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Pointing the NTT at the Sun: Studying the Solar Corona During the Total Eclipse

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As soon as we realised that the total solar eclipse of 2 July 2019 would be visible from the La Silla Observatory, we saw a rare opportunity to point a 4-metre-class telescope at the Sun to obtain spectra of its corona with unprecedented angular and spectral resolution. Despite the pessimistic reactions of many colleagues — "You are crazy, ESO will never accept..." — we pursued the idea and opened discussions with ESO in early 2018 to see how this type of observation could be carried out in practice. Our team presented a strong argument: this would not be the first time that a large telescope would be pointed at the Sun during an eclipse — it had previously been done successfully with the Observatoire de Haute-Provence (OHP) 1.93-metre telescope in 1961 (Wlérick & Fehrenbach, 1963) and the 3.6-metre Canada France Hawaii Telescope (CFHT) in 1991 (Koutchmy et al., 1994). The science case was to observe emission lines with different ionisation potentials at different positions across the corona with arcsecond angular resolution, in order to analyse the coronal heating mechanism. In the end, the team assembled included a number of people with extensive experience in both solar physics and observational techniques.

The question of which telescope to use then arose, and how we could obtain several high-resolution spectra during the short duration of totality (1m 48s). In practice, the New Technology Telescope (NTT) is the only telescope able to point as low as 13 degrees above the horizon, where totality would take place. A detailed procedure was arranged with the La Silla team to ensure the telescope could be used without risk of fire. There was, of course, no question that the telescope should be operated from a remote location (such as the Ritz control room), so computer consoles were erected right in front of the telescope (Figure 1). This allowed close monitoring, quick reaction times in case of problems, and, as a bonus, a privileged view of the eclipse — but did you ever try to read a screen with the Sun directly in front of you?! Thus, our programme using the ESO Faint Object Spectrograph and Camera v.2 (EFOSC2) at the NTT was proposed in Period 103 (Programme ID 0103.D-0139) and approved by the Observing Programmes Committee!

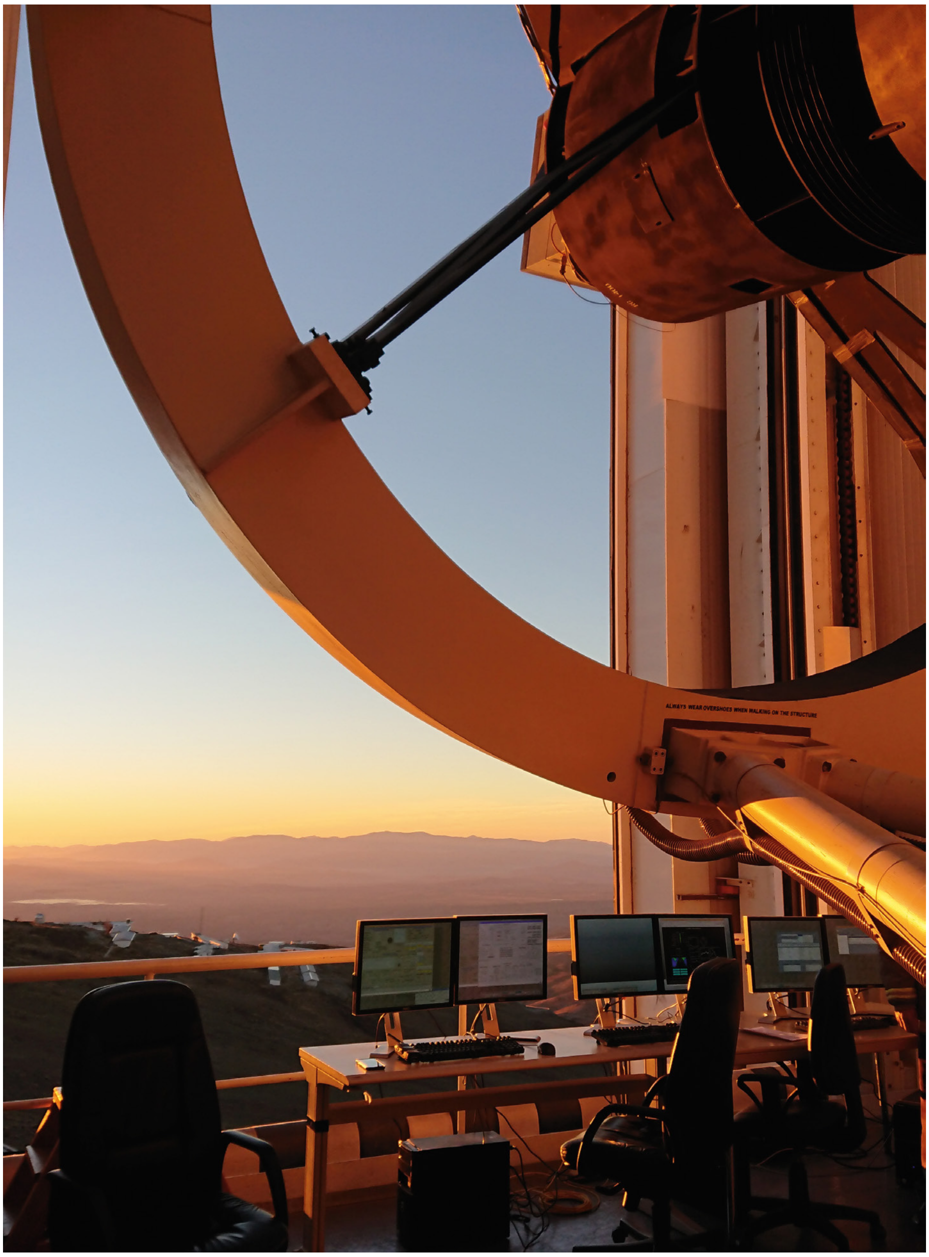
P. Sinclaire/ESO

Figure 1. The NTT pointing at the Sun, with a temporary control system set up directly in front.

The main difficulty with the observation, once the above problems had been addressed, was the comparatively long execution time needed to obtain a spectrum using the standard procedure of obtaining an image before moving to the slit — this would take more than a minute and there was no way to do the image analysis beforehand. We therefore had to rely on parameters obtained the previous night and point the telescope close to the Sun (but not at it), with the shutters closed, to first configure the mirror. It was then moved into position — defined only by coordinates and simulated coronal images — a few minutes before totality. We pointed to the west of the Sun, taking advantage of the moon protecting us from direct sunlight (Figure 2).

Exposure times had been determined weeks before through observations of the Moon; a sequence of 1-second exposures was launched with the telescope tracking normally (the Sun's motion is relatively small over the short duration of totality). The first exposures were in fact dark exposures, the Nasmyth shutter being finally opened only just before totality (C2) to obtain coronal spectra. The camera was commanded directly, without the use of Observation Blocks, allowing short total execution times of 25 s per spectrum in fast read-out mode, and the telescope was pointed away immediately at the end of totality. We obtained five good exposures of the corona, with the sixth being overexposed as Baily's beads appeared at the very end of totality (C3, Figure 2).

A high-resolution grism (Gr#20) was used with a specially manufactured offset slit (kindly provided by colleagues in Paranal) to obtain velocities and line profiles, albeit at the expense of spectral coverage. A lower-resolution, table-mounted auxiliary spectrograph was used in parallel outside the NTT to record the full coronal spectrum over a wider field of view but at a much lower spatial resolution. While the data reduction is still ongoing, preliminary results show that the coronal emission was quite weak; this is not surprising near solar activity minimum. The dominant line in the NTT spectra is the [Fe X] 6374 Å line (Figure 3). Perhaps more surprising is the Hα line, in spectra taken at the beginning and end of totality. It is of chromospheric origin, and is due to the variable illumination of the line of sight crossing low atmospheric layers

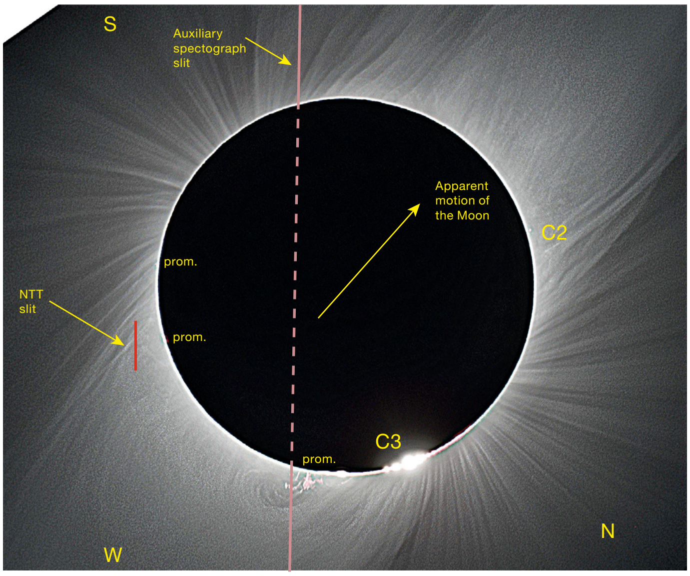

Figure 2. Slit positions plotted on a coronal image taken by Petr Horálek (ESO). Totality occurs when the lunar disc reaches the second contact point, C2 ,and lasts until it moves out at C3.

(Stellmacher & Koutchmy, 1974), as the Moon only covers the photosphere. A more careful analysis is under way to remove all artefacts, a challenging task in light of the unusual observing conditions and the fact that the telescope had to be pointed away quickly before calibrations could be obtained. Figure 3 (bottom) shows a spectrum obtained with the small auxiliary spectrograph; the lower part of the slit shows the corona, with [Fe X] dominating on the left edge. The upper part of Figure 3 shows the spectrum of a weak prominence recorded by chance (see the lower side of Figure 2), which is dominated by hydrogen and helium lines (order superposition is also present). Altogether, we obtained unique spectroscopic data during this eclipse, and we would like to warmly thank all the ESO staff who contributed to this success, both on the technical aspects and on the managerial side. A total solar eclipse is literally an extraordinary event, requiring a lot of preparatory work, but well worth the effort.

References

Wlérick, G. & Fehrenbach, C. 1963, *The Solar Corona*, Proceedings of IAU Symposium 16, ed. Evans, J. W., (New York), 199
Koutchmy, S. et al. 1994, A&A, 281, 249
Stellmacher, G. & Koutchmy, S. 1974, A&A, 35, 42

Figure 3. Top: Two EFOSC2-Gr#20 spectra of the corona taken at the same position but at two different times. The signal is dominated by the continuum of the K corona; note the presence of parasitic Hα. Bottom: Spectrum from the auxiliary spectrograph during totality.