CHEOPS

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Switzerland

LCPM-10 19.06.2013
CHEOPS mission

- Talk given for Willy Benz, the PI at:
  - University of Bern
  - Space Research and Planetary Sciences
- My affiliation
  - Udo Wehmeier
  - Swiss Federal Institute of Technology, Zurich
- Uni Bern:
  - CHEOPS Payload Manager
CHEOPS mission

- CHEOPS – “CHaracterizing ExOplanet Satellite”

- Not planetary, but EXOplanetary
  1. Swiss Led, joint ESA mission (S-class)
  2. 7 CHEOPS consortium partners (European)
  3. Cost <90 M€
  4. Cost to ESA < 50 M€ (LV, S/C)
  5. Cost to CHEOPS Consortium <40 M€ (Instrument, SOC, MOC)
Transit Method

288 planets have been “observed” with this technique as of 23.10.2012

brightness variation of sun due to:
- Jupiter: 1%
- Earth: 0.01%

depth $\propto$ radius$^2$
A landmark mission

0.95 diameter telescope
for transit detection (20 ppm)

Launch: March 6, 2009
The Kepler catalogue

June 2010

Feb 2011

Dec 2011

Size Relative to Earth

Orbital Period in days

From Natalie Batalha

From Natalie Batalha
ESO La silla Observatory
Techniques

radial velocity measurements

mass

mean density

bulk composition

transit measurements

radius
**Mass Radius Relation**

Adapted from Wagner et al. 2011
Targets: Bright stars

- Apparent magnitude of star
- Radius planet (R_{\text{Earth}})
- Mass measured by radial velocities
- Targets: Bright stars, NGTS, Kepler planets, CHEOPS

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LCMP-10, Pasadena, 19.06.2013
CHEOPS mission

- Key Points for LCPM-10
  1. European mission
  2. Low cost
  3. Fast development
  4. High TRL and flight heritage
  5. 3.5 year mission
  6. Selected for launch in 2017
CHEOPS mission

- Key Science points:
  1. Only Photometry on single targets
  2. Ground follow up to transit and RV
  3. Target follow up mission (not survey)
  4. Pointing to targets
  5. 10 hour transits at 20 ppm V9.
  6. Follow up to TESS and JWST
  7. COROT and KEPLER successes
  8. Target list TBD
ESA S-class mission

- Science
  - top rated science in any area of space science

- Schedule
  - developed and launched within 4 years

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
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<tbody>
<tr>
<td>call issued</td>
<td>March 3, 2012</td>
</tr>
<tr>
<td>proposal due</td>
<td>June 15, 2012</td>
</tr>
<tr>
<td>mission selection</td>
<td>October 19, 2012</td>
</tr>
<tr>
<td>mission adoption</td>
<td>February 2014</td>
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<tr>
<td>launch</td>
<td>2017</td>
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</table>
CHEOPS Payload

Preliminary Functional Block Diagram
Issue:2 Revision:15
Feb 2013

Udo Wehmeier

LCMP-10, Pasadena, 19.06.2013
## CIS Contributions

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Acronym</th>
<th>Organization</th>
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<tbody>
<tr>
<td>Instrument Prime</td>
<td>CIS</td>
<td>UBE</td>
</tr>
<tr>
<td>Outer baffle and door</td>
<td>BCA</td>
<td>CSL</td>
</tr>
<tr>
<td>Telescope Structure and Optical Bench</td>
<td>OTA</td>
<td>UBE</td>
</tr>
<tr>
<td>Telescope optical design and optical components</td>
<td>OPT</td>
<td>INAF</td>
</tr>
<tr>
<td>Power supply and radiators</td>
<td>DCDC</td>
<td>KON</td>
</tr>
<tr>
<td>Analog electronics: FEE / ROE</td>
<td>FEE/ROE</td>
<td>TBD</td>
</tr>
<tr>
<td>Focal Plane Assembly and thermal modeling</td>
<td>FPA</td>
<td>TBD</td>
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<tr>
<td>Detector</td>
<td>CCD</td>
<td>ESA</td>
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<tr>
<td>Thermal Control Module</td>
<td>TC</td>
<td>TBD</td>
</tr>
<tr>
<td>Payload Computer</td>
<td>DPU</td>
<td>IWF</td>
</tr>
<tr>
<td>Science Calibration</td>
<td>CAL</td>
<td>UGE</td>
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</table>
Schedule

Mission adoption 2014

Launch 2017
Mission Goals

- CHEOPS will determine the mass-radius relation in the planetary mass range from 20 MEarth down to 1 MEarth to a precision not achieved before. In particular, CHEOPS will be able to measure radii to a precision of 10% in Neptune-size planets.

- By targeting stars located anywhere on the sky which are bright enough for precise radial velocity follow-up – CHEOPS will not suffer from the limitations in the planet mass determination associated with fainter stars. CHEOPS will provide a uniquely large sample of small planets with well-measured radii, enabling robust bulk density estimates needed to test theories of planet formation and evolution.
Spacecraft

Attitude control
- 3-axis stabilized S/C - one side facing Earth
- “Payload in the loop” AOCS

Thermal stability
- detector must be stabilized to 10mK
- OTA stabilized to 10K

Power
- 54 W continuous payload power
- 70W peak

Data rate
- 1 Gbit / day downlink S-band

Total mass with payload
- \(\approx 200\) kg
System Requirements

- AOCS pointing stability < 8 arcsec rms
  - Small standard platform with modification: instrument in the loop
- Focal plane thermal control < 5-15 mK
  - quasi nadir-locked attitude - radiator facing deep space
  - sun shield
- Stray light baffling performance:
  - attenuation < 1e-12 for angles larger 35 deg
  - Worst case stray light flux in current design from Earth integration: < 0.1 ph/s/px
  - Normal case due to Sun-synchronous orbit with 6am local time orders of magnitude better
- Design meets SNR requirements
  - 20 ppm challenging (10 mK)
Observable sky

from baseline orbit in one year
Instrument Design
Overview

1. Mission requirements
2. Instrument requirements
3. Member contributions
4. Schedule
5. Instrument current design
   a. Optical Design
   b. Stray Light
   c. Detector
   d. Mechanical Design
   e. Thermal Architecture
   f. Electrical Architecture
   g. Data Handling
6. Current status
Optical Telescope Assy

- The OTA consists of a near-zero CTE structure, which carries:
  - Telescope and back-end optics (BEO)
  - Focal plane assembly (FPA) and read-out electronics (FEE)
  - Radiators for FPA and FEE
  - Optionally the star trackers (not baseline!)
Optical Telescope Assy

- Radiators
- Radiators Isostatic Mounts
- Radiators Support & Optics Hood
- Optical Bench
- Structure Tube
- FPA
- CCD
- BEO w. Folding Mirror
Optical Design

F/5 ~33.5 cm diameter on-axis telescope

outer baffle
structure (carbon fiber)
baffle tower
beam shaper
focal plane assembly

secondary mirror
primary mirror
Optical design and SL

Baffle designed for 35 degree exclusion angle.
A 20 cm baffle length increase would reduce the minimum angle from 35 to 28 degrees.
e2V CCD47-20 Detector

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Effective wavelength range</td>
<td>400-100 nm</td>
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<tr>
<td>Size</td>
<td>1024x1024 px</td>
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<tr>
<td>Operating temperature range</td>
<td>-60 .. -40 C</td>
</tr>
<tr>
<td>Temperature stability requirement</td>
<td>10 mK</td>
</tr>
<tr>
<td>Angular scale</td>
<td>approx. 1 &quot;/px</td>
</tr>
<tr>
<td>Full well capacity</td>
<td>100,000 e-</td>
</tr>
<tr>
<td>Read Noise</td>
<td>4 e/px</td>
</tr>
<tr>
<td>Dark Current</td>
<td>negligible</td>
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<tr>
<td>Readout frequency</td>
<td>5 MHz</td>
</tr>
<tr>
<td>Pixel size</td>
<td>13 um</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>e2V</td>
</tr>
</tbody>
</table>
Thermal Architecture

- Sunshield (Satellite provided)
- Radiative interface
- Conductive decoupling
- Radiative decoupling (MLI)

- OTA
- BCA
- OTA URP
- OTA SRP
- BCA URP
- BCA SRP
- Satellite +Z side
- Satellite +X wall
- Satellite
Data Management

1. Continuous data capability for image acquisition
2. Variable framerate to match target luminosity
3. 200x200 pixels at 1 minute cadence integration
4. Initial pre-processing of data on DPU possible
5. Downlink bw of 1Gb/day with compression and HK
6. Expect S-band

1. On ground processing managed by MOC
2. Science data pipeline managed by SOC

1. Mission requirement for 3 days nominal operation without ground intervention
2. Some autonomy may be required to meet this goal.
Current Status

Instrument PRR passed 12 June, 2013

Spacecraft
1. ITT for S/C published 15 March
2. Eight weeks for proposals
3. Accept two S/C candidates in July

Spacecraft
1. Detector selection completed
2. CIS to S/C IF to be developed
3. Launch Opportunities to be found for 2017
4. Iterating instrument design
5. MOC/SOC requirements
Thank you!