How were Uranus' rings formed?

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A series of the small moons of Uranus interior to the orbit of Miranda, from Cordelia to Mab, move on orbits just outside the narrow and widely separated rings of the planet. A number of orbital horizontal and vertical resonances between a ring particle in circular orbit and a moon (and Miranda) lies in the radial range 41,500-51,500 km, which spans the ring radii. Due to Uranus' oblateness, the vertical resonance lies slightly inside the corresponding horizontal resonance; the vertical resonance point and the point of the horizontal resonance can differ by a few tens of kilometres. In the framework of hydrodynamical theory, I first derive the torques exerted at inner Lindblad horizontal and vertical resonances. It is shown that the torques exerted by the moon on particles are negative at these resonances, so gaps in the disk near each resonance are created. As a result, material in the close vicinity of the resonances falls to the inner part of the system under study. Next, I seek to explain the formation of most of the Uranian narrow rings by the following idea. A fairly uniform, differentially rotating disk of large of the order of 100 cm ice particles, and not individual rings, in a planet-moon system is considered. A moon causes a number of resonant effects in this continuous viscous (through interparticle collisions) disk. Both collisions and resonant interactions lead to the material redistribution of the angular momentum content of the disk. Due to collisions, a fraction of disk mass drifts away from the planet. This positive drift is counteracted by the negative drift due to the orbital resonances. Therefore one could imagine having a bimodal, with two density maxima, narrow of the order of 10 km ringlet somewhere inside the inner gap created by the vertical resonance and the outer gap created by the corresponding horizontal resonance. It is suggested that once the bimodal gap-ringlet features are formed, they are kept in quasi-stable positions through balance between the positive and negative drifts arizing from forces in the collision disk and resonances with the moons (and probably Miranda), respectively.