Var C: Long-Term (Semi-)Periodic Variability of an LBV in M33

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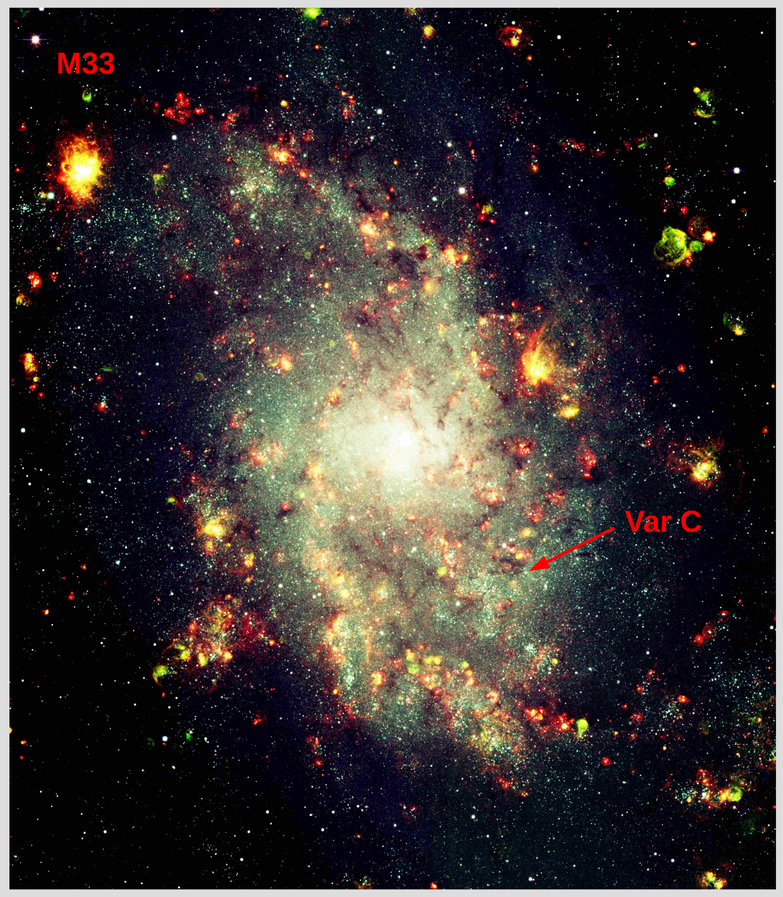
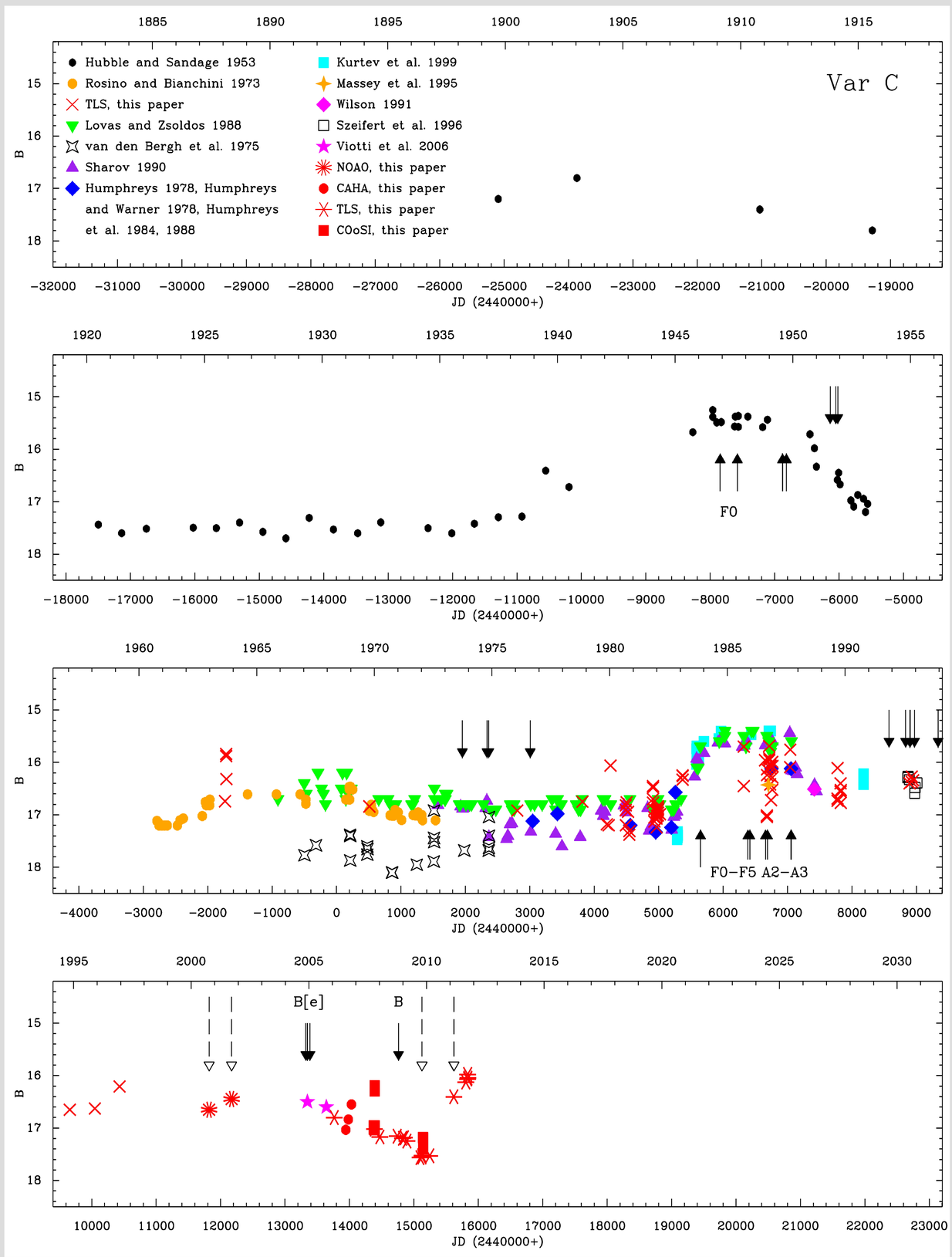
Luminous Blue Variables (LBVs) The LBV phase is a short (10^4 years) stadium in the lifetime of evolved massive stars (50 to ~120 $M_\odot$). LBVs belong to the most luminous (10^6 $L_\odot$) stars in the universe. They are characterised by irregular photometric and spectral variabilities on different time scales (from months up to years or even decades) and with different amplitudes (from some tenth of magnitudes up to >2 mag), which can be superimposed (*Humphreys & Davidson, 1994*). The typical photometric LBV variability, the so called S Dor variability (about 10-40 years, 1-2 mag) can be subdivided into long (>20 years, L-SD) and short (<10 years, S-SD) S Dor variability (*van Genderen, 2001*). During phases of minimum visual light in this S Dor cycle LBVs show spectra of hot supergiants with H, He, FeII and [FeII] lines in emission, which often also show P-Cygni profiles. At a phase of maximum light the spectrum turns into that of an A to F type star (*Humphreys & Davidson, 1994*).
So far, the underlying mechanism for these variations is not known. It is still unknown under which circumstances massive stars become LBVs, what triggers the instabilities, and whether all massive stars in a certain mass range evolve into LBVs or not.

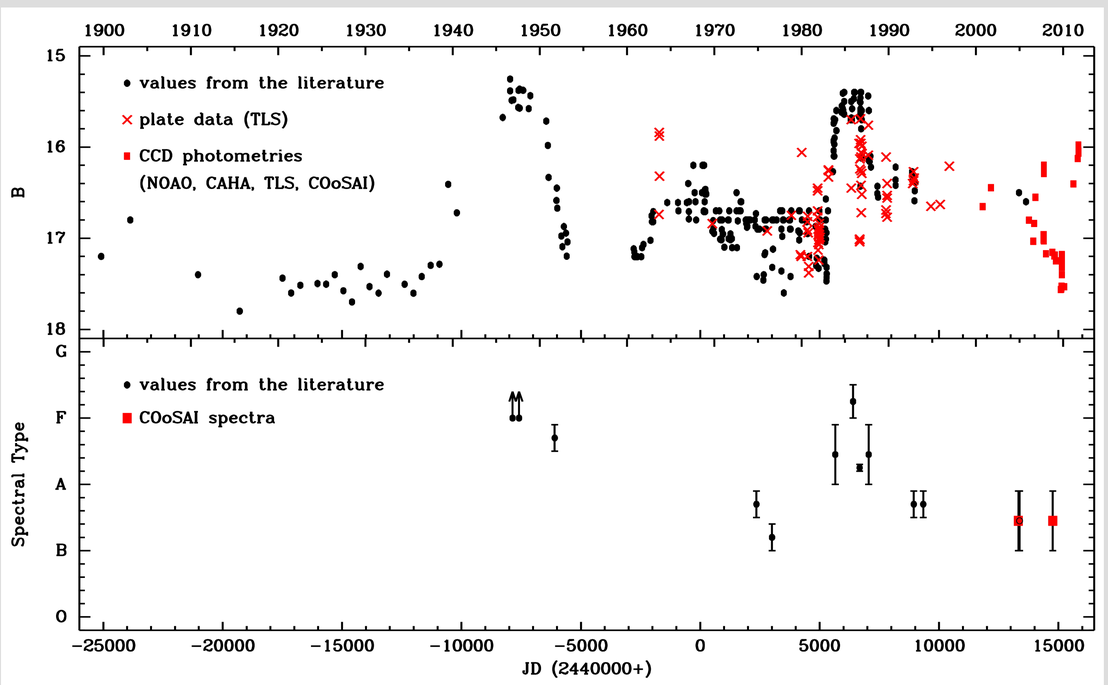


Data To investigate the long-term photometric behaviour, we generated light curves and checked for periodicity in the variabilities. Therefore, we performed CCD photometry on data from the Thüringer Landessternwarte (TLS) Tautenburg, the Centro Astronómico Hispano Alemán (CAHA) at Calar Alto, and the Crimean Observatory of Sternberg Astronomical Institute (CooSAI), as well as on archival data (e.g. NOAO). Additionally, we performed photometry on scanned photographic plates of M33 from the TLS. To complete our measurements, photometric and spectral data from the literature were added.

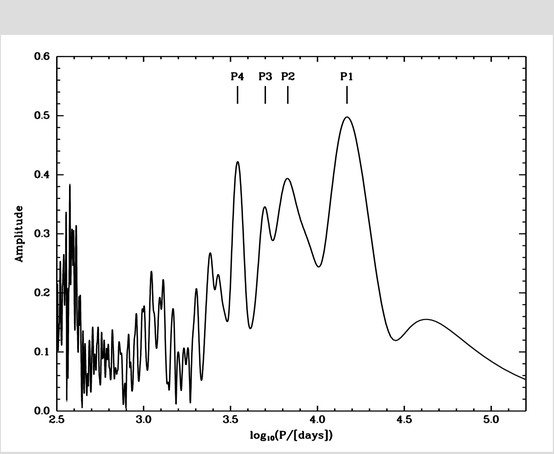
What you should take with you!

From Var C's present data a (semi-)periodic long-term variability of ≈40 years can be fitted. The next major maximum in Var C's light curve is predicted for around 2027±2. Further tracing of Var C's luminosity is still necessary to finally prove or disprove the periodic character of Var C's variations. Var C's spectrum and light curve show corresponding variations indicating an S Dor variability.

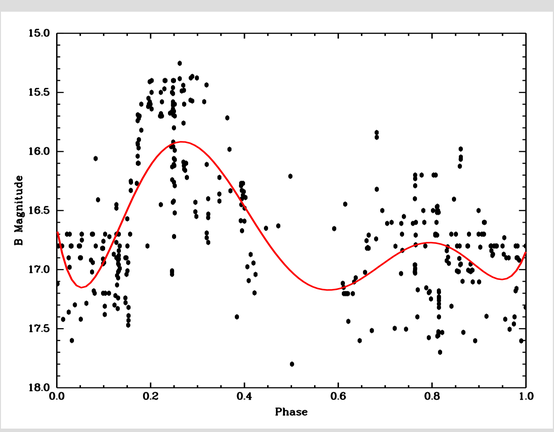




Light curves (left and above figures) of Var C in the B filter between 1899 and 2011. If known, the corresponding spectral type is indicated. Aside from two prominent maxima (around 1946 and 1986) and variations on smaller time scales, a secular trend of Var C getting brighter is seen in the light curve. With the last major maximum around 1986 and a period of P≈40.7 years (see figures below), the next large maximum phase of Var C should occur around 2027±2.
Comparing the light curve with the changes of the spectral types shows that during maximum light the star resembles an A or F type star. During phases of minimum light an O or B type star is seen.
Of special interest is the latest development of Var C. The star brightened in B of more than 2mag in less than two years. Tracing the further behaviour will show whether this is already the beginning of the next maximum or if this is just a smaller rise.



Power Spectrum derived for the B values given above. The brightest peak (P1) corresponds to a period of P=14883d≈40.7 years (ν=6.719x10^{-5} 1/d). The peak around logP≈2.6 corresponds to a period of ≈1 year and is most probably due to the data sampling. The very broad and low amplitude peak around logP≈4.7 reflects the secular trend of an overall increase of the luminosity. At least three more peaks are present.



Phase Diagram corresponding to a period of P≈40.7 years (P1). The red line is a polynomial fit to the data. At least one pronounced maximum is seen, a second, smaller maximum at roughly the half of the period might be assumed, but data scattering due to irregular variations on smaller time scales is large and renders it quite uncertain. Together with an amplitude of ≈1.5-2.0 mag for the major peak this puts Var C in the category of a strong-active S Dor member with a long S Dor cycle as defined by *van Genderen (2001)*.

Periodicity, like that of the S Dor cycle, or on even smaller timescales in the order of approximately one year is already known to occur in LBVs like e.g. AG Car (*van Genderen, 2001*). Periodicity in the order of decades was only found to be a beat cycle as the result of these smaller periods. Detecting possible periodicity on larger scales (in the order of decades) was always difficult since most of the light curves do not reach back far enough and/or are much to fragmentary.
We combined historical and new data to produce a light curve of a significant length for Var C to analyse the long-term variability by carrying out a systematic search for long-term periodicity. Therefore, we performed Fourier transformation analysis on our data set of B magnitudes by using Period04 (*Lenz & Breger, 2005*).
We found a long-term (semi-)periodicity of 40.7 years being present in Var C. Var C is the first LBV to show a periodicity in the order of decades without periodicities on smaller time scales. This indicates that the long-term periodicity has to be a result of a different underlying mechanism, which is not yet understood.

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