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OPTICS

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The science of "aspects" or "appearances" (*ʿelm al-manāẓer*), as optics was called in the Islamic Middle Ages, has a long and impressive history in both Arabic and Persian. The disciplinary, theoretical, and methodological developments of optics as the study of "direct" and "indirect" vision (*manāẓer*, "ordinary vision;" *marāyā*, "mediated vision," as in Greek *Optika* and *Catoprika*), and its relation to neighboring fields such as surveying (*masāḥa*), are treated elsewhere (Sabra, 1987, p. 376; Kheirandish, 2003, pp. 57-58). The present article focuses on specific aspects of the Persian optical tradition, beginning with a framework for identifying Persian scientific traditions as distinct from their Arabic counterparts.

Identification. The expressions "Islamic," "Arabic," or "Persian" science, commonly used to underscore the respective provenance of elements such as the *Islamic* state, *Arabic* language, or *Persian* institutions in the development of scientific traditions (Gutas, pp. 28-60; Sabra, 1996, pp. 655-57; Saliba, pp. 126-27 respectively) are acknowledged as largely problematic due to the many linguistic, ethnic, and geographic overlaps involved (Yarshater, pp. 4-13; Kheirandish, Bier, and Yousefi, pp. 433-34). But the Persian tradition of sciences such as optics may still be identified with reference to at least three distinct categories: the text's language of composition, the author's ethnic association, and the subject's geographic specifications. In terms of language, optical treatises of various lengths and merit were composed in Persian in both early and later periods, forming a corpus of Persian texts distinct from

the more standard case of the Arabic optical tradition (Kheirandish, 1998, pp. 130-36). The ethnicity of the authors is another distinct category for Persian and non-Persian texts alike. Authors of Persian origin writing on optics in Arabic range from Ebn Sinā (see AVICENNA, d. 1037) and Šahāb-al-Din Sohravardi (d. ca. 1191) from the eleventh and twelfth centuries, to Naṣir-al-Din Ṭusi (q.v.; d. ca. 1274) and Qoṭb-al-Din Širāzi (d. 1311) from the thirteenth and fourteenth centuries, to the far more scientifically advanced case of Kamāl-al-Din Fārsi (Fāresi; d. ca.1319) slightly later.

As for geographic specifications, local parameters are especially relevant to the case of optics, a field whose transmission through Persian lands is a particularly notable aspect of its development, among other outstanding features (see below).

Language. The Persian optical tradition (*manāẓer*), and its bordering traditions of catoptrics (*marāyā*) and surveying (*masāḥa*), generated a long list of works in Persian, mostly as independent compositions rather than Persian translations from Arabic. In the case of optics, known works range from the treatise "Ray" (*šoʿāʿ*) by Naṣir-al-Din Ṭusi, the director of the Maragha (Marāḡa) Observatory, to "Vision" (*ebsār*) by Ḡiāṯ-al-Din Manṣur Daštaki (d. ca. 1541; see DAŠTAKI AMIR SAYYED MANṢUR) after whom the "Manṣuriya School" (Madrasa-ye Manṣuriya) in Shiraz was named. A few combined "Optics and Catoptrics" (*Manāẓer o marāyā*) works include an anonymous Persian text with an Arabic title (ca. 1512-20; see below), one composed by Qāsem-ʿAli Qāyeni (ca. 1661) who belonged to a circle of instrument makers, and another by Qāżi Ḥosayn Jonpuri (d. 1867) as part of his *Jāmeʿ-e Bahādor-ḵāni*, with citations from a number of unknown Persian works. Other Persian optical works include *Rafiʿ al-baṣar* by Rafiʿ-al-Din Khān (d. 1877) composed slightly later, and *Manāẓer-e torābiya*/*tanwir al-ʿoyun* by Torāb-ʿAli Bolandšahri (Kheirandish, 1998, pp. 130-36), as well as earlier surveying texts such as *Ertefāʿ* by Badr-al-Din Ṭabari (ca. 1420; Kheirandish, 1999, I, pp. xlv-lxi).

Ethnicity. There are a number of optical texts by authors with a Persian ethnicity or association. The earliest is Abu Saʿd al-ʿAlāʾ Ebn Sahl at the Persian Buyid court (945–1055), better known for his early conception of the "sine law of refraction" and burning mirrors (Rashed, 1990, pp. 464-68; 1993; 2005) than his work on optics proper (Sabra, 1989, pp. lix-lx; 1994). Ebn Sinā also discussed theories of vision directly (Lindberg, pp. 43-52). He did not, however, write independent works on optics as did his contemporary, the celebrated author and native Arabic speaker Ebn al-Hayṯam (Latin: Alhacen or Alhazen;

d. ca. 1040; Sabra, 1989, 2 vols.). Other Persian authors on optics include Šahāb-al-Din Sohravardi (ca. 1154-91) who, like Naṣir-al-Din Ṭusi, and Qoṭb-al-Din Širāzi after him, wrote on the subject in both Arabic and Persian, but integrated into his works philosophical traditions such as the Illumination theory (see ILLUMINATIONISM), rather than the mathematical traditions of Ṭusi and Širāzi (Kheirandish, 1998, pp. 130-36). But by far the most impressive of the optical authors of Persian origin is Kamāl-al-Din Fārsi whose monumental commentary on the *Optics* of Ebn al-Hayṯam is only one of many works composed during his productive intellectual life.

Fārsi was a student of Širāzi, himself a pupil of Ṭusi. He wrote his various optical works only in Arabic, the standard scientific language of the time, and is best known for his theory of the rainbow. His theory is comparable in both content and date to that of a European scholar, Theodoric of Freiberg ("Dietrich of Saxony," d. ca. 1310); but in the absence of any available concrete evidence and in depth studies, one cannot at present point to any mutual direct influences (Rashed, 1973, p. 218). Fārsi's study of the rainbow involved methodological, theoretical, and disciplinary leaps. Methodologically, he extended to phenomena such as rainbows, which he explicitly claimed as "a subject properly belonging to optics," the method of "controlled experimentation," by reproducing the effect of sunlight on raindrops through flasks filled with water. Theoretically, he moved away from the Aristotelian explanations of the rainbow in terms of clouds acting as concave mirrors towards a conception of it as the passage of light through transparent spheres (in line with Ebn Sinā, and Fārsi's own teacher, Širāzi), offering explanations based on double refraction that were especially novel in their employment of artificially produced conditions for observation. From a disciplinary standpoint, he also broke with tradition when he argued for the inclusion in optics of the "notions of light, shadow, darkness, transparency, opacity and the ray... extension of certain lights (...through apertures to opposite surfaces)." (Fārsi, *Tanqiḥ*; Sabra, 1989, II, p. lxii).

Fārsi's own *Optics* was an entire corpus in itself. It contained a commentary on the seven books of Ebn al-Hayṯam's *Optics* (*Tanqiḥ al-manāẓer*) and a conclusion on refraction, a problematic subject that according to Fārsi's preface had attracted him to the field. In addition, it included his commentaries on three independent treatises composed by Ebn al-Hayṯam: "On the Quality of Shadows," "On the Form of the Eclipse," and "On Light," as well as an examination of his treatises "On Burning Spheres" and "On the

Rainbow and Halo," together with Fārsi's own treatment of those topics (ibid., p. lxxi). Less known works by the same author include *Al-Baṣāʾer fi ʿelm al-manāẓer*, a summary based on his *Tanqiḥ*, and a recently discovered "*Fi kayfiya żawʾ al-šams fi'l-hawā*" (through a manuscript dated 721/1321, a few years after the author's death date). This little known treatise on the "manner of solar propagation in the atmosphere" contains, besides occurrences of the concept of experimentation (*eʿtebār*), references to comparative examinations, including employment of instruments such as astrolabes (Kheirandish, 2009, pp. 101-2).

Geography. The preface to Fārsi's most important and influential optical work, circulating in the modest format of an optical commentary, contains a long and revealing passage that provides evidence for the discontinuous nature of scientific transmission, particularly in the case of optics. The passage includes explicit references to problematic treatments of subjects such as reflection and refraction in the works of "leading" scholars, and the resulting efforts of his own teacher, Širāzi, to obtain Ebn al-Hayṯam's *Optics* for him from a "distant land" (Fārsi, *Tanqiḥ*; Sabra, 1989, II, p. lxxi; 2007, pp. 131-32). Full explanation of the "puzzles" of Ṭusi's own optical works and its relation to Fārsi's passing mention of "more than one" problematic author may not be possible at present (Kheirandish, 2004). But the discontinuous transmission of optics including treatments of refraction is clear enough from the inaccessibility of a source such as the *Optics* of Ebn al-Hayṯam, a work with a more limited transmission in Islamic than European lands where it had a wide circulation through Latin and Italian translations and a printed edition (Sabra, 1989, II, pp. lxiv-lxxv).

The poor internal transmission of the *Optics* of both Ptolemy and Ebn al-Hayṯam is indicated by other sources, including one in Persian. This is a taxonomic work by Faḵr-al-Din Rāzi (d. ca. 1209), the Persian philosopher and theologian whose related works are not limited to a visual theory that occasioned critical remarks by Ṭusi (Kheirandish, 2008, p. 475). Rāzi's *Jāmeʿ al-ʿolum* (see ENCYCLOPAEDIAS, PERSIAN i. Pre-Modern) is a compendium that, while citing the *Optics* of Ebn al-Hayṯam and "visible properties" of Ptolemaic optics (Kheirandish, 2008, p. 475, n. 23), suggests indirect access to such works, if only by the mis-transcription of the term optics itself as *monāzera* for *manāẓer*.

The transmission of optics in the Persian regions of Islamic lands may itself be usefully contrasted with that of the Arab speaking regions, where Arabic

translation of Greek sources such as the *Optics* of Euclid (3rd Century BCE) and Ptolemy (2nd Century CE) were produced and transmitted next to Arabic compositions like the *Optics* of Yaʿqub al-Kindi (d. ca. 870 CE) and Ebn al-Hayṯam (Kheirandish, I, 1999). With the internally limited circulation of the multi-volume *Optic*s of Ptolemy and Ebn al-Hayṯam, for example, it was through Persian routes that those volumes were transmitted at all. The *Optics* of Ptolemy had the single treatment of one of its five books through a work by Ebn Sahl, a scholar with direct Persian links through both court patronage and scholarly relations, even if he himself came from more obscure origins than his contemporary namesake Abu'l-Ḥasan Ebn Sahl, from the old and notable Persian Nawbakht (Nawbaḵti) family (Rashed, 2005, pp. 1-4, esp. p. 3, n.7). The seven-volume *Optics* of Ebn al-Hayṯam, a work with full access to Ptolemy's *Optics, and* similarly unknown to indigenous scholars as prominent as Ṭusi, referred to as *Ostād-e bašar* (teacher of mankind), was curiously transmitted within Islamic lands through Persian regions at large. The Persian mathematician Fārsi wrote his influential commentary on Ebn al-Hayṯam's masterpiece after his own mentor, Širāzi, saw the great volumes in one of the libraries in Fārs (*fi baʿḍ ḵazāʾen al-kotob be Fārs*), before it was later brought from distant lands (*aqṣā al-belād*; Sabra, 2007, p. 132; 1989, II, p. lxxi).

However puzzling the internal transmission of such works are as compared to their fate in Europe, their very survival is linked to Persian channels that were not limited to compositions by Ebn Sahl and Fārsi, the latter named after his native land of Fārs. The works themselves were produced through specific Persian localities and circles; here the Buyid court and Ṭusi circle, each with various distinct "Persian" elements.

A later period in the transmission of optics further documents Persian elements beyond scholars or patrons with Persian ethnicities or geographical locations. A particularly revealing case is one from the early sixteenth century involving not only 'Persian' language, and place names, but also relevant elements outside Persian borders, including encounters with Europe. Striking details come from an anonymous optical text in Persian (mentioned above), dedicated to the Ottoman Sultan Selim I (r. 1512-1520; Kheirandish, 1998; 1999), a text overlapping with a shorter Arabic version discovered more recently, carrying the name of Saʿd Ebn ʿIsā (better known as Saʿdi Celebi: d. ca. 1529) as a possible author, owner or transcriber (Kheirandish 2009, pp. 102-3, n. 33). Most relevant to the present discussion is a passage in that text on exchanges regarding a mirror (*merʾāt*) of high standing (*ʿaẓim al-šaʾn*)

constructed (*saḵt*) by scholars (*ḥokamā*) from Europe (*farangestān*) and sent to the learned (*ʿolamā*) in Khorasan for the explanation (*bayān*) of its rationale (*ḥekmat*) in the form (sabil) of experience (*tajreba*) and testing (*emteḥān*; Kheirandish 2009, pp. 102-3, n. 34). As such, the late development of optics exposes Persian connections that extend from local practices and practitioners to wider exchanges on optical instrumentation and experimentation with cross-border communities from Islamic to European lands.

Clearly, the development of optics in both Persian and Arabic speaking lands, and their expected distinctions and interactions, involve questions of transmission that are tied to other geographic specifications such as local applications and appropriations, much of which remain subjects for further study.

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