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Formation of The Jovian and Saturnian Satellite Systems

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The Jovian satellite system mainly consists of four Galilean satellites, where the inner two satellites are rocky and outer two are icy, and only the outermost one is compositionally undifferentiated. They have similar masses and are trapped in mutual mean motion resonances. On the other hand, the Saturnian satellite system has only one big icy body, Titan, and the other satellites have masses that are two orders of magnitude smaller. Since both satellite systems would have been produced in similar circum-planetary proto-satellite disks, the origin of the diversity has been a long-standing question. Here we explain the origin of the diversity by simulating growth and orbital evolution of proto-satellites in an accreting proto-satellite disk model that is combined with the idea of different termination timescales of gas infall between Jupiter and Saturn based on a planet formation model. We show that in the case of the Jovian system, a few similar-mass satellites are likely to remain in mean motion resonances, the configuration of which is formed by type I migration, temporal stopping of the migration near the disk inner edge, and quick truncation of gas infall by gap opening in the Solar nebula. The Saturnian system tends to end up with one dominant body in the outer regions caused by the slower decay of gas infall associated with global depletion of the Solar nebula. The compositional zoning of the predicted satellite systems is consistent with the observed satellite systems. Our results indicate that the diversity of the satellite systems is closely related to how the final masses of gas giant planets are determined, which is a big debate in the context of the mass distribution and multiplicity of extrasolar gas giants. The architecture of the Galilean satellites may be fossil evidence that Jupiter opened up a clear gap in the circum-stellar proto-planetary disk to terminate its growth.

Keywords: satellites, Galilean satellites, Titan, rings, satellite formation, planetary formation