# THE HOT STAR NEWSLETTER

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eenens@carina.astro.ugto.mx http://www.star.ucl.ac.uk/∼hsn/index.html


## Contents of this newsletter



## Accepted Papers

### The line-driven instability in Sobolev approximation


**A. Feldmeier**[1]

[1] Dept. of Physics & Astronomy, University of Kentucky, Lexington, KY 40506, USA



Line-driven winds, e.g., of OB stars, are subject to a strong hydrodynamic instability. As a corollary to the comprehensive linear stability analysis performed by Owocki & Rybicki (1984), we present here a simplified derivation of the growth rates from applying a *second order* Sobolev approximation. This is applicable for perturbation wavelengths larger than the Sobolev length, and covers the physically most interesting regime of perturbations which can develop into strong reverse shocks, and heat the gas to X-ray temperatures. Since the usual WKB approximation is not applied, we furthermore find the existence of a limiting wavelength beyond which perturbances do not grow, but instead decay.



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*Preprints from* `achim@pa.uky.edu`

*or on the web at* `http://www.usm.uni-muenchen.de:8001/people/feld/feldmeier.html`

# The WC10 central stars CPD–56°8032 and He 2–113: II. Model analysis and comparison with nebular properties

**Orsola De Marco[1,2] and P.A. Crowther[2]**

[1] Institut für Astronomie, ETHZ, Häldeli-Weg 15, CH-8092 Zürich, Switzerland.

[2] Dept. of Physics and Astronomy, UCL, Gower Street, WC1E 6BT London, UK.

We present detailed atmospheric analyses of two [WC10] central stars of planetary nebulae, CPD–56°8032 and He 2–113, the results of which are compared with parameters inferred from their nebular properties. Our quantitative study is based on modelling diagnostic He I-II, C II-IV and O II-III lines identified in high resolution AAT–UCLES spectroscopy spanning 3500–9200 Å, using the non-LTE iterative scheme of Hillier (1990). We find that spectroscopic similarities are reflected in the derived stellar properties: for both stars we obtain $T_{\rm eff}$∼30kK and $\log L/L_{\odot}$=3.7; $\log(\dot{M}/M_{\odot}{\rm yr}^{-1})$=−5.4 for CPD–56°8032 and $\log(\dot{M}/M_{\odot}{\rm yr}^{-1})$=−6.1 for He 2–113, while $v_{\infty}$=225 and 160 km s$^{-1}$ for CPD–56°8032 and He 2–113, respectively. The derived stellar properties are fairly consistent with the recent study of Leuenhagen et al. (1996), when adjusted for the different distances adopted. We find excellent agreement between our $C^{2+}$ wind temperature and the independent determination by De Marco et al. (1998), supporting our assumption of radiative equilibrium. Following De Marco et al., we find that both stars are highly enriched in carbon and oxygen, but with a zero stellar hydrogen content for He 2–113 (in contrast to Leuenhagen et al. 1996). Our final abundance determinations indicate H:He:C:O mass fractions of 0:34:52:14 for CPD–56° 8032 and 0:34:53:13 for He 2–113. We confront our model flux distributions with observed nebular properties using Zanstra and photoionization techniques and identify a major discrepancy between the observed and predicted nebular properties for these PNe. The hydrogen ionizing fluxes predicted by our WR non–LTE models greatly exceed those implied by nebular observations. The lack of heavy element line blanketing in our wind models could be responsible. However, the geometry and high nebular densities of these PNe indicate that they represent poor probes of the Lyman continuum flux of their central stars.

**Accepted by MNRAS**

*Preprints from* orsola@astro.phys.ethz.ch

# Radio Observations of Stellar Winds from Early Type Stars

**S. Scuderi[1], N. Panagia[2,3], C. Stanghellini[4], C. Trigilio[4], and G. Umana[4]**

[1] Osservatorio Astrofisico di Catania, Viale Andrea Doria 6, I–95125 Catania, Italy

[2] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA. [3] Affiliated to the Astrophysics Division, Space Science Department of ESA. [4] Istituto di Radioastronomia del CNR, Stazione VLBI di Noto, C.P. 141, I–96017 Noto, Italy.

Fifteen O and B supergiants have been observed with the Very Large Array (VLA) at 4.85, 8.45, and 14.95 GHz in order to make a detailed comparative study of the mass loss rates evaluated from H$\alpha$ and radio continuum observations and reveal and quantify possible departures from standard wind conditions. We detected 12 sources, 7 of which for the first time, thus increasing by 30% the total number of detections of OB supergiants in the northern sky. Radio spectral slopes indicate that the radio emission is mainly of thermal origin in all objects with one exception (HD 190603) out of the 12 detections. Our results demonstrate the value of using H$\alpha$ for mass loss rate determinations, especially for stars that are too distant or too faint to be detected with radio techniques. The relationship

$\dot{M} - L$ for supergiants turns out to be appreciably flatter than commonly reported, *i.e.* $\log \dot{M} = (1.25 \pm 0.30) \log L$.

**Accepted by Astronomy & Astrophysics**
*Preprints from* scuderi@ct.astro.it

## Coupled Line-Profile and Continuum Variations in EZ Canis Majoris: Implications for the Driving Mechanism of Global Wind Structures in Wolf-Rayet Winds

**Thierry Morel[1], Nicole St-Louis[1], Anthony F. J. Moffat[1], Octavio Cardona[2], Gloria Koenigsberger[3], and Grant M. Hill[4]**

[1] Département de Physique, Université de Montréal, C.P. 6128, Succ. Centre-Ville, Montréal, Québec, Canada, H3C 3J7, and Observatoire du Mont Mégantic.

[2] Instituto Nacional de Astrofísica, Optica y Electronica, Apdo. Postal 51, Puebla, Pue. 72000, México.

[3] Instituto de Astronomía, UNAM, Apdo. Postal 70-264, Mexico D.F. 04510, México.

[4] National Research Council, Herzberg Institute of Astrophysics, Dominion Astrophysical Observatory, 5071 West Saanich Road, Victoria, British Columbia, Canada, V8X 4M6; now at Mc Donald Observatory, HET, P. O. Box 1337, Fort Davis, Texas, USA.

EZ CMa is an apparently unusual Wolf-Rayet (WR) star of the nitrogen sequence which exhibits strong variations on a period of 3.77 days with coherency lasting typically about 10 cycles. We have used an extensive set of optical spectroscopic observations to investigate a possible link between its line-profile and photometric continuum variability. Despite the strong epoch-dependency of the variations, a persistent correlation is found between changes in the wind line profiles (N V $\lambda\lambda$4604, 4620 in particular) and in continuum flux emanating near the stellar core.
We suggest that these observations give further support to the idea that the physical conditions prevailing in the vicinity of the star's photosphere have a significant impact on the wind structure and that a spatial dependence of these conditions at the base of the outflow induces the formation of azimuthal wind-structures in EZ CMa. The epoch-dependent nature of the variability could be related to long-term behavior of co-rotating magnetic structures, although pulsational instabilities constitute a viable alternative.

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*Preprints from* morel@astro.umontreal.ca
*or by anonymous ftp to* 132.204.60.20; cd incoming/morel/EZCMa

## Wind Velocity Varitions in the LBV-Type Eurpting Star of the Wolf-Rayet Binary HD 5980

**G.Koenigsberger[1], L.H. Auer[2], L. Georgiev[1], and E. Guinan[3]**

[1] Instituto de Astronomia, UNAM, Apdo. Postal 70-264, Mexico D.F. 04510 Mexico

[2] Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM, USA

[3] Dept. of Astronomy and Astrophysics, Villanova Univ., Villanova, PA 19085, USA

We present the wind velocity and UV luminosity variations in the Wolf-Rayet system HD 5980 obtained over a time span during which one of the stars of the system was transformed into a Luminous Blue

Variable and underwent an eruption. We are able to separate the velocity components of the two stars in the system: A stable velocity component at $-1700$ kms$^{-1}$ is associated with the non-erupting star, while the variable wind with velocities ranging from $-500$ to $-3000$ kms$^{-1}$ corresponds to the eruptor. The development of a fast wind following the slow wind eruptive phase is observed. Under the assumption of radiatively driven winds, these changing velocities indicate that the radius of the photosphere gradually increased during at least 12 years prior to the 1994 eruption, decreasing rapidly thereafter. An estimate of the stellar parameters indicates that the erupting star is massive ($M > 40\ M_\odot$) and very luminous ($L > 10^6\ L_\odot$), and that during the eruption its radius extended beyond the binary orbit ($R_* > 100\ R_\odot$).

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*Preprints from* `gloria@astroscu.unam.mx`
*or by anonymous ftp to* `kepler@astroscu.unam.mx, /incoming/koenigsberger/paper1/`

## Mass-Loss Rate and He/H Abundance of the Erupting Component in the SMC system HD 5980

**G. Koenigsberger[1], M Peña[1], W. Schmutz[2] and S. Ayala[1]**

[1] Instituto de Astronomía, Universidad Nacional Autónoma de México, Apdo. Postal 70-264, 04510 México, D.F., México
[2] Institute of Astronomy, ETH Zürich, CH-8092 Zürich, Switzerland

The binary Wolf-Rayet system HD 5980 in the Small Magellanic Cloud underwent a major LBV-type eruptive event in 1994. It is the first such recorded event in which the apparent precursor transits from WNE to WNL spectral types prior to the eruption. In this paper we analyze the spectrum of the system obtained at the time when the outburst was declining (1994 December), but when the dominant spectrum is that of the eruptor. From the non-LTE analysis we obtain $\dot{M} = 10^{-3} M_\odot$ yr$^{-1}$, $N$[He]/$N$[H] = 0.43 (by number; $Y$=0.63 by mass), $v_\infty = 600$ km s$^{-1}$, $T_* = 35\,500$ K, and $L_{\rm eruptor} = 3 \times 10^6\ L_\odot$. A comparison of the He/H abundance derived here and an estimate obtained from published data of 20 years ago leads us to conclude that the member of the binary system which underwent the eruption is the star formerly classified as an O7 supergiant. The considerable amount of He in this star indicates that it is in the transition to becoming an H-poor WR. By comparing the stellar parameters with single star evolutionary tracks we derive that the progenitor was more massive than 120 $M_\odot$, and its current mass is close to 80 $M_\odot$.

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*Preprints from* `gloria@astroscu.unam.mx`
*or by anonymous ftp to* `kepler.astroscu.unam.mx, /incoming/koenigsberger/paper2/`

## Where's the Doughnut? LBV bubbles and Aspherical Fast Winds

**Adam Frank [1], Dongsu Ryu [2], & Kris Davidson [3]**

[1] University of Rochester
[2] Chungnam National University, Korea
[3] University of Minnesota

In this paper we address the issue of the origin of LBV bipolar bubbles. Previous studies have explained the shapes of LBV nebulae, such as $\eta$ Car, by invoking the interaction of an isotropic fast

wind with a previously deposited, slow aspherical wind (a "slow torus"). In this paper we focus on the opposite scenario where an *aspherical fast wind* expands into a previously deposited *isotropic slow wind*. Using high resolution hydrodynamic simulations, which include the effects of radiative cooling, we have completed a series of numerical experiments to test if and how aspherical fast winds effect wind blown bubble morphologies. Our experiments explore a variety of models for the latitudinal variations of fast wind flow parameters. The simulations demonstrate that aspherical fast winds can produce strongly bipolar outflows. In addition the properties of outflows recover some important aspects of LBV bubbles which the previous "slow torus" models can not.

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*Preprints from* afrank@alethea.pas.rochester.edu

## Molecular Hydrogen Emission in the Wolf-Rayet Nebula NGC 2359

**Nicole St-Louis[1], René Doyon[1], François Chagnon[1,2] and Daniel Nadeau[1]**

[1] Département de Physique, Université de Montréal and Observatoire du Mont Mégantic, C.P. 6128, Succ. Centre Ville, Montréal, H3C 3J7, Canada.

[2] Department of Geophysics and Astronomy, University of British Columbia, 129-2219 Main Mall, Vancouver, British Columbia, V6T 1Z1, Canada.

We report on the first direct detection of molecular hydrogen ($H_2$) emission in the interstellar medium in the vicinity of a Wolf-Rayet star. The spatial distribution of the excited molecular gas associated with NGC 2359 is filamentary and lies mainly on the border of the ionized gas, as traced by optical emission lines such as H$\alpha$ or [OIII]$\lambda$5007. The typical $H_2$ brightness in the filaments is $5 \times 10^{-5}$ ergs s$^{-1}$ cm$^{-2}$ str$^{-1}$ and the total $H_2$ luminosity detected is $\sim 4$ L$_\odot$. The detected line flux in the 1–0 S(1) transition of $H_2$ at $\lambda$=2.122 $\mu$m could equally be explained by shock excitation or by fluorescence from the strong ultraviolet flux of the Wolf-Rayet star. The morphological distribution of the $H_2$ filaments is not inconsistent with either mode of excitation. Although the ubiquity of this phenomenon needs to be confirmed, the relatively high level of 1–0 S(1) $H_2$ emission detected in this WR nebula indicates that hot stars could potentially contribute a significant fraction of the total $H_2$ emission of young starburst galaxies.

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*Preprints from* stlouis@astro.umontreal.ca

## In Proceedings

## B[e] supergiants: What is their Evolutionary status?

**N. Langer[1] and A. Heger[2]**

[1] Univ. Potsdam, Institut für Physik, D-14415 Potsdam, Germany

[2] Max-Planck-Institut für Astrophysik, D-85740 Garching, Germany

We investigate the evolutionary status of B[e] stars from the point of view of stellar evolution theory. We try to answer to the question of how massive hot supergiants — i.e. evolved stars — can be capable of producing a circumstellar disk. We find and discuss three possibilities: very massive

evolved main sequence stars close to critical rotation due to their proximity to their Eddington-limit, blue supergiants which have just left the red supergiant branch, and single star merger remnants of a close binary system. While the latter process seems to be required to understand the properties of the spectroscopic binary R4 in the LMC, the other two scenarios may be capable of explaining the distribution of the B[e] stars in the HR diagram. The three scenarios make different predictions about the duration of the B[e] phase, the time integrated disk mass and the stellar properties during the B[e] phase, which may ultimately allow to distinguish them observationally.

**To appear in "WORKSHOP ON B[e]-STARS, Eds. C. Jaschek, A. M. Hubert**
*Preprints from* ntl@astro.physik.uni-potsdam.de
*or on the web at* http://www.astro.physik.uni-potsdam.de/astro_literatur.html

## Systematic variability in OB star winds

**Raman K. Prinja**

Dept. of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK

Spectroscopic results of OB stars, primarily from the *IUE* satellite, are reviewed which highlight the incidence of large-scale systematic wind structure. I summarize evidence for cyclic wind variability and rotational modulation, based on extended time-series UV data sets (including the '*IUE* MEGA Campaigns'). The constraints provided by these data indicate that the modulating 'clocks' apparent in some hot star winds must ultimately have an origin at the stellar photosphere. The precise mechanism connecting photospheric and wind changes (e.g. via nonradial pulsations and/or ordered weak magnetic fields) remains a crucial issue.

**Review paper to appear in the proceedings of the ESO Workshop "Cyclical Variability in Stellar Winds" (1997 Oct 14-17; Springer Conf. Series)**
*Preprints from* rkp@star.ucl.ac.uk

## Wolf-Rayet stars as seen through IUE (low resolution)

**Andrzej Niedzielski**[1]

[1] Toruń Centre for Astronomy, ul. Gagarina 11, 87-100 Toruń, Poland

Wolf-Rayet (WR) stars are very hot and massive objects, which spectra are dominated by strong and wide emission lines of such elements as He and N (nitrogen sequence – WN stars) or He, C, O and Si (carbon sequence – WC stars). They are very bright in the UV and therefore were frequently observed by IUE, also at very large distances from the Sun. In that spectral range these object appear, however, substantially reddened by interstellar matter due to their location in the disc of our Galaxy.

In this paper we describe results of our studies of UV spectra of WR stars based on low resolution data obtained by IUE. We show how spectral classification of WR stars can be done based on UV spectra alone. We also present physical parameters of WR stars as obtained from low resolution IUE data.

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*Preprints from* aniedzi@astri.uni.torun.pl
*or by anonymous ftp to* ftp.astri.uni.torun.pl as /pub/hide/aniedzi/sevilla.ps.Z

# The Superluminous Star Eta Carinae: A Multicolour, Multiyear Investigation

**R. Viotti[1], M. Corcoran[2], A. Damineli[3], C. Rossi[4], M. Villada[5]**

[1] Istituto di Astrofisica Spaziale, CNR, Area di Ricerca Tor Vergata, 00133 Roma

[2] USRA, Columbia, MD, USA and LHEA/GSFC, Greenbelt, MD 20771, USA

[3] University of Colorado, Boulder, USA and IAGUSP, São Paulo, Brazil

[4] Istituto Astronomico, Università La Sapienza, 00161 Roma

[5]Dep. Astronomia Estelar, Observatorio Astronomico U.N.C., 5000 Cordoba, Argentina

We present the results of the long–term ultraviolet and optical monitoring of $\eta$ Car after the "1992 event". The *IUE* observations from December 1992 to July 1996 revealed a gradual increase of the flux of the high excitation lines (C III], N III], Si III], Fe III). The 1996 flux decrease is probably anticipating the next event. The identification of the weak C III] emission at 1909 Å, with variable intensity, seems to confirm the carbon underabundance in the stellar wind. We also remark the variable narrow emission component of the Fe III 1914 Å which is fluorescence excited by Ly$\alpha$. The UV behaviour of $\eta$ Car is compared with the optical spectroscopic monitoring, which unveiled the long term variation of the He I emission lines with a deep minimum at the time of the events, and with the hard X–ray flux, which continuously increased after the 1992 minimum.

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*Preprints from* `uvspace@saturn.ias.rm.cnr.it`
*or by anonymous ftp to* `ftp.ias.rm.cnr.it/pub/uvspace/etacar_iue.ps.gz`

# The Spectroscopic Variety of Different Categories of B-Emission Line Stars

**R. Viotti[1], G. Muratorio[2], V.F. Polcaro[1], C. Rossi[3], M. Villada[4]**

[1] Istituto di Astrofisica Spaziale, CNR, Area di Ricerca Tor Vergata, 00133 Roma

[2] Observatoire de Marseille, Marseille, France

[3] Istituto Astronomico, Università La Sapienza, 00161 Roma

[4] Dep. Astronomia Estelar, Observatorio Astronomico U.N.C., 5000 Cordoba, Argentina

Emission lines are frequently observed, but poorly studied, in early–type stars. We discuss which information can be derived from a more systematic study of the emisison lines (including line profiles and variability) in a number of selected representatives of the different categories. (With one figure).

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*Preprints from* `uvspace@saturn.ias.rm.cnr.it`
*or by anonymous ftp to* `ftp.ias.rm.cnr.it/pub/uvspace/B[e]_spectra(spFig).ps.gz`

# The High Excitation Fe II Lines as a Diagnostics of the Outer Envelopes of Early Type Emission Line Stars

**R. Viotti[1], A. Damineli[2], C. Rossi[3]**

[1] Istituto di Astrofisica Spaziale, CNR, Area di Ricerca Tor Vergata, 00133 Roma

[2] University of Colorado, Boulder, USA and IAGUSP, São Paulo, Brazil

[3] Istituto Astronomico, Università La Sapienza, 00161 Roma

The analysis of the spectrum of emission line stars in a wide spectral range has put in evidence a number of high excitation emission lines having anomalously high intensities. We illustrate the case of the high excitation Fe II lines observed in the ultraviolet and near–IR of different stellar categories, and discuss the information which can be derived from their study. (With two figures).

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*Preprints from* `uvspace@saturn.ias.rm.cnr.it`
*or by anonymous ftp to* `ftp.ias.rm.cnr.it/pub/uvspace/B[e]_hiexc(hiFig1,hiFig2).ps.gz`

# A Revised Classification Scheme for B[e] Stars

**Henny J.G.L.M. Lamers[1], Franz-Josef Zickgraf[2], Dolf de Winter[3], Leo Houziaux[4] and Janez Zorec[5]**

[1] Astronomical Institute, Utrecht University, Princetonplein 5, NL-3584 CC, Utrecht, The Netherlands and SRON Laboratory for Space Research, Sorbonnelaan 2, NL-3584 CA, Utrecht, The Netherlands (`hennyl@sron.ruu.nl`)

[2] Observatoire de Strasbourg, 11 rue de l'Université, F-67000, Strasbourg, France (`zickgraf@astro.u-strasbg.fr`)

[3] Dpto. Física Teórica, C–XI, Facultad de Ciencias, Universidad Autónoma de Madrid, Cantoblanco, E-28049, Madrid, Spain (`dolf@astro2.ft.uam.es`)

[4] Dept d'Astrophysique, Université de Mons-Hainaut, B-7000, Mons, Belgium (`leo.houziaux@umh.ac.be`)

[5] Institute, d'Astrophysique de Paris, C.N.R.S., $98^{bis}$ bd. Arago, F-75014, Paris, France (`zorec@iap.fr`)

We review the classification criteria for the B[e] stars. These criteria can be met in different kinds of stars of different evolutionary phases. We argue that the name "B[e] phenomenon" is more appropriate than the name "B[e] stars". We propose a new definition of five classes of stars which show the B[e] phenomenon, with names that indicate the evolutionary phase:
(a) B[e] supergiants or "sgB[e] stars"
(b) pre-main sequence B[e]-type stars or "HAeB[e] stars"
(c) compact planetary nebulae B[e]-type stars or "cPNB[e] stars"
(d) symbiotic B[e]-type stars or "SymB[e] stars"
(e) unclassified B[e]-type stars or "unclB[e] stars"
If a star meets the criteria of more than one of the classes (a), (b), (c) and (d) it is automatically assigned to class unclB[e].

**To appear in "WORKSHOP ON B[e]-STARS, Eds. C. Jaschek, A. M. Hubert**
*Preprints from* `hennyl@sron.ruu.nl`

## Dust in Hydrogen–Poor Stellar Winds, from Theory to Observations

**Isabelle Cherchneff**[1]

[1] Department of Physics, UMIST, PO Box 88, Manchester M60 1QD, UK

We review the nature of dust in hydrogen-deficient stellar winds, in particular cool, carbon-rich Wolf-Rayet (WC) stars, and present new observations of WC objects taken with the Short Wavelength Spectrometer on board of the ISO satellite. Predictions from theoretical models of grain precursor formation are also presented and future directions in both observational and theoretical studies are outlined.

**To appear in: I. Cherchneff & T.J. Millar (eds.), Dust and Molecules in Evolved Stars, 1997, Kluwer, Dordrecht, in press**
*Preprints from* `imc@europa.phy.umist.ac.uk`

General Interest

## The Lutz-Kelker bias in trigonometric parallaxes

**René D. Oudmaijer**[1], **Martin A.T. Groenewegen**[2] **& Hans Schrijver**[3]

[1]Blackett Laboratory, Imperial College of Science, Technology and Medicine, Prince Consort Road, London SW7 2BZ, U.K.

[2]Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Straße 1, D-85740 Garching, Germany

[3]SRON, Sorbonnelaan 2, NL-3584 CA Utrecht, The Netherlands

The theoretical prediction that trigonometric parallaxes suffer from a statistical effect, has become topical again now that the results of the Hipparcos satellite have become available. This statistical effect, the so-called Lutz-Kelker bias, causes measured parallaxes to be too large. This has the implication that inferred distances, and hence inferred luminosities are too small. Published analytic calculations of the Lutz-Kelker bias indicate that the inferred lumonosity of an object is, on average, 30% to small when the error in the parallax is only 17.5%. Yet, this bias has never been determined empirically. In this paper we investigate whether there is such a bias by comparing the best Hipparcos parallaxes which ground-based measurements. We find that there is indeed a large bias affecting parallaxes, with an average and scatter comparable to predictions. We present a simple method to correct for the LK bias, and apply it successfully to a sub-sample of our stars. We then analyze the sample of 26 'best' Cepheids used by Feast & Catchpole (1997) to derive the zero point of the Period-Luminosity relation. The final result is based on the 20 fundamental mode pulsators and leads to a distance modulus to the Large Magellanic Cloud - based on Cepheid parallaxes - of 18.56 $\pm$ 0.08, consistent with previous estimates.

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*For preprints, contact* `r.oudmaijer@ic.ac.uk`,
*or look at* `http://www.mpa-garching.mpg.de/~groen/groen.html`