



Universiteit
Leiden
The Netherlands

Dancing with the stars

Albert, J.G.

Citation

Albert, J. G. (2020, October 28). *Dancing with the stars*. Retrieved from <https://hdl.handle.net/1887/137988>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/137988>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/137988> holds various files of this Leiden University dissertation.

Author: Albert, J.G.

Title: Dancing with the stars

Issue Date: 2020-10-28

Dancing with the Stars

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op woensdag 28 oktober 2020
klokke 13:45 uur

door

Joshua George Albert
geboren te London, Ontario, Canada
in 1990

Promotor: Prof.dr. H.J.A. Röttgering (Sterrewacht Leiden)
Co-Promotor: Dr. R.J. van Weeren (Sterrewacht Leiden)

Promotiecommissie:

Voorzitter: Prof.dr. H.J. van Langevelde (Sterrewacht Leiden)
Secretaris: Prof.dr. C.U. Keller (Sterrewacht Leiden)
Overige leden: Prof.dr. K.J. Batenburg (Mathematisch Instituut Leiden)
Prof.dr. L.V.E. Koopmans (Rijksuniversiteit Groningen)
Prof.dr. O. Smirnov (Rhodes University)
Dr.ing. H.T. Intema (Sterrewacht Leiden)
Dr. C. Tasse (L'Observatoire de Paris)
Dr. M. Mevius (Stichting ASTRON, Dwingeloo)

ISBN: 978-94-6332-685-8

© 2020 Joshua George Albert

Omslagontwerp: Joshua George Albert

Hoofdstuk illustraties: Ainsley Bernice Albert

Dit werk is gelicenseerd onder een Creative Commons Naamsvermelding-GelijkDelen 3.0 Unported licentie. Ga naar <http://creativecommons.org/licenses/by-sa/3.0/> om een kopie van de licentie te kunnen lezen.

Dit proefschrift werd ondersteund door het European Research Council Advanced Investigator programme NewClusters 321271.

For Alina, my twinkling star.

Contents

Preface	vii
Introduction	1
Radio emission mechanisms	1
Diffuse emission in galaxy clusters	4
Radio interferometry	5
History	5
Technical introduction to scattering and radio interferometry	8
Next-generation radio interferometry	17
About this thesis	19
Future directions	20
1 Complex diffuse emission in PLCK G004.5-19.5	23
1.1 Introduction	25
1.2 Observations and data reduction	26
1.2.1 GMRT observations of PLCK G004.5-19.5	26
1.2.2 <i>XMM-Newton</i> reduction	28
1.2.3 Spectroscopic data	28
1.3 Results and discussion	29
1.3.1 X-ray structure	29
1.3.2 Radio emission	31
1.3.3 Nature of the diffuse emission	35
1.4 Conclusion	36
2 Probabilistic ionospheric calibration	37
2.1 Introduction	39
2.2 Ionospheric effects on interferometric visibilities	40
2.3 Probabilistic relation between FED and Δ TEC	42
2.4 Method	45
2.4.1 Data generation	46
2.4.2 Competitor models	47
2.4.3 Model comparison	48
2.5 Results	52
2.6 Discussion	55
2.6.1 Model selection bias	55

2.6.2	Implicit tomography	55
2.6.3	Temporal differential TEC correlations	56
2.6.4	Structure function turnover and anisotropic diffractive scale	56
2.6.5	Low-accuracy numerical integration	58
2.7	Conclusion	58
3	Probabilistic ionospheric calibration for LOFAR-HBA	61
3.1	Introduction	63
3.2	Doubly differential phase screens	64
3.3	Methods	68
3.3.1	Subtract and solve	68
3.3.2	Smooth and slow-resolve	71
3.3.3	Measure DDTEC	73
3.3.4	Infer DDTEC screen	78
3.3.5	Image screen	82
3.4	Results	83
3.5	Discussion	84
3.6	Conclusion	85
4	Feasibility of ionospheric screens for LoTSS	91
4.1	Introduction	93
4.2	Method	94
4.2.1	An improved outlier detection	96
4.3	Image improvements and ionospheric robustness	101
4.4	A non-ionospheric systematic and correction	105
4.5	Information in DDTEC screens	111
4.6	Conclusion	113
	Appendix A Derivation of tomographic equivalence	135
	Appendix B ΔTEC variance function	137
	Appendix C Factoring commutative DI dependence from the RIME	141
	Appendix D Recursive Bayesian estimation	143
	Appendix E Jones scalar variational expectation	147
	Appendix F Derivation of the M-step	151
	English Summary	155
	Nederlandse Samenvatting	159
	Curriculum Vitae	163
	Acknowledgements	167



NOBODY

"You're a smart guy, but tell me this. Why is it that nobody talks about what was there before all this?" asked my grand father waving his old weathered hands around at the gently whispering trees. We sat in two chairs perched on top of an old green hill that looked out over the water of a place called Camp. An unlit cigar adorned my grand father's finger tips, and I leaned over to help shield it from the wind as he lit it.

I answered back, "What do you mean by *this*, exactly? Do you mean the space that we live in, and perhaps also the time that we occupy?"

"All of it," he replied, "If we're to believe what people say, the entire Universe started with a Big Bang, and has been expanding ever since. I mean, if you imagine the Universe is expanding, shooting out in all directions, then it must be expanding into something. What is that?" I paused for a moment. I loved these conversations with my grand father very much. Even in his eighth decade, he always had a way of stepping far outside his immediate surroundings into his imagination. Furthermore, he is a very stubborn man, and this combination – imagination and steadfast persistence – is a wonderful mindset to have when it comes to discussing the finer points of nature unknown.

"Ah, you mean if you could magically be at the edge of the Universe, would there be some sort of shock wave as the Universe expanded into something? And then, what would that something be?" He nodded. I attempted to light my own cigar in the gentle breeze, and gratefully grunted a thanks as my grand father leaned over to shield the wind. "Well, unfortunately we are stuck here on Earth, with only our minds to wonder. But let's say we were there during the Big Bang, and were riding one of the first packets of energy – let's call it a photon – as it seemingly raced out into the void. Since we were riding the first photon, we wouldn't be able to see anything in front of us, and we might shout 'watch out for the void!' as we feared collision with something we could not see. If this little photon just kept going, with us on its back, then we would always seem to be flying into the void. So I fear, whatever it is the Universe expands into, we could never describe it with things that can be seen."

"Very interesting." said my grand father, "You see why no one ever talks about this, because no one knows, but you have a good way of putting it into words. Surely there must be something we could measure of this void,

like a temperature perhaps?"

"You know what temperature is, right? It's just a measure of how fast molecules are bouncing around. If there is no matter – or energy – in the void, then it's not possible to measure temperature." I smiled at my grand father's face.

"Ah, your right. Maybe one day we'll know, and I think you're the right guy for it." The next few minutes passed without words between us, although it was by no means silent. Around us whispered the leaves, and below us the roll of the waves against the shore concealed their meanings. As it were, we'd return to this topic again some time later.

These are the sort of memories, going back as far as I can recall, that I cherish. Not only of conversations with my grand father, but with others, and myself.

It is through the childhood that a person first gains their sight of the world – that magical thing we call life. We naturally accept the guidance of those around us, who walk with us through the difficulties ahead. It seems such a messy and beautiful dance, and all lifeforms partake. Interestingly, we messy creatures have devised scientific inquiry as a tool for surveying that which lays before us. To us, we look not into a void, but into a rich landscape. And yet, we too emerge from a singularity at birth and dance forth into the unknown, so some prudence to caution is advisable.

Can we use our senses and reasoning, that which we investigate the world with, to investigate existence itself? I would argue the only such hope we have of understanding existence through reasoning is that it's a tautology, 'cogito ergo sum' in the words of René Descartes. However, outside the walls of the mind we quickly lose objectivity, if it ever existed, and is properly put by Meister Eckhart von Hochheim (ca. 1260 – 1328),

If reason presents certain actions as likely to improve your condition but your conscience does not approve, then leave them undone. Reason never grasps the world in its entirety and the means it dictates to achieving its limited aim will ultimately, and in some inscrutable way, only cause damage.

If in this life we always had a mirror in front of us in which we could see things at a glance, grasp everything in one image, acting and knowing would not cause us any problem. But, since in our viewing we must turn from one thing to another we cannot concentrate on one without obstructing the other.

In a sense, Meister Eckhart paints a type of uncertainty principle between reason and conscience, acting and knowing, epistemology and ontology. To turn toward one you must turn from the other. We may juxtapose the stumbling child's discovery of life with the ideal scientist, into whom the child yearns to become. Regarding the end state of this transformation, science may be seen as immaculate and homogeneous, and is often given titles of truth. Yet, look closer and the messy dance of the child never truly stops, like Zeno's tortoise never quite reaching the finish line. There is never time to pause and look around and feel certainty, 'a masterpiece is never finished, only abandoned' in the words of Leonardo da Vinci. Thus, I must insist, science *is* an interpretive dance, where no one may violate Meister Eckhart's uncertainty principle.

Why are we dancing with the stars? Well, I'm afraid *the medium is the message*, and that's all there is to it. Twentieth century philosopher, Michael Serres, metaphysically discusses two rats eating rich left overs on a Persian rug in the Mayor's house,

The two companions scurry off when they hear a noise at the door. It was only a noise, but it was also a message, a bit of information producing panic: an interruption, a corruption, a rupture of information. Was the noise really a message? Wasn't it, rather, static, a parasite? A parasite who has the last word, who produces disorder and who generates a different order. Let's go to the country where we eat only soup, but quietly and without interruption.

To parasite means to eat next to. The noise partakes in the meal next to the rats and causes panic. In the country quietness is the parasite.

We astronomers look up at night on a clear sky and watch the stars twinkle and consider the twinkle a noise, a corruption, a rupture of information. Is the twinkle really a message? The twinkle is a movement of light, spurred by Earth's atmosphere, as natural a thing as ever existed. We isolate the movement, and, following it, we dance our telescopes until we see a stationary shape. Oh, but such a strange shape! The struts of the telescope leave these arms of light seemingly coming out of the star, another corruption. Are these arms of light really a message? To be sure they are not, but merely a parasite. And, we may go on and on in such a way always trying to interpret what is beyond the noise without knowing. And, that is the essence of this work: we perform an interpretive dance with twinkling lights, with an impeccably powerful tool of human inquiry, trying not to confuse the message for the medium.
