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Comets, meteors, and eclipses: Art and science in early Renaissance Italy

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Abstract–We discuss eight trecento (fourteenth century) paintings containing depictions of astronomical events to reveal the revolutionary advances made in both astronomy and naturalistic painting in early Renaissance Italy, noting that an artistic interest in naturalism predisposed these pioneering painters to make their scientific observations. In turn, the convincing representations of their observations of astronomical phenomena in works of art rendered their paintings more convincing. Padua was already a renowned center for mathematics and nascent astronomy (which was separating from astrology) when Enrico Scrovegni commissioned the famous Florentine artist Giotto di Bondone to decorate his lavish family chapel (ca. 1301–1303). Giotto painted a flaming comet in lieu of the traditional Star of Bethlehem in the Adoration of the Magi scene. Moreover, he painted a historical apparition that he recently had observed with a great accuracy even by modern standards: Halley's comet of 1301 (Olson, 1979). While we do not know the identity of the artist's theological advisor, we discuss the possibility that Pietro d'Abano, the Paduan medical doctor and "astronomer" who wrote on comets, might have been influential. We also compare Giotto's blazing comet with two others painted by the artist's shop in San Francesco at Assisi (before 1316) and account for the differences. In addition, we discuss Giotto's pupil, Taddeo Gaddi, reputed to have been partially blinded by a solar eclipse, whose calamity may find expression in his frescoes in Santa Croce, Florence (1328–1330; 1338?). Giotto also influenced the Sienese painter Pietro Lorenzetti, two of whose Passion cycle frescoes at Assisi (1316–1320) contain dazzling meteor showers which reveal that the artist observed astronomical phenomena, such as the "radiant" effect of meteor showers, first recorded by Alexander von Humboldt in 1799 and accepted only in the nineteenth century. Lorenzetti also painted sporadic, independent meteors, which do not emanate from the radiant. It is also significant that these artists observed differences between comets and meteors, facts that were not absolutely established until the eighteenth century. In addition we demonstrate that artistic and scientific visual acuity were part of the burgeoning empiricism of the fourteenth century, which eventually yielded modern observational astronomy.

INTRODUCTION

In the early Renaissance, art and astronomy were not the strange handmaidens they seem in our highly specialized age on the cusp of the millennium. Astronomy, still partially encased in the cocoon of astrology, belonged to the liberal arts as part of the quadrivium, while art, especially the art of painting, was beginning its ascent into the lofty canon of the liberal arts. Both were, therefore, an integral part of the humanist movement, which was in its early infancy. In this progressive intellectual orientation, as in classical antiquity, the emphasis in intellectual inquiry was on people and this world instead of on the divine and the afterlife. This new celebration of Nature and the concomitant investigation of the phenomena of the world mark the beginning of the modern age. To demonstrate this new spirit of inquiry, we discuss several topics relating artists and their works with actual astronomical events in early Renaissance Italy to reveal the revolutionary advances made in an artistic chain beginning with Giotto di Bondone.

GIOTTO'S COMET IN HIS *ADORATION OF THE MAGI*

By the beginning of the fourteenth century, Padua, where Galileo would hold a chair at the University, was already renowned for mathematics and astronomy, which was then separating from astrology. It is no wonder then, when Enrico Scrovegni commissioned Giotto to decorate his lavish family chapel (ca. 1301–1303) that the famous Florentine artist painted a flaming comet in lieu of the Star of Bethlehem in the

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Adoration of the Magi (Figs. 1 and 2). He used as his model a naked-eye apparition that he recently had witnessed: Halley's comet of 1301. Since Olson's first publication of this idea over 20 years ago (Olson, 1979), we have expanded the argument. Nonetheless, an updated presentation is in order in light of new information, scholarship, and the restoration of the frescoes; constraints of space does not allow us the luxury to repeat all the earlier evidence, quotations, and formal analysis that render the conclusion so compelling.

Art historians view Giotto as the first painter who made physical truth a central element in his work (Gilbert, 1966). This judgment is based on an analysis of the actual works as well as on early sources, which frequently rely on *topoi* drawn from literary traditions on ancient art. While Dante Alighieri praises Giotto in his *Divine Comedy*, Giovanni Boccaccio remarks of him in the *Decameron*:

> So faithful did he remain to Nature that whatever he depicted had the appearance, not of a reproduction, but of the thing itself, so that one very often finds...that people's eyes are deceived and they mistake the picture for the real thing.

Giorgio Vasari, the father of art history, claims that when Giotto painted a fly on the nose of a figure by his teacher so "true to nature" was it that his master tried to shoo it away. These comments testify to the naturalistic goals of Giotto's art and a nascent scientific acuity that is especially apparent in the frescoes of the Scrovegni or "Arena" Chapel, so-called because of its construction on the ruins of an ancient Roman amphitheater.

While most art historians believe the artist had completed the Scrovegni frescoes by 1305 March 25 at the very latest, the date of the chapel's consecration, there are still open questions regarding the commission resulting from a lack of documentation about the architect of the building and the theological advisor of its fresco cycle. Recently, scholars have resurrected the old hypothesis that Giotto himself planned the architecture of the chapel, a structure that also functioned as an oratory, on the grounds that every architectural element is subordinate to pictorial considerations (Jacobus, 1995), although not everyone accepts this attribution. To date no theological advisor has been established for the chapel's carefully calibrated and symbolically integrated scenes, although someone must have assisted the artist in the ambitious scheme. Already in the nineteenth century, a connection between Giotto and the medical and philosophical scholar Pietro D'Abano was suggested; more recently Bellinati (1985, 1997) and Massing (1987) support the idea that d'Abano influenced Giotto's comet image. Bellinati believes that Giotto painted his comet in response to d'Abano's Aristotelian ideas and description: "After a great fire, the material loses its red color and is tinged black." ("Dopo un grande fuoco, la materia perde il colore rosso e si tinge di nero," d'Abano, 1475, 242.) While Bellinati cites other influences as well, he does not understand Giotto's *modus operandi*, that is, how the artist was inspired by objects in the natural world (see below). Bellinati also misinterprets Olson's argument about how and why Giotto would have translated his observation of an historical comet into a painted image (Olson, 1979); he claims that the Star of Bethlehem never could have been Halley's comet, a correlation which Olson never suggested. (Over the centuries the Star of Bethlehem has been associated inconclusively with a number of specific astronomical events; see, among others, Hughes, 1979; Molnar, 1999; Kidger, 1999.) Giotto himself never thought that the comet he viewed in 1301 was the Star of Bethlehem. Rather, he responded to an ancient theological tradition that the Star of Bethlehem was a comet, and when he painted that image relied on the memorable comet that he himself had observed, 1P/Halley in 1301. Indeed, there may have been no actual astronomical event at the time of Jesus's birth, making the Star of Bethlehem a figurative device, not uncommon for events seen as important in hindsight.

The hypothesis that d'Abano's description rather than the sensational 1301 apparition accounts for Giotto's powerful comet is further problematical for several reasons. First, d'Abano did not return to Padua from Paris and his other travels until after the early months of 1306 (by 1307 he is in Padua according to Paschetto, 1984, 29–30, while Marangon, 1984, 69, 72–74, 103–4, opts for probably by 1306 and absolutely by 1308), most likely too late for a personal encounter (see also Thorndike, 1923–1958). Also, since frescoes are executed from the top of the wall in descending order, the *Adoration of the Magi* dates from around the mid-point of Giotto's undocumented Paduan stay, from ca. 1301 to 1305, when he is recorded in Florence as leasing a house he owned. Second, while Bellinati links the reddish orange of Giotto's comet to d'Abano's description, he neither grapples with the technical problems of the aging fresco that have accentuated this coloration nor explains the lack of any black coloration, which figured so prominently in d'Abano's description. Instead, the semi-transparent, vaporous tail of Giotto's comet, streaked with gold lines, reveals slices of blue sky, painted in layers of pigment that culminate in the most costly of the time, non-water-soluble ultramarine blue; throughout the expanse of the skies in the fresco cycle slightly darker streaks, due to changes in the pigment over time, are evident. The comet's coloration may be partially due to flaking pigments that have exposed the red bole adhesive attaching the non-water-soluble gold onto the plaster. However some red pigment seems to have been part of the artist's original palette, which would have been logical since many comets, including Halley's, have been described in numerous texts since earliest times with a red cast, an idea adopted subsequently by d'Abano as well as many others.

It is unlikely that Giotto and D'Abano ever met, although it is probable that both men certainly knew each other by reputation. Until 1991 (Thomann, 1991) it had gone unnoticed that D'Abano, in his commentary on the *Problemata physica*, probably refers to Giotto as "Zotus" (in local dialect: "*Zoto*";

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FIG. 1. Giotto di Bondone, *Adoration of the Magi*, ca. 1301–1304, fresco, Scrovegni Chapel, Padua, Italy (detail). See Fig. 12 for a color version.

FIG. 2. Giotto di Bondone, *Adoration of the Magi*, ca. 1301–1304, fresco, Scrovegni Chapel, Padua, Italy. See Fig. 12 for a color version.

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in printed editions "Gotus"). D'Abano began this lengthy work in Paris in the 1290s, completing it in 1310. Since he refers to Giotto near the end, if he wrote in sequence, a probable date for his comment would be ca. 1310. However, it is impossible to establish a precise date because D'Abano may have prepared the work for publication in 1310 after writing it earlier (Thomann, 1991). In the end, D'Abano's mention of the artist provides neither any historical information nor evidence of acquaintance, only a knowledge of Giotto not necessarily obtained firsthand, especially since it appears he returned from Paris after most scholars, including Bellinati, believe that Giotto departed Padua for Florence.

Nevertheless, it is telling that D'Abano, who was interested in nature, mentioned Giotto in his theoretical discussion of portrait painting (at the time limited to profiles). He states that in order to produce a proper representation an artist must be able to achieve similarity or *peromnia*, like Giotto. We believe that this ability could be applied to other models in nature, including a "portrait" of a comet. In fact, comparing the profile of Giotto's comet (Fig. 2) with a photograph of Comet LINEAR (Fig. 3), the two are similar, despite the volatile nature of comets. It follows, therefore, that Giotto's comet is more or less anatomically correct; its structure shows the head and tail as they probably appeared to the naked eye with its center of condensation and coma built up in layers of reddish orange, yellow, and gold pigment. Beneath the central glowing center of condensation are traces of an eight-pointed star in gold pigment with many rays, either a *pentimento*, a first idea, that Giotto converted into a pulsing comet, or an integral part of his visualization of its head, his bow to the pictorial/literary tradition for representing comets operative during his time (comets were described as having star-like heads; Olson, 1985). Yet this image was far in advance of other depictions of comets; in fact, Giotto's comet is nearly identical to a scientific

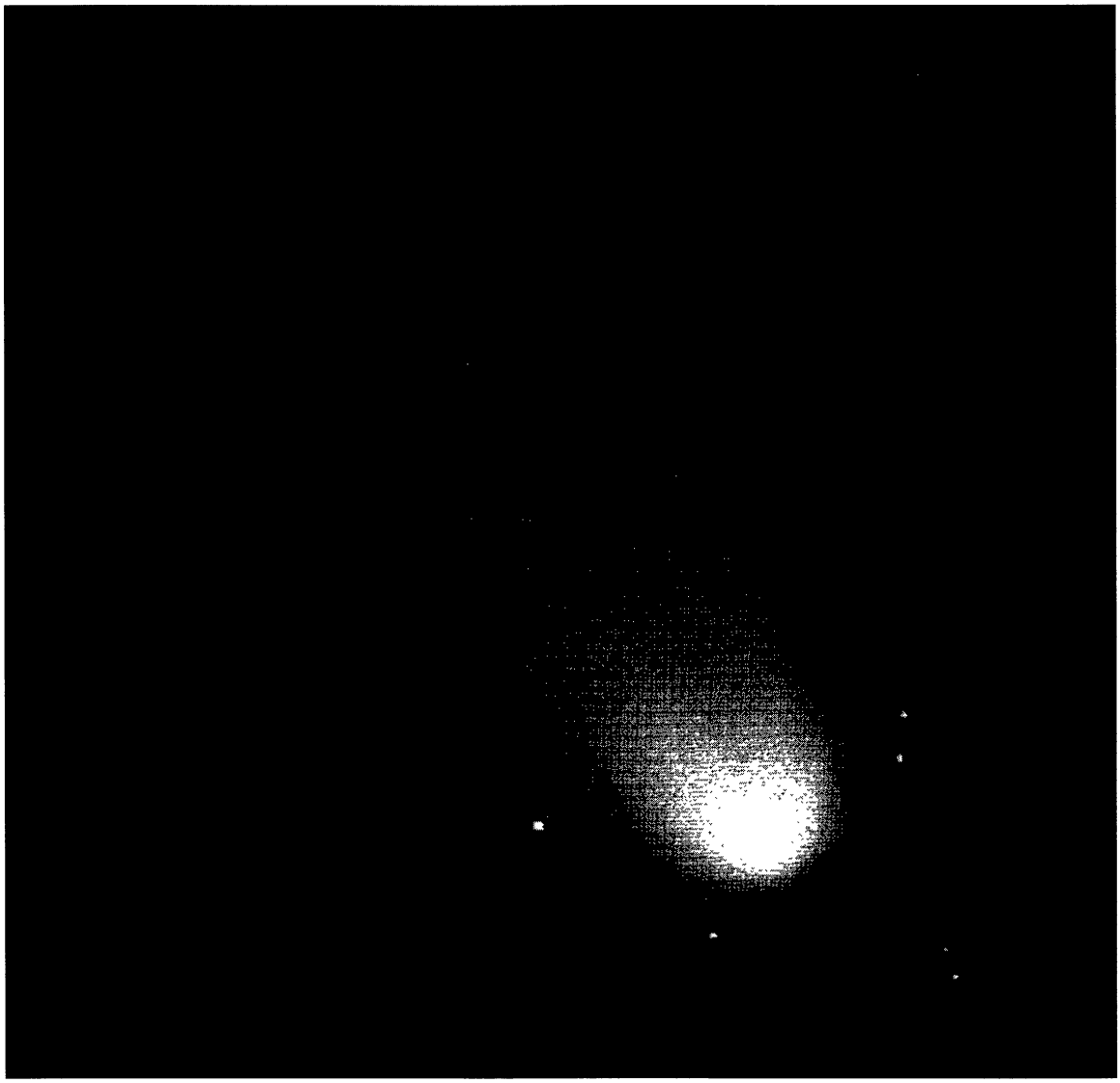

FIG. 3. Comet LINEAR (C/2000 WM1), with its anatomy matching Giotto's artistic view. (Image copyright Gordon Garradd.)

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illustration of a comet that appeared in 1652 (Maffei, 1984, Fig. 4.13). No doubt Giotto painted such a progressive image not only in response to the intellectual ambiance of Padua but also because of the private status of the Scrovegni Chapel, which afforded him the opportunity to experiment without the ecclesiastical supervision and possible censure of public places. However, when Scrovegni opened the chapel to the public, the Augustinian monks of the nearby Eremitani Church complained about its pomp and splendor on 1305 January 9, although they were powerless to change it (Basile, 1992).

Scrovegni went to great pains and costly expenditures to lure to Padua the already celebrated painter, whose naturalistic aesthetic had been formed in his native Florence and tempered in Rome. Despite these facts, Bellinati argues that Giotto's comet-star belongs to a Paduan/Aquilean tradition. The tradition for visualizing the Star of Bethlehem as a comet, however, was not unique to the Paduan area. It was found in other regions of fourteenth-century Italy as well. It was based on commentaries about the Star in patristic literature (works authored by the Church Fathers), most notably and pointedly Origen's *Against Celsus*, where the Star of Bethlehem is blatantly associated with a comet. This patristic tradition was indebted to the pagan belief that the birth of a king was signaled by a comet and also found expression in ephemeral *sacre rappresentazioni* (sacred plays) and *presepio* (Nativity) scenes. Yet it took Giotto to elevate the tradition to a higher level. Moreover, the nature of the Star was also a controversial theological topic during Giotto's lifetime, as discussed in Jacopo da Voragine's *The Golden Legend* of 1298; in the *Prediche del Beato F. Giordano da Rivalto* (born 1260), the author specifically states that the Star was *not* a comet, but rather a new star (Olson, 1979; Olson and Pasachoff, 1986, 1987).

Despite a literary tradition and contemporary trends, Giotto could not have painted his unprecedentedly vivid comet without experiencing firsthand a spectacular apparition. No written word or visual prototype can explain its revolutionary nature or approach its vivacity, not even the words of the contemporary Florentine historian Giovanni Villani, who witnessed the same apparition (1802–1803:4, 71, Book VIII, xcvii: "con grandi raggi di fumo dietro"; see also Maffei, 1984, for other descriptions). Rather, Giotto's zeal for empirical observation and his humanistic attitude made this seminal image possible. By including a naturalistic comet, Giotto was true to the method he used throughout the chapel in analogous responses to other objects painted from life with great authenticity and tangibility (often with a profound symbolic import as well). Certainly, the comet was the most unusual and challenging of the lot. The artist's excitement about the event led him to paint his comet with astronomical veracity, as described above. He increased its immediacy by rendering its vaporous tail as semi-transparent, diminishing in size and density to impart the same impression it gave to the naked eye. Because the viewers of his fresco had also witnessed this same awesome sight, it encouraged them to identify with the significance of his narrative and the awe of the Magi. In subsequent centuries, Giotto's pioneering marriage of observation with theological tradition became typical of humanist methodology.

Giotto's comet was such an advanced artistic/scientific statement that it was followed by less than a handful of timid imitations. Yet they are enough to suggest that Giotto's comet had an impact on his artistic heirs, albeit preserved in weaker images. While the subsequent diminutive comets echo the literary/theological traditions behind Giotto's comet, they do not preserve the power of its naturalistic features, proving that the artist's inspiration was his own experience and that his model was 1P/Halley of 1301 (Olson, 1984, 1985, 1994; Olson and Pasachoff, 1986, 1987). For example, followers of Giotto painted two minuscule schematically rendered comets in the *Nativity* (Fig. 4) and *Adoration of the Magi* in the Lower Church of San Francesco at Assisi. The singularity of Giotto's image is further underlined by comparison with a contemporary copy (Fig. 5) and a fourteenth-century panel of the subject (Fig. 6), both with stylized, flat and linear comets. *Pentimenti* under the comet in the latter work reveals another earlier stylized star-like comet with a single wispy tail. Its pigment, probably containing white lead, has oxidized to black, as has the comet in the *Adoration of the Magi* scene in the Lower Church of San Francesco at Assisi mentioned above. Experts at the Metropolitan Museum of Art believe that the brighter comet over these *pentimenti* may actually be a nineteenth-century addition (Olson and Pasachoff, 1987). While these later comet images derive from Giotto's blazing Paduan comet, they lack its power and immediacy that result from the artist's empirical study of an actual apparition.

Giotto's comet was not equaled in painting until the nineteenth century and not surpassed until the advent of astronomical photography (see Olson and Pasachoff, 1998). His astounding image received the highest compliment when, around 682 years later, the European Space Agency christened its satellite that encountered Halley's comet in 1985–1986 "Giotto."

SOLAR ECLIPSES IN THE WORK OF TADDEO GADDI AND ORCAGNA

Giotto bequeathed his interest in naturalism and celestial phenomena to one of his most talented pupils, Taddeo Gaddi, who may have been partially blinded by a solar eclipse (see Massing, 1987). The artist has been traditionally linked to Taddeus of Florence, who wrote to Fra Simone Fidati about this malady:

> For from days not long past I have suffered, and still suffer, from an unendurable infirmity of the eyes, which has been occasioned by my own folly. For while, this year, the Sun was in eclipse I looked at the Sun itself for a long period of time, and hence the infirmity... For I constantly have clouds before my eyes which impede the vigor of my sight.

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FIG. 4. Follower of Giotto, *Nativity*, ca. 1316, fresco, Lower Church, San Francesco, Assisi, Italy. See Fig. 12 for a color version.

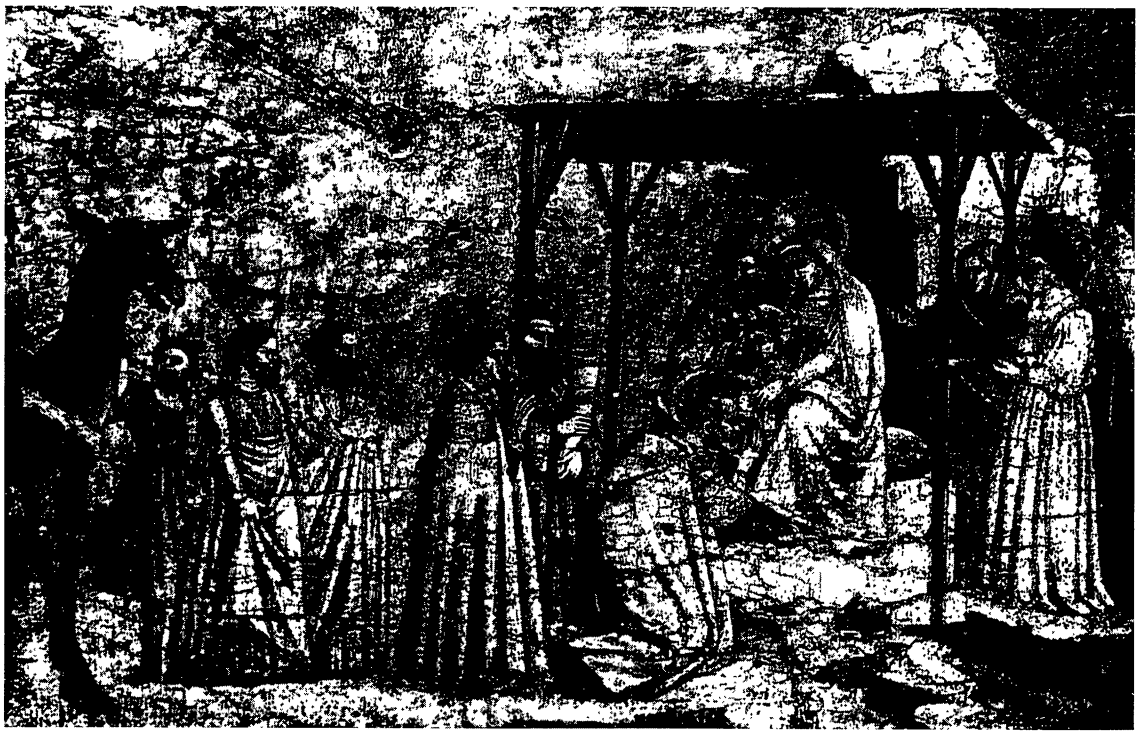

FIG. 5. Contemporary of Giotto, copy of the *Adoration of the Magi*, tempera on panel, whereabouts unknown.

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FIG. 6. Follower of Giotto, *Adoration of the Magi*, ca. 1320–1330, tempera on panel, The Metropolitan Museum of Art, New York, USA. See Fig. 12 for a color version.

Like a number of earlier scholars, Smart not only believes that Taddeus is Taddeo Gaddi (who signed one work with that Latin name) but also that a reflection of the physical and emotional trauma associated with his observation of a solar eclipse is reflected in his nocturnal *Annunciation to the Shepherds* (Fig. 7) (Smart, 1977). Here, a dazzling light emanating from the angel's body, and symbolically synonymous with God, illuminates the landscape, while one shepherd shades his eyes to gaze upwards in an attempt to ascertain its meaning. While this light was meant to be supernatural, the quality of the illumination, together with the shepherd's gesture, argues that the fresco preserves some dramatic experience of the artist, one similar to that occasioned by an eclipse. This conclusion would also account for another unusual feature, pointed out by Meiss, the painter's overriding concern with light that affects his entire technical procedure (Meiss, 1970). Taddeo darkened the wall by preparing his fresco surface with an unusual brown ground, now visible in the sky where the blue over paint has peeled away, making the yellow light of the angel "incandescent". Ladis is rightly skeptical of this circumstantial evidence and questions whether the Taddeus of the Fidati correspondence is really the same individual as the painter (Ladis, 1982). Yet the visual evidence in the Baroncelli Chapel *Annunciation to the Shepherds* scene, that is, the quality of the

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FIG. 7. Taddeo Gaddi, *Annunciation to the Shepherds*, after 1328, fresco, Baroncelli Chapel, Santa Croce, Florence, Italy. See Fig. 13 for a color version.

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light and its extreme, blinding effects on the shepherd, points to the fact that Taddeo Gaddi witnessed a solar eclipse. Even if he is not the Taddeus of the Fidati correspondence. But which solar eclipse? The answer to that question is problematical since no documents for this cycle exist to date it precisely. On the basis of stylistic analysis it has been assigned a date of ca. 1332–1338, although its most recent dating is ca. 1328–1330 (Ladis, 1982, 1996), suggesting two or three possible candidates.

Further complicating the identification of which eclipse might have impaired Taddeo's sight, is the lack of firm dates for the Taddeus–Fidati correspondence. The only date follows Fidati's response written from Rome, where he had moved in 1338. Moreover, the reading of this date has been debated: 1340 January 1 or November 1 without a year. If one believes Smart's transcription as the first day of 1340 (Smart, 1977), the unfortunate experience was most likely a partial eclipse seen in Florence on 1339 July 7, off the track of annularity/totality of the annular/total eclipse (an eclipse that leaves an annulus of Sunlight visible for most of its path but is total in part of its path). While the track of annularity/totality was to the north of Italy, Heinz Scsibrany has calculated for us that the partial phases, which lasted over 2 h, showed a maximum coverage of the Sun's diameter of 83.2%. As with 1P/Halley 1301, the Florentine historian Villani describes this solar eclipse in his chronicle (1802–1803:7, 216–217, XI, xcix). Even the alternative reading of this date as November 1 (Ladis, 1982), if the year were to remain 1340, only slightly lessens the chance that it was sent in response to the eclipse of 1339. Factoring in the imprecise dating of the fresco cycle, there are two other possible candidates for the eclipse: a partial solar eclipse on 1333 May 14, again described by Villani (1801–1803:7, 12, XI, ii), his location being off the track of annularity. For Florence the maximum obscuration was 93.6%; as the Sun went from 0% to 93.6% and back to 0% coverage over 2 h, for most of the time more than half of the Sun was visible. More likely, if one accepts an early dating for the Baroncelli Chapel, it is most likely that Taddeo studied the partial phases of the total eclipse of 1330 July 16, yet again described by Villani (1801–1803:6, 226, X, clix), which lasted 2 h and 6 min and whose maximum coverage at Florence was 86.3%.

As always when the Sun is not totally eclipsed, no matter whether it is on an ordinary day or during a partial or annular eclipse, the visible surface of the Sun is too bright to view safely without cutting down its intensity substantially. So when Taddeo studied the Sun's partially covered disk for a prolonged period of time, even tens of minutes, he suffered permanent eye damage.

While it seems Taddeo Gaddi was fascinated with the physical phenomenon of eclipses, most individuals of his age saw in such portents as eclipses and comets the signs of God's judgment. It is in such a context where another of Giotto's artistic heirs nearly contemporary with Taddeo, Andrea di Cione (called Orcagna), actually represented a solar eclipse, not just its influence on him. This fact, together with Villani's report neatly buttresses the argument that Taddeo also would have been interested in the visual effects of solar eclipses. Orcagna painted his image of a solar eclipse in a little vignette embedded in the frame of his all-but-vanished, vast fresco cycle in Santa Croce (including the *Triumph of Death*), the same church where Taddeo's *Annunciation of the Shepherds* is found. Here, two men gaze at the Sun, which is obscured by the dark disc of the Moon, both shielding their eyes with one hand (Fig. 8). What is remarkable is that a third turns away from the spectacle, his hand raised to his right eye, as if to shield it (blinding injuries from the Sun do not give a feeling of pain at the time). As with Gaddi's shepherd, the gesture is more than a conventional expression of wonder for it is related to a dazzling heavenly light. Orcagna's depiction is difficult to account for unless the artist had observed an eclipse (Smart, 1977). He placed his occulted solar disk, without a corona, near a bank of dark clouds to its lower right (perhaps an area that was meant to evoke the darkness of an eclipsed Sun *vs.* the light on the left side), which results in the solar disk appearing slightly flattened toward the horizon. Since Orcagna's fresco dates from the mid 1340s (Boskovits, 1971; Kreytenberg, 2000), the scene probably preserves Orcagna's observation of the 1339 eclipse discussed above, which Villani claims foretold future evils for Florence (the next year saw the onset of the plague). Two other small border scenes of this fresco cycle survive and illustrate calamities from the apocalyptic imagery of Revelation. Since one of these is an earthquake, more than likely among those destroyed were images of a comet and/or a meteor shower.

PIETRO LORENZETTI'S METEOR SHOWERS

The Sienese painter Pietro Lorenzetti painted his Passion cycle in the left transept of the Lower Church of San Francesco, Assisi, around 1316. This famous pilgrimage church was dedicated to St. Francis, whose doctrines are acknowledged to have had a revolutionary impact on the Church and Italian culture, including the fledgling sciences and the visual arts. His ideas stimulated empirical observation and aroused an appreciation of Nature. Pietro was also touched by these ideals, which had been demonstrated earlier in the paintings of Duccio from Siena and Giotto, both of whom influenced Pietro's unique blend of Sienese and Florentine traits.

In two scenes of this Passion cycle Pietro rendered the first known western depictions of meteor showers on a large scale (Figs. 9 and 10) revealing his acute observational skill (Olson, 1999). In the *Last Supper* and the *Betrayal*, his deep ultramarine blue skies are studded with golden stars and meteors rendered as points of light with short trails. These chaotic meteor showers occur in contexts with Judas, and thus presage evil and impending doom. It is highly significant that Pietro did not represent single meteors but rather showers, whose multiple nature differentiates them from other celestial

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FIG. 8. Andrea Orcagna, border ornament of three men observing a solar eclipse, mid-1340s, fresco fragment, Museo dell'Opera di Santa Croce, Florence, Italy. See Fig. 13 for a color version.

phenomena such as comets. Pietro's interest in recording celestial displays may constitute yet another link between the artist and Giotto. Without a doubt, Pietro noticed that followers of Giotto had portrayed the Star of Bethlehem as a tiny, stylized comet (Fig. 4) in the opposite transept, adjacent to where he worked on his Passion cycle. It is also telling that the vaults of the nearby nave, which date from roughly the same time, were decorated with the traditional motif of gold stars on a blue background, symbolizing heaven and creating a sophisticated harmony between the actual space and the stars in his painted scenes. Their 1974 cleaning has revealed a unique feature: each star contains a circular convex mirror embedded in its center to lend a convincing twinkle, heightening the naturalistic illusion. Like Pietro, the artists who painted these vaults were responding to the naturalistic impulse to mimic what they saw in nature.

Even though Pietro Lorenzetti has been justifiably praised for his unusual interior lighting effects in the *Last Supper*, he should also be lauded for its external light, painted with equal daring. In its starry sky, he placed a crescent Moon that, like the stars, is rendered *a secco* in non-water-soluble gold pigment that today is flaking off. (Curiously, the cusps of the Moon seem to be flipped left to right from their proper direction in the evening sky for the northern hemisphere, suggesting that Lorenzetti had not noted all the lunar characteristics carefully.) Accompanying the Moon in this relatively thin wedge of sky are a number of stars with traces of thin trailers, indicating that some are not fixed stars but rather falling stars or meteors, identified by their telltale trails. Two seem to be rising in the sky at angles of ~45°. It is true that, depending on one's line of sight, some meteors do appear to rise, depending on the altitude of the radiant. Due to their grievous condition, it is impossible to estimate either the original number of meteors or the direction of their trails, although it is likely that they did not point in the same direction, implying that, as with the Moon, Pietro's observation of actual meteor showers was not exacting when the scene was painted for whatever reason.

According to the technical requirements of fresco painting, the *Betrayal*, below the *Last Supper*, would have been painted at a subsequent time. It too is illuminated by both artificial,

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FIG. 9. Pietro Lorenzetti, *Last Supper*, ca. 1316, fresco, Lower Church, San Francesco, Assisi, Italy. See Fig. 13 for a color version.

torches as mentioned in the Gospel of John (XVIII:3), and natural light, a crescent Moon and stars. With this lunar repetition in which the Moon appears to be about 3 to 4 days old, Lorenzetti preserved the Aristotelian unities of time and place. By changing the Moon's position and increasing its size from the *Last Supper* ever so slightly, he attempted to indicate the passage of time. In this case, the cusps of the crescent Moon are properly open to the viewer's left, revealing a more exacting observation.

Similarly, Lorenzetti's meteor showers first appear as light and sporadic in the *Last Supper*, crescendoing in intensity and frequency to a fever pitch in the broader expanse of sky in the *Betrayal*, where Judas places his hands on Jesus, as the stars become unloosed and career through the heavens. The 16 or more meteor trails in the *Betrayal* (an exact count is hindered by the flaking of the gold pigment) seem to be pointing in the same direction. The artist has substituted, as a didactic device, the meteor with the longest trajectory pointing (in its arc, not in a straight line) in the general direction of Christ's head for the actual kiss of Judas, as though the heavens themselves reel in cosmic agony over Judas's ignominious deed. The artist has thus utilized meteors as a unique foreshadowing device and a narrative tool to move his plot ahead.

Most fourteenth-century Italians would have interpreted these meteors as symbolic omens presaging future events. While heavenly displays could herald positive events, more frequently than not they signaled disasters (the word literally means bad stars), following a well-established apocalyptic tradition. Moreover, in the three synoptic gospels' Passion narratives before the Last Supper, Christ reveals that the destruction of the temple (an allusion to his death) will be foretold by signs, among them stars falling from heaven. When Pietro executed his Passion cycle, he employed the dark side of comet/meteor symbolism, his meteors presaging the death of a heavenly king, Jesus. Nevertheless, his depictions of meteor showers in these two scenes are highly original.

In the final analysis, Pietro Lorenzetti's meteor showers function not as mere symbols but reveal that he was far in advance of most artists. His depictions depend on direct scientific observation rather than solely on artistic/religious conventions, an approach that had much in common with the empiricism of naturalistic philosophers of the period, heralding a new intellectual movement that explained the world in natural rather than supernatural terms. The realistic appearance of these meteor showers results in part from their seemingly random quality, featuring streamers (trails) of varying lengths

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FIG. 10. Pietro Lorenzetti, *Betrayal*, ca. 1316, fresco, Lower Church, San Francesco, Assisi, Italy. See Fig. 13 for a color version.

that face in slightly different directions. Due to the condition of the sky in the *Last Supper*, we cannot determine the exact directions of their trails, although they seem not to emanate from the same area, as in the *Betrayal*, arguing that the artist improved on his observations between the former and the latter. Although Pietro has not indicated the radiant (the point from which, *via* an optical illusion of perspective, they appear to emanate, first recorded by Alexander von Humboldt in 1799 and accepted only in the nineteenth century) in either fresco, all their trails in the *Betrayal*, except for the meteor with the longest trail, emanate from the same general direction. This scene thus preserves an amazingly progressive observation by an artist nearly 500 years prior to the establishment of the radiant.

Pietro's achievement seems advanced even when compared to some stylized nineteenth-century depictions of meteor showers. For example, in the woodcuts recording the Leonid storm of 1833 November 13, they unscientifically cascade in curved lines from the radiant like strings of a floor mop turned upside down, or artificial fireworks (Hughes, 1995). Rather, real meteors display straighter trails like those depicted by Pietro and an artist representing the Leonid shower of 1866 (Fig. 11). In addition, the aberrant meteor in the *Betrayal* pointing to Christ must represent Pietro's observation of a sporadic, independent meteor (or fireball), a phenonenon that occurs during showers at the rate of 1 every 10 min but does not emanate from the radiant. Moreover, as Pietro increased the frequency of his meteors from the *Last Supper* to the *Betrayal* he not only indicated the growing presence of evil but also replicated what actually happens in nature, testifying to the accuracy of his scientific observations. Meteor showers build in intensity after midnight because the Earth has rotated in its orbit around the Sun so that it is traveling into the meteors rather than having them catch up from behind.

While it is impossible to identify which showers the artist observed, it can be stated without a doubt that Pietro could not have executed his vivid meteor showers without study. By rendering them as a rain of stars in such a factual manner, Pietro Lorenzetti not only foreshadowed the calamity that befell Christ, but also gave expression to the burgeoning empiricism that eventually yielded modern astronomy.

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FIG. 11. Anonymous, *Leonid Meteor Shower of 1866 over Greenwich, England*, 1884, chromolithograph, collection of Gerald H. Morris, London, U.K.

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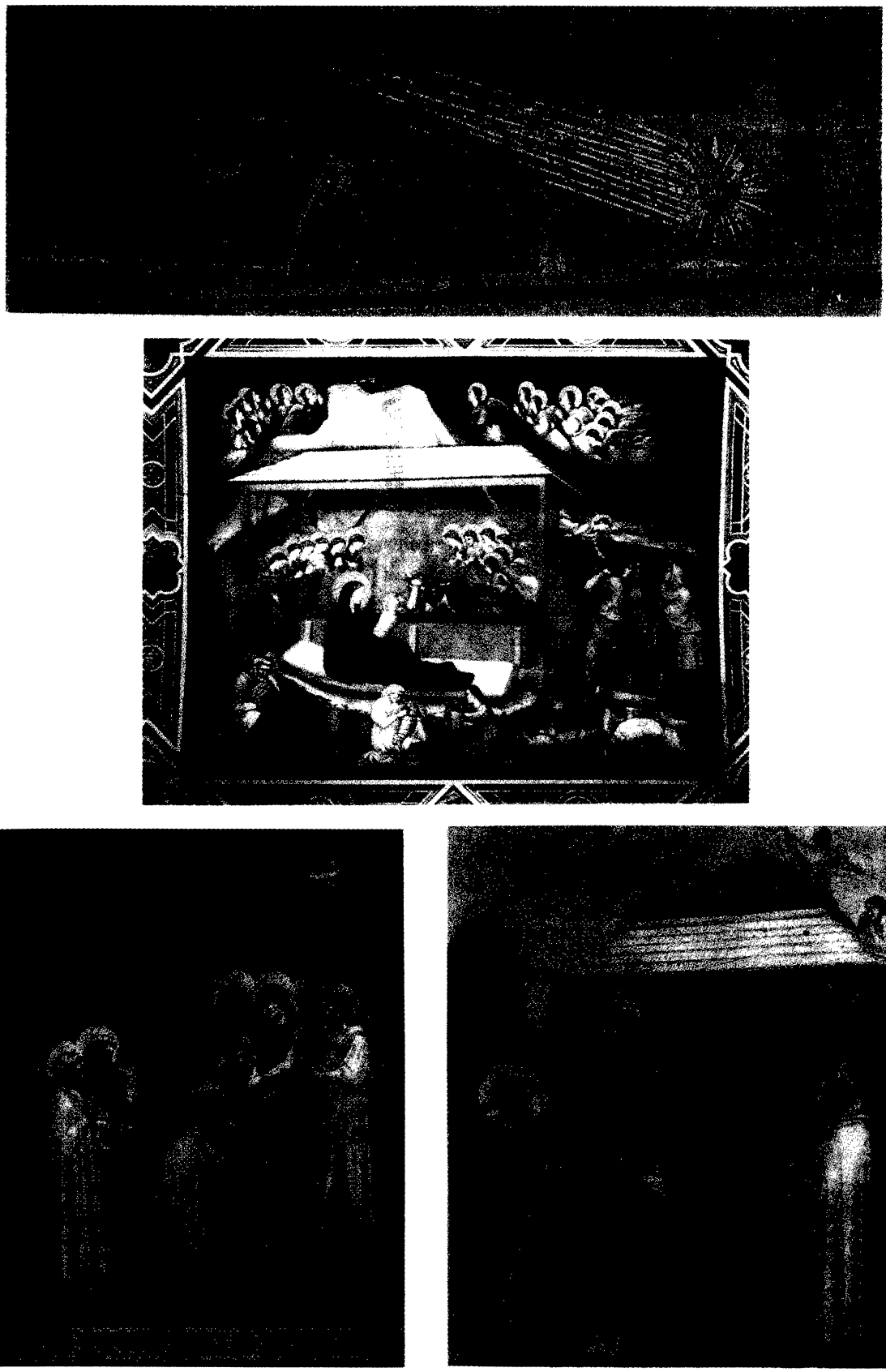

Fig. 12. (top) Giotto di Bondone, *Adoration of the Magi* (detail) (Fig. 1). (center) Follower of Giotto, *Nativity* (Fig. 4). (lower left) Giotto di Bondone, *Adoration of the Magi* (Fig. 2). (lower right) Follower of Giotto, *Adoration of the Magi* (Fig. 6).

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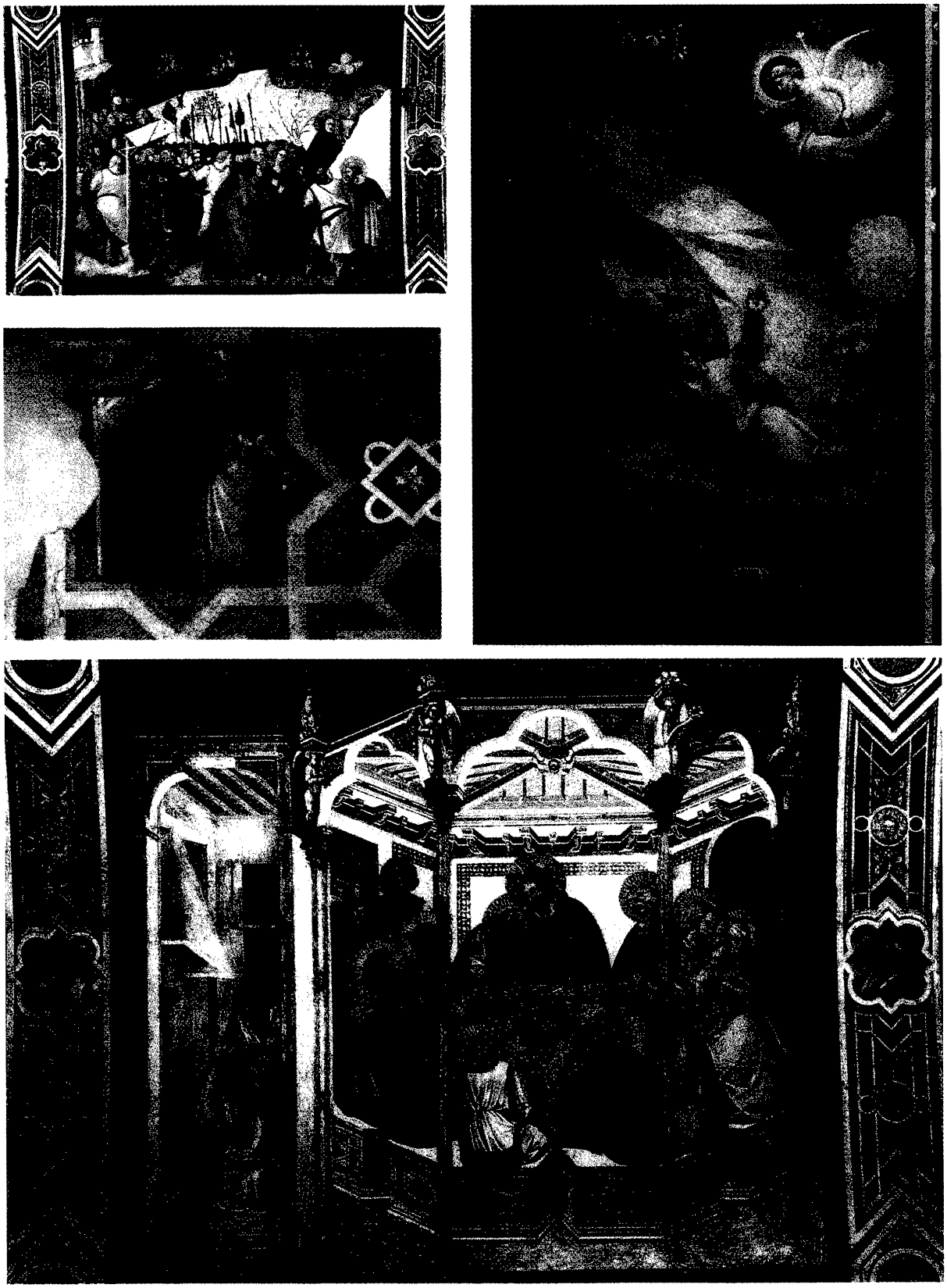

Fig. 13. (top left) Pietro Lorenzetti, *Betrayal* (Fig. 10). (middle left) Andrea Orcagna, border ornament of three men observing a solar eclipse (Fig. 8). (top right) Taddeo Gaddi, *Annunciation to the Shepherds* (Fig. 7). (bottom) Pietro Lorenzetti, *Last Supper* (Fig. 9).

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REFERENCES

D'ABANO P. (1475) *Expositio Problematum Aristotelis*. Paul of Butzbach, Mantua, Italy. 300 ff.

BASILE G. (1992) *Giotto: La Cappella degli Scrovegni*. Electa, Milan, Italy. 387 pp.

BELLINATI C. (1967) *La Cappella di Giotto all'Arena*. Tipografia del Seminario di Padova, Padua, Italy. 29 pp.

BELLINATI C. (1985) Giotto e la cometa nella Adorazione dei Magi. In *Magico Appuntamento Halley e Giotto nel Cosmo* (eds. C. Barbieri, L. Pignatto and C. Bellinati), pp. 81–85. mp/edizioni, Castel del Godego, Italy.

BELLINATI C. (1997) *Giotto: Padua Felix: Atlante Iconografico della Cappella di Giotto (1300–1305)*. Vianelli libri, Treviso, Italy. 165 pp.

BOSKOVITS M. (1971) Orcagna in 1357 and in other times. *Burlington Magazine* **113**, 239–251.

GILBERT C. (1966) Florentine painters and the origins of modern science. In *Arte in Europa: Scritti di Storia dell'Arte in onore di Edoardo Arslan*, pp. 333–340. Tipografia Artipo, Milan, Italy.

HUGHES D. W. (1979) *The Star of Bethlehem: An Astronomer's Confirmation*. Walker and Company, New York, New York, USA. 218 pp.

HUGHES D. (1995) The world's most famous meteor shower picture. *Earth, Moon, Planets* **68**, 311–322.

JACOBUS L. (1995) Giotto's design of the Arena Chapel, Padua. *Apollo* **142**, 37–42.

KIDGER M. (1999) *The Star of Bethlehem: An Astronomer's View*. Princeton Univ. Press, Princeton, New Jersey, USA. 306 pp.

KREYTENBERG G. (2000) *Orcagna: Andrea di Cione*. Verlag Philipp van Zabern, Mainz, Germany. 257 pp.

LADIS A. (1982) *Taddeo Gaddi: Critical Reappraisal and Catalogue Raisonné*. Univ. Missouri Press, Columbia, Missouri, USA. 276 pp.

LADIS A. (1996) Taddeo Gaddi. In *The Dictionary of Art, vol. XI* (ed. J. Turner), pp. 888–890. Grove's Dictionary, New York, New York, USA.

MAFFEI P. (1984) *La Cometa di Halley*. Biblioteca EST/Mondadori, Milan, Italy. 419 pp.

MARANGON P. (1984) *Il Pensiero Ereticale Nella Marca Trevigiana e a Venezia dal 1200 al 1350*. Francisi, Padua, Italy. 112 pp.

MASSING J. M. (1987) Der Stern des Giotto. In *Die Kunst und das Studium der Natur vom 14. zum 16. Jahrhundert* (eds. W. Prinz and A. Beyer), pp. 159–171. Weinheim, Germany.

MEISS M. (1970) *The Great Age of Fresco: Discoveries, Recoveries, and Survivals*. Braziller, New York, New York, USA. 251 pp.

MOLNAR M. R. (1999) *The Star of Bethlehem: The Legacy of the Magi*. Rutgers Univ. Press, New Brunswick, New Jersey, USA. 187 pp.

OLSON R. J. M. (1979) Giotto's "Portrait" of Halley's comet. *Sci. Am.* **240**, 160–170.

OLSON R. J. M. (1984) ...And they saw stars: Renaissance representations of comets and pretelescopic astronomy. *Art J.* **44**, 216–224.

OLSON R. J. M. (1985) *Fire and Ice: A History of Comets in Art*. Walker and Company, New York, New York, USA. 134 pp.

OLSON R. J. M. (1994) Much ado about Giotto's comet. *Q. J. Royal Astron. Soc.* **35**, 145–148.

OLSON R. J. M. (1999) Pietro Lorenzetti's dazzling meteor showers. *Apollo* **149**, 3–10.

OLSON R. J. M. AND PASACHOFF J. M. (1998) *Fire in the Sky: Comets and Meteors, the Decisive Centuries, in British Art and Science*. Cambridge Univ. Press, Cambridge, U.K. 364 pp.

OLSON R. J. M. AND PASACHOFF J. M. (1986) New information on comet p/Halley as depicted by Giotto di Bondone and other Western artists. In *Proc. 20th ESLAB Symp. Exploration of Halley's Comet, vol. III*, pp. 201–213. European Space Agency, Paris, France.

OLSON R. J. M. AND PASACHOFF J. M. (1987) New information on comet p/Halley as depicted by Giotto di Bondone and other Western artists. *Astron. Astrophys.* **187**, 1–11.

PASCHETTO E. (1984) *Pietro D'Abano, Medico e Filosofo*. Nuovedizioni E. Vallecchi, Florence, Italy. 358 pp.

SMART A. (1977) Taddeo Gaddi, Orcagna, and the Eclipses of 1333 and 1339. In *Studies in Medieval and Renaissance Art in Honor of Millard Meiss, vol. I* (eds. I. Lavin and J. Plummer), pp. 403–414. New York Univ. Press, New York, New York, USA.

THORNDIKE L. (1923–1958) Pietro D'Abano. In *A History of Magic and Experimental Science, vol. II*, pp. 874–947. Columbia Univ. Press, New York, New York, USA.

THOMANN J. (1991) Pietro D'Abano on Giotto. *J. Warburg Courtauld Inst.* **54**, 238–244.

VILLANI G. (1802–1803) *Istorie Fiorentine, vol. IV*. Società Tipografica de' Classici Italiani, Milan, Italy. 243 pp.

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