

Radio Interferometric Studies of Cool Evolved Stellar Outflows

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

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SCHOOL OF PHYSICS
UNIVERSITY OF DUBLIN
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Summary

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A dedication if you wish...

Acknowledgements

Some sincere acknowledgements...

List of Publications

Refereed

1. Richards, A. M. S., Davis, R. J., Decin, L., Etoke, S., Harper, G. M., Lim, J. J., Garrington, S. T., Gray, M. D., McDonald, I., **O’Gorman, E.**, Wittkowski, M.
“e-MERLIN resolves Betelgeuse at wavelength 5 cm”
Monthly Notices of the Royal Astronomical Society Letters, 432, L61 (2013)
2. **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)
3. 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)
4. 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

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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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A.1 List of Abbreviations 5

1

Introduction

Here is the introduction of the thesis, complete with a few references (??). Section [1.2](#) contains Equation [1.2](#), Section [1.4](#) has Figure ?? and Section ?? has Table ??. Chapter ?? has pretty much nothing in it.

1.1 The problem

1.2 History

lamors and cass maybe radio HR diagram

1.3 Stellar Radio Emission Mechanisms

into hr radio diagram

1.3.1 Elementary Formulas

In thermodynamic equilibrium the specific intensity I_ν of the radiation of a black body with temperature T is given by the Planck law

$$I_\nu(T)d\nu = \frac{2h\nu^3}{c^2} \frac{1}{e^{h\nu/kT} - 1} d\nu \quad (1.1)$$

and has units of flux per frequency interval per solid angle. One can easily switch to specific intensity in terms of wavelength by $I_\lambda = (c/\lambda^2)I_\nu d\nu$ which is more often used in optical astronomy. When $h\nu \ll kT$ Equation 1.1 becomes the *Rayleigh-Jeans Law*

$$I_\nu(T)d\nu = \frac{2\nu^2 kT}{c^2}. \quad (1.2)$$

which is a nice way of describing the luminosity. and can be used for all thermal radio sources except in the millimeter or sub-millimeter regime at low temperatures (?).

continue with tools of radio astron

The brightness temperature is the temperature at which a blackbody would have to be in order to reproduce the observed specific intensity of an object at frequency ν .

isothermal disk (books chap 1 and 11)

1.4 Second Section

give example of flux from nearest star



List of Abbreviations

Table A.1: List of Abbreviations

Abbreviation	Meaning
BIMA	Berkeley Illinois Maryland Association
CARMA	Combined Array for Research in Millimeter-wave Astronomy
CSE	Circumstellar Envelope
DDT	Director's Discretionary Time
e-MERLIN	e-Multi-Element Radio Linked Interferometer Network
FOV	Field of View
GREAT	German Receiver for Astronomy at Terahertz Frequencies
HPBW	Half Power Beamwidth
HST	Hubble Space Telescope
IOTA	Infrared Optical Telescope Array
IR	Infrared
IRAM	Institut de Radioastronomie Millimétrique
IUE	International Ultraviolet Explorer
LSR	Local Standard of Rest
MEM	Maximum Entropy Method
OVRO	Owens Valley Radio Observatory
RFI	Radio Frequency Interference
S/N	signal-to-noise
SOFIA	Stratospheric Observatory for Infrared Astronomy
SMA	Submillimeter Array
UV	Ultraviolet
VLA	Karl G. Jansky Very Large Array
VLBA	Very Long Baseline Array
VLT	Very Large Telescope

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- GOLDREICH, P. & SCOVILLE, N. (1976). OH-IR stars. I - Physical properties of circumstellar envelopes. *Astrophysical Journal*, **205**, 144–154. (Not cited.)
- O’GORMAN, E. & HARPER, G.M. (2011). What is Heating Arcturus’ Wind? In C. Johns-Krull, M.K. Browning & A.A. West, eds., *16th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun*, vol. 448 of *Astronomical Society of the Pacific Conference Series*, 691. (Not cited.)
- RODGERS, B. & GLASSGOLD, A.E. (1991). The temperature of the circumstellar envelope of Alpha Orionis. *Astrophysical Journal*, **382**, 606–616. (Not cited.)
- SPITZER, L. (1978). *Physical processes in the interstellar medium*. New York Wiley-Interscience, 1978. 333 p. (Not cited.)