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# The MONS/Rømer Experiment

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**Abstract.** The aim of the MONS (Measuring Oscillations in Nearby Stars) project is to use observations of stellar oscillations to perform an asteroseismic analysis of stellar interiors. We expect to obtain high precision oscillation measurements on a sample of 20 bright stars as well as oscillation data at a slightly lower level of precision, but on a larger sample of bright stars. MONS will be launched on the Danish Rømer satellite in mid 2005.

## 1. The MONS experiment

Studies of stellar evolution form the basis for a large part of modern astrophysics. Key questions related to the age of the Universe, the early evolution of galaxies, the chemical evolution of Galaxies and the origin of the chemical elements, depends on models of stellar evolution. MONS (Measuring Oscillations in Nearby Stars) is a space experiment that is expected to be launched on the Danish Rømer satellite in mid 2005. The primary objective for MONS is to strengthen the fundamental basis of astrophysics which stellar astrophysics provides. This will be done by measuring stellar oscillations at an improved level of sensitivity, to allow detailed investigations of solar-like oscillations in other stars than our Sun. The main scientific data from the MONS payload will be time series of photometric measurements of stellar intensity and colour at very high precision. Observations of stellar oscillations will be used to perform an asteroseismic analysis of stellar interiors. This is possible because the frequencies of stellar oscillations depend on the structure of the star (density, temperature, rotation, chemical composition etc.). A detailed description of the MONS experiment was provided, e.g., by Christensen-Dalsgaard (2001).

## 2. The MONS payload

The MONS payload consist of two instruments and in addition it is planned to use the Rømer Star Trackers (satellite attitude control sensors) as scientific instruments, providing photometry for a number of bright stars. The main instrument on the payload is the MONS Main Telescope. This telescope is a 32 cm (diameter) reflector designed to obtain extremely accurate photometry for a few bright stars. Due to the optical design of the MONS Main Telescope (the detector is placed out of focus) one may be affected by faint stars within a small region around the main target. Since large-amplitude variations of a faint source near the main target could be mistaken for an oscillation of the target star, we need to include a small focused telescope to monitor the field around the target. This MONS Field Monitor is a small (5 cm aperture diameter) focused telescope that is co-aligned with the main telescope optical axis. The Field Monitor is equipped with a $1024 \times 1024$ CCD detector that gives a field of view of $5° \times 5°$.

## 2.1. The MONS Main Telescope

The MONS main telescope will produce a time series of colour and intensity measurements for the primary target. There will be one data point per 10 sec. The on-board data processing will correct the data for cosmic rays, photometric errors due to pointing, bad pixels and imperfect flat-fielding. The total amount of data will be about 1 MBytes per day.

## 2.2. MONS Field Monitor Parallel Science

The Field Monitor will produce a huge amount of data on variable stars of many different types and amplitudes, as shown by the following list:

- $\delta$ Scuti stars. These stars show periods of 30 min to a few hours and typical amplitudes of 0.1% to 10%.
- Rapidly oscillating Ap stars (roAp). Periods of a few minutes and amplitudes of a few parts in a thousand.
- SPB and $\beta$ Cephei stars. Among the massive and hot stars one finds the classical pulsating $\beta$ Cephei stars and the more recently discovered SPBs.
- Eclipsing binaries. In many parts of the HR-diagram we find eclipsing binaries that are close double stars where both components during their orbit transit the other component.
- Flare stars and active stars. Stellar flares are common in late type stars. In some stars a flare may for a short period increase the brightness of the star by more than 50 %. One may also detect some cataclysmic variables.

The above list contains mostly "classical" variable stars. This will serve as an excellent support for the MONS primary science goals. In addition we expect to provide data in a number of other astrophysical research areas, including:

- Planetary transits. The MONS Field Monitor will be able to detect transits of giant planets in a large number of stars. We expect to be able to detect between 10 and 100 transiting planets throughout the mission.
- Supernovae. In a typical galaxy of the size of the Milky Way we expect one supernova per 50-100 years. Based on the sensitivity of the MONS Field Monitor we estimate that we may discover one supernova per week.
- Photometric variability of QSOs. Many quasars vary on time scales of a few days, some at the level of 0.3 - 1 magnitudes and most with much smaller amplitudes.
- Asteroids. Moving bodies in the solar system can be seen in the wide field of view of the MONS Field Monitor.

## 3. The MONS science data product

The data will consist of colour and intensity measurements obtained by the Main Telescope. The Field Monitor will produce images of the central field and photometry on selected single stars. Also a full frame at 30 minutes time resolution will be transmitted to ground. The following data will be processed on-board and transmitted to ground:

**MONS Main Telescope:**

- Colour and Intensity for main target - 10 sec time resolution

**MONS Field Monitor (white light photometry):**

- Central field: 64 × 64 pixels - no binning - 80 sec time resolution
- 6 bright stars (V > 4.0) - 2 min time resolution - FM-I
- 32 stars of medium brightness (V > 5.7) - 2 min time resolution - FM-II
- 256 stars of medium brightness (V > 6.7) - 2 min time resolution - FM-III
- 256 faint stars (V > 10.2) - 2 min time resolution - FM-IV
- Full frames (V > 10.2) - 30min time resolution (Central 4.4° × 4.4°) - FM-V

**Star Tracker parallel science:**

- 6 bright stars (V > 1.6) - 2 min time resolution - ST-I
- 32 stars (V > 3.8) - 2 min time resolution - ST-II/ST-III
- 128 stars (V > 3.8) - 2 min time resolution (Central 13.5° × 13.5°) - ST-IV

Table 1. Photometric precision for the MONS Main Telescope (colour)

| Magnitude | Colour (Blue/Red) 10 sec | Colour (Blue/Red) 2 min. | Colour (Blue/Red) 12 hrs. |
|---|---|---|---|
| $V = 0.0$ | 25 ppm | 7.2 ppm | 0.42 ppm |
| $V = 1.0$ | 40 ppm | 11 ppm | 0.66 ppm |
| $V = 2.0$ | 63 ppm | 18 ppm | 1.1 ppm |
| $V = 3.5$ | 125 ppm | 36 ppm | 2.1 ppm |
| $V = 5.0$ | 260 ppm | 75 ppm | 4.4 ppm |

## 4. The photometric capabilities of MONS

The photometric quality of a time series observation for a given star depends on the stellar magnitude and the payload instrument (Main Telescope, Field Monitor or Star Tracker) used for the data collection. Table 1 contains information on the photometric precision for the MONS Main Telescope, while Table 2 and 3 show the precision for the MONS Field Monitor and the Rømer Star Tracker. In order to estimate the detection sensitivity for a 30 days observing run (S/N=4) on should divide the noise per 2 minutes observing by 19. As an example: if the noise per 2 min. is 0.0017 one should be able to detect coherent oscillations at

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S/N=4 with an amplitude of 90 ppm (0.0017/19). For stars down to magnitude V=13 one should be able to detect mmag oscillations with the Field Monitor.

Table 2. Photometric precision per 2 minutes for the MONS Field Monitor

| Magnitude: | FM-I | FM-II | FM-III | FM-IV | FM-V($30^m$) |
|---|---|---|---|---|---|
| V = 4.0 | 0.0005 | | | | |
| V = 5.7 | 0.0013 | 0.0007 | | | |
| V = 6.7 | | 0.0012 | 0.0009 | | |
| V = 8.0 | | | 0.0017 | | |
| V = 10.2 | | | 0.0067 | 0.0025 | 0.0006 |
| V = 13.0 | | | | 0.012 | 0.0031 |
| V = 16.0 | | | | 0.13 | 0.032 |
| V = 18.0 | | | | | 0.19 |

Table 3. Photometric precision per 2 minutes for the Rømer Star Tracker

| Magnitude | ST-I | ST-II/III | ST-IV |
|---|---|---|---|
| $V = 1.6$ | 0.0003 | | |
| $V = 2.0$ | 0.0004 | | |
| $V = 3.0$ | 0.0009 | | |
| $V = 3.8$ | 0.0018 | 0.0006 | 0.0008 |
| $V = 6.0$ | | 0.0025 | 0.0045 |
| $V = 8.0$ | | 0.015 | 0.027 |

## References

Christensen-Dalsgaard, J. 2001, in Proc. 1st Eddington workshop, eds. F. Favata, I.W. Roxburgh & D. Galadi, ESA SP-485, in press