FIVE INNOVATIONS IN PLANETARY THEORY

INTRODUCED BY KEPLER IN *ASTRONOMIA NOVA*

1. Lines of apsides -- i.e. lines between aphelia and perihelia -- always pass through the true Sun, and all motions should be referenced to the true Sun rather than the mean Sun.

2. Introduce a bi-section of the eccentricity for the Earth-Sun orbit, in the manner of the other orbits, implying that the Earth-Sun motion involves a true variation in velocity, not just an apparent one; the key consequence of bi-section of the eccentricity is that, with the equant or any velocity rule refining it, the arc length velocities of the orbiting body at its maximum and minimum distances from the central body -- i.e. at aphelion and perihelion when the Sun is the central body -- are in the inverse ratio of these distances.

3. Replace the equant with the area rule -- or its equivalent, *the component of the arc length velocity normal to a radius drawn from the central body varies inversely with the distance from the central body* -- for purposes of determining the (unperturbed) location of the orbiting body versus time from aphelion.

4. Construe the trajectory of the orbiting body (or, at least, its primary motion at any time) as defining an ellipse with the central body at a focus.

5. Construe the orbital motion (at least at any time) as occurring in a plane that passes through the true Sun and is inclined at a measurable angle to the plane defined by the Earth-Sun orbit.

Qualifying remarks in parentheses in the above statements represent allowances Kepler expressly made in subsequent works; they are not inconsistent with the conclusions of *Astronomia Nova*, for what they amount to, in effect, is to allow for the possibility of the values of the elements of the Keplerian orbits changing over time. All five of these innovations are still part of orbital astronomy today.

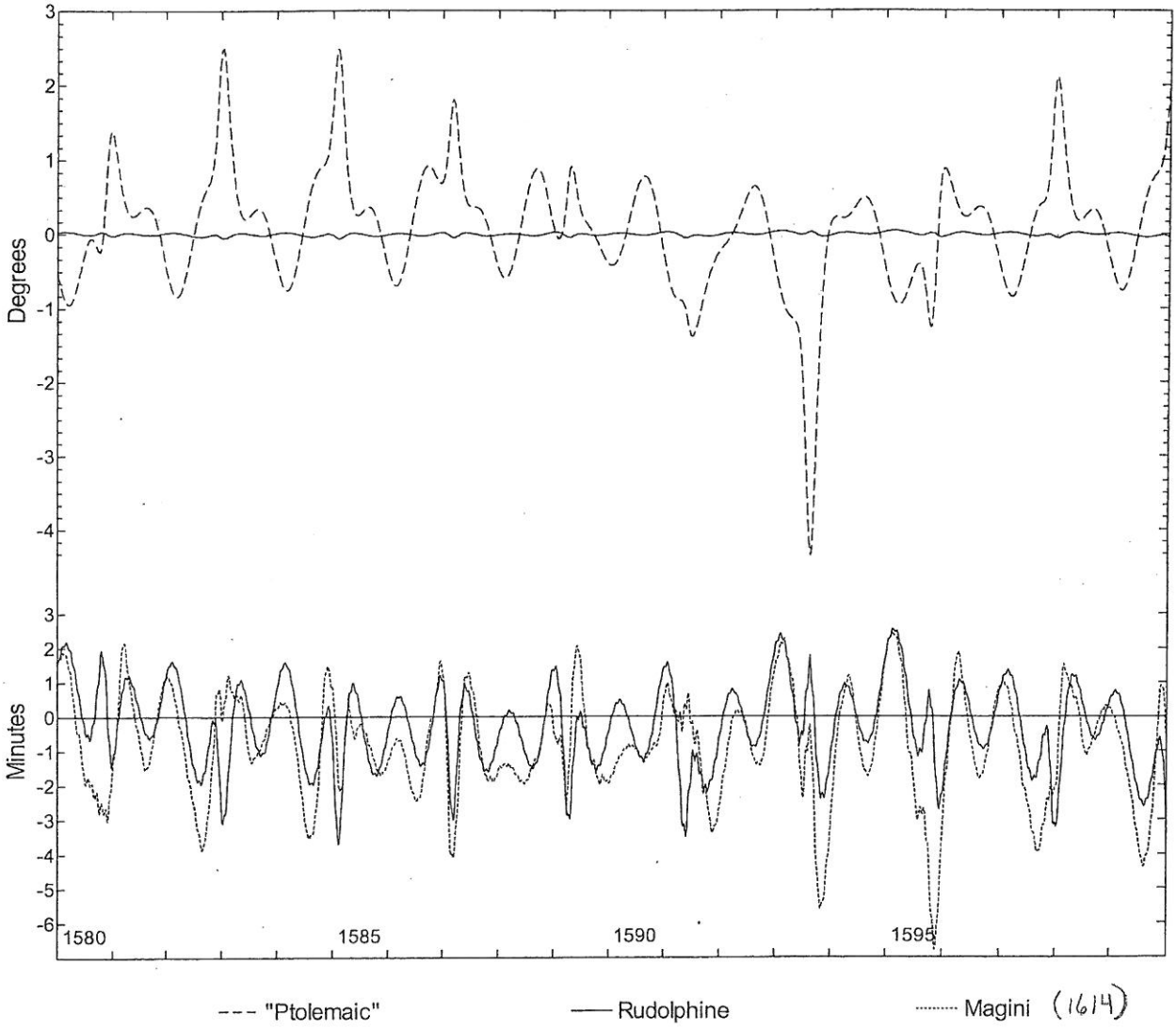

FIG. 5. Errors in geocentric longitudes of Mars. (*Above*) Ptolemaic calculation compared with Kepler's *Rudolphine tables*; (*below, at much enlarged scale*) the *Rudolphine* errors compared with those from Magini's "Keplerian" method in his *Supplementum ephemeridum*.

Tempus	Locus ☉	Solis a Terra distantia	Martis a Sole distantia	Martis eccentricus in ecliptica	Locus computatus	Locus observatus	Differentia	Latitudo
								Bor.
1582. 23 Nove. H. 16. 0	11°. 41′ ♐	98345	158852	0°. 42′. 11″ ♋	26. 40. 0 ♋	26. 38. 30 ♋	1′. 30″ +	2. 49
26 Dece. H. 8. 30	15. 4 ♑	98226	162104	16. 7. 18 ♋	17. 44. 19 ♋	17. 40. 30 ♋	3. 49 +	4. 7
30 Dece. H. 8. 10	19. 9 ♑	98252	162443	17. 56. 32 ♋	16. 6. 20 ♋	16. 0. 30 ♋	5. 50 +	4. 8
1583. 26 Janua. H. 6. 15	16. 33 ♒	98624	164421	0. 6. 24 ♌	8. 17. 57 ♋	8. 20. 30 ♋	2. 33 —	2. 52
1584. 21 Dece. H. 14. 0	10. 16 ♑	98207	164907	3. 51. 45 ♌	1. 14. 34 ♍	1. 13. 30 ♍	1. 4 +	3. 31
1585. 24 Janua. H. 9. 0	14. 53 ♒	98595	166210	18. 47. 8 ♌	24. 3. 58 ♌	24. 7. 30 ♌	3. 32 —	4. 31
4 Febr. H. 6. 40	26. 10 ♒	98830	166400	23. 33. 41 ♌	19. 43. 52 ♌	19. 47. 0 ♌	3. 8 —	4. 28
12 Mart. H. 10. 30	2. 16 ♈	99858	166170	9. 23. 14 ♍	11. 43. 31 ♌	11. 46. 0 ♌	2. 29 —	3. 22
1587. 25 Janua. H. 17. 0	16. 1 ♒	98611	166232	8. 13. 40 ♍	4. 41. 50 ♎	4. 42. 0 ♎	0. 10 —	3. 26
4 Mart. H. 13. 24	24. 0 ♓	99595	164737	24. 56. 50 ♍	26. 24. 41 ♍	26. 25. 40 ♍	0. 59 —	3. 38
10 Mart. H. 11. 30	29. 52 ♓	99780	164382	27. 35. 54 ♍	24. 5. 15 ♍	24. 5. 15 ♍	0. 0	3. 29
21 April. H. 9. 30	10. 48 ♉	101010	161027	16. 44. 51 ♎	15. 49. 50 ♍	15. 48. 20 ♍	1. 30 +	1. 48
1589. 8 Mart. H. 16. 24	28. 36 ♓	99736	161000	16. 55. 14 ♎	12. 14. 7 ♏	12. 16. 50 ♏	2. 43 —	2. 4
13 April. H. 11. 15	3. 38 ♉	100810	157141	4. 1. 50 ♏	4. 45. 0 ♏	4. 43. 20 ♏	1. 40 +	1. 10
15 April. H. 12. 5	5. 36 ♉	100866	156900	5. 1. 41 ♏	3. 58. 57 ♏	3. 58. 20 ♏	0. 37 +	1. 4
6 Maji. H. 11. 20	25. 49 ♉	101366	154326	15. 30. 36 ♏	27. 8. 17 ♎	27. 7. 20 ♎	0. 57 +	0. 7
								Aust.
1591. 13 Maji. H. 14. 0	2. 10 ♊	101467	147891	12. 7. 38 ♐	2. 15. 36 ♑	2. 20. 0 ♑	4. 24 —	2. 25
6 Junii H. 12. 20	24. 59 ♊	101769	144981	25. 38. 48 ♐	27. 11. 45 ♐	27. 15. 0 ♐	3. 15 —	3. 55
10 Junii H. 11. 50	28. 47 ♊	101789	144526	27. 56. 49 ♐	25. 57. 57 ♐	26. 2. 36 ♐	4. 39 —	4. 8
28 Junii H. 10. 24	15. 51 ♋	101770	142608	8. 29. 32 ♑	21. 4. 21 ♐	21. 10. 0 ♐	5. 39 —	4. 45
1593. 21 Julii H. 14. 0	8. 26 ♌	101498	138376	20. 1. 38 ♒	17. 43. 14 ♓	17. 45. 45 ♓	2. 31 —	5. 46
22 Aug. H. 12. 20	9. 11 ♍	100761	138463	10. 15. 25 ♓	13. 9. 39 ♓	13. 10. 15 ♓	0. 36 —	6. 7
29 Aug. H. 10. 20	11. 54 ♍	100562	138682	14. 37. 15 ♓	11. 11. 41 ♓	11. 14. 0 ♓	2. 19 —	5. 52
3 Octo. H. 8. 0	20. 15 ♎	99500	140697	6. 19. 39 ♈	7. 49. 54 ♓	7. 50. 10 ♓	0. 16 —	3. 17
1595. 17 Sept. H. 16. 45	4. 18 ♎	99990	143222	22. 49. 19 ♈	26. 5. 45 ♉	26. 7. 12 ♉	1. 27 —	1. 42
27 Octo. H. 12. 20	13. 59 ♏	98851	147890	15. 35. 38 ♉	18. 50. 46 ♉	18. 51. 15 ♉	0. 29 —	0. 6
								Bor.
3 Nove. H. 12. 0	21. 2 ♏	98694	148773	19. 26. 33 ♉	16. 18. 33 ♉	16. 18. 30 ♉	0. 3 +	0. 17
18 Dece. H. 8. 0	6. 43 ♑	98200	154539	13. 2. 29 ♊	11. 39. 1 ♉	11. 40. 0 ♉	0. 59 —	1. 40