Molecular Gas, Dust, and Star Formation in Galaxies
Proceedings IAU Symposium No. 292, 2012
T. Wong & J. Ott, eds.

doi:10.1017/S1743921313000203

An evolutionary sequence for high-mass star formation

S. L. Breen[1] and S. P. Ellingsen[2]

[1]CSIRO Astronomy and Space Science, PO Box 76, Epping, NSW 1710, Australia
email: Shari.Breen@csiro.au

[2]School of Mathematics and Physics, University of Tasmania, Private Bag 37, Hobart, Tasmania 7001, Australia

Abstract. Determining an evolutionary clock for high-mass star formation is an important step towards realizing a unified theory of star formation, as it will enable qualitative studies of the associated high-mass stars to be executed. Our recent studies have shown that masers have great potential to accurately trace the evolution of these regions. We have investigated the relative evolutionary phases associated with the presence of combinations of water, methanol and hydroxyl masers. Comparison between the characteristics of coincident sources has revealed strong evidence for an evolutionary sequence for the different maser species, a result that we now aim to corroborate through comparisons with chemical clocks.

Using our new, large samples of methanol masers at 6.7 GHz (MMB survey; Green *et al.* (2009)) and 12.2 GHz (Breen *et al.* 2012), 22 GHz water masers (Breen & Ellingsen 2012), OH masers together with complementary data, we find strong evidence that it is not only the presence or absence of the different maser species that indicates the evolutionary stage of the associated high-mass star formation region (see e.g. Breen *et al.* (2010)), but that the properties of those masers can give even finer evolutionary details. Most notably, the intensity and velocity range of detected maser emission increases as the star forming region evolves (Breen *et al.* 2011).

Subsequent work we have undertaken (Ellingsen *et al.* 2011) has shown that the presence of rare 37.7 GHz methanol masers may signal the end of the methanol maser phase. They show that 37.7 GHz methanol masers are associated only with the most luminous 6.7 and 12.2 GHz methanol masers, which combined with the rarity of these objects is consistent with them being a short lived phase towards the end of the 6.7 GHz methanol maser lifetime.

An independent confirmation of our maser evolutionary timeline can be gained through comparisons with chemical clocks. MALT90 is a legacy survey of 1000s of dense star forming cores at 90GHz, simultaneously observing 16 molecular lines with the Mopra radio telescope (see e.g. Foster *et al.* 2011). It provides the perfect dataset to test the maser evolutionary timeline due to the targeted lines and the fact that at least one-quarter of the MALT90 sources correspond to maser sites, providing a large enough sample for meaningful analysis. From our preliminary analysis, we find that star formation regions showing similar maser properties also show similar thermal line properties; as would be expected if our evolutionary scenario were accurate.

Keywords. masers — stars: formation — ISM: molecules — radio lines: ISM

References

Breen, S. L., Ellingsen, S. P., Caswell, J. L., & Lewis, B. E., 2010, *MNRAS*, 401, 2219
Breen, S. L., Ellingsen, S. P., Caswell, J. L., Green, J. A., *et al.*, 2011, *ApJ*, 733, 80
Breen, S. L. & Ellingsen, S. P., 2011, *MNRAS*, 416, 178
Breen, S. L., Ellingsen, S. P., Caswell, J. L., Green, J. A., *et al.*, 2012, *MNRAS*, 421, 2511
Ellingsen, S. P., Breen, S. L., Sobolev, A. M., Voronkov, M. A., *et al.*, 2011, *ApJ*, 742, 109
Foster, J. B., Jackson, J. M., Barnes, P. J., Barris, E., *et al.*, 2011, *ApJS*, 197, 25
Green, J. A., Caswell, J. L., Fuller, G. A., Avison, A. *et al.*, 2009, *MNRAS*, 392, 783