Eta Carinae's Historical Spectra : Complications for the Binary Model

Roberta M. Humphreys
University of Minnesota

The normal groundbased spectrum of eta Carinae shows high excitation emission lines including [NeIII], [FeIII], etc, strong He I emission lines and narrow emission components in the other lines such as FeII, [FeII], and the hydrogen lines. This is what is sometimes referred to the "high" state. At the times of the periodic "spectroscopic event ", every 5.5 years, the high excitation lines weaken and even disappear. Then eta Car has a low excitation emission line spectrum dominated by hydrogen and Fe II lines, called the "low" state. We now know that the high excitation lines are not from the star, but instead come from the inner ejecta, specifically the Weigelt blobs. During the "events", it is hypothesized that UV radiation, possibly from a hotter companion star, is somehow blocked and doesn't reach the Weigelt blobs.

Feast, Whitelock, and Marang (2001) examined the historical photographic spectra available at the Cape Observatory and found that from 1951 to the present, the spectral variations fit the expected 5.5 year periodicity. The low excitation spectra are observed at phase 0.9 to 1.1 in the 5.5 year spectroscopic cycle, corresponding to the "spectroscopic events". However, based on the spectra available at the Cape, *the star was always in its "low" state, from about 1900 to 1920, independent of phase* (0.13 to 0.82). *Thus, there were no "spectroscopic events" during that time.* Some of the later spectra are missing; therefore there is a gap in the spectroscopic record from about 1920 to the 1940's when Gaviola (1953) obtained a series of spectra beginning in 1944 that showed high excitation emission lines.

The earliest spectroscopic observation of eta Car is a visual description by Le Seuer from 1869-70, discussed by Walborn and Liller (1977), consistent with a low excitation emission line spectrum. The first photographic spectrum was obtained as part of Harvard Observatory's objective prism survey during eta Car's second eruption in 1892-93. It is described by Cannon (1901), Bok (1930) and Hoffleit (1933). It shows the absorption line spectrum of a luminous F-type supergiant (~ F5) with strong hydrogen emission lines with prominent P Cygni profiles. Humphreys, Davidson and Smith (1999) demonstrated that the 1890's second or lesser eruption was an S Dor/LBV - type outburst and that the F supergiant spectrum was formed in the opaque wind as observed in other S Dor/LBVs in eruption. Figure 1 shows eta Car's historical light curve.

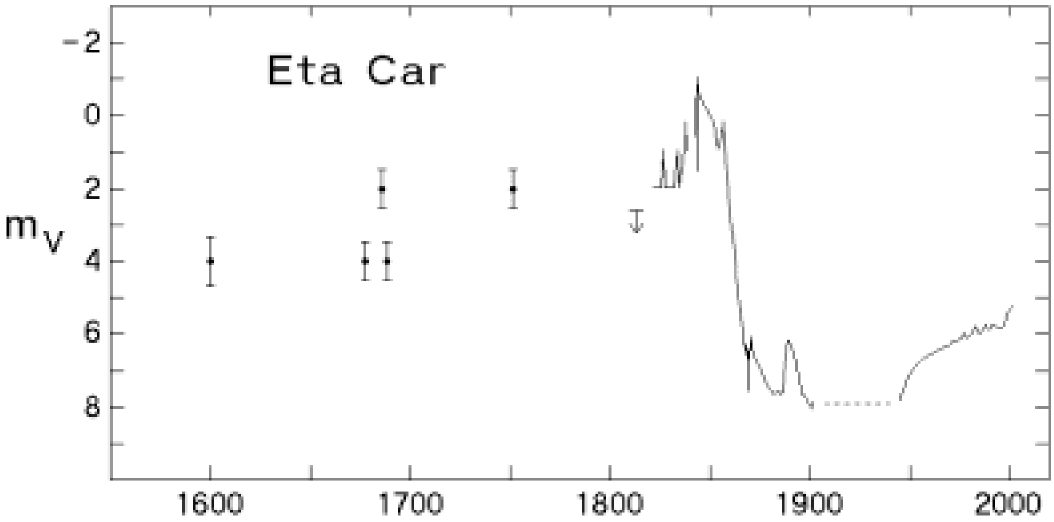

Figure 1 -- The historical light curve of et a Car from 1600 to the present. Note that magnitudes after the great eruption refer to the integrated light of th ejecta.

Thus, from ~ 1895 to the 1940's , all available spectra of eta Car show a low excitation emission spectrum. The first description of a high excitation emission spectrum is from 1944 by Gaviola (1953) who was also the first to report a low excitation spectroscopic event in 1948.

So what happened?

In the 1940's the apparent brightness of the Homunculus changed dramatically*
All reported magnitudes since the 1890's second eruption were consistent with a 7.8 - 8.0 apparent visual brightness until 1941 when it increased rapidly in brightness (de Vaucouleurs and Eggen 1952), see Figure 1. It rose ~ 1 magnitude in only one month (May to June 1941), and then varied between ~ 6.5 and 7th visual magnitude until 1949. Photovisual and early photoelectric measurements in 1951-52 give an integrated visual magnitude ~ 6.5 mag. As we know, eta Car has continued to brighten slowly since then, attributed mostly to the expansion of the Homunculus until its recent rapid brightening in 1998 (Davidson et al 1999).

A major change occurred in the spectrum and in eta Car's spectroscopic behavior between 1920 and 1944. Its light curve shows a rapid brightening in 1941and the first recorded high excitation spectrum appears after that. Therefore I am suggesting that the change in eta Car's groundbased spectrum from low excitation to high excitation and the onset of the spectroscopic events corresponds to the dramatic and rapid increase in the apparent brightness of the Homunculus in 1941; although we need to fill in the gap in the spectroscopic record from 1920 to 1940, if possible.

So we are faced with the very likely probability that there were NO spectroscopic events prior to ~ 1948.

UV radiation is necessary to produce the high excitation emission lines. Temperatures of ~ 35,000 K are required for the [NeIII], [FeIII] lines. So what are the possible explanations for the apparent lack of UV radiation prior to the 1940's?

Some Possibilities:

1. Optically thick cicumstellar dust that prevents the UV radiation from reaching the Weigelt blobs.

   However, the major axis of the proposed binary orbit is 34 AU, but the dust forms at 100 - 200 AU. (At this meeting Gehrz said 175 AU.) So the explanation can't be dust inside the orbit.

2. An optically thick wind that filled the orbit and likewise blocks the UV radiation from the proposed hot companion.

   To create and maintain this optically thick wind would require an increase in the mass loss rate by at least a factor of 5 over the current rate which then must suddenly decrease enough in the 1940's to allow the wind to become optically thin. However, the spectrum of this wind would be cool, like the F supergiant spectrum observed in the 1890's eruption when the wind was optically thick, not the low excitation emission line spectrum actually observed in the early 20th century.

Thus neither of these obvious possibilities is satisfactory. And any explanation must also account for the rapid brightening in 1941 with which the spectrum change is probably correlated.

So the outstanding question is what is the REAL source of the UV radiation?

1. the (hot) secondary?
2. the primary or eta Car itself?
3. or both?

A final remark: Eta Car is not alone. It is not unique and its great eruption is not some freakish event that astrophysicists don't have to be concerned with. There are several other eta Carinae - like variables --- P Cyg during the 1600's, SN 1961v in N1058 and SN 1954j = V12 in N2403 (see Humphreys, Davidson and Smith 1999). V1 in N2363 (Drissen et al 1997, 2001) should now be added to this rare group of stars and the "Pistol star" near the galactic center (Figer et al 1998) may be another example. There are several additional candidates in the current supernovae surveys among the Type IIn supernovae.

A somewhat catchier name for these very massive stars and their great eruptions may be "Supernovae Impostors".

References:

Bok, B. J. 1930, Pop. Astron., 38, 399.
Cannon, A. J. 1901, Harvard Ann., 28, 175.
Davidson, K. 1999, in "Eta Carinae at the Millenium", ASP Conf. Ser. 179, Ed. J. Morse, et al., pg 308.
Davidson, K. 2000, in AIP Conf. Proc., 522, "Cosmic Explosions", Ed. S. S. Holt & W. w. Zhang, pg 421.
Davidson, K., Gull, T. R., Humphreys, R. M., Ishibashi, K. et al. 1999, AJ., 118, 1777.
de Vaucouleurs, G. and Eggen, O. C. 1952, PASP, 64, 185.
Drissen, L., Roy, J.-R., and Robert, C. 1997, ApJ., 474, L35.
Drissen, L., Crowther, P. A., Smith, L. J., Robert, C., et al. 2001, ApJ., 546, 484.
Feast, M. W., Whitelock, P., and Marang, F. 2001, MNRAS, 322, 741.
Figer, D. F., Najarro, F., Morris, M., McLean, I. S., and Geballe, T. R. 1998, ApJ., 506, 384.
Gaviola, E., 1953, ApJ., 111, 408.
Hoffleit, D. 1933, Harvard Bull., 893, 11.
Humphreys, R. M., Davidson, K. and Smith, N. 1999, PASP, 111, 1124.
Walborn, N. R. and Liller, M. 1977, ApJ., 211, 181.

Discussion:

Nathan Smith -- (Remarks derived from the observed latitude-dependent wind described earlier in this meeting; see also similar comments in Davidson 1999, 2000.)

After the great eruption and the removal of the star's outer layers, the outer envelope would have been rotating slowly. The ionizing photons from the equatorial region would not have been able to escape through the dense wind. As the angular momentum from core gradually spun up the star’s envelope, gravity darkening would have increased and the low latitude regions would have become optically thin to the UV radiation. It is possible that this critical point was reached ~ 1940 resulting in the rapid brightening and the onset of the high excitation spectrum. In this case, it is changes in the primary, the spin up of its envelope, and its wind that are responsible for the increase in degree of excitation of the spectrum. This implies a lesser role for the UV radiation from a hotter companion, because the high excitation spectrum was not observed prior to this time. Of course the approach of a companion star could help to spin up the primary.