Eta Carinae at the Millennium
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Conference Introduction

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Eta Carinae is legendary as the most extreme and most mysterious naked-eye star. Its many superlatives are well known: most luminous star in our part of the Galaxy, survivor of a colossal eruption that made it a first-magnitude star for 20 years in the 19th century, site of the famous bipolar "Homunculus" nebula, etc. But, after decades of intensive observations, *we still do not understand this object.* We don't know what caused the Great Eruption; we aren't confident of Eta's basic nature (e.g., is it a binary system, and if so, is the companion essential to the problem?); a variety of bizarre morphological and dynamical features in the large-scale ejecta continue to puzzle us; we cannot account for some freakishly intense emission lines scarcely seen anywhere else; the X-rays are unusually hot and luminous; etc. So many unsolved mysteries, which would be remarkable in a faint, distant, poorly studied object, are astonishing in a naked-eye star.

A second consideration is *the remarkable diversity of astrophysical topics involved in the study of Eta.* Sir John Herschel's opinion in the 1840s, that "perhaps no other sidereal object ... unites more points of interest" than η Car, is still defensible today. Stellar physics (interiors, atmospheres, winds, instabilities, rotation, and evolution), gas dynamics, atomic physics (peculiar excitation processes), non-routine radiative transfer, abnormal dust formation, and other subjects are involved. Eta may, or may not, represent an evolutionary stage that all the most massive stars pass through. A few strange events in other galaxies (e.g., SN1961V in NGC 1058, SN1954J in NGC 2403) resemble the Great Eruption. Eta has almost unique characteristics at radio, IR, visual, UV, and X-ray wavelengths, while several major new instruments such as the HST have revolutionized our observational knowledge. This broad combination of circumstances has made η Carinae *a surprisingly large topic.* Theoretical studies, however, though urgently needed, have been scarce so far. This topic offers theorists a set of interesting problems that are far less explored than in most other areas.

Our awareness of η Car has passed through several distinct eras. First there was obscurity before the 1840s; major photometric variations were recorded but scarcely noticed. Then the Great Eruption (c. 1838–1858) became known, partly through John Herschel's famous 1847 report of his long visit to the Cape.

Eighty years later the star was almost hidden by dust, and a lack of images and spectra between 1900 and 1940 is frustrating today. In the 1950s, however, Gaviola and Thackeray drew attention to the expanding Homunculus and its unusual spectrum. During 1950–1970 a number of prominent theorists and generalists expressed suspicions that η Car was highly significant, but they had no way to settle the nature of the central object (which, according to the fashion of those years, might have been a protostar, an F-type supergiant, or a non-thermal SNR).

Major insight into Eta's true nature occurred between 1968 and 1972 when Westphal and Neugebauer made the first infrared observations and found that Eta's visible light is greatly obscured by dust and that its present-day luminosity is roughly $10^{6.6} L_\odot$, of the same order as its visual luminosity during the Great Eruption. This fact led to a recognition that the central object is a hot, very massive star, whereupon the central questions became: How can such a star produce a Great Eruption, and is this phenomenon critical for the evolution of very massive stars in general? A few years later η Car played a major role in the recognition of LBVs as a physical class of objects. (Ironically, however, today we still cannot decide whether Eta is truly a member of the class!) In the early 1980s, partly through use of the prolific International Ultraviolet Explorer (IUE), we learned that η Car is quite nitrogen-rich and moderately helium-rich. Symptomatic of the CNO cycle and mixing, this composition shows that it is a moderately evolved star. Meanwhile the first IR maps showed the essentially bipolar morphology of the Homunculus ejecta-nebula. In the 1980s the topic almost approached its "modern" state concerning theory, but the observations still had inadequate spatial resolution.

After about 1992, of course, wonderful HST data began to appear while cm- and mm-wavelength radio and X-ray observations began to show new aspects of η Car. The Homunculus became famous through its oft-reprinted HST images, spectroscopy of the star itself (separated from very bright nearby ejecta) was attained for the first time, and the modern images, spectroscopy, radio, and X-ray data solved a few old questions while opening a larger number of new ones. Some of these new morphological, dynamical, and spectroscopic puzzles are quite strange and are discussed in this book. We have omitted references throughout this brief historical sketch, but citations until late 1996 can be found in the 1997 *Annual Reviews of Astronomy and Astrophysics* (vol. 35, p. 1).

By mid-1997, various hints suggested that research on η Carinae had entered a new stage of unprecedented activity. HST, radio, and X-ray data had recently enlarged the topic as noted above, revealing many novel problems; new data of *excellent* quality were expected (particularly with the HST-STIS instrument), and X-ray monitoring had just begun to indicate unusual behavior in the stellar wind. These facts in themselves justified a meeting on the subject, and then a novel development brought the whole mixture to a boil. In 1996 Damineli had identified a possible 5.5-year cycle in Eta's spectroscopic behavior, which implied an observable "event" of some type near the end of 1997. This idea promised to be revolutionary in two ways: First, a well-defined periodicity is traditionally a very strong clue to the structure of an astrophysical object. Second, astronomers would be able to observe the predicted event in great detail even though its basic nature was very unclear beforehand.

The "event" did occur roughly as predicted, it was complex and quite dramatic at some wavelengths, and impressive new data did materialize. Although, the problems of η Car have not been solved as a result — not yet, at least! — but it is fair to say that the topic has now become very different from what it was in 1996. So a small research conference a few months after the "event" seemed the obvious time to bring together what we've learned about this unique star and what we still do not understand.