Evolutionary stages and improved temperature-dependent parameters of the binary V1375 Orionis

Norbert Hauck

Abstract: *The evolved components of the bright eclipsing binary V1375 Ori have been compared with evolutionary tracks of stellar models. An acceptable fit for both stars has been achieved at a slightly sub-solar metallicity placing the bright-giant primary on the Early-AGB. The normal-giant secondary star is crossing the Hertzsprung gap. The bright giant's Teff has been adapted to recent modelling results taken from the literature. All temperature-dependent parameters have been fitted thereto. [English and German version of this paper available at www.bav-astro.eu/rb/rb2016-4/7.html].*

A solution for this bright (6.66 Vmag) eclipsing binary consisting of a bright giant and a normal giant has already been published by the author and R.F. Griffin [1]. Recent results from McDonald et al. [2] being based on the comparison of the spectral energy distribution (SED) with model atmospheres indicate a somewhat lower effective temperature T_{eff} of 4320 (± 130) K for the bright giant, against the spectral type derived T_{eff} of 4500 (± 200) K used in our former paper [1]. This lower and more accurate T_{eff} leads to a better fit for both components of the binary in stellar models. Therefore, all temperature dependent parameters have been amended; they appear as bold typed numbers in Tables 1 and 2. The equally lowered T_{eff} of the secondary star has been determined with the *Binary Maker 3* (BM3) modelling software simultaneously in the passbands UBV.

The parameters of both binary components are now fitting with deviations of less than 2.5 % into a recent stellar model without rotation of the Geneva group from Lagarde et al. [3] at a slightly sub-solar metallicity of about Z = 0.009 (derived by interpolation between the models for Z = 0.004 and 0.014).

The normal-giant secondary component is crossing the Hertzsprung gap of the Hertzsprung-Russell (HR) diagram. Its age of about 690 Myr has been derived from this stellar model. The far more evolved bright-giant primary star having a similar age of about 730 Myr according to this stellar model is located on the Early Asymptotic Giant Branch (E-AGB). The remaining difference in their age can be attributed to the inaccuracies of the model being tested here to its limits.

As a supplement, a comparative table containing all similar binary systems, as far as known to the author, has been added to this paper under the title 'Bright binaries containing bright giants'.

Table 1: Parameters of the binary system V1375 Ori

Epoch [HJD]	2456255.41(4)	mid primary minimum
Period [days]	146.301(3)	
Total light [V/Bmag]	6.66/8.00	mean maximum value
Primary minimum depth	0.15/0.22/0.32	[Vmag/Bmag/Umag]
Second. minimum depth	0.025/0.025	[Vmag/Bmag]
Primary minimum [days]	8.19	duration contact 1-4
Total eclipse [days]	5.56	duration contact 2-3
Second. minimum [days]	11.12	duration contact 1-4
Orbital inclination i [deg]	84.4 ± 0.3	
Semi-mayor axis a [AU]	0.9100 ± 0.0024	(= 195.5 ± 0.5 R☉)
Eccentricity e	0.2076 ± 0.0014	
Longitude periastron ω	270.15 ± 0.25	i.e. orbital major axis in our line of sight !
Mass ratio (M_1/M_2)	1.118 ± 0.005	spectroscopic measurement value
Radial velocity γ [km/s]	+30.68 ± 0.04	barycenter movement
Distance [pc]	**377 ± 23**	calculated for A_v = **0.28** mag
Age [Myr]	**710 ± 40**	from stellar model[3] for Z = 0.009 ± 0.001

Table 2: Parameters of the components of V1375 Ori

Parameter	Primary star	Secondary star
Spectral type	K0/1 (II)	(F**7** III)
Temperature Teff [K]	**4320 ± 130**	**6000 ± 250**
Radius R (mean) [R☉]	41.6 ± 0.5	5.85 ± 0.07
Luminosity (bol) [log L/L☉]	**2.733 ± 0.055**	**1.599 ± 0.078**
Brightness [VMag]	**– 1.35 ± 0.13**	**+ 0.78 ± 0.18**
Mass [M☉]	2.485 ± 0.027	2.223 ± 0.032

References:

[1] N. Hauck & R.F. Griffin, The Observatory **135**, 7, (2015); available at NASA ADS http://adswww.harvard.edu/
[2] I. McDonald et al., MNRAS **427**, 343, (2012)
[3] N. Lagarde et al., A&A **543**, 108, (2012)

Acknowledgements: This research has made use of the Simbad and VizieR databases operated at the Centre de Données astronomiques de Strasbourg, France, http://cdsarc.u-strasbg.fr/.

Norbert Hauck, F-83400 Hyères, hnhauck@yahoo.com

BRIGHT BINARIES CONTAINING BRIGHT GIANTS:

Name	Spectra	Brightn. **m** (Vmag)	Period **P** (days)	Radius **R1** (Rsun)	Radius **R2** (Rsun)	**R1/a** Eccentr. **e**	Mass **M1** (Msun)	Mass **M2** (Msun)	Primary's evolution stage	Eclipse SB-type	Accuracy M1 (%) R1 (%)
V1375 Ori	**K0/1(II) +(F7III)**	**6.66**	**146**	**41.6**	**5.85**	**0.213 0.21**	**2.485**	**2.223**	**Early-AGB**	**total 2**	**1.1 1.2**
V415 Car	**G6 II + A1 V**	**4.4**	**195**	**31.3**	**1.9**	**0.128 0**	**3.14**	**1.98**	**Mass transfer (?)**	**partial 1**	**5.4 2.9**
OW Gem	**F2 Ib-II + G8II**	**8.23**	**1259**	**32.3**	**32.6**	**0.031 0.53**	**5.49**	**3.80**	**Merger (?)**	**partial 2**	**3.8 0.7**
V2291 Oph	**G9 II + B9 V**	**5.66**	**385**	**32.9**	**3.0**	**0.078 0.31**	**3.86**	**2.95**	**Blue Loop**	**total 1**	**3.9**
HR 2030	**K0 II + B8 IV**	**6.0**	**66**	**41**	**5.9**	**0.297 (0.02)**	**4.0**	**4.0**	**RGB**	**none 1**	**32.5 12.2**
QS Vul	**G5 Ib-II + B8 V**	**5.18**	**249**	**77**	**3.3**	**0.224 0**	**5.4**	**3.4**	**Mass transfer (?)**	**total 1**	**27.8**

Evolutionsstufen und verbesserte temperaturabhängige Parameter des Doppelsterns V1375 Orionis

Evolutionary stages and improved temperature-dependent parameters of the binary V1375 Orionis

Norbert Hauck

Abstract: *The evolved components of the bright eclipsing binary V1375 Ori have been compared with evolutionary tracks of stellar models. An acceptable fit for both stars has been achieved at a slightly sub-solar metallicity placing the bright-giant primary on the Early-AGB. The normal-giant secondary star is crossing the Hertzsprung gap. The bright giant's Teff has been adapted to recent modelling results taken from the literature. All temperature-dependent parameters have been fitted thereto. [English and German version of this paper available at www.bav-astro.eu/rb/rb2016-4/7.html].*

Eine Lösung für diesen 6.66 Vmag hellen Bedeckungsveränderlichen, der aus einem hellen Riesen und einem normalen Riesen besteht, wurde bereits vom Autor und R.F. Griffin [1] publiziert. Neuere Resultate von McDonald et al. [2], die auf dem Vergleich der spektralen Enegieverteilung (SED) mit Modellatmosphären basieren, ergeben für den hellen Riesen eine etwas niedrigere effektive Temperatur Teff von 4320 (± 130) K als die in unserer früheren Publikation [1] verwendete und vom Spektraltyp abgeleitete Teff von 4500 (± 200) K. Diese niedrigere und genauere Teff führt zu einem besseren Fit beider Doppelsternkomponenten in Sternmodellen. Daher wurden nun alle temperturabhängigen Parameter korrigiert; sie erscheinen in den Tabellen 1 und 2 als fettgedruckte Zahlen. Die ebenfalls niedrigere Teff des Sekundärsterns wurde mit der *Binary Maker 3* (BM3) - Modellierungssoftware in den Bändern UBV simultan bestimmt.

Die Parameter beider Doppelsternkomponenten passen nun mit Abweichungen von unter 2,5 % in ein modernes Sternmodell ohne Rotation der Genfer Gruppe von Lagarde et al. [3] bei etwas untersolarer Metallizität Z von ungefähr 0.009, abgeleitet durch Interpolation zwischen den Modellen für Z = 0.004 und 0.014.

Der normale Riese (Sekundärstern) überquert die Hertzsprunglücke im Hertzsprung-Russell (HR) - Diagramm. Sein Alter von etwa 690 Millionen Jahren wurde aus dem Sternmodell abgeleitet. Der erheblich weiterentwickelte helle Riese (Primärstern) hat nach diesem Sternmodell ein ähnliches Alter von etwa 730 Millionen Jahren und liegt auf dem frühen asmyptotischen Riesenast (E-AGB). Der verbleibende Altersunterschied kann den Ungenauigkeiten des hier bis an seine Grenzen getesteten Modells zugeschrieben werden.

Eine vergleichende Zusatztabelle mit allen dem Autor bekannten ähnlichen Doppelsternsystemen ist dieser Arbeit unter dem Titel 'Bright binaries containing bright giants' beigefügt.

Tabelle 1: Parameter des Doppelsternsystems V1375 Ori

Epoche [HJD]	2456255.41(4)	Mitte Hauptminimum
Periode [Tage]	146.301(3)	
Gesamtlicht [V/Bmag]	6.66/8.00	mittlerer Maximalwert
Hauptminimumtiefe	0.15/0.22/0.32	[Vmag/Bmag/Umag]
Nebenminimumtiefe	0.025/0.025	[Vmag/Bmag]
Hauptminimum [Tage]	8.19	Dauer von Kontakt 1-4
Totales Minimum [Tage]	5.56	Dauer von Kontakt 2-3
Nebenminimum [Tage]	11.12	Dauer von Kontakt 1-4
Bahnneigung i [Grad]	84.4 ± 0.3	
Grosse Halbachse a [AE]	0.9100 ± 0.0024	(= 195.5 ± 0.5 Rʘ)
Exzentrizität e	0.2076 ± 0.0014	
Länge Periastron ω	270.15 ± 0.25	d.h. grosse Bahnachse ~ in der Sichtlinie!
Massenverhältnis (M_1/M_2)	1.118 ± 0.005	spektroskopischer Messwert
Radialgeschw. γ [km/s]	+30.68 ± 0.04	Bewegung des Systemschwerpunktes
Entfernung [pc]	**377 ± 23**	berechnet für A_v = **0.28** mag
Alter [Myr]	**710 ± 40**	von Sternmodell [3] für Z = 0.009 ± 0.001

Tabelle 2: Parameter der Komponenten von V1375 Ori

Parameter	Primärstern	Sekundärstern
Spektraltyp	K0/1 (II)	(F**7** III)
Temperature Teff [K]	**4320 ± 130**	**6000 ± 250**
Radius R (gemittelt) [Rʘ]	41.6 ± 0.5	5.85 ± 0.07
Leuchtkraft (bol) [log L/Lʘ]	**2.733 ± 0.055**	**1.599 ± 0.078**
Helligkeit [VMag]	**– 1.35 ± 0.13**	**+ 0.78 ± 0.18**
Masse [Mʘ]	2.485 ± 0.027	2.223 ± 0.032

Quellen:

[1] N. Hauck & R.F. Griffin, The Observatory **135**, 7, (2015); available at NASA ADS http://adswww.harvard.edu/
[2] I. McDonald et al., MNRAS **427**, 343, (2012)
[3] N. Lagarde et al., A&A **543**, 108, (2012)

Danksagungen: This research has made use of the Simbad and VizieR databases operated at the Centre de Données astronomiques de Strasbourg, France, http://cdsarc.u-strasbg.fr/.

Norbert Hauck, F-83400 Hyères, hnhauck@yahoo.com

BRIGHT BINARIES CONTAINING BRIGHT GIANTS:

Name	Spectra	Brightn. **m** (Vmag)	Period **P** (days)	Radius **R1** (Rsun)	Radius **R2** (Rsun)	**R1/a** Eccentr. **e**	Mass **M1** (Msun)	Mass **M2** (Msun)	Primary's evolution stage	Eclipse SB-type	Accuracy M1 (%) R1 (%)
V1375 Ori	**K0/1(II) +(F7III)**	**6.66**	**146**	**41.6**	**5.85**	**0.213 0.21**	**2.485**	**2.223**	**Early-AGB**	**total 2**	**1.1 1.2**
V415 Car	**G6 II + A1 V**	**4.4**	**195**	**31.3**	**1.9**	**0.128 0**	**3.14**	**1.98**	**Mass transfer (?)**	**partial 1**	**5.4 2.9**
OW Gem	**F2 Ib-II + G8II**	**8.23**	**1259**	**32.3**	**32.6**	**0.031 0.53**	**5.49**	**3.80**	**Merger (?)**	**partial 2**	**3.8 0.7**
V2291 Oph	**G9 II + B9 V**	**5.66**	**385**	**32.9**	**3.0**	**0.078 0.31**	**3.86**	**2.95**	**Blue Loop**	**total 1**	**3.9**
HR 2030	**K0 II + B8 IV**	**6.0**	**66**	**41**	**5.9**	**0.297 (0.02)**	**4.0**	**4.0**	**RGB**	**none 1**	**32.5 12.2**
QS Vul	**G5 Ib-II + B8 V**	**5.18**	**249**	**77**	**3.3**	**0.224 0**	**5.4**	**3.4**	**Mass transfer (?)**	**total 1**	**27.8**