THE RINGS AND INNER MOONS OF URANUS AND NEPTUNE: RECENT ADVANCES AND OPEN QUESTIONS. Mark R. Showalter[1], [1]SETI Institute (189 Bernardo Avenue, Mountain View, CA 94043, mshowalter@seti.org).

The legacy of the Voyager mission still dominates our knowledge of the Uranus and Neptune ring-moon systems. That legacy includes the first clear images of the nine narrow, dense Uranian rings and of the ring-arcs of Neptune. Voyager's cameras also first revealed eleven small, inner moons at Uranus and six at Neptune. The interplay between these rings and moons continues to raise fundamental dynamical questions; each moon and each ring contributes a piece of the story of how these systems formed and evolved.

Nevertheless, Earth-based observations have provided and continue to provide invaluable new insights into the behavior of these systems. Our most detailed knowledge of the rings' geometry has come from Earth-based stellar occultations; one fortuitous stellar alignment revealed the moon Larissa well before Voyager reached Neptune. More recently, Earth-based observers have been watching the slow, steady decay of Neptune's arcs, and Hubble images revealed two diffuse, outer rings of Uranus. Hubble images have also revealed three small moons—Mab and Cupid at Uranus; S/2004 N 1 at Neptune—that were too small to be discovered by Voyager.

Most importantly, Earth-based observations provide the extended time baseline that enables us to study the subtle changes in these systems year by year. Uranus hosts the most densely packed family of moons in the solar system, with nine (Bianca through Perdita) all orbiting between 59,000 km and 77,000 km from the planet's center. The variations in the orbits of these moons are measurable year by year, and reveal hints of the underlying chaos that defines the long-term evolution of this system. Cupid is on a particularly precarious orbit, less than 900 km interior to the much larger Belinda. Integrations suggest that it will collide with Belinda in less than one million years. Two other moons, Cressida and Desdemona, are expected to merge on a time scale only a few times longer. Unless we are extremely "lucky" to be observing the Uranus system at such a transitional moment in its history, a mechanism must exist to create small, new Uranian moons on similarly brief time scales.

Recently, Neptune's innermost known moon Naiad, was recovered at a location 81° away from its current ephemeris; this suggests that it may follow a highly perturbed orbit, although the nature and cause of its perturbations are unknown.

The ring systems raise similarly intriguing questions. The numerous sharp ring edges in the Uranus system require active confinement, and subtle radial patterns or "modes" seem to require ongoing perturbations. It has long been hypothesized that numerous small, unseen ring-moons are responsible, just as Ophelia and Cordelia "shepherd" ring ε. However, none of the missing moons were seen by Voyager, suggesting that they must be quite small. Furthermore, the absence of moons in most of the gaps of Saturn's rings, after a decade-long search by Cassini's cameras, suggests that confinement mechanisms other than shepherding might be viable. However, the details of these processes are unknown.

The outermost μ ring of Uranus shares its orbit with the tiny moon Mab. Keck and Hubble images spanning the visual and near-infrared reveal that this ring is distinctly blue, unlike any other ring in the solar system except one—Saturn's E ring. A blue color requires an unusual size distribution, dominated by micron- and submicron-sized particles. In the case of the E ring, this is a natural outcome of the ring's source in the plumes of Enceladus. Mab, however, is a much smaller body and unlikely to be geologically active. The blue color of the μ ring remains a major unexplained aspect of the Uranus system.

The decay of Neptune's ring arcs raises additional questions. If, as we now believe, the arcs have a lifetime of no more than a few decades, then a mechanism for creating arcs on a regular basis is also required. Furthermore, an initially promising mechanism, whereby the arcs could be confined by a particular corotation resonance with nearby Galatea, remains unconfirmed.

In this review, I will review the current state of our knowledge and present a broad overview of these and other fundamental open questions about the ring-moon systems of Uranus and Neptune.