The first (and only) galactic detection of the 183 GHz water maser with an interferometer: the curious case of Serpens SMM1

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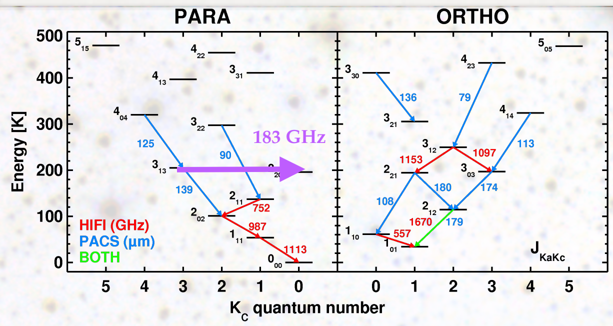
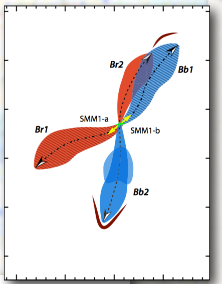
While hunting for thermal water for the WISH Herschel key program (van Dishoeck et al., 2011), the SMA made the very first (and still only) interferometric detection of a 183 GHz water maser in our Milky Way around low-mass protostar Serpens SMM1. Three blue-shifted maser spots were located along the red outflow. Later studies found a companion whose blue flow is coincidental. The spots are at a distance of almost a 1,000 AU, much further away than any previous 22 GHz maser emission. Although it was known this transition could produce maser emission, it was never expected to be found around a low-mass protostar, much less so distant from the protostar or protostars.

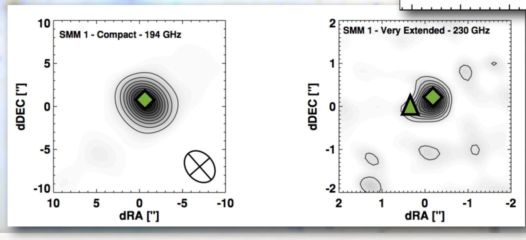


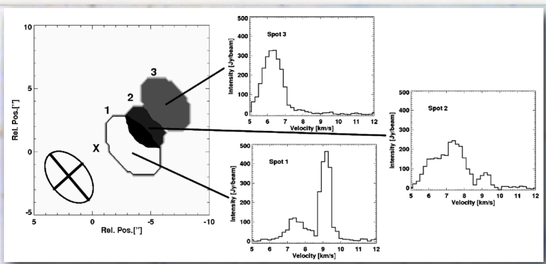
Water is one of the most abundant molecules in star-forming regions (>10^{-4}). It plays a key role in the cooling budget of protostars (Karska et al., 2013). However, it is virtually impossible to detect from the ground due to the presence of our atmosphere. The HIFI and PACS instruments on Herschel can observe all low-lying transitions. The lowest accessible line from the ground is at 183 GHz (E_{up} = 204.7 K), potentially spatially resolving water emission in the WISH key program (van Kempen et al., 2010, van Dishoeck et al, 2011, Kristensen et al., 2012). Water emission is dominated by large-scale outflow emission.

Red or Blue flow?

SMM 1 is one of the most massive nearby low-mass embedded protostars (D = 230 pc, L_{bol} = 30 $L_\odot$). It drives a powerful flow, although no molecular bullets have been seen (Kristensen et al., 2012). The embedded source is shown with a diamond. An atomic jet seen by Spitzer/Herschel revealed a close companion, previously unidentified, indicated with the triangle (Dionatos et al., 2014). In total two complete flows emerge from this system (see right)

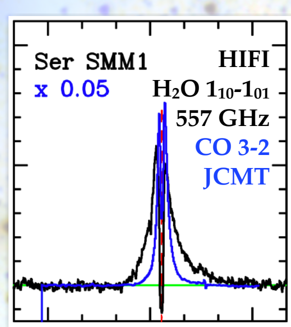


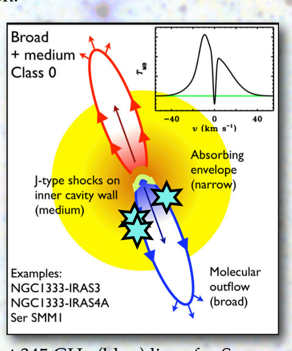




The 183 GHz transition can produce, but typical conditions were not expected to exist around a low-mass protostellar outflow ($n > 10^8$ cm^{-3}, T > 200 K). The spots were over 650 AU away and located in the outflow cavity wall, not in the protostellar disk. Local envelope densities are < 10^6 cm^{-3} and compression factors of at least 100 are required. No thermal emission was seen, although the bandpass probably limited detection of the bandpass. Also, no correlation was found with the 22 GHz maser emission, which originates much closer to the protostar (<<100 AU, Moscadelli et al., 2006). It also isn't coincidental with the "offset" component (Kristensen et al., 2013) also at <100 AU.The detection of two outflows and jets (Dionatos et al., 2014) suggests that the atomic jet of the companion is responsible for the water masers, perhaps in a collision shock and not the large molecular flow, which produces the thermal water emission.

Water observed with HIFI has been key to explore physical and chemical outflow structure as well outflow evolution over age (Kristensen et al., 2012, Visser et al., 2012, Suutarinen et al., 2014). What has been puzzling is that the maser spots appeared on the "wrong" side of the flow. However, with the confirmation by Dionatos et al., 2014, it is appears the maser spots are on the correct side of the blue flow of the companion.





Above: Water 557 GHz (black) and CO 3--2 at 345 GHz (blue) lines for Serpens SMM 1 (Kristensen et al., 2012). To the right is the "toy" model of Kristensen et al., 2012 for Serpens SMM 1. Blue stars show potential locations of the masers.

Will the spots move? We don't know...

Serpens SMM 1 has not been revisited by the SMA at 183 GHz in the last 5 years. (Lack of) movement in either velocity space or on the sky will be a very strong constraint on how outflows evolve, specifically the radiation field. 22 GHz masers are known to vary over time.

But we expect they will

why don't you use ALMA?

The 183 GHz line will always be very difficult to access due to the water in our atmosphere. Only the SMA has the receivers capable of tuning to the transition. The 183 GHz line will be within the tunable range of Band 5, but whic is not expected to be in full operation until mid-2017 on all antennas.

Because we can't. At least for the next 5 years

Relevant publications: van Kempen et al., 2009, Kristensen et al., 2012, Dionatos et al., 2014