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THE R. M. ALLER ASTRONOMICAL OBSERVATORY RESEARCH ON DOUBLE AND MULTIPLE STARS: HIGHLIGHTS AND PROJECTS

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Abstract. In this talk, I will speak about some relevant results that we have obtained in the Ramon Maria Aller Astronomical Observatory (OARMA) concerning binaries. More concretely, I will discuss our current research project and highlights of our work.

1. INTRODUCTION

The Ramon Maria Aller Astronomical Observatory (hereafter OARMA) is a center of the University of Santiago de Compostela (Galicia, the NW region of Spain). It was founded in 1943 by Ramon Maria Aller, a priest and Mathematician, who built his own private Observatory in Lalin (50 kms. from Santiago) at the beginning of the 20^{th} century.

Figure 1: The Ramon Maria Aller Astronomical Observatory (OARMA).

R. M. Aller introduced the study of double stars in Spain. In Lalin, he performed numerous micrometric measurements of binaries with his refractor and he discovered five double stars. There, in the village where he was born, he calculated the orbit of system STT 77, which was the first obtained in Spain. Later, he calculated several more. In addition, he created an important school of researchers in Santiago de Compostela among whom stand out Enrique Vidal, a Full Professor of Geometry, and Rafael Cid, later Full Professor of Astronomy in Zaragoza, Spain. It was precisely Dr. Cid who was the director of my dissertation concerning triple star systems at the University of Zaragoza. There I was an Assistant Professor for 8 years before returning to the University of Santiago de Compostela in 1981 in order to physically and scientifically renovate and revitalize the Astronomical Observatory which was in very bad condition since Ramon Maria Aller's death in 1966.

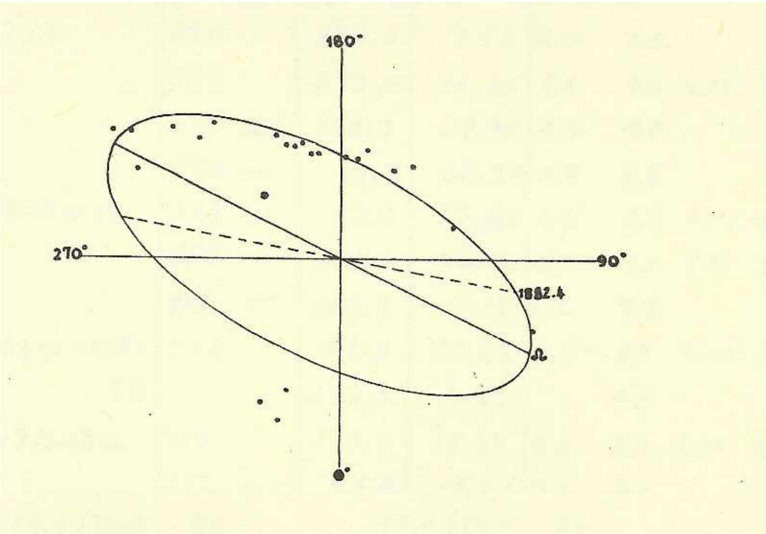
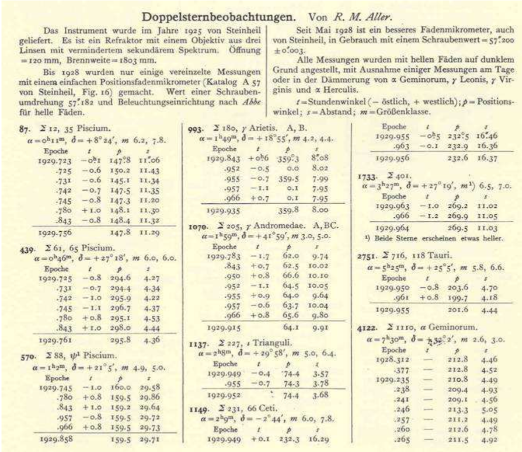


Figure 2: Orbit of system STT77 obtained by R. M. Aller.

Figure 3: E. Vidal, R. M. Aller, and R. Cid in 1947.



Doppelsternbeobachtungen. Von *R. M. Aller.*

Das Instrument wurde im Jahre 1925 von Steinheil geliefert. Es ist ein Refraktor mit einem Objektiv aus drei Linsen mit vermindertem sekundärem Spektrum. Öffnung = 120 mm, Brennweite = 1803 mm.

Bis 1928 wurden nur einige vereinzelte Messungen mit einem einfachen Positionsfadenmikrometer (Katalog A 57 von Steinheil, Fig. 16) gemacht. Wert einer Schraubenumdrehung 57.″182 und Beleuchtungseinrichtung nach *Abbe* für helle Fäden.

Seit Mai 1928 ist ein besseres Fadenmikrometer, auch von Steinheil, in Gebrauch mit einem Schraubenwert = 57.″200 ± 0.″003.

Alle Messungen wurden mit hellen Fäden auf dunklem Grund angestellt, mit Ausnahme einiger Messungen am Tage oder in der Dämmerung von α Geminorum, γ Leonis, γ Virginis und α Herculis.

t = Stundenwinkel (− östlich, + westlich); *p* = Positionswinkel; *s* = Abstand; *m* = Größenklasse.

87. Σ 12, 35 Piscium.
$\alpha = 0^h 11^m$, $\delta = +8° 24'$, *m* 6.2, 7.8.

Epoche	*t*	*p*	*s*
1929.723	−0.ʰ1	147.°8	11.″06
.725	−0.6	150.2	11.43
.731	−0.6	145.1	11.34
.742	−0.7	147.5	11.35
.745	−0.8	147.3	11.20
.780	+1.0	148.1	11.30
.843	−0.8	148.4	11.32
1929.756		147.8	11.29

439. Σ 61, 65 Piscium.
$\alpha = 0^h 46^m$, $\delta = +27° 18'$, *m* 6.0, 6.0.

Epoche	*t*	*p*	*s*
1929.725	−0.8	294.6	4.27
.731	−0.7	294.4	4.34
.742	−1.0	295.9	4.22
.745	−1.1	296.7	4.37
.780	+0.8	295.1	4.53
.843	+1.0	298.0	4.44
1929.761		295.8	4.36

570. Σ 88, ψ^1 Piscium.
$\alpha = 1^h 2^m$, $\delta = +21° 5'$, *m* 4.9, 5.0.

Epoche	*t*	*p*	*s*
1929.745	−1.0	160.0	29.58
.780	+0.8	159.5	29.86
.843	+1.0	159.2	29.64
.957	−0.8	159.5	29.72
.966	+0.8	159.5	29.73
1929.858		159.5	29.71

993. Σ 180, γ Arietis. A, B.
$\alpha = 1^h 49^m$, $\delta = +18° 55'$, *m* 4.2, 4.4.

Epoche	*t*	*p*	*s*
1929.843	+0.ʰ6	359.°3	8.″08
.952	−0.5	0.0	8.02
.955	−0.7	359.5	7.99
.957	−1.1	0.1	7.95
.966	+0.7	0.1	7.95
1929.935		359.8	8.00

1070. Σ 205, γ Andromedae. A, BC.
$\alpha = 1^h 59^m$, $\delta = +41° 59'$, *m* 3.0, 5.0.

Epoche	*t*	*p*	*s*
1929.783	−1.7	62.0	9.74
.843	+0.7	62.5	10.02
.950	+0.8	66.6	10.10
.952	−1.1	64.5	10.05
.955	+0.9	64.0	9.64
.957	−0.6	63.7	10.04
.966	+0.8	65.6	9.80
1929.915		64.1	9.91

1137. Σ 227, ι Trianguli.
$\alpha = 2^h 8^m$, $\delta = +29° 58'$, *m* 5.0, 6.4.

Epoche	*t*	*p*	*s*
1929.949	−0.4	74.4	3.57
.955	−0.7	74.3	3.78
1929.952		74.4	3.68

1149. Σ 231, 66 Ceti.
$\alpha = 2^h 9^m$, $\delta = -2° 44'$, *m* 6.0, 7.8.

Epoche	*t*	*p*	*s*
1929.949	+0.1	232.3	16.29
1929.955	−0.ʰ5	232.°5	16.″46
.963	−0.1	232.9	16.36
1929.956		232.6	16.37

1733. Σ 401.
$\alpha = 3^h 27^m$, $\delta = +27° 19'$, *m*[1]) 6.5, 7.0.

Epoche	*t*	*p*	*s*
1929.963	−1.0	269.2	11.02
.966	−1.2	269.9	11.05
1929.964		269.5	11.03

1) Beide Sterne erscheinen etwas heller.

2751. Σ 716, 118 Tauri.
$\alpha = 5^h 25^m$, $\delta = +25° 5'$, *m* 5.8, 6.6.

Epoche	*t*	*p*	*s*
1929.950	−0.8	203.6	4.70
.961	+0.8	199.7	4.18
1929.955		201.6	4.44

4122. Σ 1110, α Geminorum.
$\alpha = 7^h 30^m$, $\delta = +32° 2'$, *m* 2.6, 3.0.

Epoche	*t*	*p*	*s*
1928.312	—	212.8	4.46
.377	—	212.8	4.52
1929.235	—	210.8	4.49
.238	—	209.4	4.93
.241	—	209.1	4.56
.246	—	213.3	5.05
.257	—	211.2	4.49
.260	—	212.6	4.78
.265	—	211.5	4.92

Figure 4: From Aller's first paper on binaries (1930; AN, 238, 71-76).

The members of the OARMA team are Astronomy professors at our University. I myself am a Full Professor in Astronomy and Astrophysics. I usually teach General Astronomy as well as Astrodynamics.

University students do their practical work in the Observatory and we also offer diffusion programs for the general population and for the University community itself (e.g., the PECAS Program in which 400 people participate each year). The Observatory is very well known by the people of Galicia due to the intense diffusion efforts carried out in recent decades.

MISSIONS of OARMA

TEACHING	RESEARCH	
Mathematics degree	Double and multiple stars	
Physics degree	Celestial Mechanics	Theory of perturbations Three-body problem Mass loss
Topographic Engineering degree		
Optics degree		
Master of Mathematics (Astrodynamics)	Bolides	
Adult Education	Dynamics of exoplanets and exosatellites	
	History of Astronomy	
	Organization of workshops	National: 1983, 2000, 2005, 2009 International: 1996, 2009, 2011

OBSERVATION ACTIVITIES		DIFFUSION
Binaries	Speckle interferometry	PECAS (the Astronomy cultural extension program with 400 places)
	Photometry	Science week (November)
	Spectroscopy	Didactic visits to the Observatory during the year
Lunar occultations		Programs with the Regional Government
Bolides		Didactic editions of books and videos
		Astronomy for children
		Media: radio broadcasts, newspapers articles, tv programs, etc.

Figure 5: A diffusion session

Since my time as a doctoral student at the University of Zaragoza during the 70's, I have become familiar with the most famous names of this epoch in the field of double star research, such as, Baize, Couteau, Heintz, Worley, etc., as well as with Popovic, Zulevic, Olevic, Erceg, and others. The series of micrometric measurements and orbits published in the Bulletin of the Belgrade Observatory was an important reference for me. Since then, I have been aware of the study of binary stars in Serbia.

2. THE CURRENT RESEARCH PROJECT

We have carried out various research projects since 1981 in OARMA. Our efforts to raise the scientific level of the Observatory include the acquisition of latest generation astronomical instrumentation. Next, I will describe the objectives of our actual project, entitled: "STUDY OF ASTROPHYSICAL AND DYNAMICAL PROPERTIES OF DOUBLE AND MULTIPLE STARS ON THE BASIS OF SPECKLE INTERFEROMETRY, PHOTOMETRY, AND SPECTROSCOPY".

2. 1. SPECKLE INTERFEROMETRY

We will use our ICCD and EMCCD cameras in order to obtain high precision speckle registers. The ICCD will be attached to the 1.52m telescope at Calar Alto (Spain) and the EMCCD to the 2.6m telescope at the Buyrakan Astronomical Observatory (BAO, Armenia) where we have 30 guaranteed days per year by means of a recent Agreement. The closest binaries will be observed at the Special Astrophysical Observatory (SAO, Russia) (Docobo et al., 2010).

2. 2. ORBIT CALCULATION

Since the 80's, we have been using Docobo's analytic method (Docobo, 1985) for orbit calculation of binaries. This is a very useful, versatile, and friendly application.

Taking 3 points (θ, ρ, t), the method generates a set of Keplerian orbits whose apparent orbits pass through the 3 points. We are able to calculate an orbit for each real number, V, belonging to the interval $(0, 2\pi)$ or $(0, \infty)$ (in the last case, when the 3 points correspond to different revolutions). The selection of the final orbit can be made if we take into account several criteria: 1) selecting the orbit with minimum r.m.s. in θ and ρ; 2) choosing the orbit with a dynamic parallax close to that of Hipparcos; 3) selecting the orbit that gives a total mass compatible with the spectral types, and 4) choosing the orbit that provides an areal constant similar to that previously calculated. Note that, for this last reason, the classical method of Thiele-Innes-Van den Bos is actually a particular case of ours.

RESEARCH OBJECTIVES OF THE PROJECT

1. High precision speckle registers (astrometry and differential photometry)
2. Orbit calculation of binaries of special interest
3. Possible detection of subcomponents
4. UBVR photometry and spectroscopy
5. Discovery of new flare stars or T Tauri in binaries
6. Study of some physical phenomena in binaries
7. Refining orbits by means of radial velocities
8. Improving the empirical calibrations of masses for late-type systems
9. Dynamics of exoplanets and exosatellites in binaries
10. Maximize the agreements of collaboration signed with SAO and BAO

Figure 6: The 0.62m Ritchey-Chrétien telescope at OARMA.

2. 3. THE POSSIBLE DETECTION OF ORBITAL SUBCOMPONENTS (INCLUDING GIANT EXOPLANETS)

The paradigm of this class of objects is the possible existence of a fourth body astrometrically detected in the triple red dwarf system, Gliese 22, using a new methodology explained in a previous paper (Docobo et al, 2008).

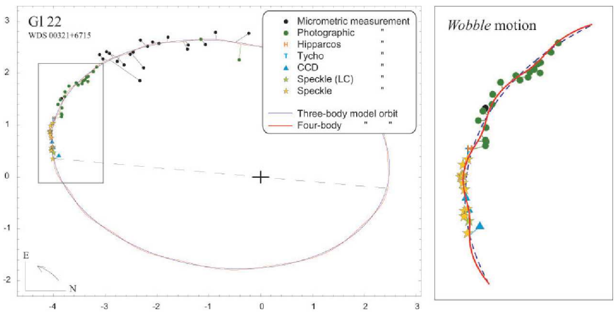


Figure 7: The wobble motion observed in the Gliese 22 system

2. 4. PHOTOMETRY AND SPECTROSCOPY

In the last decades we have included the study of late-type binaries with variable components among our research lines. We use UBVR photometry to study the variability of the stars and the spectroscopy of medium and high temporal resolution of G, K, and M star types and the IV or V luminosity classes on our list in order to classify them in the MK system. Drs. Melikian and Tamazian are responsible for this area (Tamazian et al, 1999).

2. 5. DISCOVERY OF NEW FLARE STARS / T TAURI

We are using speckle interferometry to try to prove the binary nature of a list of late-type variable stars.

2. 6. STUDY OF SOME PHYSICAL PHENOMENA

The precision of the calculated orbits, particularly those of a very short period, will permit us to study some physical phenomena of binary components that may affect the orbital dynamic. Among others, we investigate: 1) the relation of the production of flares with the position of the variable late- type components in the orbit; 2) the influence of mass-loss, and 3) the non- spherical form of the components in close binaries or in fast rotation stars.

2. 7. RADIAL VELOCITIES

It is our idea to use our Altair spectrograph to perform radial velocities in order to monitor some binaries of special interest and, in any case, to obtain radial velocities of a list of binaries in strategic positions with the objective of improving the orbits.

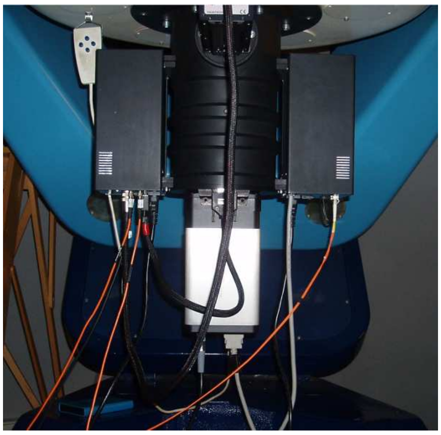


Figure 8: The EMCCD camera for speckle interferometry.

2. 8. IMPROVING THE EMPIRICAL CALIBRATIONS

It is well known that in the right part of the H-R diagram and especially close to the main sequence, we have not yet well established the empirical calibrations of mass-luminosity. To obtain precise orbits with stars belonging to this part of the diagram, it is fundamental to achieve this objective.

2. 9. DYNAMICS OF EXOPLANETS AND EXOSATELLITES IN BINARIES

There is new interest in the study of the movement of exoplanets in binaries. In this sense we have incorporated the research on stable orbits of exosatellites. We have recently presented several communications on this topic at some Workshops: "Binaries Inside and Outside the Local Interstellar Bubble" (Santiago de Compostela, February 10-11, 2011) and "Orbital Couples: PAX DE DEUX in the Solar System and the Milky Way" (Paris, October 10-12, 2011). One of our targets is to investigate the stable orbits of Earth-like satellites and the possible detection of these objects by studying the perturbations in exoplanet orbits.

Other topics about which we have obtained noteworthy results are the study of the spectroscopic subcomponents in visual double stars (Docobo and Andrade, 2006) and the study of the "periastron effect" in mass-loss scenarios. In this case, we were able to present a Hamiltonian function that describes this possible phenomenon whose principal effect is the secular increase of the orbital eccentricity (Andrade and Docobo, 2003).

2. 10. AGREEMENTS OF COLLABORATION

For the past 15 years, our team has collaborated with SAO and BAO. Our speckle cameras were assembled at SAO through scientific agreements and now we are conducting observation runs there. Recently a new Agreement with BAO will permit us to have guaranteed observation time with the 2.6m telescope, including also the interchange of students and other academic activities. We also have professional contacts with different groups in the USA, Germany, Belgium, France, UK, and yourselves.

Figure 9: The OARMA team.

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