Green Shadows

Goethe, Ritter & Ørsted on the Polarity of Green and Purple

Green – Conference of the Society for Literature, Science and the Arts
June 15th, 2018 Statens Museum for Kunst (SMK), København

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I. Goethe in a Fairy World

December 10th, 1777:

> "Once, on a winter's journey in the Harz Mountains, I made my descent from the Brocken as evening fell. The broad slope above and below me was snow-covered, the meadow lay beneath a blanked of snow, every isolated tree and [...] every rocky prominence was rimed with frost, and the sun was just setting beyond the Oder ponds. Because of the snow's *yellowish* cast, *pale violet* shadows had accompanied us all day, but now they were *deep blue*, as the illumination exhibited a *yellow deepening to orange*. At last the sun began to disappear and its rays, subdued by the strong haze, spread the most beautiful *purple* over my surroundings. At that point the colour of the shadows was transformed into a *green* comparable in clarity to a sea green and in beauty to an emerald green. The effect grew ever more vivid; it was as if we found ourselves in a fairy world for everything had clothed itself in these two lively colours so beautifully harmonious with one another" (Goethe, *Farbenlehre* (1810), §75).

Colour of the shadow	pale violet	dark blue	green
Colour of the surrounding light	yellowish	intens. yellow (orange?)	purple

With this accidental observation, Goethe was drawn into his largest project: The investigation of colour, light – and darkness. Poetic, but entirely unscientific?

II. Newton and the Heterogeneity of White Light (Letter to the Royal Society, February 6th, 1672)

The sun's white light consists of violet, blue, cyan, green, yellow, intensive yellow (orange) and red light rays:

(a) As they pass through a prism, violet light rays will be more strongly refracted than blue rays, these in turn more strongly than green rays, etc.

Darkness does not play any causal role in the experiments:

(b) With this assumption, Newton replaced the polarity between darkness and light that had been assumend by earlier theories of colour.

III. Scientific Coincidence: Stars or Lice?

Newton happened to be interested in astronomy; he was annoyed by the low quality of telescopes and their chromatic aberration:

(a) If you use a refractive telescope to look at the stars, then their images are blurred and unsharp – you see elongated Newtonian spectra instead of white circles.

Had Newton been interested in biology, and insects, he would have been annoyed by the low quality of *micro*scopes and *their* chromatic aberration:

(b) If you use a refractive *micro*scope to look at little lice, then their images are blurred and unsharp, too – you see elongated spectra instead of *black* circles; but the colours are the *opposites* of the Newtonian ones.

stars	pale violet	dark blue	cyan	green	yellow	red
lice	yellow	orange	red	purple	blue	cyan

There are other possibilities which also lead to the complementary spectrum (given that the roles of light and darkness are switched):

(c) Invert the aperture (Goethe); invert the sky (Pater Lucas).

Goethe arrived at a bold empirical claim:

(*) To *each* Newtonian experiment there exists a complementary counterpart (its colour negative).

IV. Polarity – Goethe's Main Point against Newton

Goethe expected polarity everywhere in nature, particularly in optics:

> "the formula of polarity has been borrowed from magnetism and extented to electricity, etc. The concepts of *plus* and *minus*, which represent this formula, have found suitable application to many a phenomenon [...] We, too, have long wished to introduce the term *polarity* into the theory of colour, and the present work woll show our justification and purpose in doing so" (Goethe, *Farbenlehre* (1810), §756/7).

With this aim, Goethe followed recent trends in scientific research (e.g. Bergman):

(+/–) When you *heat* the tourmaline in warm water, the crystal's ends exhibit the same behaviour as the magnet's poles.

(–/+) When you *cool down* the tourmaline, its electrical polarity is reversed.

The opposition of warm and cold appeared to be connected with that of electrical plus and minus.

Before the connection was transferred to prismatic spectra, Goethe had already introduced the metaphor of warm *versus* cool colours.

V. Infrared and Ultraviolet

Herschel (1800) investigated the temperature in Newton's spectrum:

(IR) The thermometer indicates infrared radiation beyond the red end of Newton's spectrum, but no radiation at the opposite end.

This apparent breakdown of the symmetry worried the circle around Goethe – Ritter came to the rescue (1801) with photochemistry:

(UV) White silver chloride gets dark most speedily beyond the violet end of Newton's spectrum, but does not react at the other end of the spectrum.

On Goethe's request, Ritter searched for, and detected, further polarities in the spectra.

VI. Electricity and Magnetism

On September 18th, 1801, Ørsted visited Ritter, who showed him his prismatic experiments:

(∞) Both believed that the entirety of nature is governed by polar laws.

When they had made friendship, Ørsted went to Paris and translated Ritter's discoveries into French (1803), including his premature speculations about a possible connection between electrical and magnetic polarity:

(± SN) Only in 1820, Ørsted managed to demonstrate magnetic effects of electricity.

Until Goethe's death (1832), his idea of an overall polarity in nature was anything but unusal:

Effect / **Cause** ↗	**S/N Magnetism**	**+/– Electricity**	**Warm/Cold**	**Bright/Dark**	**compl. Colours**
S/N Magnetism	Gilbert	Faraday			
+/– Electricity	Ørsted	Aepin			
Warm/Cold		Bergman	Rumford		
Bright/Dark				before Newton	Goethe
compl. Colours			Herschel & Ritter	Goethe	Leonardo da Vinci

VII. Darkness Rays? Purple Photons?

Very scientific objection:

(-1) Nowadays we know that neither coldness nor darkness exist; they are nothing but absence of warmth and light.

But Goethe requested measurements of temperature in his complementary spectrum; they were performed much later, and they vindicated Goethe's view:

(+1) As compared to the *bright* surroundings of the complementary spectrum, the temperature decreases in that spectrum; the minimum temperature is in the infra-cyan.

Tougher objection:

(-2) Nowadays we know that Newton's spectrum is basic as it is made of photons – its centre shows e.g. homogeneous green photons (of medium wave length).

(-3) But Goethe's spectrum is not basic – its purple centre is not made of one kind of photon (it's a mixture of all photons with the exception of the green ones).

Reply – perhaps there are no purple photons because we have not searched for them:

(↔) So let us deconstruct the privileged role of green photons!