Seismology of Neptune

- A unique opportunity target for K2, Field 3 –

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K2 could lead to a major breakthrough in planetology by providing the first identification of oscillation modes of an ice giant planet, opening a window on its interior.

Giant planets are planets massive enough to have retained the hydrogen and helium initially present in the circumstellar disk that led to the formation of the central star and its planets. The study of their composition is important to understand both the mechanisms enabling their formation and the origins of planetary systems, in particular our own. Unfortunately, its determination is complicated by the fact that their interior is thought not to be homogeneous, so that spectroscopic determinations of atmospheric abundances are probably not representative of the planet as a whole.

Seismology of giant planets has long been considered as both a potentially powerful tool for probing their interiors and a natural extension of helioseismology, because the common fluid nature of giant planets and the Sun is expected to lead to similar oscillations and the possibility of using similar observational techniques. The confidence that acoustic modes are excited in giant planets mainly relies on the large reservoirs of energy for Jupiter, Saturn and Neptune, because the infrared excess luminosity respectively represents 67, 78, and 161 % of the incident solar flux. This inner energy drives a significant convective flux. Uranus stays apart with only 6 % infrared flux in excess.

By being the biggest and closest, Jupiter has attracted most of the studies on giant planet seismology. Theoretical works predict that Jovian global oscillations should have a frequency range of [800, 3500] μHz with 10 to 100 cm s^{-1} (Vorontsov 1976, Bercovici & Schubert 1987). Several attempts to observe Jovian global modes have been carried out since the mid-1980s, and the major result is the detection of acoustic modes by the dedicated spectro-imager SYMPA (Gaulme et al. 2011). The low signal-to-noise ratio of this detection coupled with a 23% duty cycle prevented from identifying the modes in terms of spherical harmonics. Since then, Cassini (NASA) has detected the signature of Saturn's f-modes in the C ring (Hedman & Nicholson 2013) as was suggested by Marley & Porco (1993). These two results confirm that oscillations are excited in giant planets.

A possible approach to detect oscillations is to search for variations of the solar light reflected by a planet, resulting from distortions of its external radius by acoustic modes (Mosser 1995). Gaulme & Mosser (2005) also showed that the signal could be enhanced by the presence of clouds. In the case of Neptune, by assuming oscillations of same amplitude as those measured on Jupiter (~0.5 m s^{-1}), photometric fluctuations would be of about 2 ppm. Neptune's frequency at maximum amplitude is expected to be about ν_{max}~1300 μHz and its large frequency spacing $\Delta\nu$~200 μHz.

In a white paper for K2, Marley, Lissauer and Rowe suggested observing Neptune. It is indeed a unique opportunity for detecting oscillations modes of a giant planet. Three months of continuous observation in such stable conditions cannot be - currently and for many years - reached by any other mean. Neptune is the ideal target for K2 because its 8^{th} magnitude is in the sweet spot of Kepler, and because its relative excess luminosity is the largest of the four giants. The planet will be observed as a star (no spatial resolution) so that oscillation modes until degree l = 2 are expected to be detected. Short cadence sampling is mandatory to access to the frequency range of oscillations.

A continuous observation of Neptune for three months will also be important for studying how active is the atmosphere. Light curves will provide information on structures (a dark spot was observed by Voyager II), as they provide information on stellar atmospheric activity. The number, size, and lifetime of spots can be deduced from modeling the light curve.