et al. 2007)
- Detailed frequency analysis/class of preselected + newly discovered pulsators
- Detailed stellar modeling/class targets

Kepler: discovery of many new pulsators



Goal: assign all periodic Kepler variables to known classes of pulsators

Use automated routines, based on multivariate statistics

Can be done after 2 weeks of in-orbit data...

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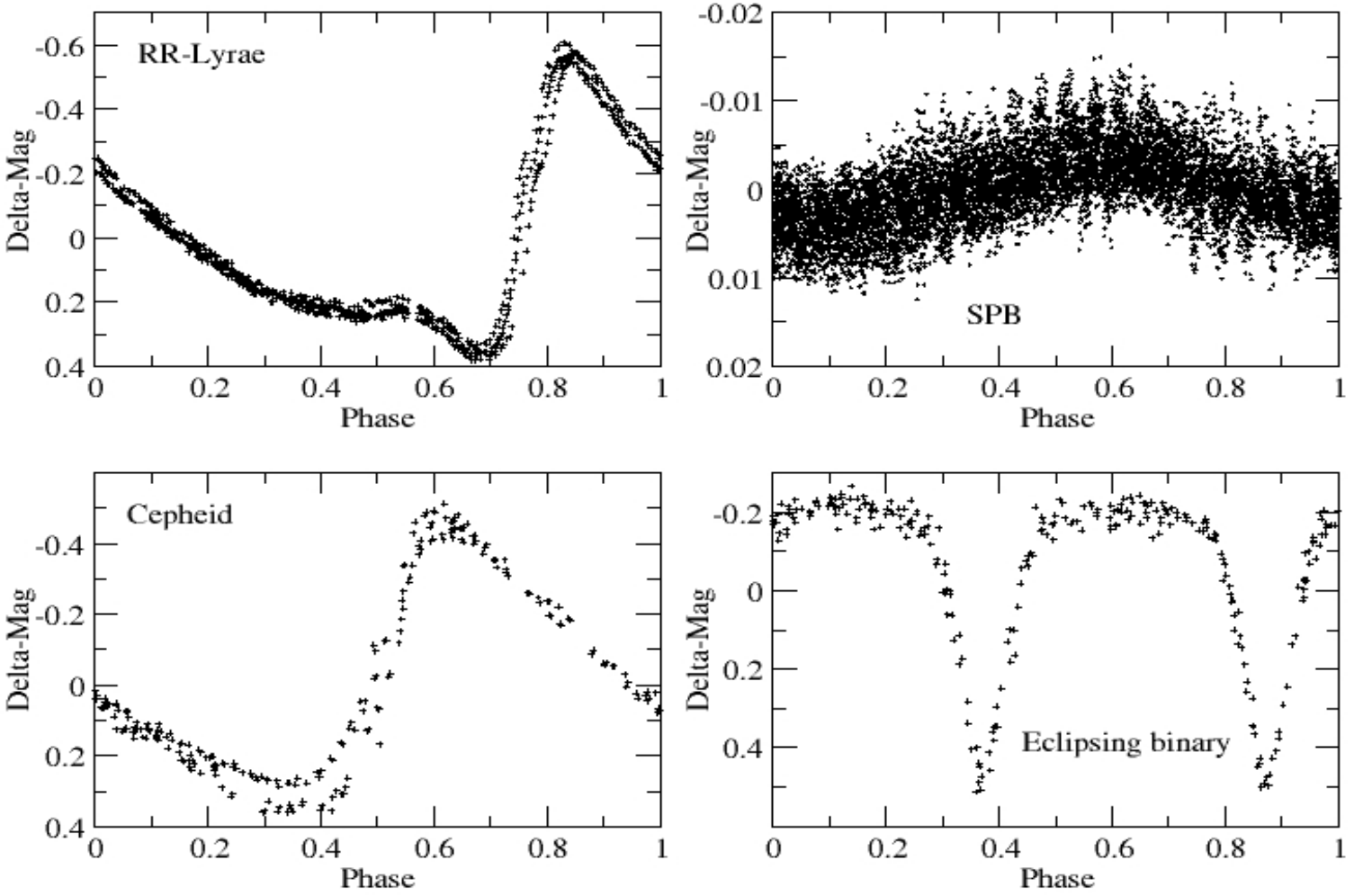
Kepler: discovery of many new variables



Goal: Automated classification of these variables in the Kepler fields

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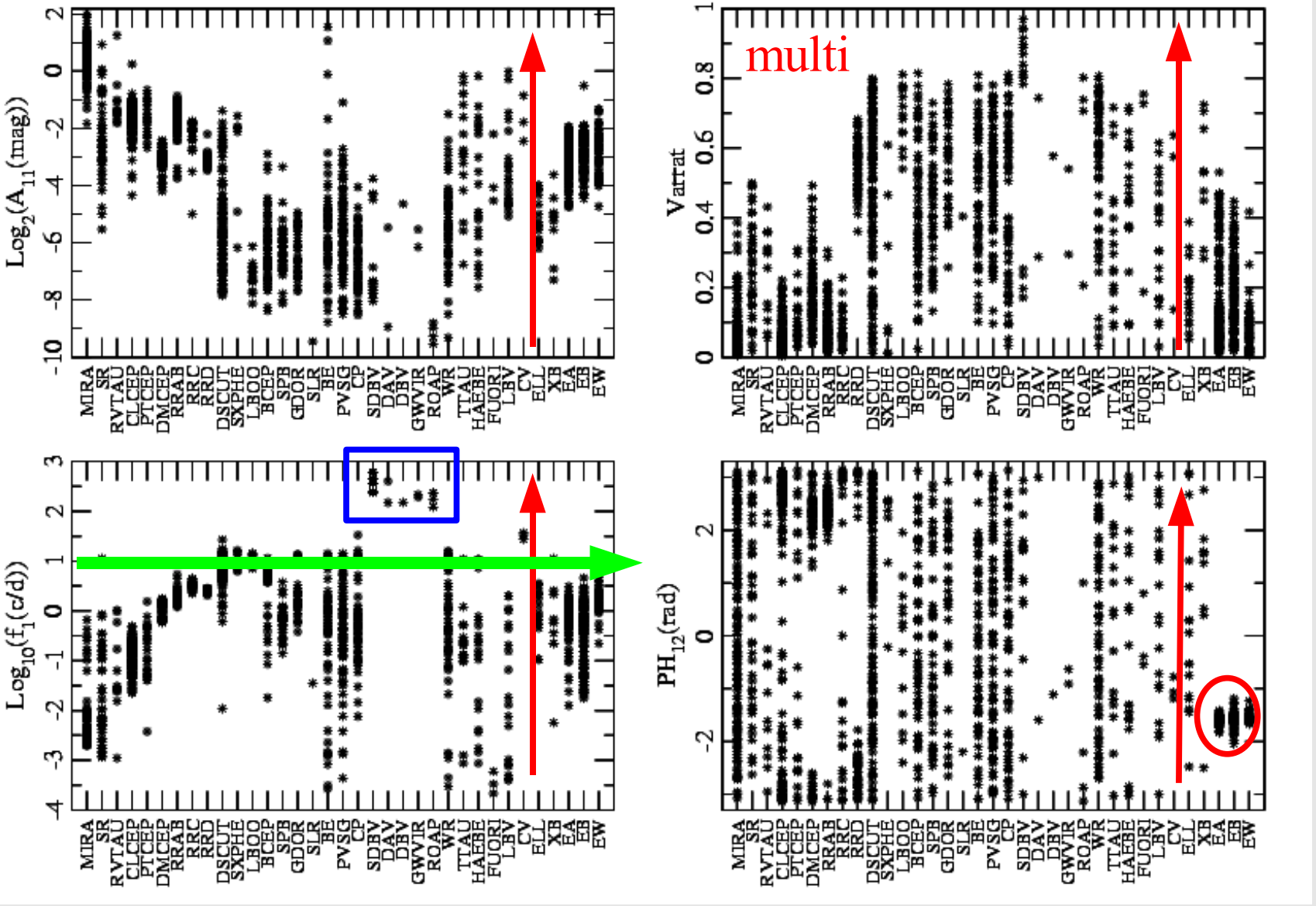
Automated frequency search

- Gaia framework: tested performance of some 10 different methods (Cuypers, De Cat et al.)
  - based on Fourier methods: sinusoidal comp.
  - based on ANOVA (PDM-like methods): non-sinusoidal variations
- All have similar performance:
  - take one of each group at maximum
  - preference: ultrafast implementation of Lomb-Scargle periodogram (instead of FFT)
- Perform automated (weighted) (N)LLS fit with starting values from LS search (covar. Matrix !)
  => ATTRIBUTES

CoRoT heritage (J. Debosscher)



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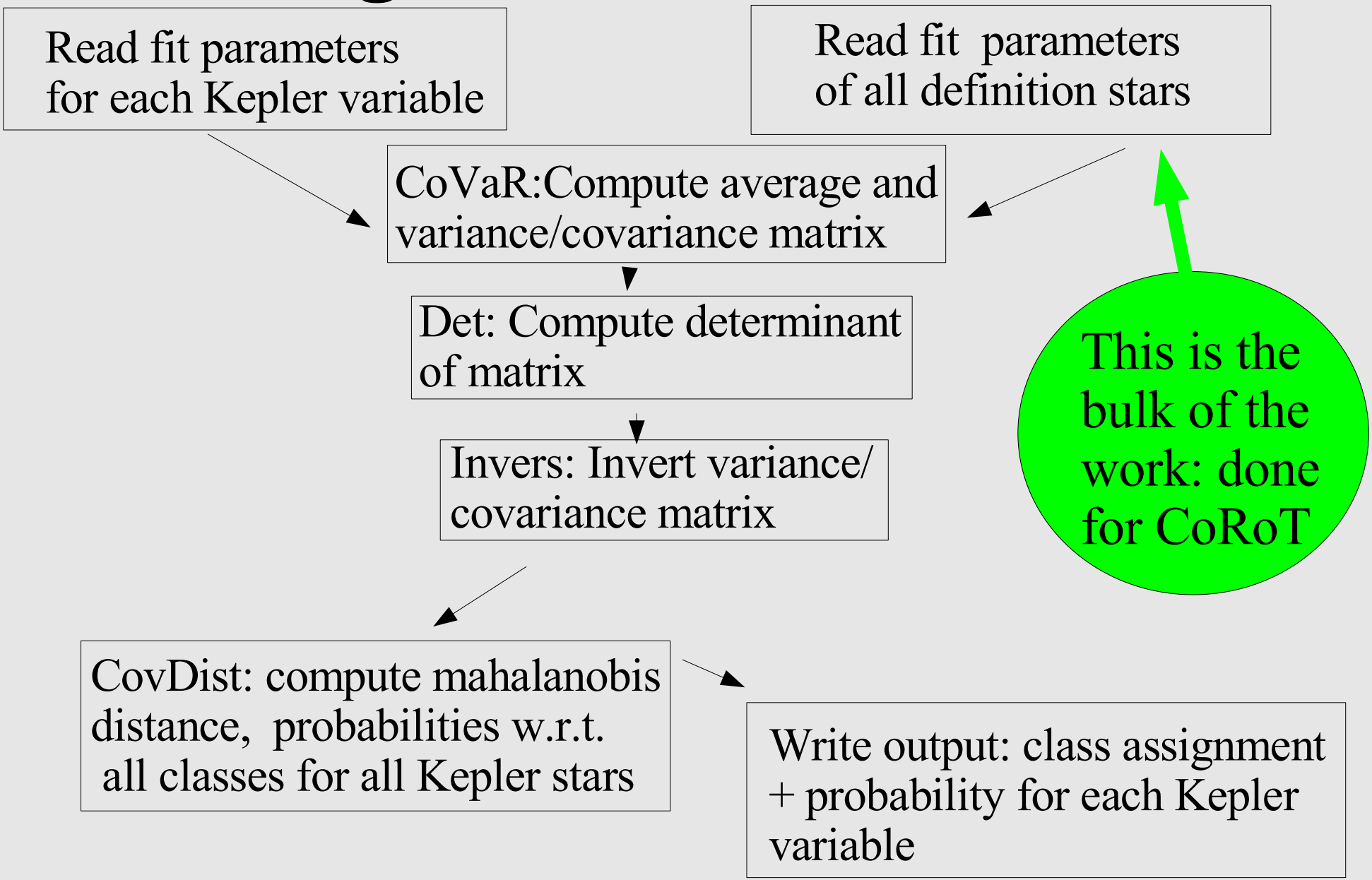
Automated classification of OGLE stars

- 260 000 OGLE stars were subjected to our software (few days on dedicated Linux cluster):
  - LS periodogram to derive 3 dominant freqs
  - Harmonic fits: parameters used as attributes
- Classification: takes 20 seconds !!
  - success rate > 95% compared with extractor-type manual classification
  - resulted in 100s new non-radial pulsators with periods > few hours
    (Debosscher et al. 2007 & Sarro et al. 2008)

Context diagram for Gaussian Mixture



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Automated classification of Kepler stars

- **Debosscher et al. (2007), Sarro et al. (2008):**
  we suggest the Kepler team to use this software because the high-pass filter will destroy the classification and seismic modeling capabilities...
- **We suggest to start with target list for asteroseismology and to adapt it from in-orbit data of ~ 2 weeks**
- **Classification of the pulsating stars will imply an immense step forward in the asteroseismic data interpretation of the newly discovered pulsators...**

Detailed frequency analysis of pulsators

- Same as automated frequency search, but with specific emphasis on: (Gerald's pitfalls)
  - Detrending, signals due to rotation, activity,...
  - Phase averaging for fast pulsators
  - Significance level to end the prewhitening
  - Frequency error estimation
- Solar-like oscillation frequency detection requires specific treatment; more difficult to automate (KASOC document)
- Compute differences & other simple relations between frequencies (g-modes: Miglio et al.)

Detailed modeling of frequencies

- Use pattern recognition techniques in databases of stellar models (≠ input physics, see ESTA talk) and their predicted oscillation frequencies
- **IMPORTANT: do not restrict to 'the' best model, but consider log-likelihood methods to select all acceptable models, including frequency error propagation and mode identification uncertainty**
- Check if modes can be identified; if yes:
  - **Fit large and small frequency separation,... and confront with pattern recognition results to eliminate more acceptable models**

Conclusions

- Get maximum out of Kepler database in terms of variability and stellar pulsation
  REQUIRES CLASSIFICATION OF VARIABLES
- Make sure to have optimal list of pulsators for high sampling rate (incl. exoplanet host stars)
  REQUIRES CLASSIFICATION OF VARIABLES
- Cover entire HR diagram + pulsating binaries:
  - See lists in KASOC document
  - Add subdwarf OB stars !
  - Add supergiants !
  - Add pulsators in binaries (WIRE !)