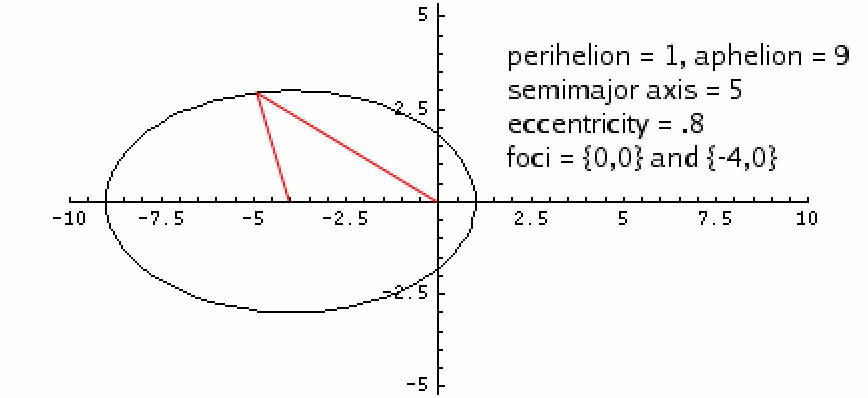
Body	Perihelion	Aphelion	Ang. Diam. @	Orbital	Orbital	Rotational	Axial Tilt
	(AU)	(AU)	ca. (as)	Period (Yrs)	Inclination	Period (Days)	
Sun			1918	$2.2 * 10^{8}$		25.38	7.25
Mercury	0.3075	0.4667	13.03	0.241	7	58.65	0
Venus	0.718	0.728	65.44	0.615	3.39	-243	177.3
Earth	0.983	1.017		1	$5. * 10^{-5}$	0.9973	23.45
The Moon	0.00243	0.00271	1968	0.075	5.145	27.32	6.68
Mars	1.381	1.666	25.73	1.881	1.8	1.026	25.19
Phobos	$6.175 * 10^{-5}$	$6.363 * 10^{-5}$	0.1047	$8.731 * 10^{-4}$	1	1.026	
Deimos	$1.567 * 10^{-4}$	$1.569 * 10^{-4}$	0.05824	0.003456	1.8	1.026	
Gaspra						0.2917	
Ida						0.193	
Jupiter	4.952	5.455	50.1	11.86	1.305	0.4135	3.12
Io	0.00281	0.002832	1.2761	0.004844	0.04	1.769	
Europa	0.004445	0.004526	1.097	0.009723	0.47	3.551	
Ganymede	0.007138	0.007167	1.846	0.01959	0.21	7.155	
Callisto	0.0125	0.01268	1.684	0.04569	0.51	16.69	
Saturn	9.021	10.05	20.76	29.4	2.484	0.444	26.73
Mimas	0.001215	0.001265	0.06753	0.00258	1.53	0.9424	
Enceladus	0.001584	0.001598	0.0851	0.003751	0	1.37	
Tethys	0.00197	0.00197	0.1826	0.005169	1.86	1.888	
Dione	0.002517	0.002528	0.1929	0.007493	0.02	2.737	
Rhea	0.00352	0.003527	0.2632	0.01237	0.35	4.518	
Titan	0.007929	0.008406	0.8871	0.04366	0.33	15.95	
Hyperion	0.00887	0.01093	0.03062	0.0583	0.43	13	(chaotic)
Iaepetus	0.02313	0.02448	0.2474	0.2172	14.72	79.33	

Uranus	18.29	20.1	4.086	84.02	0.77	-0.7196	97.86
Miranda	$8.658 * 10^{-4}$	$8.705 * 10^{-4}$	0.03769	0.00387	4.2	1.413	
Ariel	0.001272	0.001281	0.09246	0.0069	0.3	2.52	
Titania	0.00291	0.002923	0.126	0.02384	0.14	8.706	
Neptune	29.81	30.33	2.372	164.8	1.769	0.6712	29.58
Triton	0.002371	0.002371	0.1295	-0.01609	157.3	-5.877	

("ca." stands for "closest approach".)



In this plot, the sum of the lengths of the two red lines is a constant for every point on the ellipse.

Using the above information and the equations

- perihelion = semimajor axis * (1 - eccentricity)
- aphelion = semimajor axis * (1 + eccentricity)

and

- radians = π * degrees / 180
- diameter = distance * angular diameter$_{radians}$

we can compute the following parameters:

Body	***a*(AU)**	**Eccentricity, *e***	**R (m)**	**R(Earth)**
Sun	$1.62 * 10^9$		$6.955 * 10^8$	109
Mercury	0.3871	0.2056	$2.44 * 10^6$	0.3825
Venus	0.7233	0.0068	$6.052 * 10^6$	0.9488
Earth	1	0.01671	$6.378 * 10^6$	1
The Moon	0.00257	0.0549	$1.734 * 10^6$	0.2719
Mars	1.524	0.0934	$3.397 * 10^6$	0.5326
Phobos	$6.269 * 10^{-5}$	0.015	$1.3816 * 10^4$	0.002166
Deimos	$1.568 * 10^{-4}$	$5. * 10^{-4}$	7688	0.001205
Gaspra			8428	0.001321
Ida			$1.57 * 10^4$	0.002462
Mathilde			$2.971 * 10^4$	0.004658
Jupiter	5.203	0.04839	$7.149 * 10^7$	11.21
Io	0.002821	0.004	$1.821 * 10^6$	0.2855
Europa	0.004485	0.009	$1.565 * 10^6$	0.2454
Ganymede	0.007153	0.002	$2.634 * 10^6$	0.413
Callisto	0.01259	0.007	$2.403 * 10^6$	0.3768
Saturn	9.537	0.05415	$6.027 * 10^7$	9.449
Mimas	0.00124	0.0202	$1.96 * 10^5$	0.03073
Enceladus	0.001591	0.00452	$2.47 * 10^5$	0.03873
Tethys	0.00197	0	$5.3 * 10^5$	0.0831
Dione	0.002523	0.00223	$5.6 * 10^5$	0.0878
Rhea	0.003523	0.001	$7.64 * 10^5$	0.1198
Titan	0.008167	0.02919	$2.575 * 10^6$	0.4037

Hyperion	0.0099	0.104	$8.878 * 10^4$	0.01392
Iaepetus	0.02381	0.02828	$7.18 * 10^5$	0.1126
Uranus	19.19	0.04717	$2.559 * 10^7$	4.012
Miranda	$8.681 * 10^{-4}$	0.0027	$2.36 * 10^5$	0.037
Ariel	0.001276	0.0034	$5.79 * 10^5$	0.09078
Titania	0.002916	0.0022	$7.889 * 10^5$	0.1237
Neptune	30.07	0.00859	$2.476 * 10^7$	3.883
Triton	0.002371	$1.6 * 10^{-5}$	$1.352 * 10^6$	0.212
Tempel 1			3103	$4.865 * 10^{-4}$
Wild 2			2750	$4.312 * 10^{-4}$

Of course, *a* and ε are sufficient to describe any *one* of these orbits, but in order to understand how the planets are oriented with respect to each other we need 4 additional values:

- the orientation of the ellipse with respect to, for instance, the direction of the galactic center;
- the angle of inclination of the plane of the ellipse with respect to the plane of the Earth's orbit;
- the angle of the twist of the plane of the ellipse (around the semimajor axis), and
- the position of the planet on its ellipse at a specific time.

Together these 6 values are called **orbital elements**. From them we can predict the past and future positions of any of the planets, to reasonable accuracy, within about 20 years of the time mentioned above. Beyond those dates, gravitational interactions between the planets must be taken into account.

http://www.rwc.uc.edu/koehler/astrophys/toc.html

Note that this value of the Earth's central pressure is 14.23 *million* times the atmospheric pressure on the surface.

Body	**M (kg)**	**M(Earth)**	**Density**	**g (Earth)**	**L (kgm^2/s)**	**L(Earth)**	**Central Pres.**	**Central Pres.**
			(g/cm^3)				**(Pa)**	**(Earth)**
Sun	$1.989 * 10^{30}$	$3.33 * 10^5$	1.411	28	$1.424 * 10^{56}$	$5.349 * 10^{15}$	$1.128 * 10^{15}$	784.1

Mercury	$3.302 * 10^{23}$	0.05528	5.429	0.3778	$9.149 * 10^{38}$	0.03437	$2.054 * 10^{11}$	0.1427
Venus	$4.868 * 10^{24}$	0.815	5.244	0.9053	$1.846 * 10^{40}$	0.6934	$1.179 * 10^{12}$	0.8195
Earth	$5.974 * 10^{24}$	1	5.496	1	$2.662 * 10^{40}$	1	$1.439 * 10^{12}$	1
The Moon	$7.348 * 10^{22}$	0.0123	3.365	0.1664	$2.884 * 10^{34}$	$1.083 * 10^{-6}$	$3.986 * 10^{10}$	0.0277
Mars	$6.418 * 10^{23}$	0.1074	3.909	0.3788	$3.531 * 10^{39}$	0.1326	$2.064 * 10^{11}$	0.1435
Phobos	$1.063 * 10^{16}$	$1.779 * 10^{-9}$	0.9623	$3.792 * 10^{-4}$	$2.132 * 10^{26}$	$8.009 * 10^{-15}$	$2.07 * 10^{5}$	$1.438 * 10^{-7}$
Deimos	$2.38 * 10^{15}$	$3.984 * 10^{-10}$	1.25	$2.742 * 10^{-4}$	$7.545 * 10^{25}$	$2.835 * 10^{-15}$	$1.082 * 10^{5}$	$7.52 * 10^{-8}$
Jupiter	$1.899 * 10^{27}$	317.8	1.24	2.53	$1.932 * 10^{43}$	725.8	$9.209 * 10^{12}$	6.4
Io	$8.932 * 10^{22}$	0.01495	3.531	0.1834	$6.538 * 10^{35}$	$2.456 * 10^{-5}$	$4.841 * 10^{10}$	0.03364
Europa	$4.8 * 10^{22}$	0.008035	2.989	0.1335	$4.426 * 10^{35}$	$1.663 * 10^{-5}$	$2.563 * 10^{10}$	0.01781
Ganymede	$1.482 * 10^{23}$	0.02481	1.936	0.1455	$1.725 * 10^{36}$	$6.479 * 10^{-5}$	$3.044 * 10^{10}$	0.02116
Callisto	$1.076 * 10^{23}$	0.01801	1.851	0.1269	$1.662 * 10^{36}$	$6.245 * 10^{-5}$	$2.317 * 10^{10}$	0.0161
Saturn	$5.685 * 10^{26}$	95.17	0.62	1.066	$7.837 * 10^{42}$	294.4	$1.635 * 10^{12}$	1.136
Mimas	$3.75 * 10^{19}$	$6.278 * 10^{-6}$	1.189	0.006648	$9.96 * 10^{31}$	$3.742 * 10^{-9}$	$6.359 * 10^{7}$	$4.419 * 10^{-5}$
Enceladus	$7. * 10^{19}$	$1.172 * 10^{-5}$	1.109	0.007814	$2.105 * 10^{32}$	$7.907 * 10^{-9}$	$8.785 * 10^{7}$	$6.105 * 10^{-5}$
Tethys	$6.27 * 10^{20}$	$1.05 * 10^{-4}$	1.005	0.0152	$2.097 * 10^{33}$	$7.879 * 10^{-8}$	$3.325 * 10^{8}$	$2.311 * 10^{-4}$
Dione	$1.1 * 10^{21}$	$1.841 * 10^{-4}$	1.495	0.02389	$4.163 * 10^{33}$	$1.564 * 10^{-7}$	$8.21 * 10^{8}$	$5.706 * 10^{-4}$
Rhea	$2.31 * 10^{21}$	$3.867 * 10^{-4}$	1.237	0.02695	$1.033 * 10^{34}$	$3.881 * 10^{-7}$	$1.045 * 10^{9}$	$7.263 * 10^{-4}$
Titan	$1.346 * 10^{23}$	0.02252	1.881	0.1382	$9.161 * 10^{35}$	$3.442 * 10^{-5}$	$2.748 * 10^{10}$	0.0191
Hyperion	$8 * 10^{17}$	$1.339 * 10^{-7}$	0.2729	$6.912 * 10^{-4}$	$5.993 * 10^{30}$	$2.251 * 10^{-10}$	$6.875 * 10^{5}$	$4.778 * 10^{-7}$
Iaepetus	$1.6 * 10^{21}$	$2.678 * 10^{-4}$	1.032	0.02114	$1.86 * 10^{34}$	$6.989 * 10^{-7}$	$6.428 * 10^{8}$	$4.467 * 10^{-4}$
Uranus	$8.685 * 10^{25}$	14.54	1.237	0.9032	$1.696 * 10^{42}$	63.73	$1.174 * 10^{12}$	0.8157
Miranda	$6.6 * 10^{19}$	$1.105 * 10^{-5}$	1.199	0.00807	$5.728 * 10^{31}$	$2.152 * 10^{-9}$	$9.371 * 10^{7}$	$6.512 * 10^{-5}$
Ariel	$1.35 * 10^{21}$	$2.26 * 10^{-4}$	1.66	0.02742	$1.42 * 10^{33}$	$5.336 * 10^{-8}$	$1.082 * 10^{9}$	$7.52 * 10^{-4}$
Titania	$3.53 * 10^{21}$	$5.909 * 10^{-4}$	1.716	0.03863	$5.613 * 10^{33}$	$2.109 * 10^{-7}$	$2.147 * 10^{9}$	0.001492
Neptune	$1.024 * 10^{26}$	17.15	1.61	1.138	$2.505 * 10^{42}$	94.09	$1.862 * 10^{12}$	1.294

Triton	$2.14 * 10^{22}$	0.003582	2.067	0.07973	$-3.333 * 10^{34}$	$-1.252 * 10^{-6}$	$9.146 * 10^{9}$	0.006356

Several densities of interest:

- liquid water at 4 C - 1 g / cm^3
- gaseous H_2 at 0 C and 1 atm - .00009 g / cm^3
- metallic H - 1.3 to 1.6 g / cm^3
- silicate minerals - 3 to 4 g / cm^3
- ferric/ferrous minerals - 7 to 8 g / cm^3

Using the masses above, it is interesting to compare the strengths of the gravitational forces among some of these bodies. This table gives the gravitational force between some of the planets and their moons, expressed as a fraction of the gravitational force between the Sun and that planet:

Planet	**Body**	**F_{grav} (Sun)**
Earth	The Moon	0.005594
Jupiter	Io	0.1528
Jupiter	Europa	0.03248
Jupiter	Ganymede	0.03943
Jupiter	Callisto	0.009244
Saturn	Jupiter	0.004623
Saturn	Tethys	0.00739
Saturn	Dione	0.007904
Saturn	Rhea	0.008511
Saturn	Titan	0.09224
Uranus	Miranda	0.01622
Uranus	Ariel	0.1534
Uranus	Titania	0.07685
Neptune	Triton	1.73

In all cases, the length of the orbital semimajor axis has been used to compute the distance:

Body 1	**Body 2**	**a_{tidal} (Moon on Earth)**	**a_{tidal} / g**
Sun	Mercury	2.955	$9.008 * 10^{-7}$
Sun	Venus	1.123	$1.429 * 10^{-7}$
Sun	Earth	0.4481	$5.161 * 10^{-8}$
Sun	The Moon	0.1218	$8.43 * 10^{-8}$
Earth	The Moon	21.7	$1.502 * 10^{-5}$
The Moon	Earth	1	$1.152 * 10^{-7}$
Mars	Phobos	1274	0.387
Mars	Deimos	45.22	0.01899
Jupiter	Io	5476	0.003438
Jupiter	Europa	1167	0.001007
Jupiter	Ganymede	484.5	$3.837 * 10^{-4}$
Jupiter	Callisto	80.96	$7.349 * 10^{-5}$
Io	Jupiter	13.33	$6.069 * 10^{-7}$
Io	Europa	1.081	$9.327 * 10^{-7}$
Io	Ganymede	0.1029	$8.146 * 10^{-8}$
Europa	Jupiter	1.593	$7.252 * 10^{-8}$
Europa	Io	0.6768	$4.25 * 10^{-7}$
Europa	Ganymede	0.2377	$1.882 * 10^{-7}$
Ganymede	Jupiter	1.135	$5.168 * 10^{-8}$
Ganymede	Io	0.1178	$7.395 * 10^{-8}$
Ganymede	Europa	0.4343	$3.748 * 10^{-7}$
Callisto	Jupiter	0.1444	$6.574 * 10^{-9}$
Saturn	Mimas	2067	0.03581

Saturn	Enceladus	1233	0.01818
Saturn	Tethys	1396	0.01058
Saturn	Dione	701.9	0.003384
Saturn	Rhea	351.6	0.001503
Saturn	Titan	95.2	$7.935 * 10^{-5}$
Saturn	Hyperion	1.837	$3.062 * 10^{-4}$
Saturn	Iaepetus	1.069	$5.825 * 10^{-6}$
Tethys	Saturn	0.2478	$2.677 * 10^{-8}$
Tethys	Enceladus	0.1015	$1.496 * 10^{-6}$
Dione	Saturn	0.19	$2.053 * 10^{-8}$
Dione	Tethys	0.1229	$9.31 * 10^{-7}$
Rhea	Saturn	0.1352	$1.461 * 10^{-8}$
Titan	Saturn	0.5673	$6.13 * 10^{-8}$
Titan	Hyperion	0.08113	$1.352 * 10^{-5}$
Uranus	Miranda	1109	0.01583
Uranus	Ariel	858	0.003604
Uranus	Titania	97.81	$2.917 * 10^{-4}$
Miranda	Uranus	0.1275	$1.626 * 10^{-8}$
Ariel	Uranus	0.73	$9.309 * 10^{-8}$
Ariel	Miranda	0.1663	$2.374 * 10^{-6}$
Titania	Uranus	0.1409	$1.797 * 10^{-8}$
Neptune	Triton	368.9	$5.33 * 10^{-4}$
Triton	Neptune	1.565	$1.585 * 10^{-7}$

All of the moons in this table are locked in **synchronous orbits**: their rotational period is equal to their orbital period. This is due to tidal deformations (bulges toward the planet) which hold the same face toward the planet at all times. Mercury is also in a sychronous orbit, but in a more complicated fashion because of its higher eccentricity: it rotates 3 times for every 2 orbits around the Sun.

Planetary magnetic fields are believed to be the product of rotation and liquid metallic cores. We have been able to measure the magnetic fields of some of these bodies using space probes:

Body	Magnetic Field (Earth)
Sun	2
Mercury	0.011
Venus	0.001
Earth	1
Mars	0.001
Jupiter	13.89
Saturn	0.67
Uranus	0.74
Neptune	0.43

The designation "(Earth)", here and below, indicates that the number is a multiple of Earth's value.

Body	Teff K	I_{Sun} (Earth)	I_{out}/I_{in}	Max Tsurface	Min Mol. Wt.	Major Atmos. Comp.	Surface Atmos. Pressure (Earth)
Sun	5777				0	H	
Mercury	533	6.674	1.005	700	34		$2 * 10^{-12}$
Venus	227	1.911	0.2308	735	6	$C O_2$	90
Earth	255	1	0.7025	331	2	N_2	1
The Moon	387	1	3.727	396	62		$1 * 10^{-12}$
Mars	217	0.4308	0.8553	268	9	$C O_2$	.006
Jupiter	125	0.03694	1.098		0	H_2	
Io	128	0.03694	1.198		17		
Europa	128	0.03694	1.204		27		10^{-7}

Ganymede	128	0.03694	1.206		15		
Callisto	128	0.03694	1.207		19		
Saturn	95	0.0101	1.231		0	H_2	
Titan	85	0.0101	0.7883	94	11	N_2	1.6
Uranus	57	0.002715	0.646		0	H_2	
Miranda	86	0.002715	3.327		2044		
Ariel	84	0.002715	3.038		239		
Neptune	59	0.001106	1.82		0	H_2	
Triton	38	0.001106	0.3126		15	N_2	$1.4 * 10^{-5}$

"I" denotes intensity. The closer I_{out}/I_{in} is to 1, the nearer the body is to being in thermal equilibrium; values less than one indicate the body is warming (within the accuracy of the data, and Wien's and Stefan's laws, which are both approximations).

Some possible atmospheric components of interest are:

Atom or Molecule	**Molecular Weight**
H_2	2
He	4
CH_4 (methane)	16
NH_3 (ammonia)	17
H_2O	18
C O	28
N_2	28
C_2H_6 (ethane)	30
O_2	32
Ar	40

CO_2	44
C_3H_8 (propane)	44

radiation	λ	ν (Hz)	energy (eV)	source
radio	> 1 m	$< 3 * 10^{8}$	$< 1.24 * 10^{-6}$	low-energy atomic or molecular motions
microwave	> .1 mm	$< 3 * 10^{12}$	< .0124	rigid molecular motions
infrared	> 7000 Angstroms	$< 4.3 * 10^{14}$	< 1.78	molecular bond motions
visible light	> 4000 Angstroms	$< 7.5 * 10^{14}$	< 3.1	atomic electron transitions
ultraviolet	> 50 Angstroms	$< 6 * 10^{16}$	< 248	atomic electron transitions
x-rays	> .03 Angstroms	$< 10^{20}$	< 414 K	electron transitions in heavy atoms
gamma rays	< .03 Angstroms	$> 10^{20}$	> 414 K	nuclear decays

An **Angstrom (A)** is 10^{-10} meters. An **electron-volt (eV)** is $1.602 * 10^{-19}$ Joules (a 60 Watt light bulb uses 60 Joules of energy every second).

Solar System Formation

Temperatures in the **protoplanetary disc** are much higher in the central regions where the star is forming, due to the increased density and pressure. Further away the temperatures cool quickly, with the outer regions cooling faster. The general makeup of planets as a function of distance from the protostar can be understood by the various melting points of the materials involved:

Material	Melting Point (K)
Iron	1808
Silicon	1684
Ice	273
Ammonia	195

Methane	91

So we have gas giants beyond the so-called **ice line** (beyond which water freezes), and rocky planets inside.

AU Microscopii is a red dwarf star approximately 12 million years old with a debris disc. AU Microscopii; the radius of the cleared central region is approximately 7 AU

Source: http://www.rwc.uc.edu/koehler/astrophys/toc.html