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ESSAY REVIEW

THE INVENTION OF THE TELESCOPE

The Long Route to the Invention of the Telescope. Rolf Willach (*Transactions of the American Philosophical Society*, xcviii/5; American Philosophical Society, Philadelphia, 2008). Pp. x + 116. $35. ISBN 978-60618-985-6.

Willach's work first reached wider audiences at a 2001 symposium, at which he described his efforts to move the history of the telescope beyond textual analysis by conducting careful investigations of surviving artifacts. He has since examined optical objects all over Europe and, in conjunction with readings of key optical texts, he has carefully developed the dramatic account presented in the current volume. His story traces several key episodes in the development of optical aids that, by his analysis, led to the telescope's appearance in 1608. He begins with the use of rock-crystal reading stones in the early Middle Ages, continues with an account of the spread of reliquaries in the high Middle Ages, which he claims led to an increased use of the magnifying effect of crystal coverings placed upon them, addresses the emergence of spectacle lenses in Italy at the end of the thirteenth century, and concludes with a summary of the evolution of glass- and lens-making techniques over the next several hundred years. While many of the details he relates remain somewhat sketchy, an issue to which we will return, his account makes an extraordinary and valuable contribution to the history of astronomy and its material culture.

Historians and casual readers will note many instances of the most troubling aspect of Willach's tale: the fairly regular use of "logical assumptions" when evidence is lacking — see, for example, twice on page 19 alone, or "there can be only one explanation for such inconsistencies" (p. 53). Such locutions appear dozens of times. Because historians typically avoid such language and evict it from their students' writing, its frequency here will make some readers suspicious, frustrated, and perhaps even prone to dismiss the conclusions of Willach, an optical engineer and independent scholar.

Admittedly, this language is problematic and yet, I submit, refreshing. It is problematic for familiar reasons. Humans do not always, or perhaps even often, act with reason: the historian's task is to weave tales recounting what people have done, not what they should have done or could have done had they behaved or chosen logically; historical events usually turn out to be more complex and unexpected than one might anticipate or want them to be. The burden of proof on historians and other scholars is to provide compelling evidence in favour of their thesis, and not to suggest possible claims for others to support or refute. In Willach's defence, however, the story he tells covers many centuries and disciplines, and requires expertise beyond that embodied in any one scholar. That will lead some readers to object to his or anyone's telling the story told here. There is simply no explicit evidence, at least not yet known, for many of the claims and episodes in the trajectory leading up to the invention of the telescope; Willach has given, for the first time, a road map for telescope historians

and their collaborators to locate diverse sources that might shed light on the development of this significant instrument. Conversely, Willach's story is refreshing in that he makes very explicit his assumptions and gaps of evidence, avoiding the masking techniques that many of us use all too frequently to cover our tracks.

Willach's innovative approach appears on the first page, where he defines a telescope as "an optical system whose resolution of distant objects is superior to what one would see with the naked eye". This is an intriguing suggestion, as it avoids such technical anachronisms as "a focal system" or its variants, many of which make use of a modern understanding of optics not available in 1600. His emphasis on resolution — on whether or not an instrument allows one to see distant details not visible to the naked eye — rather than on magnification, lens type, or lens arrangement has many virtues. In particular, it enables Willach to avoid basing his conclusions on many pre-1608 rhetorical claims of telescopic invention (see Eileen Reeve's *Galileo's glassworks* for an extensive compilation of this literary topos) and instead to rely on physical and optical evidence, his own area of considerable expertise.

In the end, we want evidence, and evidence Willach gives in abundance. We learn of glass-making recipes, grinding and polishing techniques, and the uses of optical aids that preceded the invention of the telescope. His resulting account is also an excellent example of how to use easily understood and compelling visual evidence without resorting to technological overkill and unnecessary detail. While there are many merits to careful wavefront analysis, interferometry, and other techniques of modern physics, Willach chooses to demonstrate the quality of optical artifacts by using a simple yet illustrative technique developed a century ago by Vasco Ronchi, who applied it to his own investigation of the telescopes in Florence associated with Galileo. Willach's empirical technique is inexpensive and portable, allowing examination of artifacts in their current location, illuminating the optical performance of the entire range of optical aids examined in his account, and producing a helpful, visually compelling comparison of the optical assistance provided by crystals, eyeglasses, and telescopes.

The English version of Willach's thesis first appeared in September 2008 in Middelburg, at a conference celebrating the 400th anniversary of Lipperhey's unveiling of his telescope. There, Willach repeated the conclusions he had first made public in German in May 2007 on the occasion of the celebration of pre-eminent telescope historian Rolf Riekher's 85th birthday and which appeared in print in the *Festschrift* edited by Jürgen Hamel and Inge Keil, *Der Meister und die Fernrohre: Das Wechselspiel zwischen Astronomie und Optik in der Geschichte* (*Acta historica astronomiae*, xxxiii). His thesis answers the question behind Albert van Helden's evocative observation that appears on the back cover of (and in the foreword to) Willach's book: "In the summer of 1608, no one had a telescope; in the summer of 1609, everyone had one." How was this possible?

Willach's solution to this riddle is straightforward and compelling. Elsewhere, he has shown that whereas the eye makes use of just 5 mm or so of a spectacle lens, the image produced by a telescope objective is formed by its entire aperture. Thus only about 5 mm of a spectacle lens needs to be shaped with a consistent radius of

curvature, but for a telescope objective, the entire usable portion must feature the same radius. Willach argues that while lens grinders in the sixteenth century could consistently make eyeglass lenses to such limited specifications, they could not do so over the 10–20 mm diameter of these lenses. Using Ronchi tests of early spectacle lenses and combining these lenses with a modern eyepiece, Willach demonstrates that prior to 1600, anyone putting together lenses (say, one for near- and the other for far-sightedness) to make a "telescope" might see an enlarged image but not one with greater resolution, and would thus see little merit in putting together lenses for any useful purpose. The key final step to the telescope's invention, Willach argues, consists in masking or stopping down the aperture of a good-quality objective lens, creating a central zone of reasonably consistent curvature that, in combination with an eyepiece, yields an image with greater resolution than that provided by the naked eye.

Several dozen historians experienced Willach's compelling demonstration of his thesis at that conference in Middelburg and saw for themselves the dramatic impact of the aperture stop placed over a telescope objective lens. The fewer than two dozen surviving telescopes made prior to 1650 provide convincing evidence for Willach's optical argument. Moreover, a previously unknown telescope, likely dating to 1628 or earlier, that a colleague and I discovered in Germany in 2006, offered the chance for a double blind test. The Ronchi test of its central and peripheral regions was in accord with Willach's claim, which until then he had put forth only in private. Willach's claim also helps to explain the rapid spread of the telescope after its first public appearance in 1608 and the reason for the failure to award a patent to Lipperhey or another claimant. Once people knew the simple trick to stop down the lens, anyone could take widely available spectacle lenses, choose the best among them, and produce a telescope using a suitably made objective stop. With the demise of Middelburg's archives in the Second World War, hopes of finding textual evidence of Lipperhey's mention of this innovation (if any existed) seem unlikely to be realized.

Of course, it would be nice to have some explicit textual documentation about the crucial role of the aperture stop and other claims in this volume. Although Willach cannot provide that, he has given us suggestions for identifying very specific sorts of evidence for investigating the pre-history of the telescope. As we continue to look in various archives and at more early lenses and telescopes, we have a bold hypothesis with many contributing claims to confirm or disconfirm.

Whether or not in the end Willach is correct, and I do believe that he is fundamentally correct, he has developed the most exciting thesis on the development of the telescope to appear in decades and he deserves much credit for his bold and carefully proposed and illustrated conjectures. Willach has done superb work in applying his optical and experimental expertise to questions concerning the origins and evolution of the telescope. With this assemblage and sequence of a wide range of evidence over many centuries, Willach's volume will inform any serious early telescope scholarship for the foreseeable future, and should be read by anyone interested in the origins of the telescope.

Adler Planetarium & Astronomy Museum MARVIN BOLT