A search for pulsating B-type variable stars in the southern open clusters NGC 6204 and Hogg 22

Jaco Mentz, B.Sc. Hons.

A dissertation submitted in partial fulfillment of the requirements for the degree *Magister Scientiae* at the Potchefstroom Campus of the North-West University

Supervisor : Prof. D.J. van der Walt
Assistant supervisor : Prof. A Pigulski

February 2013

Abstract

The theory of stellar evolution and stellar structure relies on the observation of stars in different phases of their evolutionary cycle. The relation between observations and theory can be strengthened by obtaining observational data of a large sample of stars in a particular evolutionary phase. The search for β Cephei stars, as conducted in this study, can contribute to the sample of known β Cephei stars, where these interesting stars are massive non-supergiant early B-type stars, displaying pulsating behaviour which is not well understood.

Stars tend to form in clusters where it can therefore be expected that young massive stars can be found in open clusters. For this reason two young southern open clusters were observed in order to search for B-type pulsating stars. The region of NGC 6204 and Hogg 22 was observed over a period of thirteen nights in Johnson B, V and I bands. NGC 6204 is believed to be the oldest cluster of the two at a distance of 0.8 kpc while the much younger Hogg 22 is more distant at 2.8 kpc. These two open clusters are located 6 arcminutes apart which made it possible to observe them simultaneously with a 12.8 $\times$ 12.8 arcminute field of view. The observations were done with the newly installed 16$''$ telescope of the North-West University, South Africa.

In order to do a variability search, periodic stars need to be identified from the cluster data, where a typical data set may contain thousands of scientific images. In addition to the main motivation for this study, a pipeline was created in order to automate the photometry and data reduction processes. A Lomb-Scargle transform was applied to the stellar light curves in order to identify periodic sources. 354 significantly periodic stars were identified from the 3182 observed stars. Amongst them, two new possible β Cephei stars were found together with a possible slowly pulsating B star (SPB), and numerous eclipsing binary systems.

By using photometry of this region obtained by Forbes & Short (1996), instrumental magnitudes were transformed to a standard system in order to compare photometry results. From the constructed colour magnitude diagram of the two clusters, it could be seen that some stars, indicated by Forbes & Short (1996) to be cluster members, were in fact field stars belonging to neither cluster.

The reduction and photometry pipeline was implemented successfully on the data set, which also highlighted the importance of instrumentation and correct data analysis procedures. Possible improvements were identified in order to overcome difficulties experienced during this study.

Keywords: stellar evolution, stellar structure, evolutionary cycle, β Cephei stars, pulsating stars, open star clusters, photometry, Lomb-Scargle transform, light curves, slowly pulsating B stars, eclipsing binary systems, colour magnitude diagram, field stars.

Opsomming

Die teorieë rakende die struktuur en evolusie van sterre is afhanklik van genoegsame observasie van sterre in verskillende fases van hulle evolusionêre siklus. Die verband tussen observasie en teorie kan versterk word deur die waarneming van ‘n groot aantal sterre in ‘n spesifieke evolusionêre fase. Die soektog na β Cephei veranderlike sterre, soos gedoen in die huidige studie, kan bydra tot die totale aantal bekende sterre van die bepaalde klas. Hierdie interessante pulserende sterre is massiewe nie-superreus sterre met spektraaltipe B wat pulserende gedrag toon waaroor daar nog heelwat onsekerheid bestaan.

Sterre word in sterswerms gevorm en daarom kan verwag word dat jong massiewe sterre in oop sterswerms gevind kan word. Om hierdie rede is twee jong suidelike sterswerms waargeneem met die doel om vir B-tipe pulserende sterre te soek. Die gebied van NGC 6204 and Hogg 22 was waargeneem oor ‘n tydperk van dertien nagte in Johnson B, V en I filters. NGC 6204 is vermoedelik die oudste en geleë op ‘n afstand van 0.8 kpc terwyl Hogg 22 heelwat jonger is maar verder geleë is op ‘n afstand van 2.8 kpc. Hierdie twee oop sterswerms is 6 boogminute van mekaar geleë wat gelyktydige waarnemings van die twee sterswerms moontlik gemaak het deur ‘n sigveld van 12.8×12.8 boogminute. Die waarnemings is gedoen deur gebruik te maak van die nuwe $16''$ teleskoop van die Noordwes-Universiteit, Suid-Afrika.

Die hoofsaak van ‘n veranderlikheidstudie is die identifisering van periodiese sterre vanuit ‘n datastel wat duisende beelde kan bevat. ‘n Pyplyn was ontwikkel bykomend tot die hoof motivering van die huidige studie om die prosesse van data verwerking en fotometrie te outomatiseer. ‘n Lomb-Scargle transform was op die ligkrommes van sterre toegepas om sodoende periodiese bronne uit die data te identifiseer. 354 periodiese sterre is geïdentifiseer uit ‘n moontlike 3128 sterre wat waargeneem is. Daaronder was twee nuwe moontlike β Cephei sterre gevind. ‘n Moontlike stadig pulserende B-tipe ster is gevind asook ‘n aantal verduisterende dubbelsterre.

Die instrumentele magnitudes vanuit die huidige studie is getransformeer na ‘n standaard sisteem, deur gebruik te maak van fotometrie verkry deur Forbes & Short (1996), wat noodsaaklik is voordat fotometrie van verskeie studies vergelyk kan word. Vanaf die saamgestelde kleur-magnitude diagram van die twee sterswerms kan daar gesien word dat sommige sterre wat deur Forbes & Short (1996) aangedui is as lede van die sterswerm, as veldsterre gereken moet word wat nie aan een van die swerms behoort nie.

Die pyplyn wat saamgestel is vir die dataverwerking en fotometrie was suksesvol geïmplementeer, waardeur die belangrikheid van instrumentasie en korrekte dataverwerking weereens beklemtoon is. Moontlike verbeterings op die bestaande verwerkingsmetodes is geïdentifiseer om sommige probleme wat ondervind is tydens die studie op te los.

Sleutelwoorde: ster evolusie, ster struktuur, evolusionêre siklus, β Cephei sterre, pulserende sterre, oop sterswerm, fotometrie, Lomb-Scargle transform, ligkrommes, stadig pulserende B-tipe sterre, verduisterende dubbelsterre, kleur-magnitude diagram, veldsterre.

Acknowledgements

I hereby wish to express my sincere gratitude and appreciation to those who made this study possible and assisted in its completion.

- My supervisor Prof Johan van der Walt for his support and guidance throughout my undergraduate and postgraduate studies.
- Prof Andrzej Pigulski, my assistant supervisor, for his expert advice, encouragement and for all the valuable skills learned during this study regarding observations and data analysis.
- Mrs. M.P. Sieberhagen, Mrs. E van Rooyen, and Mrs. L. van Wyk for their assistance in administrative matters.
- The National Research Foundation and the Center for Space Research at the North-West University for financial support throughout my studies.
- My parents for their interest and the way in which they supported and encouraged me.
- My father for his assistance in the technical editing.
- My wife Annariet for her love, support and encouragement throughout my studies.

To God be the glory.

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Dedicated to Annariet