

Near-IR observations of Red Supergiant stars in the Local Group of galaxies

Lee. R. Patrick



Doctor of Philosophy
The University of Edinburgh
May 2015

Abstract

Red Supergiant stars represent the most luminous stars in the infrared sky. Their intrinsic luminosities combined with the low dust extinction observed in this regime makes these objects very attractive to study in the near-IR. Added to this is the fact that RSGs are necessarily young objects, therefore these stars are tracers of recent star formation in extra-galactic systems. As the next generation of telescopes will be optimised for study in the near-IR, it is clear that in the coming years RSGs will play a prominent role in the way which astronomers probe the local universe and out to larger distances with space-based observations. Therefore, bettering our understanding of these objects now and developing the tools which will allow us to take full advantage of the suite of instrumentation which will become available in the near future is vital. This thesis aims to further the understanding of RSGs by focusing on photometry and spectroscopy at near-IR wavelengths.

I develop a more robust criteria for selecting RSGs using near-IR photometry alone. This has the advantage of decreasing the dependence of optical colours which are known to select only a sub-sample of RSGs. This selection criteria is tested on data for >300 red stars in M33 and the efficiency of this technique is detailed.

I describe the implementation of the J-band analysis technique which is used to derive stellar parameters using near-IR spectra of RSGs. This implementation is tested on a variety of synthetic and real spectra and is shown to work well across a broad range of input spectra.

Using the selection criteria developed as well as the analysis routines described, 11 RSGs in NGC 6822 are observed with the new K-band multi-object spectrograph (KMOS) and have stellar parameters estimated. The data reduction process with KMOS is described in detail, in particular where the reduction has been

optimised for our data. The metallicity of these stars is compared to previous estimates and is shown to be in good agreement. Additionally, KMOS spectra of RSGs in NGC 55 is presented and stellar parameters are derived for these stars. These results are compared to previous estimates in this galaxy and the spatial distribution of the chemical abundances is assessed.

Contents

Abstract	i
Contents	iii
1 Introduction	1
2 Near-IR selection of Red Supergiants	2
3 J-band Sythentic Spectral Fitting	3
4 KMOS Observations in NGC 6822	4
5 Red Supergiants in NGC 55	5

Chapter 1

Introduction

Completeness: 85%

This estimation is based on the work done in the first year report.

Description:

The introduction will be split into three main sections:

1. The life and death of massive stars

Where I will outline the physical processes of the birth, the evolution from the onset of hydrogen fusion and finally the death of massive stars focusing in particular on the Red Supergiant phase of stellar evolution

2. The Physical Properties of Red Supergiants

I will detail the properties of RSGs from Galactic studies and outline our present understanding of what a RSG is and some of their characteristic features e.g. mass loss rates.

3. The Chemical evolution of galaxies

In this section I will give an account of how galaxies build up their present abundances via star formation and feedback. I will describe the mass-metallicity relationship and how RSGs will play a role in furthering our understanding of this relationship.

Chapter 2

Near-IR selection of Red Supergiants

Completeness: 30%

Observations complete, still currently working with the pipeline team to fix, the data reduction pipeline for this instrument.

Description:

This chapter will discuss how to select RSGs based on their near-IR properties. A more robust selection criteria will be established based on a J-band colour-magnitude diagram. These results will be tested on a set of observations in M33 where effectiveness of the technique will be estimated.

These results will be compared to the recently developed ‘Q-parameter’.

Chapter 3

J-band Sythentic Spectral Fitting

Completeness: 60%

My implementation of the J-band spectral fitting technique is in the final stages of testing and has performed well in a variety of tests. More testing still remains before I can use this implementation confidently on a new data set.

I tandem to developing this implementation of the technique I have also documented my progress which will serve as the bones of this chapter.

Description:

This chapter will describe in detail the process by which one can estimate stellar parameters based on near-IR spectra of Red Supergiant stars. I will document the progress to date using this technique and describe how my implementation will allow an independent check to results which have been obtained using other implementations of the same technique.

I will focus in particular on the differences between my implementation and those in the literature.

Chapter 4

KMOS Observations in NGC 6822

Completeness: 95%

This work is published in Patrick et al. (2015, ApJ, 804, 14) and has been adapted and expanded into a thesis chapter

Description:

This chapter describes the observations of RSGs in NGC 6822 a local dwarf irregular galaxy. This chapter details the observations obtained with KMOS and the data reduction process as well as what has been optimised in this process for our observations. Target selection is based on that described in a previous chapter

The analysis for this section is that described in a previous chapter.

The results of this chapter are that we obtain stellar parameters for 11 RSGs in this galaxy and quantify the lack of stellar metallicity gradient within this galaxy. We show that our results compare well to previous estimates of stellar metallicity from young stars and HII regions in this galaxy. Using a simple chemical evolution model we show that the present-day metallicity can be explained in terms of the simple closed-box chemical evolution model which is remarkable given the morphology of this galaxy. Finally we compare the stellar parameters derived in this study with all those derived using the same technique in different environments. We show that there appears to be no significant variation of temperature of RSGs with respect to metallicity, in direct contrast with recent evolutionary models.

Chapter 5

Red Supergiants in NGC 55

Completeness: 30%

The observations for this section are complete and the data reduction is currently being optimised.

Description:

This chapter will outline KMOS observations of 20 RSGs in NGC 55. I will describe the work I have done in preparation for these observations.

I will discuss the optimisations which have been made for this data set and describe the challenges of obtaining the best possible data from a set of challenging observations.

I will comment on the spatial distribution of the chemical abundances in this galaxy and discuss a potential metallicity gradient previously suggested in the literature.