Nº PROYECTO : 3130403  DURACIÓN : 3 años  AÑO ETAPA : 2015
TÍTULO PROYECTO : ISOLATED AND CLUSTER ELLIPTICAL GALAXIES UNDER THE LAMBDA CDM PARADIGM: A CRITICAL CENSUS

DISCIPLINA PRINCIPAL : ASTRONOMIA
GRUPO DE ESTUDIO : ASTRON.,COSMOL.Y PAR
INVESTIGADOR(A) RESPONSABLE : RICHARD READE LANE
DIRECCIÓN :
COMUNA :
CIUDAD :
REGIÓN : VIII REGION

FONDO NACIONAL DE DESARROLLO CIENTIFICO Y TECNOLOGICO (FONDECYT)
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OBJETIVOS

Cumplimiento de los Objetivos planteados en la etapa final, o pendientes de cumplir. Recuerde que en esta sección debe referirse a objetivos desarrollados, NO listar actividades desarrolladas.

<table>
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<th>Nº</th>
<th>OBJETIVOS</th>
<th>CUMPLIMIENTO</th>
<th>FUNDAMENTO</th>
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<td>1</td>
<td>Analyse the data from various galaxies, including NGC 5812, NGC 7507, NGC 2271, NGC 2865, NGC 3962, NGC 4240, IC 4889 and the Sagittarius Dwarf Galaxy which were obtained from observing proposals in the last year.</td>
<td>TOTAL</td>
<td>These data have now been analysed and papers based on these data have been written and published.</td>
</tr>
<tr>
<td>2</td>
<td>Write papers from data received from observing proposals submitted during the previous year.</td>
<td>TOTAL</td>
<td>We have written, and published, 3 papers based on the data obtained during the previous years of this project. One using data from the GMOS instrument on the Gemini South telescope covering NGC 2271, NGC 2865, NGC 3962, NGC 4240, and IC 4889. Another using data from GMOS South analysing the dynamics of NGC 7507 and another focussing on the Sgr Dwarf Galaxy using data from the AAOmega instrument on the Anglo-Australian Telescope. We are in the process of writing a paper on NGC 5812, following a paper from the first year of this project, which shows very interesting dynamics and also a paucity of dark matter.</td>
</tr>
<tr>
<td>3</td>
<td>Finalise the objectives of the project</td>
<td>TOTAL</td>
<td>Over the past three years we have used both photometric and spectroscopic data from large optical telescopes to show that not all galaxies can be reconciled with the cold dark matter paradigm. We have achieved our project goals of confronting current dark matter theories with observation and found that every galaxy for which we obtained data is different. Some are able to be reconciled with current dark matter theories, and some cannot.</td>
</tr>
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Otro(s) aspecto(s) que Ud. considere importante(s) en la evaluación del cumplimiento de objetivos planteados en la propuesta original o en las modificaciones autorizadas por los Consejos.
RESULTS OBTAINED:

Goal 1: Analyse the data from various galaxies obtained from observing proposals in the last year.

As stated in our “objectivos”, most of these data have now been analysed and we have published three papers in the last year based on these data.

The data analysis from NGC 5812 is ongoing and is expected to be finalised before the end of the year.

Analysis for the data from the MUSE spectrograph, obtained in 2014, as discussed in the end of year report of this project for 2014, is also ongoing. These data have presented significant challenges in both reduction and analysis due to the volume of the data that the instrument creates, and because the instrument having only been commissioned last year. To overcome these challenges it has been necessary for Tom Richtler, the patrocinante of this project, to travel to the European Southern Observatory in Garching, Germany, where there is a dedicated computer for reducing MUSE data, as well as experts in the reduction and analysis of the vast quantities of data which MUSE delivers. We expect that the analysis of these MUSE data will be finalised before the end of the year.

Goal 2: Write papers from data received from observing proposals submitted during the previous year.

We have published three papers, and a proceeding from the IAU General Assembly, Meeting #29, this year based on data from the GMOS and AAOmega spectrographs, on the Gemini South telescope and Anglo-Australian Telescope, respectively. Two of these were published in the journal Astronomy & Astrophysics and the other in the Astrophysical Journal. Two of these papers have addressed isolated elliptical galaxies and one focussing on the Sagittarius dwarf galaxy. We include figures of some of the most important results from one of the published papers below.

Note that new, spectroscopic data of NGC 5812 using the GMOS South instrument revealed a possible flaw in the calibrations used in our previous paper published in the first year of this project entitled:

“Isolated ellipticals and their globular cluster systems. I. Washington photometry of NGC 3585 and NGC 5812”

We had intended to have a paper published based on these GMOS South observations of NGC 5812 analysing the dynamics of this system, however, it has taken some time to finalise the calibration of these data, write an erratum for the previous paper, then finalise the new paper using the new calibrations. We expect to have this finalised before the end of the year.

Furthermore, we published a proceeding form the 29th symposium of the International Astronomical Union, based on the data for various galaxies discussed here.
Figure 1: Figure 3 from the paper entitled “Dark matter deprivation in the field elliptical galaxy NGC 7507”. Rotational velocity versus position angle (PA) of the halo of NGC 7507 in three radial bins, shown in each panel, as per the methodology described in the paper text. The error bars represent the RMS errors for each PA. The best fit sine curve is overplotted. Note that the $\Delta v_r$ values calculated by the method described in the text are twice the actual rotational velocity. We have taken this into account so that the values shown here represent the actual rotational velocity at each PA.
Figure 2: Figure 5 from the paper entitled “Dark matter deprivation in the field elliptical galaxy NGC 7507”. Dynamical models. Black open diamonds are the measurements from Salinas et al. 2012, while blue triangles are the velocity dispersions from the current work. **Left panel:** Models which consider all the velocity dispersion points. The solid black curve is the stars-only model. The red dotted curve is the best-fitting model with $\beta = 0.3$ and NFW halo with $c = 10$. The green dashed curve is the model under the anisotropy by Mamon et al. 2005 allowing the maximum amount of dark matter. **Right panel:** Same as in left panel, but excluding the velocity dispersion between $70'' < R < 80''$ when performing the fits.
Figure 3: Figure 6 from the paper entitled “Dark matter deprivation in the field elliptical galaxy NGC 7507”. MOND models. As in the previous Figure, black diamonds are the measurements from Salinas et al. 2012, while blue triangles are the velocity dispersions from the current work. The blue hatched area covers isotropic models with the range of $a_0$ values discussed in the paper text, while the red area represents the same range for $a_0$ but under the Mamon et al. 2005 anisotropy profile.
Goal 3: Finalise the goals of the project

As discussed in the end of year report for 2014, every galaxy we analyse is different. Some behave as predicted by dark matter theory and others do not. This is an ongoing conundrum that is, as yet, not fully resolved. The aim of this project has been to confront dark matter theories with observation, and this we have done, in spectacular fashion. If not all galaxies fall within the expected dark matter paradigm then what does this mean for dark matter theories as they stand today? This project has shown further flaws in current dark matter theories that must be addressed if we are to understand dark matter in any realistic manner. It is now up to the theoretical astrophysics community to use our results to further advance dark matter research by attempting to find solutions that can explain all available data in the literature, including the data we have presented and published throughout this project.
ACHIEVEMENTS OF THE PROJECT:

1 - In March 2015 I attended a conference in Concepción, Chile, entitled “MODEST 15 – Modelling and Observing Dense Stellar Systems” to present our work on the globular cluster systems of isolated elliptical galaxies.

2 - In April 2015 I attended a conference in Santiago, Chile, entitled “Satellites and Streams in Santiago” to present our work on the globular cluster systems of isolated elliptical galaxies.

3 - In August 2015 I attended the International Astronomical Union General Assembly in Hawaii, United States, to present our work on the globular cluster systems of isolated elliptical galaxies.
V. EVALUATION REPORT FROM POSTDOCTORAL RESEARCHER
SPONSOR:

SPONSOR NAME: Tom Richtler
This project was started with the ambition to contribute to one of the pestering question of modern astrophysics: the nature of dark matter in galaxies. It is no surprise that after three years of work the nature of dark matter is still unknown, but after all, the project has posed questions and pointed to problems that will occupy many scientists for some years to come. Isolated elliptical galaxies, because their dark halos are not grossly modified by galaxy interactions, represent handy test objects for the standard cosmology, because theoretical simulations can be easily compared with observations. These observations need both photometric and spectroscopic data with quite different techniques. Richard Lane (hereafter RL) did a very good job in obtaining, reducing, analysing, and presenting the data at several occasions. Although the full data set obtained during the last years could not be analysed and presented in all details, RL managed to achieve important results for galaxies, of which I want to mention NGC 7507, NGC 5812 and NGC7796. The small stellar M/L-value of NGC7507 clearly indicates a quite massive intermediate-age galaxy, where one would expect also a massive dark halo. By very deep spectroscopic multi-object spectroscopy, RL could measure the projected velocity dispersion out to radii, where a massive dark halo must have become visible. The fact that the present data and analysis provide no hint for a dark halo, does not necessarily mean that there is no dark matter at all. Until now, only models without rotation have been applied. The ”second generation” of dynamical models, which will include rotation, may show some dark matter and maybe also the consistency with MOND. But a conflict between cosmological simulations and the low (if any) dark matter content of NGC7507 will probably remain and NGC7507 will be a intensively discussed galaxy in the future.

The photometric campaign on NGC 5812, another bright isolated elliptical, provided the structural parameters and identified globular cluster candidates applying photometric criteria. A interesting side product was the discovery of a tidal tail of a companion galaxy. The analysis of NGC 5812 has been completed. The paper on NGC 5812 is still in process (as it is stated in the final report). For NGC5812 it has been possible to measure radial velocities of about 30 globular clusters. This is a sample, which is too small to precisely define a mass profile. However, the application of well established mass estimators at least lead to exclude a very massive dark halo. If confirmed then we have another isolated elliptical with little dark matter. But dark matter deprivation is not necessarily a characteristic of isolated galaxies.
NGC 7796 is another galaxy for which a mass profile by X-ray studies is available. Surprisingly, its globular cluster system turned out to be quite rich and the high X-ray luminosity is strongly indicative of a dark halo. One may classify NGC7796 as a fossil group, which once more emphasises that isolated ellipticals are of very different nature. During this project also a lot of photometric data of more isolated elliptical galaxies has been produced which are still awaiting analysis, but it is the nature of such a project that much work remains uncompleted. As a final remark, it should be said that RL worked with dedication and enthusiasm. However, there remains much to do and numerous publications are still expected to emerge from the project.

Sponsor signature: Tom Richtler

Date: Garching, 30-09-2015
PRODUCTOS

ARTÍCULOS
Para trabajos en Prensa/ Aceptados/Enviados adjunte copia de carta de aceptación o de recepción.

N° : 1
Autor (a)(es/as) : Salinas R; Alabi A; Richtler T; Lane RR
Nombre Completo de la Revista : Astronomy & Astrophysics
Título (Idioma original) : Isolated ellipticals and their globular cluster systems III. NGC 2271, NGC 2865, NGC 3962, NGC 4240, and IC 4889
Indexación : ISI
ISSN :
Año : 2015
Vol. : 577
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aa25574-14.pdf

N° : 2
Autor (a)(es/as) : Lane RR; Salinas R; Richtler T
Nombre Completo de la Revista : Astronomy & Astrophysics
Título (Idioma original) : Dark matter deprivation in the field elliptical galaxy NGC 7507
Indexación : ISI
ISSN :
Año : 2015
Vol. : 574
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Páginas : 1-9
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aa24074-14.pdf
Nº : 3
Autor (a)(es/as) : Hyde EA; Keller S; Lane RR; Martell S
Nombre Completo de la Revista : The Astrophysical Journal
Título (Idioma original) : Selecting Sagittarius: Identification and Chemical Characterization of the Sagittarius Stream
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sagittarius.pdf

Nº : 4
Autor (a)(es/as) : Richtler, T; Salinas, R; Lane, RR; Hilker, M; Schirmer, M
Nombre Completo de la Revista : Astronomy & Astrophysics
Título (Idioma original) : Isolated elliptical galaxies and their globular cluster systems. II. NGC 7796 - globular clusters, dynamics, companion
Indexación : ISI
ISSN :
Año :
Vol. :
Nº :
Páginas :
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Nº : 5
Autor (a)(es/as) : Ness, M.; Freeman, K.; Athanassoula, E.; Wylie-de-Boer, E.; Bland-Hawthorn, J.; Asplund, M.; Lewis, GF.; Yong, D.; Lane, RR.; Kiss, LL.; Ibata, R.
ARGOS - IV. The kinematics of the Milky Way bulge

ISSN:
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Nº : 6
Autor (a)(es/as) : Caso, JP.; Richtler, T.; Bassino, LP.; Salinas, R.; Lane, RR.; Romanowsky, A.
Nombre Completo de la Revista : Astronomy & Astrophysics
Título (Idioma original) : The paucity of globular clusters around the field elliptical NGC 7507
Indexación : ISI
ISSN :
Año : 2013
Vol. : 555
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Autor (a)(es/as) : Ness, M.; Freeman, K.; Athanassoula, E.; Wylie-de-Boer, E.; Bland-Hawthorn, J.; Asplund, M.; Lewis, GF.; Yong, D.; Lane, RR.; Kiss, LL.
Nombre Completo de la Revista : Monthly Notices of the Royal Astronomical Society
Título (Idioma original) : ARGOS - III. Stellar populations in the Galactic bulge of the Milky Way
Indexación : ISI
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Vol. : 430
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Páginas : 836-857
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Nombre Completo de la Revista : Monthly Notices of the Royal Astronomical Society
Título (Idioma original) : ARGOS - II. The Galactic bulge survey
Indexación : ISI
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Vol. : 428
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Nº : 9
Autor (a)(es/as) : Lane, RR.; Salinas, R.; Richtler, T.
Nombre Completo de la Revista : Astronomy & Astrophysics
Título (Idioma original) : Isolated ellipticals and their globular cluster systems. I. Washington photometry of NGC 3585 and NGC 5812
Indexación : ISI
ISSN :
Año : 2013
Vol. : 549
Nº : A148
### OTRAS PUBLICACIONES / PRODUCTOS

*Sin información ingresada.*

### CONGRESOS

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<td>Título (Idioma original)</td>
<td>The globular cluster systems of isolated ellipticals – what can they tell us about ΛCDM?</td>
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poster_v6.pdf

Nº : 3
Autor (a)(es/as) : Salinas, R., Lane RR.; Alabi, A.; Richtler, T.
Título (Idioma original) : Alone in the dark: globular clusters in isolated ellipticals
Nombre del Congreso : The Physical Link between Galaxies and their Haloes
País : ALEMANIA
Ciudad : Garching
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isolated_garching_V2-1.pdf

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Autor (a)(es/as) : Richtler T; Salinas R; Lane RR; Hilker M; Caso J P; Bassino L
Título (Idioma original) : News from the isolated ellipticals NGC 5812, NGC 7507, and NGC 7796
Nombre del Congreso : Galaxies in 3D across the Universe - IAU Symposium 309
País : AUSTRIA
Ciudad : Vienna
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Nombre Publicación : Proceedings of the International Astronomical Union, IAU Symposium 309
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ANEXOS

A continuación se detallan los anexos físicos/papel que no se incluyen en el informe en formato PDF.