An Examination of Selective Imaging Techniques

By

Andrew Grant Smith

A thesis submitted to Macquarie University
for the degree of
Master of Science
Department of Physics & Astronomy
August 2010

MACQUARIE UNIVERSITY
FACULTY OF SCIENCE

Typeset in $\LaTeX\,2_\varepsilon$.

Except where acknowledged in the customary manner, the material presented in this thesis is, to the best of my knowledge, original and has not been submitted in whole or part for a degree in any university.

Andrew Grant Smith

Acknowledgements

My greatest thanks to my supervisors for sharing their experience and expertise: to Alan Vaughan, who made me worry about uncertainties, and who quietly soldiered on in the face of great adversity; to Mark Wardle, for taking me on when Alan retired, and for seeing it through; and most of all to Jeremy Bailey, for starting the whole project off and including me in it, for the experiences of the observing trips, and for patience when my study took me significantly longer than I expected.

My appreciation to the Director of the AAO, Matthew Colless, for provision of time on the AAT, and the RSAA Time Allocation Committee for assignments of time on the ANU 1m telescope. I would like to thank Steve Massey, as well as the support staff at SSO and the AAO, especially Steven Lee, for their assistance during our observations.

My hawk-eyed proof-readers, Stan Fry and Rachel Merton, thanks for your time and diligence.

Many of my fellow postgraduate students in the Astronomy group at Macquarie gave assistance with technical problems, friendship and light relief, listened to gripes, and also shared the fun and challenge of organising the Harley Wood Winter School. Thanks to all of these stars, most especially Korinne McDonnell.

Undertaking a postgraduate degree part-time while working almost full-time hours is very demanding. Life keeps getting in the way. For understanding and accommodating my needs, thanks to my boss Darren Vogrig, and to his boss David Trotter for allowing me study leave. Also, a big hug to all my colleagues at the Sydney CSIROSEC, for making it a great, fun place to work.

To all of my friends who have been waiting, patiently or otherwise, for me to finish this thesis, thank you all for your friendship, teasing, fun and encouragement.

To my mother, Nancye, for instilling in me a critical and inquiring mind, and to my father, David, for technical aptitude, thank you.

Two men who have helped keep me sane, and helped me to see that I have something worthwhile to say, were David Lonie and Mark Howard. I would not have had the confidence to see this through without them.

Finally, to my loving partner in life, Sue, who first encouraged me to return to tertiary study. It was tough on you, especially as the years dragged on. You provided a home, encouragement, patience above and beyond, reality checks, and nagging when needed. I hope I can repay the debt.

Abstract

An extensive empirical study of the frame selection method of high-resolution astronomical imaging, also known as lucky imaging, has been carried out. This method involves the capture of many hundreds or thousands of short exposure frames, the scanning and ranking of all the frames for sharpness, and the co-alignment and averaging of only the best frames into a final image. The performance of the selective imaging technique was tested by imaging several bright stars, binaries and clusters, and using the brightest pixel value in each frame as the sharpness metric. The lucky imaging parameters are the frame exposure time, telescope aperture, seeing, frame selection fraction, colour band, and distance from the co-alignment position. By using a range of aperture masks and colour filters, and a camera with adjustable exposure, we explored the widest range of parameter space of any frame selection study to date.

The results from the stellar images show that frame selection is very effective at reducing the effects of atmospheric turbulence on astronomical images. When all frames in an observation are combined, the seeing disc is diminished and a bright central core is apparent. By selecting just the best 1% of frames the core is brighter while the halo almost vanishes. In many of these cases faint spikes and dark rings appeared, indicating difraction limited images. The results were best when small apertures were used, particularly at longer wavelengths. It was found that, for the Siding Spring site, the exposure time should be limited to 10 ms, although images were improved at all times tested. It was also found that when image frames of binaries and clusters were co-aligned on the brightest star, the improvement in sharpness was greatest at this point, and the improvement decreased with angular radius.

To prepare for future research, solar system planets and lunar features were also imaged. These were processed with sharpness metrics suited to extended objects. It was found that frame selection was effective at improving the planetary images over traditional long exposure images. However the results were not as good as for the stellar images. Possible reasons for this are discussed.

Contents

List of Figures

List of Tables