SATURN

At the eye of the storm

F. Michael Flasar

WHEN the two Voyager spacecraft flew by Saturn in 1980–81, they observed an atmosphere which, although banded like Jupiter's, had far less contrast and fewer conspicuous features. This is the usual situation; Saturn is fairly bland. Within the past two months, however, a giant 'storm' has erupted in Saturn's atmosphere. The phenomenon first appeared as a bright compact spot, just north of the equator, and was discovered on 25 September by S. Wilber, an amateur astronomer in Las Cruces, New Mexico. The word quickly got round, and Saturn became the object of close monitoring at several observatories.

According to R. F. Beebe of New Mexico State University and C. Barnet of the Goddard Space Center, astronomers who had been analysing images obtained with the University's telescope, the spot expanded in the ensuing days, maintaining an elliptical shape. By the beginning of October it extended 30° in longitude and 20° in latitude At the same time a tail of more diffuse, cloudy material extended westwards from the spot, particularly from its northern edge. Several observers reported the appearance of a few localized brightenings within the vicinity of the spot. By mid-October the diffuse cloud extended around the planet within a latitude band extending from approximately 20° N to 9° S, and the original spot itself was much less distinct. Early in November, planetary astronomers were able to dedicate the Hubble Space Telescope for two days to observing Saturn. Despite the telescope's faulty primary mirror, clean images were possible, owing to Saturn's brightness and the consequent availability of digital enhancement techniques. The observable detail in the images (see figure) is much finer than that derivable from ground-based telescopes. One sees a distinct pattern of undulations along the northern edge of the cloudy band.

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Saturn's Great White Spot, as seen by the Hubble Space Telescope.

Some aspects of the storm admit a straightforward interpretation. At low latitudes the prevailing winds on Saturn are eastward. The original spot and the extended cloud are in a region of strong meridional shear. Time-lapsed tracking of discrete cloudy features in images obtained with the Voyager spacecraft (A. P. Ingersoll *et al.* in *Saturn* (eds T. Gehrels & M. S. Matthews) 195–238 (University of Arizona Press, 1984)) indicated that the eastward winds decrease from 500 m s^{-1} near the equator to less than 200 m s^{-1} at 20° N and S latitude. (Saturn has no visible surface, so the winds are pegged to its internal rotation rate, which is inferred from the observed periodic modulation in Saturn's kilometric radio emission, on the assumption that this is tied to the planetary magnetic field which rotates rigidly with the interior.) If the source of the cloudy material is near the equator, any meridional motion of the cloudy material would result in the material being stretched out around the planet in the matter of a few weeks.

Less obvious is why the storm occurs at all. Large tropical storms were also observed during Saturn's northern summer (the current season) in 1933 and 1876 (A. Sanchez-Lavega *Astr. Astrophys.* **185**, 315–326; 1987), or approximately every two saturnian years (Saturn's orbital period is 29.5 years). Similar storms occurred at northern midlatitudes during the same season in alternate saturnian years (1960 and 1903). The large storms have not been observed very often at other seasons, although obscuration of low latitudes by the rings could cause some bias. There may be a connection with the seasonally modulated solar heating, but the response of the atmosphere is complicated and not simply periodic or predictable. A. P. Ingersoll, an atmospheric dynamicist at California Institute of Technology, has, not entirely facetiously, termed the occurrences of these storms as "burps".

The typical bland appearance of Saturn is usually ascribed to the presence of condensate hazes, presumably of ammonia, that obscure the thick clouds below. Jupiter, being warmer than Saturn, has less of this haze, and its cloudy features are more distinct. The eruption of the present saturnian storm suggests an instability, of as yet unknown origin, that has induced violent vertical motions, raising condensate to high altitudes of the atmosphere. Observations are currently being made at wavelengths in the electromagnetic spectrum other than the visible, and they may shed light on this process. Infrared observations, in particular, have the potential of determining the altitudes of the new clouds. They may also provide information on temperatures in the vicinity of the storm, which would be diagnostic of vertical motions.

Observers on the Hubble team are also measuring the meridional profile of the winds, by tracking cloud motions much as was done earlier with the Voyager images, to see if the storm has altered the prevailing wind pattern. The temporal variation of Saturn's winds is not well known. Historically, measurements of winds from ground-based images have indicated rough agreement with the winds inferred from Voyager. But because of Saturn's low contrast and the lower spatial resolution of these observations, the number of such measurements is small, and they typically have been based on the large clouds observable during the epochs of the storms. Understandably, they have large uncertainties. Indeed, the driving force for the overall pattern of Saturn's winds is not understood, nor is it even known how deeply they extend below the visible clouds. (This state of affairs also holds for the circulation on the other outer planets.) The degree of steadiness inferred from the Hubble observations may shed some light on these questions.

Ideally, a giant saturnian storm would be subjected to observations at relatively close range by a battery of remote sensing instruments, such as those on the Cassini spacecraft, scheduled to begin orbiting Saturn at the end of 2002. We may not be so fortunate. The past great storms have dissipated in less than 100 days, and the current storm does not seem to be an exception. Saturn will be in its southern summer in 2002, and only one great storm has erupted during this season, at low southern latitudes in 1946. Hence, the long-term coverage afforded by ground-based and Earth-orbiting observatories may provide most of the clues to unravel this mystery. □

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