a. That is, it drops some of the pathways that Kepler reported and inferences drawn from them; also several of the cross-checks he pursued in order not to be misled by discrepancies he had derived; and, in rearranging the logic a little, it glosses over some of the arithmetical errors

b. Save for its understating how much use Kepler makes of triangulated distances (corrected here), we can think of Wilson's reconstruction as the sort of thing a good reader at the time might have extracted from *Astronomia Nova* in laying out the central argument of the book for the ellipse

c. Save for its focus on the ellipse, this is what we want, for we are interested more in the development of evidence for the community than in biographical details concerning Kepler himself

B. "Phase 0": On the Real versus the Mean Sun

1. From a quick glance at its Table of Contents, you can see that *Astronomia Nova* has five main parts
   a. On the relationships among the hypotheses
   b. An initial approach to the first inequality, in the manner of the past astronomical tradition
   c. Towards a new approach to the second inequality, through a new account of the earth-sun orbit
   d. The new theory of the first inequality for Mars: the ellipse and area rule
   e. The new theory of latitudes, verified and explained

2. Wilson glosses over the first part, which takes the important step of showing that the choice between using the mean sun and the actual -- i.e. visible -- sun as reference point is potentially important
   a. Astronomically significant by yielding different sun-planet distances
   b. Empirically detectable, though only with a change in evidence practice

3. Kepler himself had shifted from the mean to the actual sun in his *Mysterium cosmographicum*, for reasons of physics, independently of any compelling empirical evidence for doing so
   a. Once one abandons crystalline celestial spheres, the center of the Earth's (or Sun's) orbit ceases to have any physical significance; it becomes a mere point in space, echoing Copernicus's complaint about the equant
   b. The step to the actual sun is thus abetted by a conceptual shift; Kepler, being of the new, post-Copernican generation, saw the mean sun differently
   c. Instead of crystalline spheres, Kepler assumed a physics of forces acting between actual bodies in the manner described in Gilbert's *De Magnete*, generating motions

4. Tycho had challenged Kepler on using the actual sun instead of the mean sun, arguing that, with his theory of the sun, employing the mean sun as reference point, he was able to achieve good agreement with observed longitudes of planets, and hence there was no reason to switch

5. Kepler's reply, in Chapters 5 and 6, argues that Tycho's good agreement may well be misleading (see figure in Appendix)
   a. Chapter 5: So long as one restricts oneself to acronychal observations -- i.e. observations when near opposition, so that Mars rises in evening and sets near dawn -- difference in longitude for the actual and the mean sun will be small, as in the case of X and Y in the figure

b. But this is because these observations eliminate distance from central to orbiting body as a factor

c. Chapter 6: By contrast, data in which the earth, sun, and planet are not aligned will reveal large observable differences in longitude resulting from the different distances

d. Kepler goes through the exercise of comparing the orbit in reference to the actual versus the mean sun first for the Copernican, next for the Ptolemaic, and then part way for the Tychonic (leaving the rest to the reader), identifying in each case a maximal observable difference in longitude and showing it would be greater than 1 deg -- i.e. more than two Moon diameters

e. That is, he forms what later became known, thanks to Francis Bacon, as an *experimentum crucis* – an "experiment of the cross" or "cross-roads" experiment -- for each of the three systems

6. Even though this is just a hypothetical argument, as it occurs in Part I (postponing further confirmation until Part V), it contributes significantly to the overall evidential argument in three ways

   a. First, when the reference point is switched from the mean to the actual sun, and no such discrepancies show up when theory and data are compared, one will have an empirical argument for using the actual sun -- i.e. having lines of apsides pass through true sun

   b. Second, when a classical orbit about the actual sun yields comparatively small discrepancies in acronychal longitudes, one can infer that a significant fraction of the longitude errors in past theories results from having used the mean sun

   c. Third, the difference implies that one must look to longitude observations removed from periods of retrograde motion to determine the true orbit -- a change in astronomical practice that Kepler takes to heart

C. "Phase 1": An Account of the Latitudes

1. What Wilson calls "Phase 1" of Kepler's "War on Mars", the account of the latitudes, is in Chapters 12-14, with a second final pass in Chapters 62-66, very late in the book

   a. Chapters 12-14: three different methods of determining inclination of Mars orbit with line of nodes passing through actual sun

   b. Inference to specific inclination angle in each method presupposes heliocentric longitudes, whence the refinement at the end of the book using his new account of longitudes

   c. Also need earth-Mars distances to infer geocentric latitudes from heliocentric latitudes

2. Basic result: orbit of Mars is inclined at a constant angle of 1 deg 50 min vis-a-vis the ecliptic

   a. Claim: no variation as Mars goes around orbit

   b. Result initially using a pre-Keplerian model of the orbit, but same result at the end of his book after he reaches his new model

   c. Claim: result confirms line of nodes through true sun

3. Using the true sun, instead of the mean sun, as reference point is the key to the breakthrough

   a. The first example of a payoff from Kepler's "physics" -- use an actual physical body as a reference point, and not the preferred mathematical point that everyone else had used

b. Ptolemy's and Copernicus's treatments of latitude so complicated, and so unsuccessful, in large part because of this

c. Kepler ends up offering an explanation of the inclination in terms of an interaction between the (hypothesized) magnetic actions between the sun and Mars

4. Kepler's approach was to use certain privileged observations -- e.g. when the Earth is on the line of nodes and the line from Earth to Mars is perpendicular to the line of nodes (Wilson, Fig 4)

    a. Used a number of privileged observations of this sort, obtaining stable values for the inclination

    b. Then at end, after orbit defined and inclination corrected to 1 deg 50 min, 30 sec, compared calculated and observed geocentric latitudes for a large number of observations at opposition, concluding, contrary to Copernicus, that no other element needed to account for latitudes

    c. Finally, takes the trouble to check Ptolemy's observed latitudes (for fear of changes over long periods of time): consistent with little change (Ch. 68-70)

    d. (First pass needed because Kepler had to locate the nodes of Mars preparatory to using Tycho's data to determine oppositions to the actual sun in deriving his first theory of the orbit)

5. A tremendous step forward in the history of planetary astronomy

    a. E.g. comparison of calculated and observed latitudes for the 12 oppositions used by Kepler shows several in the 2-5 min range and one of 13 min -- owing to a mistake in calculation: 3 deg 20 min should be 3 deg 26 min (p. 388)

    b. Attributes remaining discrepancies to uncertainties in parallax and atmospheric refraction

D. "Phase 2": The "Vicarious Theory"

1. To use triangulation to infer Mars-sun distances, need earth-sun distances and, more important, heliocentric longitudes for Mars and earth

    a. Tycho's (improved) theory for the sun was known to give accurate heliocentric longitudes for earth -- this via comparison of theory and measurement for Tycho's large number of observations of midday altitudes of the sun

    b. Worst problem, then, was to obtain trajectory-independent heliocentric longitudes of Mars

2. Approach: use observations at opposition, when heliocentric longitude of Mars is the same as that of earth -- i.e. when heliocentric and geocentric longitudes of Mars coincide

    a. Calculated 12 oppositions from groups of observations made roughly at the times of opposition -- extracting an "observation" from Tycho's observations

    b. Took opposition relative to true sun, and not to mean sun (as had been the customary way to define it, in keeping with the mean sun being the reference point for the basic time unit)

    c. Not just redefining "opposition", but then also inferring the time when opposition occurs from observations near, but not at opposition

3. Assumed a quasi-Ptolemaic model for Mars -- an eccentric circle, with an equant at an independent eccentricity along the line of apsides