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# BRUNELLESCHI'S DOME AND DUFAY'S MOTET

By CHARLES W. WARREN

ON March 25, 1436, Pope Eugenius IV dedicated the cathedral at Florence with its great dome designed by Filippo Brunelleschi, and the Papal choir performed a motet that Guillaume Dufay had composed for the event. Both dome and motet occupy special places in the history of their respective disciplines, the former as the most important achievement of "the father of Renaissance architecture," and the latter as one of the most impressive occasional pieces ever written. A great deal has been said about the motet, but there is one aspect of the music that has been overlooked — its fundamental relationship to the architecture of Brunelleschi. In fact, there are a number of interesting correspondences between the structure of the dome and that of the motet, correspondences involving extraordinary procedures on the part of both architect and composer. The relationship is striking enough to suggest that the unique and compelling features of *Nuper rosarum flores* — its use of two tenors with the same cantus firmus, its isorhythmic and isomelic symmetries, its impressive sonorities, even its overall design — are not purely musical after all, but the results of a deliberate attempt on the part of Dufay to create a sounding model of Brunelleschi's architecture.

The significance of the correspondences between the dome and the motet can best be appreciated in the context of Brunelleschi's achievement as an architect. In the eyes of his contemporaries he was the first builder of his age to think in terms of the "proporzioni musicali" of the ancients.<sup>1</sup> Recent studies have tended to vindicate this view, finding evidence in nothing that Brunelleschi himself

<sup>1</sup> Antonio di Tuccio Manetti, *The Life of Brunelleschi*, ed. Howard Saalman, trans. Catherine Engass (University Park, Pa., 1970), p. 51.

wrote or was reputed to have said, but in the buildings themselves. According to Wittkower, "the principal formal characteristics of Brunelleschi's new Renaissance architecture may be summarized under the terms of homogeneity of wall, space, light and articulation. These homogeneities are the necessary conditions not only to guarantee coherent metrical development in plan and elevation, but also to ascertain continued ratios in perspective view."<sup>2</sup> Leon Battista Alberti and Leonardo da Vinci may have been the first clearly to articulate a metrical and harmonic concept of space based on musical consonances, but Brunelleschi was the earliest of the Renaissance masters to emphasize these simple arithmetic ratios in the overall design of his buildings and to understand the laws of perspective that are based on them.<sup>3</sup>

It is easy enough to perceive these "musical consonances" in churches such as San Lorenzo and Santo Spirito in Florence. They were designed by Brunelleschi according to a modular scheme that presupposes a harmonic organization of space.<sup>4</sup> In the case of the dome that he raised over Santa Maria del Fiore, however, the matter is not so simple. The cathedral was built in the Trecento according to a gothic system in which the measurements and dimensions are derived from a set of simple geometrical proportions based on the square. In the terminology of the workshop and the building site, *a due quadri* was the same as a two to one proportion and *a uno quadro e mezzo* the same as a one to one and a half proportion. Other proportions were taken from the diagonals of these squares, however, and are incommensurable in terms of harmonic ratios. That is, *a uno quadro il diametro* can only be expressed as  $\sqrt{2}:1$ , while *a due quadri il diametro* is equivalent to  $\sqrt{5}:1$ .<sup>5</sup>

This harmonic incommensurability became exaggerated in actual practice, when in a procedure called "quadrature" a series of expanding or contracting squares was taken from the diagonal, as in the cross of Santa Maria del Fiore (Fig. 1). Here most of the basic coordinates appear to be related to the large crossing square that is

<sup>2</sup> Rudolf Wittkower, "Brunelleschi and 'Proportion in Perspective,'" *Journal of the Warburg and Courtauld Institutes*, XVI (1953), 288.

<sup>3</sup> On the use of musical proportions in medieval church architecture see Otto von Simson, *The Gothic Cathedral* (New York, 1956), pp. 37-38 *et passim*.

<sup>4</sup> Wittkower, *op. cit.*, pp. 288-89.

<sup>5</sup> Howard Saalman, "Early Renaissance Architectural Theory and Practice in Antonio Filarete's *Trattato di architettura*," *The Art Bulletin*, XLI (1959),

circumscribed by the central octagon. By drawing larger squares with sides equal to the diagonal of the smaller and smaller squares with sides equal to one half the diagonal of the larger, the dimensions of the entire cruciform structure may be derived from a single quadrature series. What is interesting about this series is that it may be reduced to a set of ratios that contain the *proporzioni musicali*. Multiplying the sides of the squares consecutively by the numerical equivalent of  $\sqrt{2}:1$  ( $= 0.707$ ) and rounding off the reduced series to the nearest whole numbers, one obtains the proportions 6:4:3:2.<sup>6</sup> According to Howard Saalman, the ratios of "simplified" quadrature were not unknown to Brunelleschi's predecessors and may have been used in determining the pier-to-foundation relationships of Santa Maria del Fiore.<sup>7</sup>

Measurements of the dome suggest that Brunelleschi also used these proportions, but on a much larger architectural scale, and that he conceived of them in terms of a modular system imposed on the existing dimensions of the cathedral. Indeed, if we take the square inside the octagon (Fig. 1) as a basic module, these dimensions may

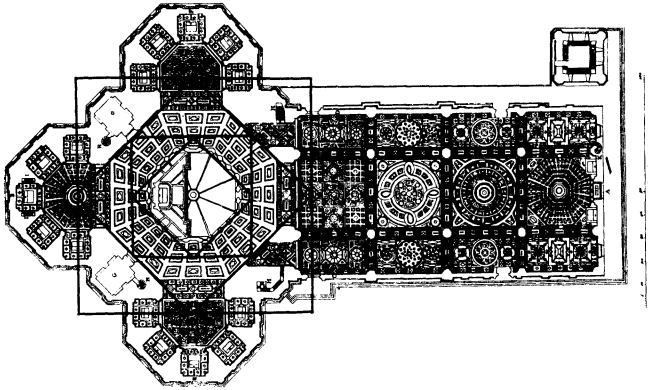


Fig. 1.

<sup>6</sup> The complete series of figures obtained by this calculation is: 101.8, 72.0, 50.8 (crossing square), 35.9, 25.4, 17.9, 12.6, 8.9, 6.3, 4.4, 3.1, 2.2. Dimensions are given in terms of Florentine *braccia* (the *braccia* is about two feet), and are based on measurements and reports taken from the scale drawings of Bernardo Sgrilli, *Descrizione e studi dell'insigne fabbrica di S. Maria del Fiore* (Florence, 1733), Figs. II, III, and IV, and Giuseppe Molini, *La metropolitana fiorentina* (Florence, 1820), Figs. II, III, and IV.

<sup>7</sup> Saalman, *op. cit.*, p. 98, note 28.

be expressed precisely in terms of the ratio 6:4:2:3. Three of these squares are contained in the nave, two in the transept (one on either side of the crossing square), one in the apse, and one and one half in the elevation of the dome proper, measuring from the base of the tambour to the close of the vault (Figs. 2 and 3, dotted lines).

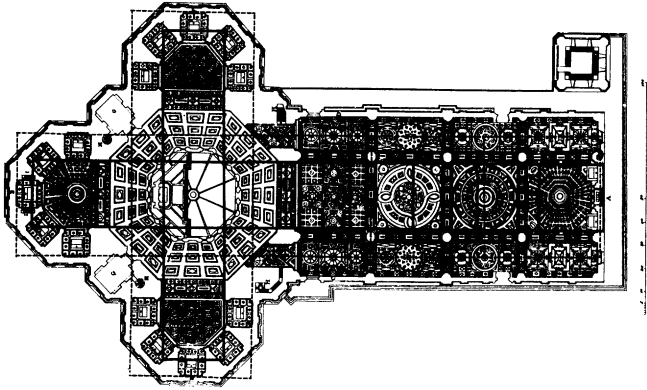
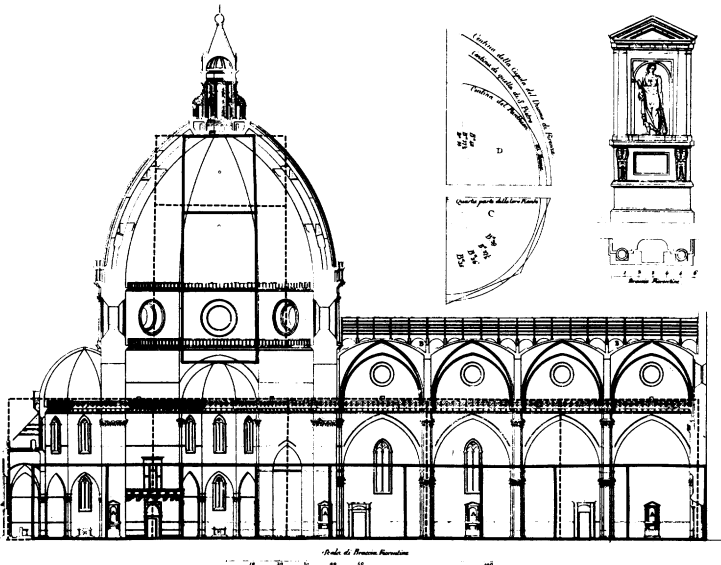
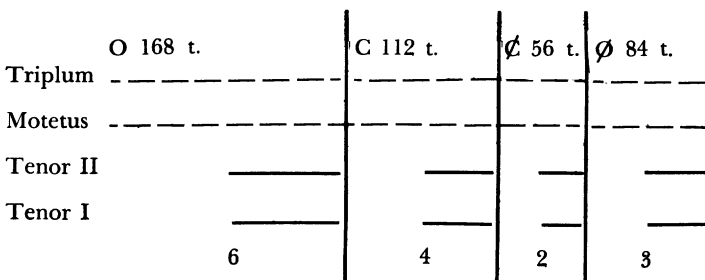


Fig. 2.



These same proportions may also be derived from a different modular scheme based on the twenty-eight *braccia* squares of the nave bays (Figs. 2 and 3, solid lines). Six of these squares are contained in the nave, four in the transept (two on either side of the crossing square), two in the apse, and three in the elevation of the dome, measuring from the peaks of the arches to the close of the vault (one module to the base of the cupola and two from the base to the top).

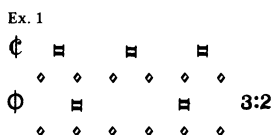
In effect, Brunelleschi reduced the interior dimensions of the cathedral to a set of proportions based on a whole number ratio, and it is precisely these proportions that are used in the motet that Dufay wrote for the consecration of the cathedral. Not only do the mensurations in its four sections have a proportional relationship of 6:4:2:3, but the number of tactus in each of the sections is the same as the number of *braccia* contained in the modular scheme based on twenty-eight *braccia* squares: one hundred sixty-eight in the nave, one hundred twelve in the transept, fifty-six in the apse, and eighty-four in the dome of Brunelleschi. What is more, there are twenty-eight breves in each of the two-voice and four-voice subsections of the motet, which means that the "module" of the motet is the same as that of the cathedral:



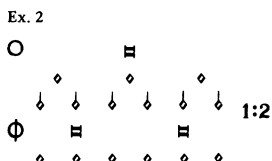
It must be emphasized, however, that the length of the last section of the motet is expressed here in terms of a uniform tactus and not the slower or faster beat that was apparently required for *tempus perfectum diminutum* in actual practice. Ornithoparchus reports that in the opinion of the "veteres," referring to the generation of Dufay, the diminution of perfect signs took away a third part and not a half.<sup>8</sup> Coussemaker's Anonymous XII also writes: "If at the

<sup>8</sup>"Diminutio: ut veteres sensere: est tertia partis ab ipsa mensura abstractio." *Musice active Micrologus Andree Ornithoparchi* (Leipzig, 1519), Bk. I, chap. viii.

beginning a line is placed in the middle of a circle not having a dot inside, as here:  $\emptyset$ ; in this sort of song half is not taken away but only a third part; that is to say, it is sung faster than if the line were not placed in the middle."<sup>9</sup> In practical terms, the only way one could take away exactly a third part of the speed of the last section of *Nuper rosarum flores* would be by keeping the speed of the semi-breve constant with that of the third section. With a constant semi-breve two breves of *tempus perfectum diminutum* will be used up for every three of *tempus imperfectum diminutum*:



This results in a breve that loses a third part of its speed, as the theorists suggest. Thus the fifty-six breves in the last section of the motet will expand in length by a third compared to the fifty-six breves in the previous section and take up the time of eighty-four tactus. On the other hand, given a constant semibreve between the two last sections, two breves of *tempus perfectum diminutum* will be taken up for every one of *tempus perfectum non diminutum*, making the final section of the motet half as long as the first:



In its overall dimension, then, *Nuper rosarum flores* has exactly the same proportions as the interior of the cross and dome of Santa Maria del Fiore. The mensurations producing these proportions occur in only one other motet of Dufay, *Magnanimae gentes*, written some two years later than *Nuper rosarum flores*, but in this piece a canon doubles the length of the first section, making a proportion of 12:4:2:3.

An examination of Brunelleschi's specifications for the dome indicates that the correspondence in overall dimensions between the

<sup>9</sup> *Scriptorum de musica medii aevi* (Paris, 1864-76), III, 484.

architecture of the cathedral and that of the motet was not accidental. The specifications, dated 1420, are preserved as a notarial record of the Florentine Woolen Guild and describe in summary fashion the form and measure of the component parts of the dome:

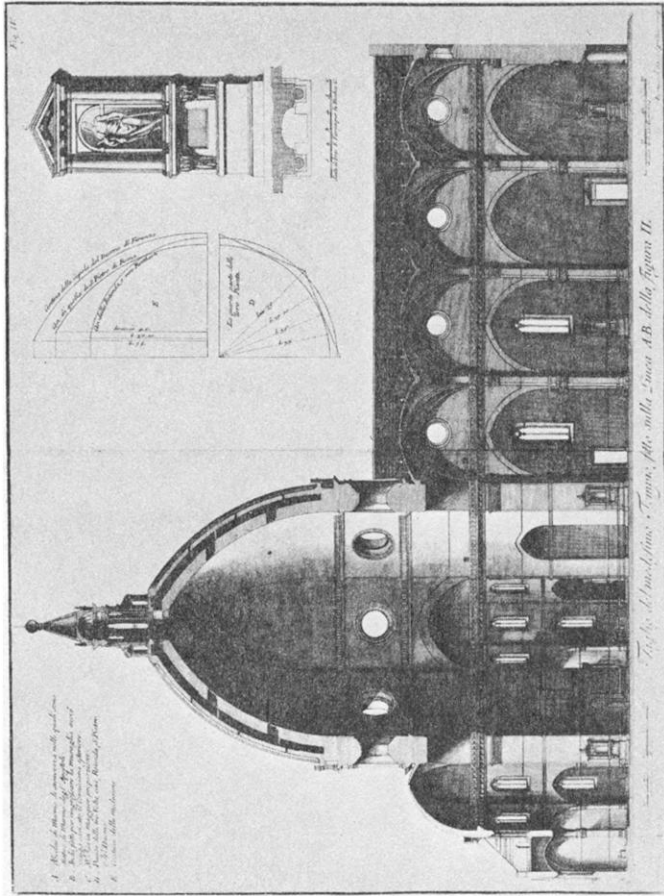
. . . the inner cupola is vaulted in five-part form in the corners. Its thickness at the bottom point from which it springs is  $3\frac{3}{4}$  braccia. It tapers so that the end portion surrounding the upper oculus is only  $2\frac{1}{2}$  braccia thick. A second, outer cupola is placed over this one to preserve it from the weather and to vault it in a more magnificent and swelling form. It is  $1\frac{1}{4}$  braccia thick at the bottom point from which it springs, and tapers to the upper oculus, where it is only  $\frac{2}{3}$  braccia thick.<sup>10</sup>

In this passage Brunelleschi describes his dome as having two shells — an inner one and an outer one separated by a space (Plate I). The idea of a double cupola was a startling innovation, a tour de force of engineering whose chief function was apparently an esthetic one. In fact, it is only here that Brunelleschi allows himself to lapse into anything approaching extravagant language. An outer cupola is to be placed over an inner one in order “to vault it in a more magnificent and swelling form” (“piu magnifica e gonfiata”). This double cupola has a close musical counterpart in the double tenor of *Nuper rosarum flores* (Plate II). Breaking with tradition, Dufay has two tenors sound the same cantus firmus a fifth apart, and the effect is primarily aesthetic — the amplification of sonority. One tenor is placed a fifth below another in order to harmonize it in a “more magnificent and swelling form.”

The mensurations of the tenors also correspond to the thicknesses of the two cupolas. Brunelleschi gives these measurements as  $3\frac{3}{4}$  braccia for the thickness of the inner shell at the tambour and  $2\frac{1}{2}$  braccia for its thickness at the lantern. The inner shell is  $1\frac{1}{4}$  braccia thick at the tambour and  $\frac{2}{3}$  braccia at the lantern. The first three measurements have exactly the same proportions as the nave, transept, and apse of the cathedral and the first three mensurations of Dufay’s tenors. It may be no more than a curious coincidence, but the one incommensurate dimension in Brunelleschi’s series of measurements, the fraction  $\frac{2}{3}$  braccia for the thickness of the outer shell at the top, does suggest a proportional relationship of 2:3.

<sup>10</sup> Frank D. Prager and Gustina Scaglia, *Brunelleschi: Studies of his Technology and Inventions* (Cambridge, Mass., 1970), text, pp. 139-40; trans., pp. 32f.





Courtesy of the Yale University Library.

Plate I.

Santa Maria del Fiore as shown in Bernardo Sgrilli's *Descrizione e studi dell'insigne fabbrica di S. Maria del Fiore* (1733), Figure IV.

per solennia flage et hinc pontificis hinc hiero berna...  
 Soci et pe et sancte deum  
 quibus regibus maxime. Secum per pontificis hinc hiero berna  
 tri facilia. Eugenio hinc de aplissima sacris regibus hinc  
 hinc hinc Confite de gimus est) Et nivalina pu  
 regna n tu. et flia. vr Sp de quingua suis in flacoa  
 no nob eat populo vr quoniam corp  
 in mudo que qua et e m rre  
 nante in a emane dementis in scabio amre.

per solennia flage et hinc pontificis hinc hiero berna...  
 edi corp et cruce de diani  
 quibus regibus maxime. Secum per  
 hodie uam in spi et peru facilia Eugenio hinc de aplissima sacris regibus  
 sacris et hinc hinc Confite de gimus est) hinc nivalina pu  
 in hinc vr Sp Nois iugum hinc flage de Xiuente corp pulis  
 vr quoniam corp mudo quom quoniam. O  
 rante in a emane dementis in scabio.

carion.  
 Et nos  
 Et nos scabio  
 Et nos scabio

Modena, Biblioteca Estense, MS a. X.1, 11, folios 67r-68r.

One other passage in the initial section of the specifications is of interest to us. He states at the beginning: "Imprima la cupola da lato dentro e volta a misura del quinto acuto neglangoli." The sentence has been variously interpreted, but a drawing of the dome by Giovanni Gherardo da Prato, one of the artists associated with Brunelleschi, indicates that the base line of the cupola was divided into five equal parts and that the turn of the vault was determined by radii emanating from this line.<sup>11</sup> Perhaps coincidentally, there are five points of imitation in the canon of Dufay's tenors.

The next section of the specifications relates to the reinforcements of the cupola and the kinds of materials to be used. "There are twenty-four ribs, eight in the corners and sixteen in the sides. Each corner rib has a thickness of seven braccia at the outside. . . . The ribs tie the two vaults together. They converge proportionally to the top, where the oculus is." In this passage Brunelleschi describes what is visually the most distinctive feature of the dome — the eight corner ribs that project from the outer surface of the cupola and tie the two shells together. Each of these eight ribs is seven braccia thick, which may relate to the fact that each of the four sections of *Nuper rosarum flores* consists of  $8 \times 7$  breves. More intriguing, however, is the fact that in the four-voice sections of the motet Dufay employs an unusual variation technique in which the motives in the upper two parts are compressed and elided to accommodate the smaller mensurations. In effect, the melodies converge proportionally in these sections as do the ribs of the cupola:

Ex. 3

The image shows three staves of musical notation. The top staff is in treble clef with a common time signature (C) and contains a sequence of notes with various mensural values (breves, minims, crotchets). The middle staff is also in treble clef with a common time signature (C) and contains a similar sequence of notes. The bottom staff is in treble clef with a common time signature (C) and contains a sequence of notes. Lines connect specific notes across the staves, illustrating the convergence of motives in the upper two parts.

Next to the ribs, the most important reinforcement of the dome consists of circles of strong sandstone blocks that girdle the cupola. "These blocks are long, and are well linked by tin-plated iron. . . .

<sup>11</sup> Howard Saalman, "Giovanni di Ghirardo da Prato's Designs concerning the Cupola of Santa Maria del Fiore in Florence," *Journal of the Society of Architectural Historians*, XVIII, No. 1 (1959), 15-16.

The first and second circles are two braccia high, the third and fourth circles are  $1\frac{1}{3}$  braccia high, and the fifth and sixth circles one braccia high." These stone rings girdle the cupola at three different levels, the first and second side by side at the bottom, the third and fourth at an intermediate level, and the fifth and sixth near the top of the dome. Dufay may have had these reinforcing blocks in mind when he added extra tones to the texture at the beginning, the middle, and the end of the four-voice sections of the motet (see motetus in black notation). In fact, these extra tones serve as harmonic reinforcement and are as numerous in roughly the same proportion as the stone rings are thick. Just as the thicknesses of the stone rings decrease at the intermediate and upper levels so do the number of reinforcing tones in the middle and at the end of the four-voice sections of the motet. Such reinforcing tones are not uncommon in the music of the period, but I know of no other work in which so many of them are used so systematically.

Apart from the structural correspondences suggested by Brunelleschi's specifications, there is one other aspect of Dufay's music that seems related to Santa Maria del Fiore — its extraordinary reliance on the number seven. There are  $8 \times 7$  breves in each of the four main sections of the motet,  $4 \times 7$  breves in each two-voice and four-voice subsection,  $2 \times 7$  tones in the cantus firmus, seven lines of text in each strophe, and seven syllables in each line. Furthermore, the most extensive duos (those in the O and C sections of the motet) are organized into phrases of  $4 + 3$  and  $3 + 4$  longs. According to the chief authorities on ecclesiastical symbolism in the late Middle Ages and early Renaissance, seven was the number of the Church:<sup>12</sup> "Wisdom hath builded her house, she hath hewn out her seven pillars" (Prov. 9:1). In fact, one of the documents having to do with the construction of Santa Maria del Fiore records a payment of six barrels of wine and a sum of money for the *fundamenti* of the seven columns called "ecclesia."<sup>13</sup>

Number symbolism also played a crucial role in the consecration of a cathedral. In the ceremonies preceding the Mass, according to Sicardus, the four extremities of the cross are sprinkled three times, as are the seven altars, while twelve priests carry crosses

<sup>12</sup> Vincent Foster Hopper, *Medieval Number Symbolism* (New York, 1938), p. 111.

<sup>13</sup> Cesare Guasti, *Santa Maria del Fiore* (Florence, 1887), pp. 165-66.

through the four parts of the church.<sup>14</sup> In this context, it is not improbable that *Nuper rosarum flores* was conceived as a musical analogy of the ceremony of consecration, one in which the introit *Terribilis est locus iste* is used as the basic emblem in a musical representation of the cathedral as a whole. As we have seen, the first section of the motet relates proportionally to the nave, the second to the transept, the third to the apse, and the fourth to the dome. Just as the dome serves as a central space that the extremities of the cross share in common, so the four-voice sections of the motet with their isorhythmic and isomelic structure may be regarded as a kind of "same musical space" that the four parts of the motet share in common. The flattened contours of the upper voices, the sonorities of the double tenor, and the reinforcing tones in these sections create an audible shift from the linear to the vertical, as if to symbolize a physical movement from one dimension into the other, from the extremities of the church, that is, into the crossing under the vault. The acoustical effects of these sonorities, it may be recalled, were by no means lost on the ears of Dufay's contemporaries. In his account of the consecration of Santa Maria del Fiore, Gianozzo Manetti relates that as the altar was being prepared for the Office of Dedication a piece was performed "by so many varied and melodious voices, and was sung from time to time with so many symphonies exalted toward heaven that indeed they appeared to the listeners as angelic and divine songs."<sup>15</sup>

There can be little doubt that these "exalted symphonies," presumably those of *Nuper rosarum flores*, bear a more interesting and more intimate relationship to the architecture of Brunelleschi than has been previously suspected. If the correspondences described here involved ordinary devices in the making of domes or motets, one could easily discount them as coincidence. But in every instance the unusual features of the dome may be related directly to unusual aspects of the motet. It seems improbable that these correspondences were accidental, and I doubt that Dufay could have written the motet as he did without some special knowledge of the architecture of the cathedral. Could he have gotten this information directly

<sup>14</sup> *Mitræ seu de officiis ecclesiasticis summa*, chap. vi, "De consecratione Ecclesie" (Migne, *Patrologia Latina*, CXIII, cols. 23ff.).

<sup>15</sup> *Oratio de secularibus et pontificalibus pompis in consecratione basilice florentine*, Biblioteca Apostolica Vaticana, Vat. Lat., 2919, 22<sup>v</sup>.

from Brunelleschi? Certainly they were both in Florence at the same time, Dufay as an already highly regarded musician in the papal retinue, and Brunelleschi as the master builder charged with closing the dome and designing the choir of the cathedral. One has to weigh the probabilities, but the most logical conclusion is that they did meet, and that they left behind as a record of their meeting a unique example of "architecture painting" in the music of the Renaissance.

The implications of this apparent collaboration are intriguing, particularly in view of the fact that *Nuper rosarum flores* is one of the earliest of Dufay's works, if not the earliest, to clearly anticipate the form and style of his late Masses. Nearly all of the most important stylistic and formal elements that characterize the individual movements of the *Missa Caput* or the *Missa Se la face ay pale* are here: the presence of a fourth voice acting as a bass, the division into two or more metrically contrasted sections with introductory duos, the chantlike contours of the upper voices and their occasional imitations, the "disparity in the figuration of the upper and lower voices, which form two distinct architectural groups,"<sup>16</sup> and, above all, the balanced juxtaposition of linear texture in the introductory duos with a vertical emphasis in the four-voice tutti.<sup>17</sup>

One can point to various influences in the late Masses of Dufay, but the real "missing link" in their evolution may very well have been the late motets of Dufay himself, beginning with *Nuper rosarum flores*. It is no mere coincidence that the motet disappears from his repertory just as the tenor Mass is introduced. It may even be an illusion; the stylistic and formal apparatus of the motet may simply have been applied on a larger scale to the texts of the Mass, so that the motet, rather than disappearing, was transformed into a motet cycle with a common cantus firmus.

In this context, the architectural allegory of *Nuper rosarum flores* ought to be regarded as something more than a unique or curious extramusical exercise, for it is the extramusical aspect of the motet that appears to anticipate the style of the tenor Mass. I am not suggesting that the elements of style and form in *Nuper rosarum flores* that are typical of Dufay's later Masses do not appear in music

<sup>16</sup> Dufay, *Opera Omnia*, ed. Guillaume de Van (Rome, 1949), III, p. ii.

<sup>17</sup> See, for example, the opening of the Gloria of the *Missa Caput* (Dufay, *Opera Omnia*, ed. Heinrich Besseler [Rome, 1960], II, 81).

written before 1436, or that they did not originally serve a purely musical function. It does seem to me, however, that these components are combined for the first time in *Nuper rosarum flores* in an overall pattern that is characteristic of some of his more mature works. What confronts us is the very interesting possibility that certain aspects of this pattern may have been catalyzed in part by the architectural concepts of Brunelleschi and the acoustical properties of his awesome dome. In a real and demonstrable sense, both dome and motet reduce gothic dimensions to classical symmetry and proportion, both extricate themselves from the harmonic incommensurability of older systems and emerge as self-contained, self-sustaining forms — the very models of Renaissance sensibility.<sup>18</sup>

<sup>18</sup> A version of this paper was read at the annual meeting of the American Musicological Society in Chapel Hill, N. C., November 12, 1971.