First published ALMA Early Science Cycle 0 Result — Mapping of the Fomalhaut Debris Disc

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The Atacama Large Millimeter/submillimeter Array (ALMA) Early Science Cycle 0 observations have been proceeding with up to 24 antennas since 30 September 2011. The first result of Cycle 0 observations has recently been published (Boley et al., 2012): ALMA 850 μm continuum mapping of the dust in the debris disc around the nearby A3V star Fomalhaut (the naked eye star alpha Piscis Austrini, V mag. 1.16). These observations were observed with only 13 and 15 antennas, but amply demonstrate the quality of science that ALMA can achieve and provide a foretaste of what can be expected in the coming years.

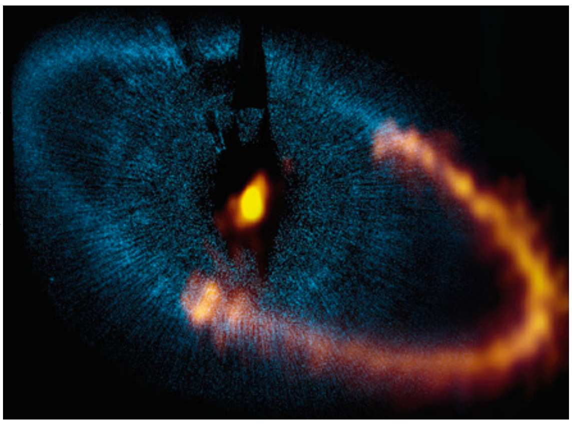
The presence of a dusty disc around the young main sequence star Fomalhaut had been known since the detection of an infrared excess (Aumann, 1985) with the Infrared Astronomical Satellite (IRAS). The filigree structure of the disc was revealed by Hubble Space Telescope (HST) imaging with the Advanced Camera for Surveys (ACS) with a coronagraph (Kalas et al., 2005). The disc is slightly elliptical in appearance with a major axis length of about 140 Astronomical Units (AU) and eccentric with respect to the stellar position. The puzzle about discs/rings around main sequence stars is that they cannot be the original proto-stellar disc, which would have long since dissipated, but must be actively replenished or trapped to be detected at all. From a second epoch of HST ACS imaging, Kalas et al. (2008) detected the proper motion of a bright spot in the outer disc around Fomalhaut and proposed this as a planet candidate (Fomalhaut b) with a mass of up to three Jupiter masses. The interactions between this candidate planet and the debris disc could explain the eccentricity of the dust ring, well measured with HST (Chiang et al., 2008).

However subsequent near-infrared (NIR) imaging with the Spitzer Space Telescope at 3.6 and 4.5 μm (Marengo et al., 2009), did not detect this planet when it was expected to be brighter than in the HST optical imaging. This implied either an unusual atmospheric composition or that it was not a true planet but a dust feature, perhaps enshrouding a lower mass planet. Janson et al. (2012) obtained deeper Spitzer 4.5 μm observations and concluded that the optical and NIR data pointed to a transient, optically thin dust cloud. However, what is not disputed is that there must be one or more planets in the Fomalhaut system to preserve a dust disc.

The longest wavelength observations of emission from large dust grains around Fomalhaut were made by the Australia Telescope Compact Array at 7 mm (Ricci et al., 2012) at a spatial resolution of about 12 arcseconds. The higher resolution ALMA observations were performed in the continuum at 850 μm which is mostly sensitive to emission from millimetre-sized dust grains. ALMA was used in its compact configuration with baselines from 14 to 175 metres and with Band 7 (275–373 GHz). The spatial resolution (synthesised beam) was 1.5 by 1.2 arcseconds, but the dusty ring was too large to be encompassed by a single ALMA primary beam, so ALMA was pointed at the northern half of the disc (where Fomalhaut b lies).

Figure 1 shows the ALMA map (corrected for the response of the primary beam) from Boley et al. (2012) superimposed on the HST ACS image from Kalas et al. (2005; 2008). This reveals a very narrow distribution of millimetre-sized grains with a radial width of only 16 AU; moreover the inner and outer radii of the disc are much sharper than indicated by the sub-micron sized particle distribution from the HST map. The millimetre-sized grains in the ring are much less affected by radiation pressure than the smaller (sub-micron) grains which have a broad tail of emission to large radii. Boley et al. suggest several explanations for the existence of the ring and its form; the favoured interpretation was that it is shaped by two shepherding planets, similar to the shepherding moons of the ε ring of Uranus — Cordelia and Ophelia. The required planet masses would be around several Earth masses, concordant with their non-detection by HST or Spitzer. A further intriguing result from the data is a possible flux excess on the star itself, suggesting an additional dusty region much closer to the star.

ESO astronomer Bill Dent (ALMA, Chile), one of the observing team, concluded in the press release: “ALMA may be still under construction, but it is already the most powerful telescope of its kind. This is just the beginning of an exciting new era in the study of discs and planet formation around other stars”[1].



ALMA (ESO/NAOJ/NRAO), NASA/ESA HST

Figure 1. Superposition of part of the NASA/ESA Hubble Space Telescope ACS image of the scattered optical light of the Fomalhaut debris disc (from Kalas et al., 2005, 2008) and the ALMA 850 μm continuum image (from Boley et al., 2012) of the northern section of the disc.

References

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Ricci, L. et al. 2012, A&A, 539, L6

Links

[1] ESO press release: http://www.eso.org/public/news/eso1216/