Exoplanet search

... with CoRoT
The exoplanet « channel »

Secondary targets $m_v < 9$

Primary target $m_v \leq 6$

Exo Field $11 < m_v < 16$

Field: $3.05^\circ \times 2.8^\circ$ - 1 pixel = 2.32"

Data
- Analyzed: ~45,000 LCs
- Processed: ~33,000 LCs
- Observed: ~12,000 stars

~ 6000 targets/CCD
A two speed data analysis

Early analysis of the data (« alarm » mode)
- On nearly raw data (N1 level)
- During the run of the observation
- Using automated procedures

Detailed analysis (regular mode)
- On completely reduced data (N2)
- At ~mid run and at the end of run
- Performed by 8 different teams
On board change in the rate of the observations

- **Goal:**
  - A better coverage of the transit profile (TTVs, etc..)
  - To reduce the noise level
  - To trigger Follow up operations as soon as possible

- **Capacity:**
  - Sampling rate: 1/512s → 1/32s
  - Possible only for 1000 windows

- **Management of the target lists:**
  - Initial list: the best targets, ..known to host planets
  - Update: after early detection in quickly reduced data
**The regular mode**

Use fully processed data (up to 8 teams on the bridge)

- **Pre-processing**
  - Removal of outliers
  - Identifying hot pixels
  - Filtering star variability
    (median or NL filters, etc ..)
  - Studying systematics

- **Detection**
  - Standard methods: Bayesian, Box fitting LS
  - Others: based on correlation, wavelets, ...

→ Folded light curves

![Graphs showing frequency and phase](image)

(after Mazeh et al.)

![Correlation map](image)

(After Borde et al)
Example of detected signals

Many binaries →
**Possible blends**

- **Eclipsing binary**
  Secondary transit diluted in the noise

- **Background impostors**
  - B. Eclipsing Binaries
  - Eclipse (star or planet) diluted by a third star
  - Neighbourhood ....

→ Follow up confirmation mandatory
The wheat and the chaff (2)

Low mass stellar binary
DF/F = 1.6% ; D = 6.8h ; P = 15 days

Confirmed planet Exo_3b
DF/F = 0.45% ; D = 3.5 h ; P=4.26 d ; mv = 13.3

Background Eclipsing binary
DF/F = 0.15% ; D= 2.8 h ; P= 3.5 d ; mv = 15.7

Massive Be star
DF/F = 1.3% ; D= 8.7 h ; P= 30 d ; mv = 13.56
Detection/confirmation

- Detection
  - Made by different teams
  - Merging of the results
- Case by case analysis
  - Remove binaries
  - Compare depth/duration
  - Out of transit modulations
  - Look at colours
- Sorting by priorities
- Follow up confirmation
  - On/off photometry
  - Radial velocities

From light curves to planets
Organization of the work

Different working groups:

- Data reduction N1→N2
- Light-curve analysis (8 different teams)
  * Detrending/Detection
  * Sorting of candidates
- Follow-up operations
  * On/Off Photometry
  * Radial Velocities
  * Stellar Parameters
  * Space observations

- Light curve fitting and modeling

→ Coordination of detection & follow-up

Goal: to start the follow up obs. as soon as possible
Tools for the Follow up

- On/Off photometry
  - IAC 80cm
  - ESO VLT FORS & NTT/SUSI2
  - EULER La Silla
  - OHP 120cm
  - CFHT 3.6m
  - Wise obs. 1m

- Radial velocities
  - CORALIE
  - SOPHIE at OHP
  - HARPS

- Star parameters
  - High res. Spectros.

- Space facilities
CoRoT Exo. Science Team

Composition of the Team (core program)

- CoRoT Exoplanet Co-Is: 26
  - France (IAS, LAM, LESIA, LUTH, OCA)
  - Austria (SRI)
  - Belgium, Brasil
  - ESA (ESTEC)
  - Germany (DLR, Köln Univ., Tautenburg Obs.)
  - Spain (IAC)
  - Switzerland (Geneva obs.) - UK (univ. Exeter)

- Associated Scientists: ~ 20

→ Work as a single coherent group
What is found in the analyzed light curves

Present sample: 45,222 light curves

* Anticenter (IRa01, LRa01, SRc01) : 26,759
* Center (LRc01, SRc01) : 18,463
Only 1168 light curves contain transit like signals

- All kind of signals
  - Eclipsing binaries
  - Transiting planets
  - Others …

- Peak at short periods
  - Due to piling up on the line of sight
  - Some A/C differences (cut off in the piling up !?)
The fainter the star, the higher the detection limit.

Transit like signals (2)

- **anticenter**: IRa01, LRa01, SRa01 → 684 detections
- **center**: LRc01, SRc01 → 484 detections

![Graph showing depth percentage vs. magnitude (m_R) with points indicating detections.](image)
Transit like signals (3)

Many short periods on the faint stars

Faint stars are the most numerous

- **anticenter**
  - IRa01, LRa01, SRa01
  - $\rightarrow$ 684 detections

- **center**
  - LRc01, SRc01
  - $\rightarrow$ 484 detections
Transit like signals (4)

Short period planets are easier to detect

- anticenter
  - IRa01, LRa01, SRa01
- center
  - LRc01, SRc01
from 1168 detected signals only 374 consistent with planetary transits

- **Anticenter** → 294 candidates
  - Exo-1b
  - Exo-4b
  - Exo-5b
  - Exo-7b

- **Center** → 93 candidates
  - Exo-2b
  - Exo-3b
  - Exo-6b
  - .......
  - # Exo-nb
Planet candidates (2)

Period (h) vs. $P^{1/3}$

- Exo-1b
- Exo-2b
- Exo-3b
- Exo-4b
- Exo-5b
- Exo-6b
- Exo-7b
- # Exo-nb

Legend:
- Blue dots: anticenter
- Green dots: center
Test of the detection capacity

and test with simulated transits (different teams were involved)

From the data
- anticenter
- center

From the blind test
- Injected transits
- Detected transits (by at least 1 team)

Participation:
- P. Borde
- J. Cabrera
- L. Carone
- S. Carpano
- C. Regulo
### Results for the first 5 runs

<table>
<thead>
<tr>
<th>Run</th>
<th>Stars</th>
<th>Transit signals</th>
<th>Discussed</th>
<th>candidates</th>
<th>F. Up</th>
<th>Planets</th>
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<td><strong>Total</strong></td>
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<td><strong>1168</strong></td>
<td><strong>~354</strong></td>
<td><strong>217</strong></td>
<td><strong>208</strong></td>
<td><strong>6</strong></td>
</tr>
</tbody>
</table>

2.5% of the targets have transit like signals from which: ~70% are eclipsing binaries and 30% planet candidates

6 confirmed planets (5 completely characterized)
Final comments (1)

Up to now CoRoT has detected:
- Six giants planets (see talk by H. Rauer)
- One small planet (see talk by D. Rouan)

But particularly interesting objects!

We expect more planets:
- With the next runs of observations
- When data will be reprocessed with the new pipeline version
- Thanks to our experience of the first runs

Theoretical interpretation are just beginning:
- Structure and composition of CoRoT’s planets (talks by T. Guillot, J. Laskar, D. Vidal, J. Laskar, etc.)
What we learned from the first runs:

- From the initial run (talks by S. Carpano & C. Moutou)
- Studying the detection limits (talks by Pont & Samuel)
- Using the color information (talk by P. Borde)
- From the photometric Follow up (talks by Deeg & Gillon)
- From the radial velocity Follow up (talk by F. Bouchy)
- From the study of stars (talks by M. Deleuil, D. Gandolfi & M. Barbieri)
- Studying the noise level (talks by M. Auvergne, M. Olivier, S. Aigrain, D. Fialho, T. Mazeh)