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OH as a Probe of The Milky Way's Hidden Gas: First Results from SPLASH

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Abstract. SPLASH (the Southern Parkes Large-Area Survey in Hydroxyl) is a deep survey of ground-state OH absorption and emission from the Galactic Plane, as well as an unbiased search for OH masers. Key early results include the detection of a rich and complex distribution of diffuse, optically thin OH with strongly non-thermal excitation temperatures, and the detection of numerous new maser sources. The survey aims to use OH as a probe of CO-dark H_2 ISM Galactic scales, with future plans including comprehensive comparisons with CO and HI, as well as non-LTE excitation modelling of the four ground-state lines.

Keywords. ISM: clouds, ISM: evolution, ISM: molecules, masers, surveys

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In recent years it has become clear that standard radio line tracers of the interstellar medium fail to account for a substantial fraction of the neutral gas (e.g. Grenier *et al.*2005; Planck Collaboration 2011). Historically, the HI 21 cm line (in both emission and absorption), together with the mm/sub-mm rotational lines of CO, have been used to map the atomic and molecular ISM across a broad range of spatial scales and environments. However, while CO is a good proxy for H_2 in well-shielded regions, it cannot trace more diffuse molecular gas of $A_V \lesssim 1$, where CO abundances are low (e.g. Wolfire *et al.*2010). Similarly, while HI integrated intensity is proportional to the atomic gas column in warm, optically thin gas, it underestimates column density in cool, optically thick clouds.

The 18 cm ground state transitions of OH are a promising tracer of CO-dark H_2 (e.g. Wannier *et al.*1993; Allen *et al.*2012, 2015) and/or partially molecular gas (Liszt & Lucas 1996; Li & Goldsmith 2003), but one that has not been exploited on large scales before now. SPLASH (http://splash-survey.org/; the Southern Parkes Large-Area Survey in Hydroxyl) has spent close to 2000 hours mapping the Southern Galactic Plane between $l = 332°$ and $10°$, $b < |2°|$, in all four ground-state transitions of OH (1612.231, 1665.402, 1667.359, 1720.530 MHz) achieving the necessary sensitivities to detect widespread diffuse (non-masing) OH emission and absorption throughout the Milky Way.

Early results from the pilot region of the survey ($l = 334°$ to $344°$) have been published in Dawson *et al.*(2014) and include the following key points:

- The OH lines are always optically thin – at least when averaged over the $\sim 13'$ telescope beam.
- In general, none of the lines are in local thermodynamic equilibrium (LTE) – even the main lines (1665 and 1667 MHz), for which LTE has sometimes been assumed. Incorrect usage of the LTE assumption will introduce large errors into column density estimates.
- The continuum background brightness temperature (T_C) is critically important in determining the detectability of the weak OH emission/absorption characteristic of CO-dark gas. In contrast to other works at similar sensitivities which mapped local and outer Galaxy clouds (Wannier *et al.*1993, Allen *et al.*2015), only 1% of voxels in the SPLASH pilot region show OH

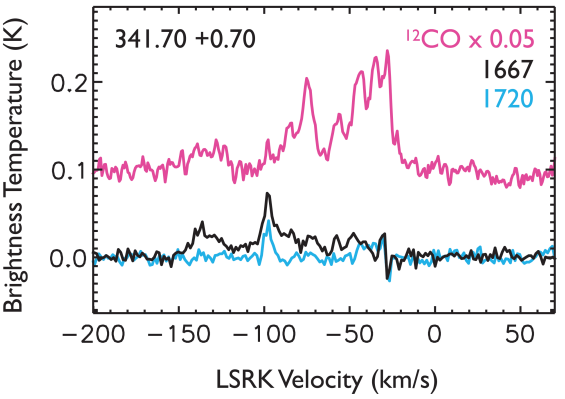

Figure 1. Example of OH lines and ^{12}CO(J=1–0) emission (from the NANTEN Galactic Plane Survey) towards a single sightline in the SPLASH survey region.

with no detected CO. This is likely in part due to the similarity of T_C to line excitation temperatures, but may also indicate genuinely different gas properties in the inner Galaxy, where ambient densities are higher.

While OH is not widely detected extending spatially outside of CO clouds, line profiles suggest that OH and CO preferentially trace different gas components along the line of sight (see Fig. 1). By focussing on low Galactic Latitudes where T_C is high, and modelling the continuum distribution along each sight line to solve for OH column densities, OH-derived H_2 columns will be compared with those derived from ^{12}CO(J=1–0) and ^{13}CO(J=1–0) data to identify and map CO-dark H_2.

Finally, the satellite lines (1612 and 1720 MHz) are anomalously excited, with excitation temperature strongly subthermal in one line and very high or negative in the other. Excitation is sensitively dependent on physical environment – particularly density, kinetic temperature and IR field. Future work plans to use the MOLEX non-LTE excitation code (Hewitt *et al.*2006) to produce model spectra and map patterns of temperature, density and IR field in the OH-bright ISM throughout the Inner Galaxy. SPLASH is the only large-scale, sensitive survey to have obtained both satellite lines, and hence the only dataset with which to carry out this analysis.

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