

# Radio Interferometric Studies of Cool Evolved Stellar Outflows

A dissertation submitted to the University of Dublin  
for the degree of Doctor of Philosophy

**Eamon O’Gorman**

Supervisor: Dr. Graham M. Harper

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SCHOOL OF PHYSICS  
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## Declaration

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## Summary

You should write a nice summary here...

*A dedication if you wish...*

## Acknowledgements

Some sincere acknowledgements...

# List of Publications

## Refereed

1. **O’Gorman, E.**, Harper, G. M., Brown, J. M., Brown, A., Redfield, S., Richter, M. J., and Requena-Torres, M. A.  
“CARMA CO(J = 2 - 1) Observations of the Circumstellar Envelope of Betelgeuse”  
The Astronomical Journal, 144, 36 (2012)
2. Sada, P. V., Deming, D., Jennings, D. E., Jackson, B. K., Hamilton, C. M., Fraine, J., Peterson, S. W., Haase, F., Bays, K., Lunsford, A., and **O’Gorman, E.**  
“Extrasolar Planet Transits Observed at Kitt Peak National Observatory”  
Publications of the Astronomical Society of the Pacific, 124, 212 (2012)
3. Sada, P. V., Deming, D., Jackson, B. K., Jennings, D. E., Peterson, S. W., Haase, F., Bays, K., **O’Gorman, E.**, and Lundsford, A.  
“Recent Transits of the Super-Earth Exoplanet GJ 1214b”  
The Astrophysical Journal Letters, 720, L215 (2010)

## Non-Refereed

1. **O’Gorman, E.**, & Harper, G. M.  
“What is Heating Arcturus’ Wind?”,  
Proceedings of the 16th Cambridge Workshop on Cool Stars, Stellar Systems and the Sun. Astronomical Society of the Pacific Conference Series, 448, 691 (2011)

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# 1

## Scientific Overview

Here is the introduction of the thesis, complete with a few references (Prothero & Buell, 2007; Sagan, 1997). Section 3.1 contains Equation 1.1, Section 3.2 has Figure 1.1 and Section 3.3 has Table 1.1. Chapter 2 has pretty much nothing in it.

### 1.1 First Section

This section has an equation. Here it is:

$$L_{\odot} = 4\pi R_{\odot}^2 \sigma T_e^4 \tag{1.1}$$

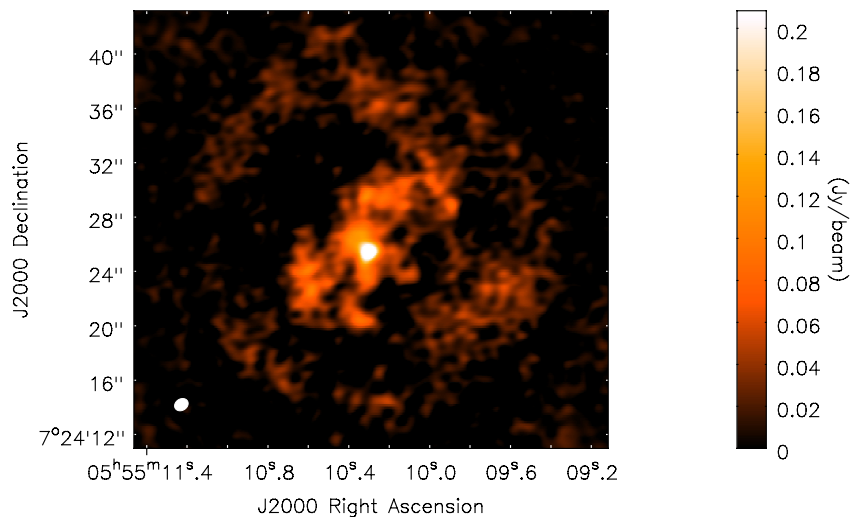
which is a nice way of describing the luminosity.

### 1.2 Second Section

So this section has a figure in it<sup>1</sup>. That figure depicts the basic structure of a red giant.

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<sup>1</sup>And also a footnote.



**Figure 1.1:** Red Giant and Asymptotic Giant Branch Stars. The left side of the figure shows the basic structure of a star on the giant branch of the HR diagram, while the right side shows a similar star after it has evolved to ascend the asymptotic giant branch. *Image Credit: Australian Telescope National Facility.*

## 1.3 Second Section

This section contains a basic table.

**Table 1.1:** Physical Properties of  $\alpha$  Boo and  $\alpha$  Tau.

Property	$\alpha$ Boo	$\alpha$ Tau	Reference
HD Number	124897	29139	...
Spectral Type	K2 III	K5 III	1, 2
ra (ICRS: ep=J2000)	14 <sup>h</sup> 15 <sup>m</sup> 39.672 <sup>s</sup>	04 <sup>h</sup> 35 <sup>m</sup> 55.239 <sup>s</sup>	3
dec (ICRS: ep=J2000)	+19 10 56.673	+16 30 33.489	3
pm-ra (mas yr <sup>-1</sup> )	-1093.39 $\pm$ 0.44	63.45 $\pm$ 0.84	3
pm-dec (mas yr <sup>-1</sup> )	-2000.06 $\pm$ 0.39	-188.94 $\pm$ 0.65	3
$\pi$ (mas)	88.83 $\pm$ 0.54	48.94 $\pm$ 0.77	3
Distance (pc)	11.3 $\pm$ 0.1	20.4 $\pm$ 0.3	3
$M$ ( $M_{\odot}$ )	0.8 $\pm$ 0.2	1.3 $\pm$ 0.3	6, 4
$\theta_{UD}$ (mas)	21.0 $\pm$ 0.2	20.2 $\pm$ 0.3	5
$\theta_{LD}$ (mas)	21.0 $\pm$ 0.2	20.2 $\pm$ 0.3	5
$L$ ( $L_{\odot}$ )			
$R$ ( $R_{\odot}$ )	25.4 $\pm$ 0.3	44.4 $\pm$ 1.0	...
Log $g$			
$T_{\text{eff}}$ (K)	4294 $\pm$ 30	3970 $\pm$ 49	5
$v_{\text{rad}}$ (km s <sup>-1</sup> )	+5.19 $\pm$ 0.04	+54.11 $\pm$ 0.04	9
$v_{\text{esc}}$ (km s <sup>-1</sup> )	110	106	...
$v_{\infty}$ (km s <sup>-1</sup> )	$\sim$ 40	$\sim$ 30	7, 8
$T_{\text{wind}}$ (K)	$\sim$ 10,000	<10,000	7, 8
$\dot{M}$ ( $M_{\odot}$ yr <sup>-1</sup> )	$2 \times 10^{-10}$	$1.6 \times 10^{-11}$	7, 8
$H$ ( $H_{\odot}$ )			...

References.-(1);(2)Gray *et al.* (2006); (3)van Leeuwen (2007); (5)di Benedetto (1993); (6)Kallinger *et al.* (2010); (7)Drake (1985); (8)Robinson *et al.* (1998) (9)Massarotti *et al.* (2008)

# 2

## Introduction to Radio Interferometry

The need....

### **2.1 Radio Antenna Basics**

### **2.2 Basic Principle of Astronomical Interferometry**

### **2.3 The Measurement Equation**

# 3

## Instrumentation and Observations

So this Chapter has nothing really, apart from a shout out to Appendix [A](#), and maybe a few more sample references ([Harper & Brown, 2006](#); [Seaquist & Taylor, 1990](#)).



## 3.1 CARMA

### 3.1.1 The Basic Instrument

### 3.1.2 The CARMA Electronic System

### 3.1.3 Observations

## 3.2 VLA

### 3.2.1 The Basic Instrument

### 3.2.2 The VLA Electronic System

### 3.2.3 Observation Preparation

### 3.2.4 Observations

## 3.3 GMRT



## A Nice Appendix

This is where the appendix would go...

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