HERBIG Ae/Be STARS: AN INVESTIGATION OF MOLECULAR ENVIRONMENTS AND ASSOCIATED STELLAR POPULATIONS

A Dissertation Presented

by

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Unfortunately, by tradition this is usually the shortest section of such a document. Being a traditional sort only on the surface, however, i suspect this precedent may not hold true in my case – so be prepared!

There are three folks without whose influence over the past several years (both intended and unintended), i would have evolved very differently. I owe each of them a proper chapter's worth (at least) of unexpressed thoughts, and of course my deepest thanks for their friendship. Steve Strom prompted me to re-investigate many of the ideas and carry out many of the projects which he and others initiated in various forms decades ago. This was accomplished, in part, by piling my desk with old, musty file folders containing hand drawn graphs, pencilled notes on index cards, photographic prints, and spectrogram traces. Despite our sometimes vehement disagreements between impressions derived from data viewed through his "one-sigma eyes" *vs* my "three-sigma eyes," he did impart to me that neither is more powerful than belief in a result. Suzan Edwards encouraged my habit of not following paths, even though she herself was often my only path. Particularly during the admittedly far - too - hurried assembly of this document, her guidance was invaluable, "ke*ru*tial" in fact. Michael Meyer gracefully offered scientific explanations when needed, as well as wonderfully encompassing myths about how great all of this was – usually just when i really *didn't* want to hear it. He also brought some needed integrity to the infrared data acquisition, and developed and coded "the method" for deriving masses for embedded stellar populations.

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Abstract

HERBIG Ae/Be STARS: AN INVESTIGATION OF MOLECULAR ENVIRONMENTS AND ASSOCIATED STELLAR POPULATIONS

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We have carried out a molecular mapping, optical and infrared imaging, and stellar-classification spectroscopic survey of star-forming sites containing young ($\tau <$ 1 Myr) intermediate- and high-mass ($M > 3M_{\odot}$) stars. Our target sample is drawn from the set of pre-main sequence Herbig Ae/Be stars with spectral types earlier than B7, and focusses on those which are isolated from large complexes of extensive star-formation. Our aim is to quantify the local environmental characteristics (molecular and stellar clustering) of regions in which high-mass stars are being produced, in order to compare these properties with those of regions in which only low-mass stars are being produced.

In the current analysis, we first investigate the general attributes of the small clouds within which our sample of massive Ae/Be stars is found. We then define an appropriate size scale (1/3 pc $\times$ 1/3 pc in area) over which to investigate stellar clustering properties, and identify small (a few to tens in number), dense (several hundred to several thousand stars per cubic parsec), partially - obscured stellar aggregates projected onto the same molecular cores as are our sample of Ae/Be stars. We find an apparent correlation between cluster density and the mass of the defining Ae/Be star. We then present evidence based on the observation of infrared and spectroscopic circumstellar activity signatures usually indicative of stellar youth, as well as on the actual location of the members of several of these groups in the HR

diagram, that indeed the companions to young massive Ae/Be stars are also young pre-main sequence stars, of lower mass. Given the significant amount of ambient molecular material and the apparent youthfulness of the stellar populations, any and all objects found near the cores are likely not to have wandered far from their birthplaces. Thus, our survey enables us to carry out a complete census of stars formed relatively contemporaneously with the high-mass "signpost."

Our particular goals then, are to determine 1) *the initial stellar mass spectrum* in spatially and temporally coherent (*i.e.*, truly "initial") units which have given birth to at least one high-mass star, as well as 2) *the time sequence of star formation as a function of stellar mass*, that is, whether stars of all masses are formed simultaneously in a dense stellar environment, or whether high-mass stars might form significantly before or after the initiation of low-mass star-formation. With these goals, we explore techniques for investigating the distributions of stellar masses and stellar ages in young groups, as well as the observational and theoretical limits of these techniques.

Finally, in our discussion we address the issue of differences in local stellar environment between star-forming regions producing high-mass stars and those producing only low-mass stars. We pursue the hypothesis that if the Ae/Be stars studied herein are representative of a stellar evolutionary phase through which all young high-mass stars pass, and if their association with dense aggregates of stars is typical, then these young stellar *systems* may provide important clues to the physical processes associated with forming high-mass stars. We therefore urge the theoretical consideration of star formation in dense groups ($\approx 1000\ stars\ pc^{-3}$) as an expansion to the developing theory of protostellar collapse for individual high-mass stars.

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