working with his numbers and Tycho's observations in his new framework

5. These five were strikingly different people, coming from five separate countries, and from three different generations
    a. Kepler and Newton worked largely in isolation; Descartes less so by virtue of his tie to Mersenne; Galileo constantly surrounded by students and protegés; and Huygens in constant personal contact with other leading scientific figures of the time
    b. More important from our point of view, they had substantially contrasting views of "scientific method" -- of how empirical inquiry was most likely to succeed
6. But the five also had a number of things in common over and above their commitment to forging an intellectual revolution in which empirical inquiry would achieve a dominant position
    a. They had ties to one another: Kepler and Galileo corresponded for 30 years; Galileo and Descartes had contact through Father Mersenne; Descartes was a close acquaintance of Huygens's father and a visitor to Huygens's home while he was growing up; and Huygens and Newton corresponded off and on for 15 years, finally meeting face to face in 1689
    b. Each of them made contributions to mathematics as well as to empirical science, and, while each made major advances before the age of 30, they all did much of their most important work after the age of 35
    c. And each of them worked with an intensity that never ceases to amaze me -- five of the hardest working individuals you will ever find

B. Galileo Galilei: A Biographical Sketch
1. Galileo born in Pisa to a long established Florentine family; his father was a cloth merchant, but also an accomplished musician (and author of books on music)
    a. Educated at University of Pisa, undoubtedly at some hardship to his father, who wanted him to study medicine
    b. Interest turned to mathematics, in which taught by Ricci, someone who emphasized the practical side of mathematics
2. His intellectual career stretched over 53 years, the first 21 of which as a university professor
    a. 1589-1592: Chair in mathematics at Pisa (poorly paid)
    b. 1592-1610: Professor of mathematics in Padua (near Venice), where he has three children by his mistress
    c. 1610: returns to Florence as Chief Mathematician and Philosopher (latter at Galileo's insistence) to Grand Duke de Medici
    d. 1611: elected to Lincean Academy of Rome
    e. 1616: Copernican theory condemned, and Galileo told by Bellarmine to abandon it
    f. 1633: trial and abjuration, with remaining years under house arrest in Arcetri, near Florence (and near the convent of his daughter Virginia)
3. First 20 years (1589-1609) devoted largely to questions about the nature of motion and other aspects of simple mechanics, along with various designs for military applications

a. Little publication, but still prominent because of willingness to engage in public controversy against the "Aristotelians"
b. Notebooks from this period, but work ultimately brought together into the book most important to this course, *Two New Sciences*, written while under house arrest and published (in violation of terms of his arrest) in Leyden in 1638
c. No interest in mathematical astronomy, nor even any apparent interest in astronomy, though he identified himself as a Copernican to Kepler in the late 1590's

4. Publication of *Sidereal Messenger* in 1610 (in Latin) not only got him the position he wanted in Florence, but also made him, at age 45, the most prominent "scientific" figure in the world among the general educated public
   a. Followed by a series of publications over the next dozen years -- e.g. *Letters on Sunspots* etc. -- in which he continued to report new telescopic findings
   b. These publications, displaying a strong Copernican bent and profoundly undercutting the dogmatism of the time, stimulated an active opposition, especially within some Church circles and among the Jesuits who at the time dominated Italian universities
   c. Various other publications -- e.g. on floating bodies -- most notably *Il Saggiatore* (*The Assayer*) (1623), a virulent polemic against Father Grassi, a prominent young Jesuit astronomer who had argued that comets are celestial, not sublunary
5. The *Dialogue on the Two Chief World Systems* (in Italian) was promised in 1610, then delayed after the 1616 audience with Bellarmine, reinitiated following a "testing of the waters" in 1624, finished in 1630, published (after delays with censors) in 1632
   a. Undoubtedly the most intellectually influential book of the century, and one of the most influential ever -- in part because of the Trial, but also because it is wonderfully accessible and entertaining
   b. Translated into Latin (1635) and then other languages (e.g. English in 1661)

C. Galileo Galilei: Some Personal Remarks
1. Need to caution about my mixed feelings toward Galileo -- the only one of the prominent figures in 16th and 17th century science toward whom I have such strongly mixed feelings
   a. Generally feel that his contributions are a little exaggerated, undoubtedly because they are less technical and hence more accessible, and he was so successful in promoting himself
   b. But that you can judge for yourself
   c. Real misgivings come from a loss of respect for his intellectual integrity
2. My problems are not so much with Galileo's being an incessant self-promoter, nor with his lack of honesty about what experiments he had actually performed, versus not merely conducted in thought
   a. His self-promotion did a great deal toward gaining respect for the new "science" within the general educated public
   b. And his "dry" experiments had little impact, thanks to Father Marin Mersenne, who made a

career of trying to replicate Galileo's announced results during the 1630's and 1640's

3. Also, do not want to deny that Galileo made extraordinary contributions to the development of modern science
    a. *Two New Sciences* did indeed make giant strides toward giving us a mathematical physics of elementary motion, and it established a style for combining mathematics and physics
    b. Not so much the advent of the telescope, for others did so at virtually the same time, but the way in which he presented telescopic results did a great deal to end the old dogmatism
    c. And he constantly announced a commitment to resolving issues empirically, and to learning to live with ignorance until such answers were forthcoming (in contrast to the philosophers)
4. What bothers me so much is a certain loss of intellectual integrity in his disputes with others -- not just with those deeply opposed to his values, but also with such people as Mayr and Kepler
    a. Galileo perhaps the greatest polemicist of all time, and he clearly enjoyed polemics above anything else
    b. But his overwhelming desire to win disputes led to excesses, both in his attacks on others and in the confidence with which he expressed his own positions
5. This is visible in the *Dialogue*, but it reaches an extreme in *The Assayer*, which -- polemics aside -- is one of the more important early works on "scientific method"
    a. Father Grassi an advocate of view that comets are superlunary; Galileo "destroys" him without the least restraint
    b. (Not the last instance in which superior arguments about scientific methodology will be used to win arguments for the wrong side of a substantive issue)
    c. Grassi did not forget – appears to have been an important figure in the Vatican discussions leading to Galileo's trial

II. Galileo's Contributions to Astronomy, 1609-1633

A. *Sidereus Nuncius* -- The First Telescopic Results (1610)

1. Published in March, just months after first observations, in part because of desire to secure position in Florence, but also because of concerns that others might publish too
    a. Spyglass invented in Holland before 1608, and then surfaced in Paris
    b. But Galileo unquestionably perfected it, and he was among the first to use it astronomically even though Thomas Harriot made celestial observations before him in England
    c. And he was definitely the first to publish, making him an international celebrity
2. The second revolution in astronomy in 1609-10: a new, totally unanticipated form of data enters the discipline, which for 1500 years had been confined to assessing theory and calculations (e.g. of loops) against basically naked-eye positional observations of acuity no better than 1⌈
    a. Not the only time in the history of science in which a new entirely unanticipated form of data changed a field: chemistry with electrolysis following Volta's battery (1800), Fraun-hofer'' spectra (1814), Roentgen's x-rays (1895)
    b. *Siderius Nuncius*, however, unique in its impact on western civilization: shocking reali-