On the Origin and Evolution of Wolf-Rayet Central Stars of Planetary Nebulae

By

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Except where acknowledged in the customary manner, the material presented in this thesis is, to the best of my knowledge, original and has not been submitted in whole or part for a degree in any university.

Kyle David DePew

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List of Publications

Papers and Conference Proceedings Produced in the Course of This Thesis

- **DePew K.**, Parker Q.A., Miszalski B., De Marco O., Frew D.J., Acker A., Kovacevic A.V., Sharp R.G., 2011. *Newly Discovered Wolf-Rayet and Weak Emission-Line Central Stars of Planetary Nebulae.* MNRAS, in press.

- Corradi R.L.M., Valentini M., Munari U., Drew J.E., Rodríguez-Flores E.R., Viironen K., Greimel R., Santander-García M., Sabin L., Mampaso A., Parker Q., **DePew K.**, Sale S.E., Unruh Y.C., Vink J.S., Rodríguez-Gil P., Barlow M.J., Lennon D.J., Groot P.J., Giammanco C., Zijlstra A.A., Walton N.A., 2010. *IPHAS and the symbiotic stars. II. New discoveries and a sample of the most common mimics.* A&A, 509, 41.

- **DePew K.**, Frew D.J., Parker Q.A., De Marco O., 2011. *Wolf-Rayet Central Stars of Planetary Nebulae: Their Evolution and Properties.* APN5 Conf. Proceedings, A.A. Zijlstra, F. Lykou, I. McDonald, E. Lagadec, eds., 160.

Abstract

The origin of hydrogen-deficiency in the central stars of planetary nebulae (CSPNe) is currently a topic of heated debate. This class of objects is comprised of Wolf-Rayet ([WR]) stars, weak emission-line stars (WELS), and PG 1159 stars, each differentiated by a set of unique spectral characteristics. For some time, there have been questions surrounding the evolutionary status of these rare stars: what environmental conditions, such as chemical abundances, are necessary for their emergence, whether any of them represent different stages of development in the same class of stars, and what the characteristics of their progenitors may be. However, such investigations have been hampered by a lack of a sufficient number of these stars and their various sub-classes until recently.

This thesis presents the significant discovery of 22 new [WR] stars and 10 new WELS, many uncovered specifically during this thesis in the course of the MASH survey and through serendipitous fibre placement during follow-up of MASH objects. All examples have been carefully classified as accurately as possible using the best current available data though for many this remains a preliminary assignment pending deeper spectra. This work expands the known sample of H-deficient stars by 30%, allowing a more detailed study of their properties than previously possible and moving us closer to a more complete census of local H-deficient CSPNe.

In the course of our classifications, Abell 48 was found to be a particularly interesting object. Further analysis of nebular chemical abundances, modeled temperature, and ionization state as indicated by the chemical species present suggests that the CSPN of Abell 48 may be very similar to the CSPN of PB 8, which has recently been redesignated as the founding member of a new and rare [WN/WC] class (Todt et al. 2010). Its similarity to and differences with other oxygen-rich [WO] and carbon-rich [WC] stars as well as previously identified [WN] stars are examined.

All these stars have also been studied in the context of a new subclass-dynamical age relationship that we have also discovered. This major finding is the first to show evidence of an evolutionary trend amongst the [WR] population and was made possible by use of the powerful new surface brightness-radius (SB-r) relation of Frew (2008) that can, at last, provide accurate distances to PN (and hence also their central stars). Key data acquired here as well as modeled effective temperatures and excitation classes of other [WR]s, WELS and PG 1159 central stars found in the literature were also utilized in generating this relationship.

Finally, continuing with the SB-r relation, the scale heights of the most complete available sample of [WR], WELS and PG 1159 CS populations are determined and compared. These data show that both WELS and PG 1159 stars are found to possess significantly higher Galactic heights than the members of the [WR] class, implying that PG 1159s do not all descend from [WR]s, and that WELS are not evolutionarily related to [WR]s. This is another major finding of this work. It is possible, however, that the WELS class, and perhaps the PG 1159 class as well, are heterogeneous groups.

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