Goethe on Interferometry

I HAVE had occasion recently to re-read Goethe's *Theory of Colours* (1810) and have found that he described the nature of the microtopographical interference pattern given by a crystal surface, presumably from the description, that of a cleavage. In chapter 33, which deals with interference colours (Goethe calls these epoptical colours), first a precise account is given of the (already known) appearances of white light, Newton's rings produced when glass lenses are pressed together. Colour sequences at various pressures are described in detail.

Goethe then reports that the pressing of plane [*sic*] glasses together produces colours which "undulate like watered silks", a perfect description of the typical wavy form of interferogram given by polished glass plates (Fig. 1). These colours he traces through under varying pressures and varying angles of incidence. He notes that clear fringes only arise with clean glass, which, he advises, should be handled with gloves, and even recommends observation in a vacuum. The effects, he rightly states, are most brilliant when concave and convex surfaces of the same curvature are brought into juxtaposition, and thus his fringes are seen to advantage with achromatic telescope objectives. Goethe discusses in some detail the central reflected black spot and makes the acute observation that this reflected black spot is a very bright spot in transmission. Since he was not aware of wave theory and phase changes he makes the reasonable suggestion that the reflectivity at the pressure point has dropped to zero.

In paragraph 446 Goethe gives a remarkable description of the interference fringe pattern he sees with a crystal. He says, "A remarkable appearance takes place when dissimilar surfaces are pressed together, for example, a polished crystal and a plate of glass. The appearance does not exhibit large flowing waves, as in the combination of glass with glass, but is small and angular, and, as it were, disjointed".

In another section of the same treatise Goethe mentions that he has available a rhomb of Iceland spar. I venture to conjecture that this is the polished [*sic*] crystal he is using. There is not the slightest doubt that what he is describing is just what is seen when a well cleaved calcite crystal is matched against a piece of polished glass. There is just the alternative (but less likely) possibility that a natural crystal such as quartz with good growth features was being matched. However, the description of interference fringes as "small, angular and disjointed" is exactly what is revealed by a good cleavage surface like that of calcite (Fig. 2).

This really notable observation by Goethe seems to have been completely missed by both physicists and historians of the nineteenth and twentieth centuries. Could it be that this was due to the cold disdain by which Goethe's critique of Newton was received by contemporary and later scientists? Because the major colour theory was condemned, maybe the associated notable excellent observations were ignored.

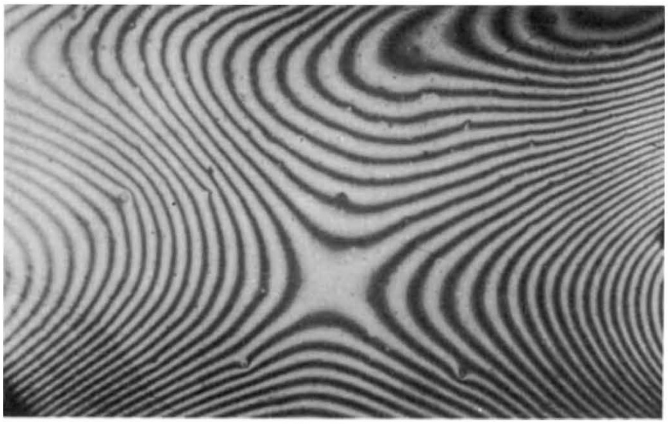

Fig. 1

Fig. 2.

In succeeding sections Goethe gives notable descriptions of his penetrating observations on a very wide range of thin film interference fringes. All these effects he regretfully attempts to account for by his now discredited theory of the origin of colours. Nevertheless, theory apart, this fascinating text teems with novel interferometric observations, making the text a joy to read.

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X-ray Observation of Cen XR-4 and Nor XR-2

WE wish to present the results of an X-ray astronomy experiment conducted from a Centaure rocket launched from Thumba Equatorial Rocket Launching Station (TERLS), India, at 0035 UT on December 7, 1969. The detector consisted of a xenon–methane proportional counter of useful area of 55 cm^2 with a 18 mg cm^{-2} thick beryllium window and a slat collimator with a field of view of 7° × 15°. It had a resolution of 20% for 6 keV X-rays from a ^{55}Fe radioactive source. The rocket aspect[1] determined from onboard magnetic and Sun sensors showed that it had a spin rate of 5.5 r.p.s. and a precession with a half cone angle of about 3° around an axis centred at R.A. 8 h 56 m ± 4 m and declination $3° \pm 1°$. The X-ray data were pulse height analysed into three contiguous energy channels in the energy range 2–18 keV.

Fig. 1 shows the plot of count rate in the 2–9 keV range as a function of spin azimuth. Various sources within the scan region of the detector are marked in the figure, the source positions having been obtained from earlier observations[2-4]. As the figure shows, the fluxes from Cen XR-1, Cen XR-2 and Cen XR-4 are much below the limit of detectability and hence only upper limits of flux for these sources are derived (Table 1).

All available observations of Cen XR-4 at different epochs[3,5,6] are plotted in Fig. 2. Data from Vela satellites used in this diagram have been corrected for transmission efficiency of the

Table 1 Upper Limits for the X-ray Flux from Cen XR-1, Cen XR-2 and Cen XR-4 in the Energy Range 2–18 keV (2 σ level)

Energy range (keV)	Flux in photons cm^{-2} s^{-1} keV^{-1}		
	Cen XR-1	Cen XR-2	Cen XR-4
2–5	1.4×10^{-2}	3.6×10^{-2}	1.5×10^{-2}
5–9	0.95×10^{-2}	2.4×10^{-2}	1.0×10^{-2}
9–18	0.52×10^{-2}	1.3×10^{-2}	0.55×10^{-2}