Moving beyond Cassini

Cassini has been a pinnacle of our quest for the understanding of the space around us. Its end symbolically marks the beginning of a period of relative dearth for Solar System exploration, but planetary science won't stop thriving.

This is it: on 15 September, at 12:04 UTC, the Cassini spacecraft will end its journey by plunging into Saturn's atmosphere, temporarily turning into an in situ entry probe until it will be destroyed by Saturn's great pressure and temperature. This will be the final act of the aptly named Grand Finale: a series of orbits that started a few months ago, allowing Cassini to explore the uncharted region between the planet and its innermost ring. Thus ends a mission that arrived in orbit around Saturn more than 13 years ago, was launched 20 years ago and for which planning started around 35 years ago.

It is easy to drown Cassini in records and superlatives: the longest-lived space mission after the Voyagers; the farthest orbital mission; the farthest object ever deployed on the surface of a body (the Huygens probe on Titan); around 4,000 peer-reviewed publications and so on (for other numbers see the JPL infographic). The mission planning itself has been a matter of high complexity: the spacecraft changed orbits multiple times to accomplish its scientific goals and technical needs. This cloud of orbits, called the 'ball of yarn' by the team, inspired the pictured artist's impression (JPL's animation shows the real thing). Cassini will surely be considered a milestone in human exploration.

Image credit: James Tuttle Keane, California Institute of Technology

Numbers aside, it is difficult to overstate the importance of Cassini for planetary science. *Nature Astronomy* celebrates Cassini's achievements with a cover commissioned for the occasion, a dedicated Mission Control column and a special feature: we asked 12 Cassini-connected researchers (and an editor) to select their favourite image of the mission accompanied by a short description highlighting its meaning. In addition to the inherent beauty of the photos, what stands out immediately is the huge variety of topics Cassini made a mark on. Atmospheres of giant and terrestrial planetary bodies, rocky and icy surfaces, ocean worlds, rings, magnetospheric physics: all of planetology is contained in these pictures. And we could have easily consulted twice as many scientists with no fear of redundancy.

The individual bits are extremely interesting and important in themselves, but probably the most astonishing Cassini discovery in perspective is the interconnection of the Kronian system as a whole. Several moons, some even smaller than 10 km in linear dimension, shepherd expansive rings. The ejecta from Enceladus's plumes are the direct source of another one (the E ring). The smaller Phoebe smears Iapetus's surface with dark material, helping to create the characteristic albedo dichotomy of the latter. The pervasive Saturn magnetosphere both affects and is affected by the moons, helping, amongst other things, the transfer of oxygen from Enceladus's interior to Titan's atmosphere. Plenty of orbital resonances also link the various bodies together and determine the evolution of the whole system. This complex intertwining is probably the norm in compact systems even at planetary scale (like the TRAPPIST-1 suite of seven known planets).

Science with Cassini will not end with the demise of the spacecraft. The immense dataset from its 12 instruments will keep scientists busy for a long time. The Galileo probe still produced ten papers or so in the past year, 14 years since it was deorbited from Jupiter! The only limitation here will be funding, as agencies and review panels tend to move quickly to the 'next shiny thing', and obtaining money for dedicated Cassini studies will be increasingly difficult in the coming years.

But the next shiny thing is not immediately identifiable in planetary science, at least in the short- and medium-term. With the Dawn spacecraft running out of fuel during 2018 and Jupiter probe Juno expected to meet the same fate as Cassini at roughly the same time (even if the change in its mission planning from a 14-day orbit to a 53-day one will hopefully prolong its life beyond 2019), the Solar System will have no standard or dwarf planet with a spacecraft in orbit, except for the traffic-jammed Mars and the lonely Akatsuki probe in an unfavourable orbit around Venus after its miracle recovery in 2015. This state of affairs, unprecedented since the end of the 1970s (except for a few months here and there), will continue until the mid- to late-2020s, when we will see a fresh batch of probes reach their destinations: ESA's BepiColombo at Mercury and JUICE at Jupiter, NASA's Europa Clipper and maybe the Russian Venera-D.

Of course, this does not spell the end of Solar System studies by spacecraft. The small bodies are going to be in the spotlight, with the sample-return missions OSIRIS-REx and Hayabusa 2 arriving at their targets next year and the first flyby of a Kuiper belt object by New Horizons at the beginning of 2019. Small bodies also have a bright long-term future, as demonstrated by the selection of Lucy and Psyche as the next NASA Discovery missions (see our Comment by the late Mike A'Hearn). But after years with a daily influx of great images and data, planetary scientists will need to adapt. Luckily, we are not without tools. 'Old' facilities like Hubble and the Very Large Telescope are still going strong, and new or upcoming ground- and space-based telescopes (such as ALMA and JWST, not to mention the first extremely large telescopes that will achieve first light in the first half of the 2020s) are going to be major actors for planetary science. It is telling that the JWST has had a deputy project scientist dedicated to planetary science since early on (Stefanie Milam), and the community has produced a series of white papers dedicated to planetary studies with JWST. But it is also telling that the relationship between JWST and the planetary community hasn't always been smooth (for example, see the September 2011 editorial by the Planetary Exploration Newsletter).

We are thus entering a period of new challenges (conceptual and practical, such as a higher reliance on observing-time proposals than on dedicated spacecraft data, with all that that entails) for planetary exploration and science, but it will still be a period very rich in science. It is going to be a different era, but surely not the dark ages. ❒

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