etaCar2014

An international campaign for monitoring the next periastron passage of eta Carinae in 2014[*]

SUMMARY

This document presents the basis for a spectroscopic campaign to densely monitor the periastron passage of eta Carinae in 2014. The design of the observational setup is presented in order to warranty a homogeneous dataset suitable to solve pending scientific questions and thus generating one or more publications in peer-reviewed journals. The full campaign corresponds to 60 spectra (6 nights of 10 hours).

The core of the campaign (July and August), when most of the efforts will be spent, is centered on the periastron itself and will demand just 30 spectra, corresponding to 6 nights on small/medium-sized telescopes. However, there are additional related phenomena, just before and after it, not well studied yet and that deserve monitoring. Participants are welcome to join the entire campaign or some particular phase (e.g. due to weather conditions). Observations in late August and early September will be very difficult to perform since eta Car will be high in the southern sky during daytime, but they would be important and must be attempted.

*We welcome the collaboration of both amateur and professional observers***,** *as occurred during the ProAm ConVento campaign on WR140, which included a workshop after the campaign (see www.stsci.de/wr134, www.astrosruf.com/joseribeiro/e_arrabida.htm). A very dense monitoring "a la" Whole Earth Telescope (WET) is greatly encouraged as such offers the potential of greatly improving the accuracy of the binary period.*

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[*] People interested in collaborate with this campaign should send an e-mail to etacar2014@gmail.com with full name and affiliation.

OPEN QUESTIONS ON ETA CARINAE

New, important discoveries about eta Carinae have occurred in recent years thanks to frequent observations from space and ground telescopes, from X-rays to radio wavelengths. Many of those came from modest-sized telescopes. Regarding observations of eta Car, the importance of small telescopes is increasing with time, as the observational techniques progress and the object becomes too bright for the large telescopes. Telescopes with 0.5 to 2 m aperture equipped with moderate-dispersion CCD spectrographs are sufficiently available across the southern hemisphere to provide dense time monitoring, especially during the critical period (July 23 thru Aug 2).

In the following, we summarise questions, which can be answered by a coordinated spectroscopic campaign involving observatories in the southern hemisphere. Observers are welcome to join the campaign and participate as co-authors of the paper(s) expected from the collaborative effort. Telescopes south to latitude -30 degrees are specially important, since the star is far south (-60 degrees) and crosses the meridian at noon one month after periastron passage.

Eta Carinae is a binary system with a period P=2022.7+/-1.3d (Damineli, Hillier, Corcoran, Stahl, Groh, et al. 2008a). The system is composed of two massive stars, eta Car A, which is an LBV with Teff~9400 K (Hillier et al. 2001; Groh et al. 2012) and a hotter companion, eta Car B, with Teff~36000 K (Verner et al. 2005; Iping et al. 2005; Teodoro et al. 2008; Mehner et al. 2010), in a highly eccentric orbit (e>0.9). Both companions have large mass-loss rates, leading to violent wind collisions (Damineli et al. 1997). The apex of the wind-wind collision zone (WWC) reaches temperatures up to 100 million K, resulting in a bright, variable X-ray source (Corcoran 2005; Parkin et al. 2010). The orbital parameters are known with a reasonable accuracy, mainly from 2D modelling of the HST/STIS spatially resolved spectra (Madura et al. 2012; Groh et al. 2012). The accuracy in the period length must be improved by ~10 times in order to be able to measure variations in the orbital period.

The system is getting secularly brighter. The cause is not clear. Dust dissipation has been suggested, but Fernández-Lajús (http://etacar.fcaglp.unlp.edu.ar/) showed that the brightening ratio between the central star and the envelope presents jumps after the periastron passages, indicating a possible influence of the binary interaction on the circumstellar environment. Moreover, Smith & Frew (2011) claim that the period length during the 1827-45 big eruption was shorter than it is today. This would indicate that the tidal interaction between the companion stars is stronger than is possible with an eccentricity of 0.9, demanding e~0.95. For these reasons we wish to monitor the effects related to period changes and brightness jumps around periastron. We need to measure the period length and the epoch of periastron as accurately as possible. Our proposed campaign should decrease the present uncertainty to 0.5 day.

Several problems are connected with the low excitation event, which occurs across the periastron passage. The duration of the minimum in X-rays is too long for an eclipse (~2 months) likewise the longer absence of the high excitation emission lines (~5 months). Moreover, the X-ray recovery from the 2009 minimum occurred 1 month earlier (Corcoran et al. 2010) than the previous monitored minima (2003.5, 1998.0). Therefore, an additional mechanism must extend the minimum. Following Teodoro et al. (2012), soon after the onset of the minimum (which is due to a conjunction) the system reaches periastron. The two stars get so close to each other that the radiative flux of the primary inhibits the acceleration of the secondary wind. As a consequence, the secondary wind slows and the momentum of the primary's wind then overcomes the secondary wind, causing a collapse of the WWC structure onto the surface of the secondary star (Parkin et al. 2010). The X-ray emission is diminished, causing an extended minimum. However, since the primary's wind is clumpy, the recovery from the collapsed state can change from cycle to cycle, depending on the arrival of the denser or thinner blobs in the wind. Clumps in the primary's wind can also explain the flares seen before periastron in X-rays and HeII 4686 emission line (Moffat & Corcoran 2009; Teodoro et al. 2012).

The recent discovery of a huge enhancement of the HeII 4686 just before periastron (from EW~0.05 to EW~3A; see Fig. 1) indicates that a luminous source of extreme UV is ignited close to periastron. At a luminosity of $L\sim10^6\ L_\odot$, the HeII 4686 flux is 100x more intense than the mechanical power available in the secondary's wind. The denser, slower primary wind might be the origin of such an extreme UV source (Teodoro et al. 2012). Furthermore, a special mechanism powering the HeII 4686 line, as discussed by Martin et al. (2006), might enhance the production of UV photons.

An additional mystery involving the HeII 4686 line is its rebirth after the minimum, peaking ~30 days after phase zero. It is anti-correlated with X-ray emission, contrary to what occurs before periastron. The flux enhancement cannot be due to clumps in the primary's wind but may correspond to the collapse of the WWC structure, which emits more at lower energies at the expense of the hard X-rays. Such a rebirth in HeII 4686 is hinted in observations taken during the previous 3 cycles, but for those cycles observations did not fully monitor across the low state. This leaves room for a debate if such a feature occurred only in the 2009 periastron (Mehner et al. 2011) or if it is a phase-locked feature, physically linked to the orbital motion. Only monitoring across the next periastron passage can clarify the dispute.

In addition, the P2 peak in the HeII 4686 line just before the minimum is uncomfortably close to the same phase as in previous cycles (see Fig. 1). The problem is that such an emission peak is correlated with X-rays, which is attributed to flares produced by clumps in the primary's wind hitting the WWC shock front. Since clumps are stochastic, phase-lock to the X-rays would not be expected. The observed near-coincidence in time might be due to chance, since we recorded the phenomenon only in the last 2 cycles. A third coincidence is very improbable. If the P2 peak appears again near the same phase in the next periastron passage, then we could confidently say that they are not produced by clumps in the primary's wind.

GOALS

Measure the intensity and radial velocity of the HeII 4686 emission line around periastron and compare to the behaviour seen in previous cycles (Teodoro et al. 2012, Mehner et al.2011).

Check for the phase-locked behaviour of the HeII 4686 intensity peaks before (P1, P2) and after periastron (P3). Predicted times are (uncertainty ~1 week) P1:June/27; P2:July/20 and P3:September/12.

Improve the accuracy of the period length, presently with an uncertainty of 1.3 days (0.06%). Relevant features: [FeII]5746/[NII]5754 narrow components, HeI 6678, HeI 7065, [NeIII] 3868, [FeIII] 4656, 4701; fading of HeII 4686. Relevant time-frame is July/10-August/10.

Contribute to the development of amateur spectroscopy in the southern hemisphere and keep small telescopes working at the professional observatories.

RELEVANT DATES

Phase=0.0 is expected to occur on **JD=2456864.599**, which corresponds to **2014 July 26 02:23:00UT** (this date is not absolute and should be taken as a reference only). Regarding the HeII4686 line, it is expected to reach zero intensity on 2014 August 1st.

a) *Phases of large variations* (**May/1 through July/10**). This time frame marks the rising to the high luminosity in HeII 4686 spectral line, and encompasses the P1 and P2 peaks, which epoch and intensity are not firmly known. For this time frame, 1 spectrum every 3 days is necessary. Number of spectra for this phase: 17.

b) *Critical phases* (**July/11 through August/10**). This encompasses the HeII 4686 peak before minimum (P2), the phases of fast drop in all emission lines, plus the short minimum in HeII4686. For that time-frame at least 1 spectrum per night is necessary. The ideal situation would be to record 2 spectra per day, to improve the period length. Number of spectra for this phase: 30.

c) *Periastro passage* (**July/23 through August/02**). A specially dense monitoring should be organized for this 10 days time interval. Combining telescopes in New Zealand, Australia, South Africa, Brazil, Argentine and Chile, we should be able to cover enough time zones so as to improve the accuracy in the period (currently 1.3 days) by a factor greater than 5. A similar improvement would demand >25 years, if we were to cover just a few time zones, as we have done in the past periastron passages.

d) *Collapse phase* (**August/11 through September/30**). The HeII 4686 P3 peak - corresponding to the collapse of the secondary's wind - is expected to occur around September/13. These phases are very challenging to observe, since the star crosses the meridian at noon on September/01. Only a few observatories in the world would be able to make it. Spectra 1x/week are necessary. Number of spectra for this phase: 13.

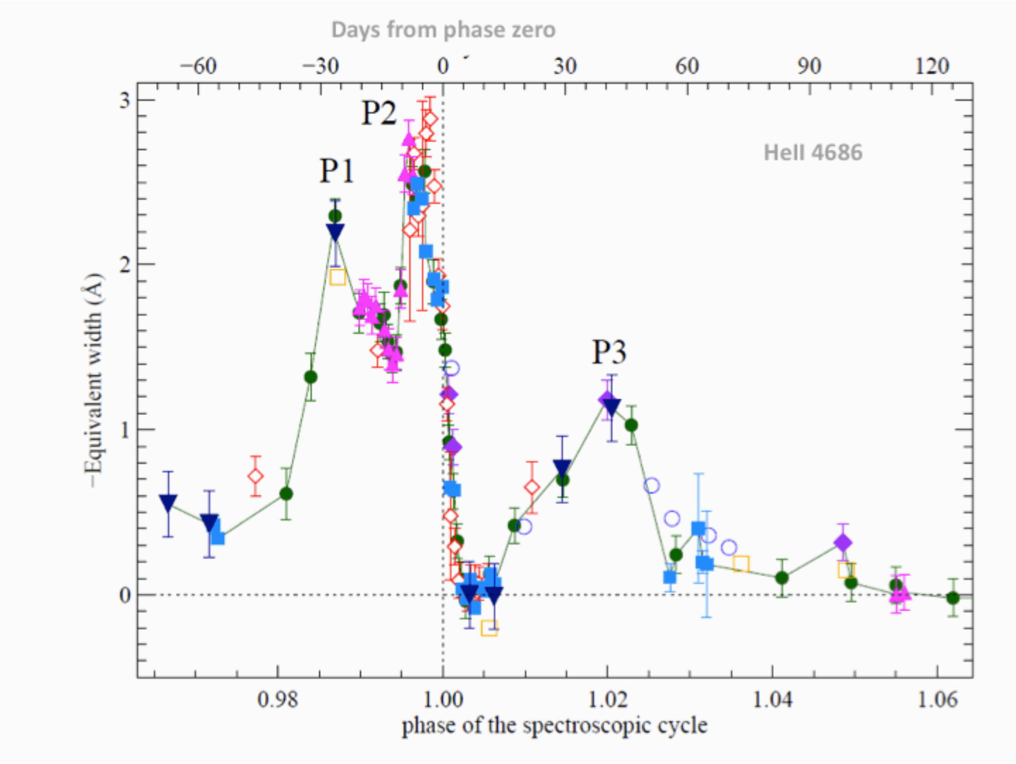

Fig. 1 – HeII 4686 equivalent width during the last 4 cycles showing the 3 peaks around phase zero. The first 2 are correlated with X-rays and the 3^rd is anti-correlated. The critical time-frame for monitoring the 2014 periastron is shown in red (adapted from Teodoro et al. 2012).

We split the program into typical phases, in order to facilitate the organisation of the campaign and help the participants to focus on the phases they are more interested in.

Total number of spectra: >60 spectra

Period	**May/01-Jul/10**	**July11-Aug/10**	**Jul/23-Aug/02**	**Aug/11-Sep/30**
Item	**a)**	**b)**	**c)**	**d)**

Table 1. *Summary of the phases for the campaign.*

OBSERVATIONAL SETUP

The ideal signal-to-noise ratio (S/N) is S/N~400 per resolution element (in the stellar continuum, without smoothing). S/N>200 is still acceptable for HeII 4686. Lower S/N might be useful for other emission lines.

Resolving power: R=5000 to 20000.

Wavelength coverage:

- it is *desirable* to cover the following lines: [NeIII], HeII 4686, Hβ, [FeII]5746/[NII] 5754, HeI 5876, 6678 and 7065, Hα. With an echelle, all these lines can be picked up in a single shot. The pair [FeII] 5746 and [NII] 5754 is strategic for defining the phase zero. It is defined when the line peaks are at equal intensity, but for a spectral resolution degraded to R=5000 (Damineli, Hillier, Corcoran, Stahl, Levenhagen, et al. 2008b). Alternatively, phase zero coincides with the disappearance of the narrow component of the HeI 6678 line (S/N>150).
- *minimum* spectral range: 460-475 nm (for Cassegrain/Littrow or Coudé spectrographs with short wavelength coverage).

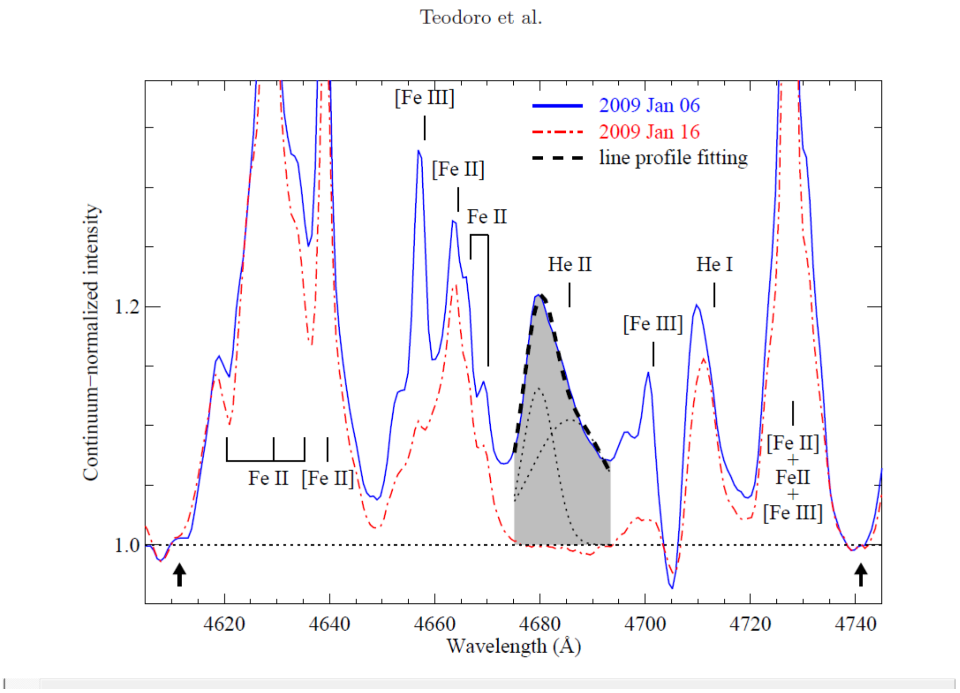

Fig 2. Crucial wavelength range, showing the position of the continuum and the zone for measuring equivalent width (grey shade). The red plot is for a phase when EW~0 and blue for EW~3A (Teodoro et al. 2012).

For an echelle with R~15000 on a 50 cm telescope, under reasonable seeing (<1”.5), a S/N~200 is expected to be reached in 1 hour (divided in 3x20 min spectra to clean for cosmic rays) @ λ~470 nm. This is assuming a star brightness of B~5.5 (http://etacar.fcaglp.unlp.edu.ar/).

Calibration spectra: bias subtraction (average of more than 15 frames), division for a flat field (average of more than 15 frames), lamp for wavelength calibration before and after the science spectrum. Spectra are expected to be in FITS format, containing the info for the star and the observatory, in addition to the UT and JD of the observation.

For a faint line like HeII 4686, it is crucial to get an accurately normalized stellar continuum over a broad range of wavelength. Observations of the hot star theta Carinae, soon before or just after eta Carinae are crucial for that task. A polynomial fit through the continuum of theta Car can be used to flatten eta Car’s spectrum (even if both spectra were already flattened with the flat field lamp).

In total, we need 60 science spectra distributed across the relevant phases. The entire campaign would corresponds to ~6 nights of observations (with 10 hours each). This is rather short telescope time for the expected scientific results. Of course, with many participants, there will be more than this number of spectra, but, as usual, some spectra will be rejected for one or other reason. Multiple spectra in the same night, from different instruments, are very important to evaluate the real errors in the measurements.

If the observer must choose a very limited spectral range, than we would suggest centering on 468 nm (*if possible*, encompassing the window 380-490 nm).

POLICY FOR DATA/PUBLICATIONS

There will be one collective publication with the main results of the campaign, describing the general behaviour of the lines. All the participants who contributed useful spectra will be co-authors. *The first authors will be the 2 coordinators (professional and amateur) of the campaign and the co-authors will be listed in order of the number of nights he/she contributed with spectra. In case of equal numbers, the alphabetic order is used (this policy will be improved as the campaign is running).* The coordinators will be in charge of validating the useful spectra and performing the measurements (EWs and RVs). The duty of the coordinators includes providing a collaborative page for exchanging info between the participants in real time. In addition, they will send progress reports and other matter of interest for the campaign, which can be followed in the web page created for the campaing: **etacar2014.wikidot.com**. This web page will be accessible via password, which will be sent by the coordinators to those who wish to join the campaign.

The 2 coordinators are responsible to organize the campaign within their specific communities.

The collective paper is expected to answer the following questions:

i. *When did the system reach phase zero, and what is the new period and its uncertainty? Are these quantities inside the errors, or is there an improvement? ([NeIII], [FeIII] and [ArIII]; HeI 6678/7065 narrow line components; [FeII]5746/[NII] 5754 intensity peaks)*

ii. *Did the 3 peaks in HeII 4686 re-occur, if so, what are the phases, intensities, and radial velocities? What was the UV luminosity?*

iii. *How do the P Cygni absorption components (intensity and radial velocity) compare with previous cycles? (Balmer lines, HeI lines, SiII 6347).*

Regarding these specific questions, the related spectra/information are a collective property of the co-authors. As happened in previous observations of the periastron, unexpected phenomena may show up. We want to encourage additional collaborative studies.

Each observer remains owner of their own data and should be acknowledged in any publication. Every participant will be granted access to the campaign's data bank and will be able to search/fetch data from it. However, for any additional publication other than the collective paper described above, each participant must contact the data owner in order to get permission to publish their results.

It is expected that theoreticians and modellers (who may not be formally part of the campaign) will play an important role in analysing the outcome of the campaign.

COORDINATES

Star	**RA (J2000)**	**DEC (J2000)**	**V**
eta Car	10:45:04	-59:41:03	~5
theta Car	10:42:57	-64:23:40	3.0

COORDINATORS/CONTACTS OF THE CAMPAIGN

- Professional astronomers: *Mairan Teodoro* (mairan.teodoro@nasa.gov);
- Amateur astronomers: *Bernard Heathcote* (spectrasouth@bigpond.com).

PARTICIPATING OBSERVATORIES (as of 2012 November)

1. **OPD/Brazil** – Local.: *Long 45:34:57W Lat: 22:32:04S;* telescope: 160 cm; spectr. R~7000; telescope: 50 cm; spectr. R~15000). Observer: Augusto Damineli and others at IAGUSP (augusto.damineli@gmail.com). Best observational season: May-September

2. **Barfold/Australia** – Local.: *Long 144:32:229E Lat:37:05:56S*; telescope: 36 cm and 28 cm; spectr. R~11000 (echelle) and R~17000 (Littrow). Observer: Bernard Heathcote. Best observational season: May-October

3. **Mt. John/New Zealand** – Local.: Long *170:27:54E Lat.: 43:59:12S*; telescope: 1 m; spectr. R~42000 (echelle). Observer: Karen Pollard. Best observational season June-September.

4. **SOAR/Chile** – Local.: *Long 70:44:01W Lat: 30:14:17S*; telescope: 4.1 m; spectr. R~50000 (echelle) and R~6000 (Cassegrain). Observer: Mairan Teodoro. Best observational season: October-May.

5. **SAAO/South Africa** – Local.: *Long 20:48:39E Lat.: 32:22:33S*; telescope: 1.9 m; spectr. R~39000 (echelle). Observer: Patricia Whitelock.

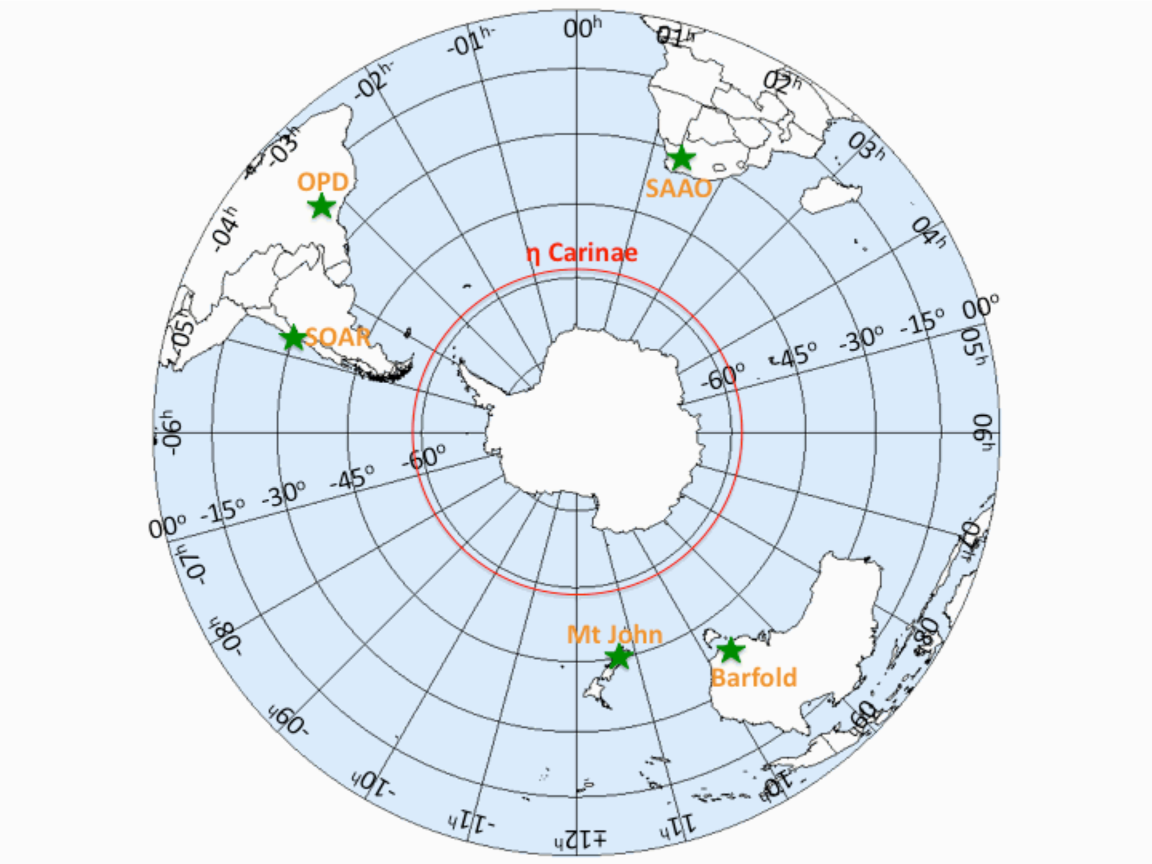

Fig. 3 – Geographical location of the participating observatories. The red circle corresponds to the position of eta Car in the sky.

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