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Border Spectra in the Skies of Hokusai and Hiroshige: Japanese Traces of Newton or Goethe? A Colour Mystery

Prof. Dr. Olaf L. Müller (Humboldt-Universität zu Berlin, www.farbenstreit.de)

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ABSTRACT. In his earliest prismatic experiments (1665), the young Newton discovered the two border spectra (black-blue-turquoise/cyan-white; white-yellow-red-black). Newton chose to ignore them in his celebrated theory of light and colours (1672), as he took them to be derivative phenomena. In Goethe's *Beyträge zur Optik* (1791) and in his *Farbenlehre* (1808/10), they regained prominent attention. To the human eye, their colours appear much cleaner than the colours of Newton's spectra – particularly in the case of yellow and turquoise. This undeniable *phenomenological* fact, however, has not added strength to Goethe's attack on Newton's *theory*. Are, then, the border spectra perhaps prominent in the art of painting? Not in European art. But they make a surprise appearance in the art of Japanese ukiyo-e. Many of Hokusai's and Hiroshige's prints have skies with the colour sequence black-blue-turquoise-white, arranged in parallel stripes. I find this remarkable, for it is a combination of colours that exactly matches one of the two border spectra. With such a precise geometrical arrangement, it occurs only in quite specific prismatic experiments and not outside the lab. At that time, Japan was isolated from European influences. Were the border spectra discovered for a second time? That is one of the questions I want to raise in my paper. I will end the paper with a few remarks on the aesthetical effects of those colours in ukiyo-e woodblock prints.

NOTE. This electronic version of the text is not entirely identical with the printed version. The electronic version differs from its official counterpart in terms of typography, layout and footnotes. (The arguments, however, are the same in both versions).

Border Spectra in the Skies of Hokusai and Hiroshige: Japanese Traces of Newton or Goethe? A Colour Mystery

Olaf L. Müller

In the seventeenth century, Newton used his famous prism to found the physics of spectral light, thus revolutionising our thinking about colours; more than a hundred years later, Goethe protested against Newton's theory and discovered a number of new prismatic colour phenomena. Did these episodes in the history of science have any influence on the visual arts? For a decade now my visits to art museums have had an agenda: I have been looking for nineteenth-century paintings with certain spectral colours (which will be described in the first half of this paper). While my search has been unsuccessful in traditional Western art, I found what I was looking for in Japanese art: in woodblock prints by Hokusai and Hiroshige. This is surprising; little Western science had reached Japan in their time. The second half of the paper presents this riddle, which I am nowhere near solving. Even without a solution, however, a riddle can be instructive. In this case, it may help to bring into focus the fascinating exchange between two distant cultures. Much has been written on the cultural relativity of colour perception, colour systematisation and colour aesthetics; I want to introduce a new and so far unknown case that might contribute to this debate – though the debate itself remains beyond the scope of this paper.

I. Newton's First Prismatic Discovery (1665)

The Newtonian spectrum S_N is an icon of early modern science. It consists of the following colours:

[black]
blue
turquoise, i.e., cyan
green
yellow
red
[black]



This spectrum appears in an experiment that Newton first conducted between 1666 and 1668 (see Fig. 1).¹ Rays of sunlight are sent through a hole in a window shutter and into a glass prism, where they are split into their multi-coloured components and refracted onto the opposite wall of the dark chamber. The degree of refraction depends on the colour of the rays: blue rays change direction the most, red rays the least, while green rays fall between these. Newton's ground-breaking conclusion from this experiment and from many others was that these spectral colours (and all intermediate hues) are contained in white light: the prism merely extracts them by analysing the sun's white light.²

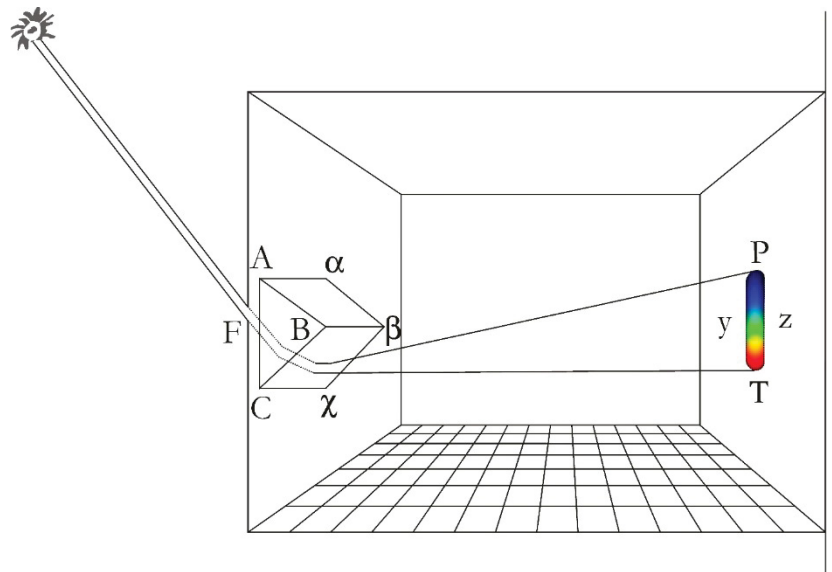


Fig. 1: Newton's basic experiment (1666-1668)

In the autobiographical introduction to his first publication *A New Theory about Light and Colors* (1672), Newton claims to have discovered the full spectrum at the very beginning of his optical investigations.³ Newton's notebooks, however, tell a different story. His first prismatic experiments had little in common with the iconic prism experiment, see Fig. 2.⁴ Instead of a narrow ray of light surrounded by darkness on all sides, Newton sent a different configuration of

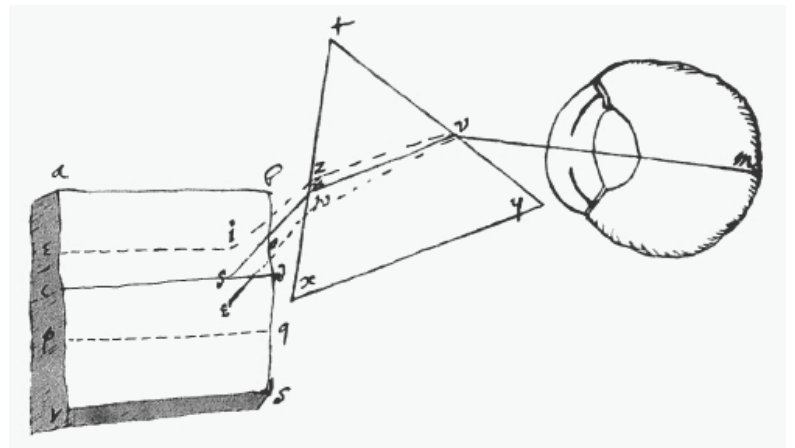


Fig. 2: Newton's first subjective experiment (1665)

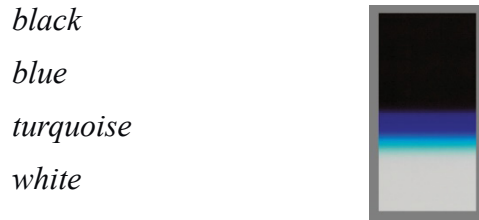
1 Newton 1672, 3076–3078. For details of the experiment's history see Lohne 1965, 126–7.

2 Newton 1704/1964, Book I.

3 Newton 1672, 3075–76.

4 Further details in Lohne 1961, 393–395, Lohne 1965, 131–133, Hall 1948, 247. The latter two references contain translations of the relevant parts of Newton's notebook; for the Latin original see Newton 1983, 122r.

illumination through the prism: a border between darkness (at the top) and light (at the bottom); this is the pattern you would see if you placed a black tile above a white tile with no gap. It leads to the following spectrum S_C (which appears cool):



If the two tiles are swapped, so that there is light at the top and darkness at the bottom, the prism creates yet another spectrum S_W . Newton also discovered this third spectrum (of warm colours) at the beginning of his research:



Nowadays the spectra S_C and S_W are known as border spectra. Newton did not mention these spectra in his first publication, and he cannot be faulted for this omission. According to his theory, the border spectra are not basic or fundamental. Rather, they have to be derived from the theory in a complicated way.⁵ If Newton had burdened his argument with the details of their derivation, his short text would have lost some of its punch. It was a smart rhetorical move to ignore such complications. After all, Newton did not deny the existence of the border spectra. And a scientist should not be blamed for not discussing all the interesting phenomena that the research has uncovered – *exemplum docet, exempla obscurant*.

II. Goethe's Rediscovery of the Border Spectra

One hundred and twenty-five years after Newton's discovery of the border spectra, Goethe discovered them for a second time.⁶ At this point, he probably had not yet read Newton's *Opticks*.⁷ Accordingly, he did not know that the border spectra follow from Newton's theory (albeit in a complicated way). Worse still, he thought they could be used to refute the theory.

⁵ See the small print in his *Opticks* (Newton 1704/1964, 103–4: Book I, Part II, Proposition VIII, Problem III). Also see Fig. 6 in section V on p. 12.

⁶ Goethe 1791/1951, §50–§59.

⁷ Ruppert 1958, §4932.

This premature claim was published in his *Beyträge zur Optik*.⁸ Since Newton's theory was well established at that time, it did not take long for physicists to point out Goethe's mistake.⁹ Goethe understood and accepted the criticism.¹⁰ He no longer claimed that Newton's theory could be falsified by experiments alone. Instead, he took a more philosophical approach, arguing in his *Farbenlehre* (1810) that no theoretical claim whatsoever could be proven or refuted empirically.¹¹ In this respect Goethe was closer than Newton to recent trends of thought in the philosophy of science.¹² Let us take Goethe's side – and that of most contemporary philosophers of science. Newton did not in any sense manage to *prove* his theory with optical experiments, nor was he able to show that no other theory agrees with these experiments. With this in mind, Goethe's project in his *Farbenlehre* makes good sense: he was trying to provide a theory that fits the optical experiments just as well as Newton's theory does.¹³

According to Goethe, the basis of all colour phenomena does not lie in the Newtonian spectrum S_N (as Newton would have it), but rather in the border spectra S_C and S_W . This claim was not unreasonable, for Goethe was able to derive the Newtonian spectrum S_N from the border spectra S_C and S_W .¹⁴ The derivation is successful – given the assumption that the border spectra are fundamental; in the same way Newton's derivation of the border spectra succeeds under the assumption that his full spectrum S_N is fundamental. In Goethe's time that may have been enough for a draw. Nowadays we know that the full spectrum is fundamental and that the border spectra are not; from the current point of view Goethe has lost the dispute.¹⁵ Nevertheless I want to highlight three aspects in favour of Goethe's point of view. They have to do with how we perceive colours: with the phenomenology of colours.

8 Goethe 1791/1951, §56.

9 Anonymous 1792, 242–244, Gren 1793, 13–17.

10 Pace Weizsäcker 1954/1998, 539. See e.g. Goethe 1810/1957, 79–91.

11 Goethe 1810/1958, §31.

12 For a *locus classicus* see e.g. Quine 1951/1961. Newton had claimed to prove his theory (Newton 1959, 209; Newton 1704/1964, 5: Book I, Part I). Most contemporary commentators think that this claim was overconfident, see Sabra 1981, 249f, Thompson 1994, 8f, Laymon 1978, 62. The latest monograph on Newton's methodology offers a similar verdict, see Ducheyne 2012, 179, 186–200 (esp. 196), 219–222.

13 Goethe 1808/1955, §218–§242, §335–§338. That Goethe (unlike Newton) was not aiming to provide the only possible theory can be seen e.g. in Goethe 1962, 182.

14 Goethe 1810/1958, §109; for some details see O.M. 2016, sections IV and VI.

15 Here is roughly what current physics says about the matter: white light consists of different types of photons, whose frequencies correspond to the various spectral colours (as long as enough photons of the same frequency reach a white screen); in particular, there are photons of a certain frequency that produce light of green appearance – so there is such a thing as unmixed, pure spectral green (speaking loosely). On Goethe's view, however, green can only be composed of different colours, namely of the turquoise section in border spectrum S_C and of the yellow section in S_W , see Goethe 1810/1958, §109.

III. The Phenomenal Strengths of the Border Spectra

Although Goethe's border spectra did not prevail in optical theory, they should not be neglected. In this section, I will offer three considerations that illustrate their significance. First, they can be made visible with simpler technical means than Newton's spectrum S_N ; that is why they were discovered before the Newtonian spectrum. Of course, temporal priority does not provide a conclusive argument for theoretical priority, but it does count as evidence for simplicity, and simplicity is an important (though not always overriding) criterion for theoretical truth.

Secondly, the colours of the border spectra look more convincing than those of the full spectrum S_N . This is particularly obvious in the case of yellow.¹⁶ Newton's spectrum S_N does contain a small stripe of yellow between green and red, but it is brownish and dark. The yellow in border spectrum S_W , however, shines brightly and looks as clean as a ripe lemon. If the aim is to construct an optical theory of *colour* (as it was for both Newton and Goethe) and not merely an optical theory of *light*, this consideration ought to have some weight. It gives us an additional reason to favour Goethe's theory.

Outside the *theoretical* dispute concerning optics and colour theory, it is certainly true that the colours of the border spectra are *aesthetically* prior to those of the full spectrum S_N . To see this, imagine two painters. The first has a palette of the usual pigments, including a pigment suitable to depict the yellow from the warm border spectrum S_W ; the second painter's yellowish pigment, however, resembles the yellow from Newton's spectrum S_N . Now both have to paint a realistic picture of lemons. While that proves easy for the first painter, it is impossible for the second, whose unclean yellow pigment cannot be improved by adding other pigments. What if both have to paint a picture of the Newtonian spectrum? That is easy for the second painter, but it is also possible for the first, who simply has to add ochre to the yellow pigment (or possibly a few colours that mix into brown). The upshot is that brilliant yellow (as in Goethe's warm border spectrum S_W) can easily be made darker and less clean on a painter's palette, while unclean yellow (as in Newton's spectrum) cannot be made brighter, cleaner or more saturated through mixing.

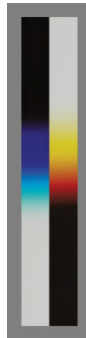
The previous example involved realistic depiction of coloured objects, but the same point can be made within non-naturalistic aesthetics. Mondrian, for example, might not have succeeded

¹⁶ Bjerke 1963, 42. The Viennese painter and colour researcher Ingo Nussbaumer voiced similar criticism of Newton's yellow in his talk "Paradigma, Urphänomen, Hypothese und Prinzip" (philosophy of science colloquium at the Humboldt University Berlin on 21 June 2007).

if he had painted his yellow rectangles with pigments matching the yellow from Newton's spectrum: he wanted to use yellow as a basic colour, and Newton's yellow would hardly have suited this role.¹⁷

Let us turn to the third aspect in favour of Goethe's theory. There is no clear organising principle in Newton's spectrum; but the two border spectra are *exact* counterparts to each other:

| <i>Cool border spectrum S_C</i> | | <i>Warm border spectrum S_W</i> |
|--|--|--|
| <i>black</i> | | <i>white</i> |
| <i>blue</i> | | <i>yellow</i> |
| <i>turquoise</i> | | <i>red</i> |
| <i>white</i> | | <i>black</i> |



The spectra are counterparts because each section of the cool border spectrum S_C contains the precise complementary colour of its warm opposite S_W : blue is the colour complement to yellow, turquoise the complement to red. (The same holds for the intermediate colours as well as for black and white.) So if you were to stare at a part of one border spectrum and then turn your eyes to a grey or white surface, you would see an afterimage which matches the colour of the corresponding part in the other border spectrum.

This symmetry of colours between the two border spectra was a clear sign for Goethe: in his view, it indicated that he had discovered a general principle. In all of his scientific work, whether theoretical or experimental, Goethe would actively search for symmetries – just as the physicists of our time do.¹⁸ Here we have a final aspect that supports Goethe's theory; today, of course, it is trumped by other, contrary reasons.

Be that as it may, the colour symmetries are relevant not only for scientific, but also for aesthetic purposes. According to Goethe, there is colour harmony in a painting if its main colours are balanced by their complements. Yellow, for example, *calls for* a blue

¹⁷ Things are further complicated by the fact that Mondrian's yellow changes from picture to picture, according to the exact shades of white, black and grey elsewhere on the canvas (Ingo Nussbaumer, p.c.).

¹⁸ Goethe's systematic search for symmetry is discussed in O.M. 2013 and O.M. 2015; symmetries in science are the subject of O.M. 2017.

counterweight; likewise, red *calls for* turquoise.¹⁹ Following Goethe, one might say that colour harmony requires all the colours that are needed for completeness. A painting displays perfect colour harmony if all of its colours are balanced out, that is to say, if their additive mixture would result in a neutral overall impression (white or grey). This insight of Goethe's was shared even by his fiercest critics.²⁰ It has held its ground to the present day,²¹ although we now tend to avoid postulating absolute aesthetic norms. I will return to this point at the end of my paper.

IV. A Curious Discovery in Japanese Colour Wood Prints

So, in my view, Goethe was wrong to ascribe a fundamental *scientific* role to the border spectra, while he was right to claim that their colours and the relationships between them are *aesthetically* prior to those of the Newtonian spectrum.

But did Goethe's aesthetic insights into colour harmony have any impact on the visual arts of his time and of the generation that followed? I have not yet systematically pursued this question; thus I am far from sure whether many paintings exhibit Goethean colour harmony. In any case, it seems that there is no well-known nineteenth-century Western painting in which the two border spectra are confronted with each other.²² Goethe's favourite spectra are absent in Western art.

Surprisingly, however, they are prominent in numerous Japanese woodblock prints by Hokusai and Hiroshige. The pictures I want to discuss were created between 1830 and 1860. They all show magnificent views of the Japanese countryside – famous tourist sites, as it were. Each of these landscape paintings was printed with up to ten carved wooden blocks, one for each colour. They depict various places, events and seasons, and employ different types of composition, but they all exhibit vibrant colours and have one further aspect in common: their way of representing the sky.

19 Goethe 1808/1955, §803–§815, esp. §810.

20 See e.g. Young 1814, 433–439.

21 For example, they made their way into the works of Johannes Itten, a colour theorist who is still influential today (see Wagner 2012, 19–20).

22 An abstract painting consisting only of the two border spectra S_C and S_W would exhibit colour harmony (according to the test mentioned at the end of the previous section). Of course paintings in which these colours are distributed differently (though in suitable proportions) could also pass the test; thus non-abstract paintings could also exhibit colour harmony.

The pictures in question feature a schematic sky marked by four horizontal, strictly parallel lines of colour. These colours are remarkable – they align precisely with those of the first, cool border spectrum S_C :

black

blue

turquoise

white



Fig.3: Hokusai "People Crossing Bridge" (c. 1834).

My oldest example is a woodblock print by Hokusai (shown in Fig. 3). At first sight, the black stripe at the upper edge of the image appears to constitute some sort of frame, but as this uppermost colour does not continue along the other three edges, it must belong to the content of the print rather than to its frame. Immediately below, there is an horizontal stripe of dark blue, bordering a turquoise stripe. The border between these two bluish bands is blurred, but it is noticeable that the transitional area of intermediate hues is quite narrow and does not appear

to be emphasised.²³ Finally, below the turquoise stripe, there is a broad band of white which occupies the largest part of the sky and has been created by simply leaving the paper in its original, uncoloured state.

This print is not an exceptional case, see e.g. Fig. 4. Both Hokusai and Hiroshige produced many others with skies coloured in a similar manner. Their decision to depict the sky in this way seems peculiar – even more so if one takes into account that in real life both the sky's spatial composition and its colours look quite different.

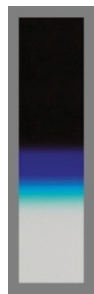


Fig. 4: Hiroshige "Sugatami Bridge, Omokage Bridge and Jariba at Takata" (1856–58).



Let me demonstrate this first for the odd way in which Hokusai and Hiroshige organise the space of the sky, its topology. The sky does not usually offer a very tidy impression, and

²³ The transition, both blurred and at the same time abrupt in the print, is mirrored by the surprisingly sharp colour transition in prismatically produced border spectra, see Jennings 2010, 12 (Figure 8). The fact that Hokusai's colours nonetheless appear to blend into each other may have to do with a certain printing technique called *bokashi*, by which different colours are applied in different strengths to the same area of the printing block (Harris 2010, 31–2).

certainly not one of strictly parallel horizontal stripes. Rather, it is scattered with various amorphous shapes: clouds of all kinds alternate with areas of blue, blending into one another or mixing with veils of haze.²⁴ Only in clear blue weather and at night does the sky become tidier: uniformly blue or black (with small gaps for sun, moon and stars).

This brings me to differences in colour between our usual sky and that of the print: it is hardly ever the case that the upper part of the sky is black while the lower part is white. During the day, the sky seldom contains any black (and especially no geometrical black stripe); and at night it is never white. Furthermore, turquoise and blue areas do not tend to sit next to each other in a strictly parallel configuration. Are there exceptions? In other words, are there other woodblock prints with unrealistically coloured skies that do not echo the cool border spectrum? Yes. In some cases the geometry matches that of the spectrum, while the colours have been changed; that may well be interpreted as a deliberate breach of convention, see Fig. 5.²⁵

Fig. 5: Hiroshige "Suwa Bluff in Nippori" (1856).



24 Clouds or banks of fog do seem to occur in two of the prints from my sample, but – surprisingly – under the sky rather than in it, see Fig. 3 on p. 8 and Fig. 4 on p. 9.

25 Compare also Hiroshige's print "View of Nihonbashi Tori-itchome", in Trede/Bichler 2010, 118–9 (in each case with violet aubergine hues instead of blue). Also see Hiroshige's print "Fuji über dem Nebel des Flusses Tama", Forrer 1991, Image Nr. 14 (without turquoise).

V. Japan in Splendid Isolation?

As has become apparent in the previous section, we can be fairly sure that the border-spectral colours in the skies of Japanese woodblock prints are not meant as realistic depictions of the atmospheric colours. Why and how, then, did the cool border spectrum S_C end up on so many of Hokusai's and Hiroshige's works? Given their dates, Hiroshige (1797–1859) may well have borrowed these colours from Hokusai (1760–1849). There are earlier prints by Hokusai featuring the spectral colours than by Hiroshige. So in the first instance the mystery concerns the older one of the two artists.

The relevant woodblock prints by Hokusai date from between 1830 and 1849. These two decades formed the end of a long period in which Japan had isolated itself from the Western world; it was not until 1853–54 that American Commodore Matthew Perry used American maritime strength, and ungentlemanly tactics, to force the Japanese to open their markets to trade with the West. The isolation in the previous decades, however, was never perfect.²⁶ Let us, therefore, look at a few of the loopholes through which Goethe's border spectra may have entered Japan.

To begin with the most straightforward issue: Goethe's *Farbenlehre* was almost certainly not received by the Japanese between 1830 and 1850. Goethe's name makes its first appearance in Japanese writing shortly after 1870.²⁷ His *Farbenlehre* is not mentioned until twenty-three years later.²⁸

Newton's *Opticks* may have reached Japan earlier, but that is of little importance; the *Opticks* touch on border spectra only in the small print, and unlike Goethe's writings, they do not provide any colour plates. It would be a remarkable coincidence if a Japanese artist (or someone close to him) had paid careful attention to Newton's description of phenomena that Newton thought insignificant and theoretically complex (see Fig. 6). If there had been any influence of Newton's *Opticks* on Japanese art, then it should have resulted in works featuring

26 Screech has conclusively debunked the widespread myth that Japan was completely cut off from Western influence before 1853–54, see Screech 2002, 1, 3, 8, 11, 13 *et passim*. Still, exchange between the West and Japan was greatly impeded. (Some of the prints by Hiroshige I am using as examples were created after 1853–54 and not long before his death in 1858. This short temporal overlap does not seem significant for my riddle – especially as Screech has repudiated the myth of Japanese isolation.)

27 It turned up in the Japanese translation of John Stuart Mill's *On liberty* (see Kimura 2001, 127).

28 It occurred in the Japanese Goethe monograph by Isaku Takagi, who followed an English Goethe biography by James Sime. I owe this information to Naoji Kimura, who authored the new Japanese translation of the didactic part of Goethe's *Farbenlehre* in the Ushio-edition (p.c. from 16 March 2012). See Kimura 2001, 86, Sime 1888, 130–1.

the Newtonian spectrum S_N – the centrepiece of Newton's theory. But Hokusai and Hiroshige did not even print the rainbow in Newtonian colours.²⁹

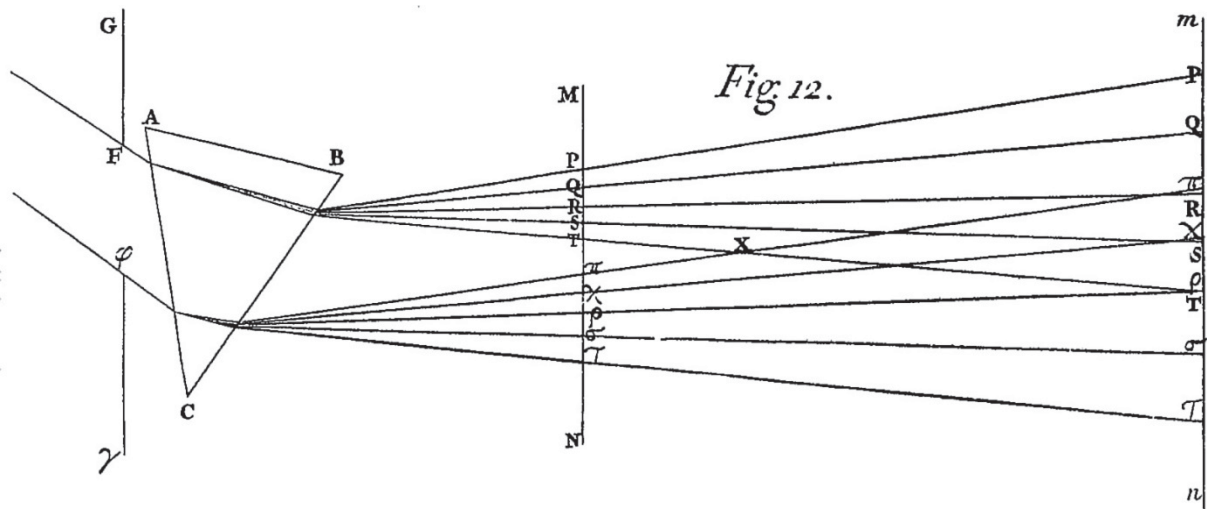


Fig. 6: Newton's schematic explanation of the border spectra.

So far we have a negative result: Hokusai's idea of incorporating the colours of the cool border spectrum S_C in his prints can hardly stem from reading Goethe's or Newton's works. But might Hokusai (or his circle) have come across the border spectra through optical experiments? This possibility might seem plausible if he had had access to prisms. But so far I have found no reliable evidence for the existence of prisms in Japan at that time. From 1609 onwards, the Dutch East India Company VOC (*Vereenigde Oostindische Compagnie*) had permission to establish a small trading base on an artificial island in the bay of Nagasaki. While other official Western trading stations were not permitted at all, the traders of the Dutch station were strongly constrained in their movements. Only three Dutchmen were allowed to (and had to) travel to Edo each year, and only for two weeks at a time – this was called the *hofreis* and it included the leader of the trading station as well as the physician.³⁰

Interaction between Japan and the West was far from easy, but it went on for centuries. Scientific writings reached Japan via the Dutch island.³¹ Moreover, the medical skills of the Dutch physicians were sought after by the Japanese; the physician would often be engaged in

29 See Hokusai's print "Vogel aus 'Malereialbum des alten Manji, ehemals Hokusai' ", in Seiji 2011, 418 as well as Hiroshige's print "Ushimachi in Takanawa", in Trede/Bichler 2010, 192–3.

30 Screech 2002, 15–6.

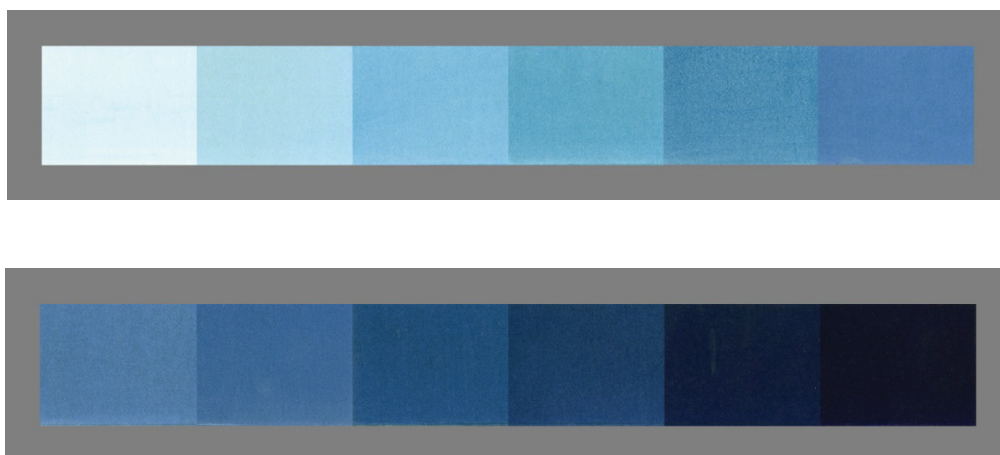
31 Such writings are documented in lists of imported books, e.g. the list of books imported to Japan by Philipp Franz von Siebold, a German physician and founder of Japanese studies (see Takeuchi 1983, also see Kimura 2001, 403–405). Neither Newton's *Opticks* nor Goethe's *Farbenlehre* are mentioned in this list; but it does contain two works of physics that one would have to examine for optical content (Kastner 1820; Parrot 1811).

scientific discussions during the *hofreis*, and optics may well have been the topic of some of these discussions (if the physician was suitably specialised).³² Finally, Western scientific instruments – especially optical instruments, such as mirrors, glasses, magnifying glasses, microscopes and telescopes – entered Japan in large quantities. None of the published reports of the VOC mention any prisms,³³ and it is unlikely that any were produced in Japan.³⁴

VI. Open Questions

So how did the colours of the cool border spectrum S_C end up on Japanese woodblock prints? This question has to remain unanswered here. Constraints on space do not even allow me to mention all the pertinent conjectures, so I will sketch only one of my various hypotheses.

Around 1830, the Japanese print industry was caught up in a craze in which the imported artificial pigment *Berlin blue* played a key role.³⁵ Depending on its concentration, the pigment can appear in all shades of blue, ranging from turquoise to dark blue – even violet and shiny black:



32 The Dutch physicians had a high standing in Japan because of their knowledge of ophthalmology, a discipline that had been neglected in Japanese medicine (Screech 2002, 166–170). Siebold, for example, was quite successful in practicing ophthalmology in Japan and was even called a miracle doctor (Kimura 2001, 401). His interests in this area might well have gone hand in hand with knowledge of Goethe's *Farbenlehre* (this is suggested by Kimura 2001, 127, 392, 394–402). One would have to look for similar evidence in connection with the other Dutch physicians, especially with those who had studied at German universities (some names are given by Kimura 2001, 374).

33 Two editions of such lists have been published so far, see Bachofner *et al.* 1992 and Blussé *et al.* 2004. As these editions cover only the period until 1800 it is conceivable that the Dutch imported prisms after the turn of the century. A negative result in this search should not be given too much weight, however, as the official records of the VOC only show a small number of the numerous Western items that arrived in Japan (e.g. through smuggling), see Screech 2002, 11.

34 Books on glassmaking did reach Japan through the VOC; this led to the first Japanese production of glass (Screech 2002, 133). But I have found no evidence that the Japanese produced their own prisms. However, they quickly acquired the second part of Newton's experiments: *camera obscura* in various sizes, even as darkened rooms in which one could move freely (Screech 2002, 56–60, 172).

35 In English, the pigment in question is often called "Prussian blue". For details see Smith 2005.

The protagonists of the blue craze, Hokusai among them, produced prints using only Berlin blue, and discovered the expressive power of the pigment. My hypothesis, then, is that at the height of the craze Hokusai may have started depicting the sky using nothing but Berlin blue. In appropriate concentrations, the pigment resulted in two colours (turquoise and dark blue). For aesthetic reasons it was natural to round off this effect with white below and black above.³⁶ Let us assume that Hokusai was aesthetically satisfied with the effects he achieved. Then we might conjecture that he repeated the original accidental result deliberately again and again. He may even have started a trend, which was joined by Hiroshige later on, see Fig. 7.



Fig. 7: Hiroshige "Otonashi River Dam, Oji, Popularly Called 'Great Waterfall'" (1856–58).

In short, the greatest visual artist of Japan used artistic means to discover and canonise a combination of colours which the greatest British physicist had previously discovered and explained away with scientific means, and which the greatest German poet then rediscovered and scientifically reassessed for aesthetic reasons (though without success).

³⁶ Here is an appealing speculation: white would correspond to Berlin blue in zero per cent concentration and black to maximal concentration. (Of course the black end of the sky could be realised with pigments less costly than Berlin blue.)

To be sure, I have just used two clichés; but they may well contain a grain of truth. The first is that of congeniality between Japan and Germany: Goethe and Hokusai *contra* Newton.³⁷ According to the second cliché, Japanese tend to use scientific discoveries for the sake of edification, while Europeans use them for tougher goals: so we have the Japanese use of gunpowder for fireworks as against the European use of it for artillery, and the Japanese use of Western precision instruments for amusement and for spiritual education as against their European use for science and commerce.³⁸

Instead of considering how much truth there is in such clichés, let us take a step back and look at the many open questions that remain. Which East Asian artwork was the first to feature a sky coloured as in the woodblock prints discussed? Did these atmospheric colours really consist purely of different concentrations of Berlin blue? How many of his skies did Hokusai depict in the colours of the border spectra? Were there really no prisms in Japan before 1830? Had the phenomenon of refraction in lenses been understood in the country? How strong were the chromatic aberrations of the optical instruments imported to Japan from the Netherlands? Was the colourful internal structure of these chromatic aberrations distinct enough to show a noticeable difference between blue and turquoise? Was Hokusai or his circle well versed in Western science? How much of Newton's work was known in Japan at that time? When did Japanese scientists understand the phenomenon of chromatic aberration? What did Hokusai know about Goethe? Are there any clues in his writings about why he coloured the sky in the way that he did?³⁹ How much contact did Hokusai have with Europeans?⁴⁰ How close were his relations with German members of the VOC, especially with Siebold? What did Siebold know of Goethe's *Farbenlehre*? How close were Hokusai's relations to the protagonists of the so-called Dutch studies, who were concerned with Western writings? From what moment on was Japan in contact with Western books on prisms, Newton's spectrum or even the border spectra? Questions upon questions; let me finish my paper with a colourful surprise.

37 There are a number of indications of congeniality between Goethean science and Japanese culture; just take note of facts about Japan highlighted by Screech and compare them with some of the known characteristics of Goethe's research on colour. See Screech 2002, 2, 42, 43, 172, 235 as well as Schöne 1987.

38 Examples are provided by Screech 2002, 10–11, 189–90, 200, 202, 208, 211, 233.

39 To answer this question one would have to examine his numerous writings, particularly the treatise on colour (Hokusai 1848/2008). Here, Berlin blue is called *bero*; Hokusai recommends this pigment e.g. for shadows (Hokusai 1848/2008, 68) or for depicting the pupils of birds (according to Retta 1994, 240–41). Furthermore, he recommends the pigment's variety of nuances (Hokusai 1848/2008, 153, 190, 230–31). On p. 152, Hokusai talks explicitly about the colouration of skies.

40 He drew their residence in Edo, received commissions there and must have been a frequent visitor – otherwise there could hardly have been rumours that he was spying for the Dutch (Screech 2002, 17 and note 58 as well as Screech's Figure 3).

VII. Outlook for Aestheticians

You may have noticed that in the last three sections I have been concerned only with the cool border spectrum S_C . How about its twin of warmer colours, the complementary spectrum S_W ? If the colourful Japanese skies have anything to do with Western science, should there not be prints with warm atmospheric colours?

The surprise is that some of Hiroshige's prints fit the bill. While he does not use strictly *geometrical* stripes of yellow and red as often as their blue and turquoise counterparts from S_C , their existence can hardly be denied; see, for example, Fig. 8. The upper cool border spectrum is perfectly balanced by the warm border spectrum on the horizon, which in turn is opposed by the cool border spectrum in the water. This beautiful print is my trump card – it contains everything that was nearest and dearest to Goethe.



Fig. 8: Hiroshige
"The Moto Hachiman
Shrine at Sunamura"
(1856).

In my view this small sensation supports the following conjecture: if Hiroshige did not know about the European empirical and theoretical basis of the two complementary border spectra

then he must have discovered the warm border spectrum S_w by himself. And he must have done so via *aesthetic* means. He felt that the existing colours of the cool border spectrum S_w call for a colourful counterpoint; his artistically trained eyes demanded the warm complementary colours, as exhibited in Fig. 9.

If that is what happened, it speaks for Goethe's aesthetics of colours. According to the poet, we appreciate balanced colour harmonies in which every colour is augmented by its complement. Goethe's aesthetic advice applies far beyond the culture in which it originated. Weimar is everywhere.



Fig. 9: Hiroshige "Inside Kameido Tenjin Shrine" (1856–58).

Appendix

A. Bibliography

This list contains some entries that are not cited in the text, but that would be relevant for further research.

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B. Figures (repeated; enlarged and described)

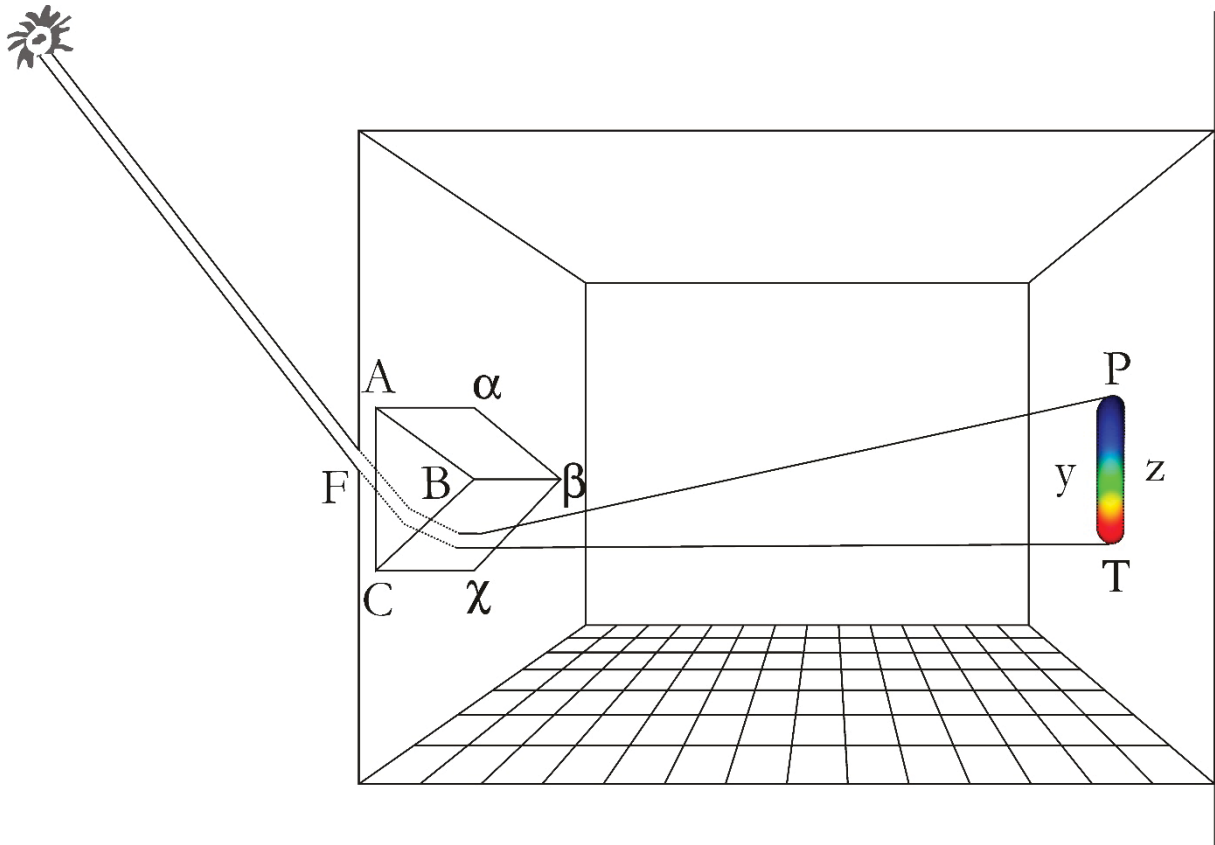


Fig. 1: Newton's basic experiment (1666-1668). Rays of sunlight are sent through a hole in the window shutter F into a prism. The light is refracted and split into its multi-coloured components. [Diagram by Matthias Herder and Ingo Nussbaumer, based on a black and white drawing in Newton's sketchbook].

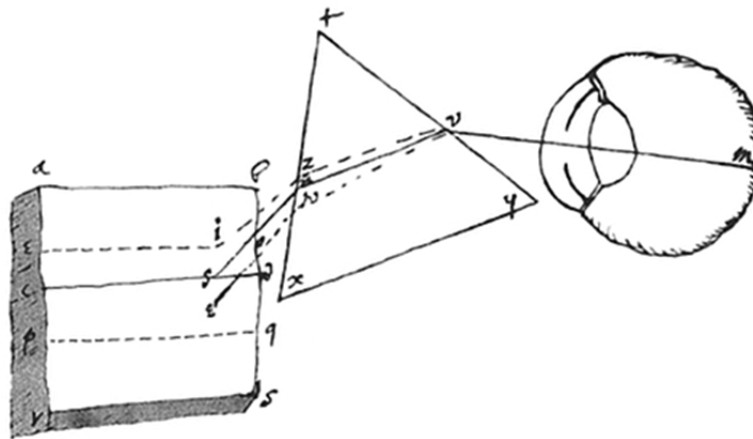


Fig. 2: Newton's first subjective experiment (1665). Newton is looking through a prism at an image that is one half white and one half black; the changes in colour that appear at the border lead either to border spectrum S_C or to its warm counterpart, border spectrum S_W – depending on the orientation of the image. [The original drawing is from Newton 1983, 122r].



Fig. 3: Hokusai "People Crossing Bridge" (c. 1834). Four parallel stripes of colours are depicted in the sky (above the top of the dark green mountain on the horizon): black, dark blue, turquoise, white. [From Forrer 1994, G204].



Fig. 4: Hiroshige "Sugatami Bridge, Omokage Bridge and Jariba at Takata" (1856–58). The atmospheric colours are the same as in Fig. 3; Hiroshige has added a yellow stripe above the horizon and (just above the centre of the image) even a red stripe, which is reflected in the water. [From Trede/Bichler 2010, 262–63].



Fig. 5: Hiroshige "Suwa Bluff in Nippori" (1856). This is one of the exceptional cases where dark violet replaces dark blue as an atmospheric colour; the entire print contains no turquoise or yellow, and has thus been moved away from yellow ("un-yellowed", so to speak). [From Trede/Bichler 2010, 60/1].

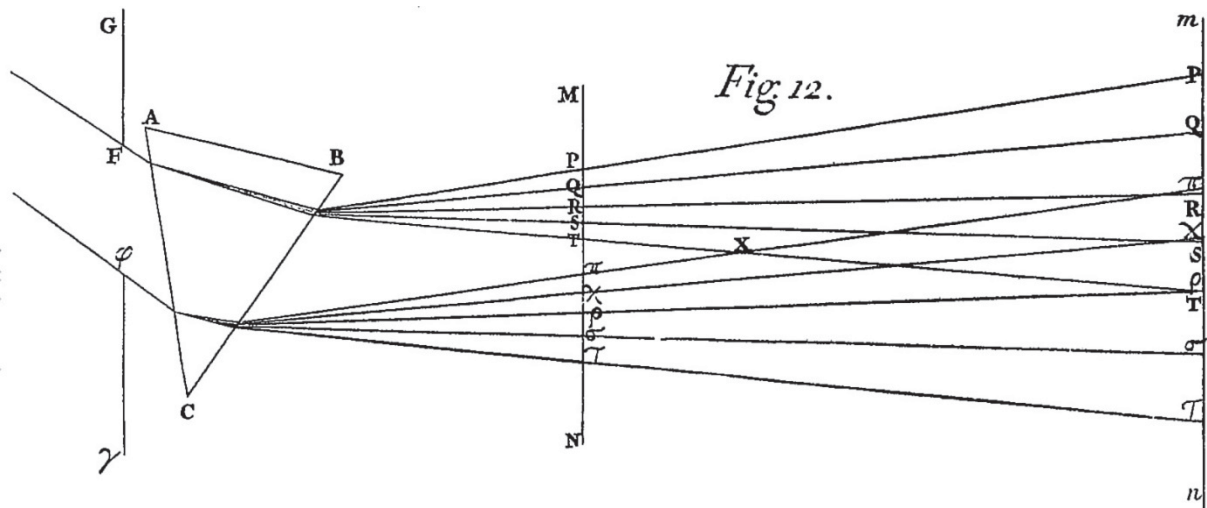


Fig. 6: Newton's schematic explanation of the border spectra. A broad white bundle of rays of white light passes through the hole in the window shutter $F\phi$ and enters prism ABC . Where it leaves ABC , five broad and diversely coloured bundles of rays appear, which continue in slightly different directions: the (blue) bundle of rays $PP\pi\pi$ is refracted the most, the (red) bundle of rays $TT\tau\tau$ is refracted the least; the other three bundles of rays lie somewhere in between. In the centre of the nearby screen NM all of these bundles of rays are superimposed and add up to a white appearance (between T and π); neither the red bundle nor the yellow bundle reaches the area above the centre, which explains its bluish appearance (accordingly for the area below the white centre). [In Newton's writings this figure is called "Fig. 12" (Newton 1704/1964, Lib. I Par. II Tab. III). Mirrored rendering by Matthias Herder].



Fig. 7: Hiroshige "Otonashi River Dam, Oji, Popularly Called 'Great Waterfall'" (1856-58). The atmospheric colours are the same as in Fig. 3; Hiroshige has added a red stripe above the horizon (and even some yellow on wooden or bamboo structures slightly above the centre of the image). [From Trede/Bichler 2010, 68-69].

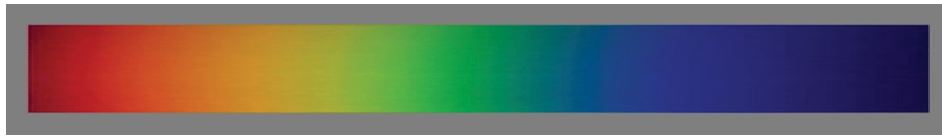


Fig. 8: Hiroshige "The Moto Hachiman Shrine at Sunamura" (1856). A bold cool border spectrum occupies the top of the print; above the horizon one can see the following less bold, but still distinct colours: white, yellow, red, greyish black. [From Trede/Bichler 2010, 88/9].

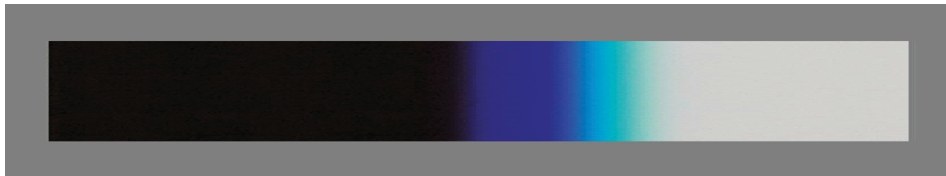


Fig. 9: Hiroshige "Inside Kameido Tenjin Shrine" (1856–58). One half of the warm border spectrum has moved to the upper edge of the print (red), the other is curved over the bridge railing. The psychedelic colours below the bridge ridicule any colour realism. [From Trede/Bichler 2010, 160–61].

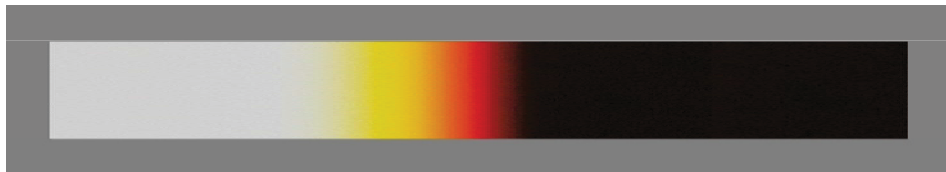
C. Colour Samples (repeated; enlarged)



Newtonian spectrum S_N . [Photo by Ingo Nussbaumer, cropped by Matthias Herder].



Cool border spectrum S_C . [Photo by Ingo Nussbaumer, cropped by Matthias Herder].



Warm border spectrum S_W [Photo by Ingo Nussbaumer, cropped by Matthias Herder].



The two border spectra as complements. [Photo by Ingo Nussbaumer, cropped by Matthias Herder].



Berlin blue in six low degrees of concentration.
[Colour sample from Muntwyler, 2010, 59; cropped by Matthias Herder].



Berlin blue in six high degrees of concentration.
[Colour sample from Muntwyler, 2010, 59; cropped by Matthias Herder].

D. Acknowledgements

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E. Origin of Figures and Colour Samples

The woodblock print in Fig. 3 is reproduced by kind permission of the Baur Collection, Musée des Arts d'Extrême-Orient (Geneva). The woodblock prints in Fig. 4, 5, 7-9 are reproduced by kind permission of Nobuko Kotani of the Ota Memorial Museum of Art (Tokyo). The spectra are reproduced by kind permission of Ingo Nussbaumer; the Berlin Blue colour samples are reproduced by kind permission of Stefan Muntwyler.