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The Great Dimming of Betelgeuse: the atmosphere revealed by envelope tomography during the past 14 years

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"Betelgeuse, a red supergiant star of semi-regular variability, underwent a historical minimum of brightness in February 2020, the Great Dimming. Even though the brightness has returned to the values prior to the Great Dimming by now, it continues to exhibit highly unusual behavior.
Understanding the long-term atmospheric motions of Betelgeuse and its variability could be a clue to the nature of the Great Dimming. Our goal is to find evidence of what caused the Great Dimming.
We apply a tomographic method, which allows probing different layers in the stellar atmosphere, to reconstruct depth- dependent velocity fields. The method is based on constructing template spectra, called masks, by grouping spectral lines from specific optical depths. These masks are cross-correlated with the observed spectra to recover the velocity field inside each atmospheric slice.
Due to above 2000 spectra from 14 years, observed with the STELLA robotic telescope in Tenerife, we were able to analyse the variability of five different layers of Betelgeuse's atmosphere. The time variations of the widths of the cross-correlation function unveil propagation of two shock waves. We detected a previously reported shock wave that presumably caused the Great Dimming, and we report a following one, which was even stronger and continued to change the structure of the atmosphere. After the Great
Dimming, the dominant mode of pulsations changed. However, these changes did not take effect in all layers simultaneously. The inner layers started to pulsate with a shorter period of about 200 d, possibly the first overtone, while outer layers remained less affected, continuing their previous movement with the original period of about 400 d. The rearrangement of the photosphere was likely completed in 2022, when all the layers seemingly started to follow a similar behavior as before the Great Dimming, but now pulsating with the shorter period of about 200 d."

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