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Rafael A. García
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Scott W. McIntosh *Editors*

# Dynamics of the Sun and Stars

## Honoring the Life and Work of Michael J. Thompson

Springer

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Cover illustration: Michael J. Thompson, photographed in Nov. 2015, in Taiwan, by Ying-Hwa "Bill" Kuo (UCAR)

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# Foreword

Dear friends and colleagues of Michael,

Thank you for allowing me to add my voice to this volume, honouring the life and work of Michael J. Thompson, my beloved husband. And thank you for your friendship and community over the last 35 years. I am not a scientist and so it is with a different, entirely personal, perspective that I write.

I first met Michael when he was a Part III student in Cambridge. He was a shy and intense young man, a typical 'Cambridge mathematician' with that combination of introversion and confidence. At the end of that year, he won something called The Tyson Medal, described by Wikipedia as being *'awarded for the best performance in subjects related to astronomy at the University of Cambridge, England. It is awarded annually for achievement in the examinations for Part III of the Mathematical Tripos when there is a candidate deserving of the prize'*. Deserving of the prize, indeed. Being an undergraduate in English Literature, I had no idea what this meant or who Michael was in his world.

Some of the contributors to this volume would have known Michael at least as long as I did, some perhaps longer. He loved collaborating with you and being a member of the solar and stellar physics community. I had the privilege to travel with Michael to places where I met many of you. In the last 35 years, you, Michael and I have shared many stimulating conversations, rich cultural experiences, natural disasters, food and drink.

As I write, I do not know exactly what the other contributions to this volume are, other than a research article by Robin Thompson, our son. But, attending the conference, I heard talks from those who had known Michael, speaking personally about what he meant to them and how his work had influenced them. I am, of course, deeply saddened that we gathered to honour Michael's memory and not to celebrate his 60th birthday. Despite this, he would have been pleased and perhaps surprised to hear about the many positive impacts that he had on people, both through his work and through other aspects of his life and person. We heard from numerous individuals about how he had been so generous to them—the cafeteria staff, the IT

department, the early career and senior scientists and many more. W.B. Yeats wrote that

> The intellect of man is forced to choose
> Perfection of the life, or of the work.

As tributes here show, Michael, like so many of us, aspired to some combination of those.

The language of this subject—the Dynamics of the Sun and Stars—has become somewhat familiar to me over the decades; I understand many of the words (from helioseismology onwards) if not the concepts they are used to describe. The meeting allowed me to hear this language spoken inside and outside the conference room, and although it is not really a language I speak, I enjoyed hearing it this way. It gave me a deeper sense of a part of Michael's life that was always important to him.

I know that you will continue this science and this language, and so Michael's work and his contributions to the subject will also live on. He would be pleased to have been useful and to have shared in this. As the research continues, your collaborations and calculations will bring new understanding of the forces and objects in our universe. This contributes to the sum of human knowledge. Who could not be proud of this? I know Michael would want to have been a part of that and also to know that you and those who come later will be taking the research in new directions. This volume represents the continuation of this field and the start of those future discoveries.

Boulder, CO, USA Kate L. Thompson
March 2020

# Preface

This volume is a collection of original articles resulting from the contributions presented at the conference on

DYNAMICS OF THE SUN AND STARS:
HONOURING THE LIFE AND WORK OF MICHAEL J. THOMPSON
*24–26 September 2019, NCAR–USA*
Website: https://www2.hao.ucar.edu/MJTWorkshop2019

## Rationale for the Conference and Proceedings

This meeting celebrated Michael Thompson's seminal work on solar and stellar physics, as well as his major contributions to the development of the National Center for Atmospheric Research, and marks his untimely death in October 2018. Michael played a key role in the development of helioseismology and its application to the study of the structure and dynamics of the solar interior, and he provided a strong foundation for the extension of seismic studies for other stars. After focussing for several years on more administrative activities, he was returning to leading the seismic studies of solar interior rotation and he was deeply involved in the understanding of the dynamics of the core of stars, when his life was tragically lost.

The conference focussed on dynamical aspects of the Sun and stars, based on the large amount data available on solar and stellar oscillations, and the extensive and detailed modelling now becoming feasible. By combining observations, seismic analysis and modelling, we hope that this will be a fitting memorial for a close colleague and friend, much missed.

## Organisation and Committees

The conference was organised by the *National Center for Atmospheric Research (NCAR)* located in Boulder, Colorado, USA.

The scientific programme occupied three working days, complemented by the social programme. On the first day, there was a specific session dedicated to remember and honour Michael's work and role in science administration. It was a very dense programme with a long list of communications, including a total of 36 oral communications (two of these were public talks), a discussion session and 37 posters. The social programme included a concert.

### *Scientific Organising Committee*

| | |
|---|---|
| Jørgen Christensen-Dalsgaard | Chair—Aarhus University, DK |
| Sarbani Basu | Yale University, USA |
| Rafael A. García | Astrophysics Division, CEA, Saclay, FR |
| Douglas O. Gough | University of Cambridge, UK |
| Frank Hill | NSO, USA |
| Rachel Howe | University of Birmingham, UK |
| Rekha Jain | University of Sheffield, UK |
| Scott McIntosh | NCAR, USA |
| Mário J. P. F. G. Monteiro | University of Porto, PT |
| Jesper Schou | Max Planck Inst. for Solar System Research, DE |
| Takashi Sekii | NAOJ, JP |
| Juri Toomre | University of Colorado, USA |

### *Local Organising Committee*

| | |
|---|---|
| Steve Tomczyk | Chair—NCAR, USA |
| Sheryl Shapiro | NCAR, USA |

A special thank you from the SOC and the participants must go to the local organisation, for the excellent work done in ensuring we all had a perfect meeting. Also, we are very grateful to Kate and Robin Thompson for their contributions to the conference, including the social programme.

## Sponsors

The organisation of the conference and the publication of the present volume were supported by:

- *National Science Foundation, USA*
- *National Center for Atmospheric Research (NCAR), USA*, through funding of the local organisation, events and participant support.
- *Stellar Astrophysics Centre, Aarhus University, Denmark*, by funding the support of some participants.
- *Instituto de Astrofísica e Ciências do Espaço—Centro de Astrofísica da Universidade do Porto* (IA U.Porto), and the *Departamento de Física e Astronomia—Faculdade de Ciências da Universidade do Porto*, through funding of the publication of this volume of proceedings.
- *Centre National d'Etudes Spatiales* (CNES) through the GOLF and PLATO grants at the Astrophysics Division of the CEA/Saclay, France, by funding the color pictures of this volume.
- *Private donations* in support of student travel.

Porto, Portugal — Mário J. P. F. G. Monteiro
Gif-sur-Yvette, France — Rafael A. García
Aarhus, Denmark — Jørgen Christensen-Dalsgaard
Boulder, CO, USA — Scott W. McIntosh
July 2020

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# Part I
# The Life and Work of Michael J. Thompson

# Michael Thompson's Legacy in Solar and Stellar Physics


**William J. Chaplin**

**Abstract** Professor Michael J. Thompson died on 15 October 2018. Michael made long-lasting contributions to the international research community as both a research pioneer in the field of solar and stellar astrophysics and as an administrator who held major leadership positions in the UK and the USA. In this review we summarize his outstanding contributions to research.

It was a huge honour to be asked to give the opening talk of this conference, commemorating Michael's numerous and very significant achievements. He left a significant and long-lasting legacy, not only in terms of the results and outputs from his research in solar and stellar physics, but also from the way he achieved that impact. He made his mark through work in theory, in analysing and interpreting data, and in developing the methodology and techniques of analysis applied to seismic data on stars.

In his research Michael tackled a wide variety of subjects, reflecting a broad range of interests and an inquiring disposition. This breadth is captured by the word cloud in Fig. 1, created from the titles of research papers on which Michael was a co-author.

Michael liked to work with other people, and had a range of collaborators who without fail enjoyed working with him. Figure 2 is a visual representation of his collaborative network. It shows co-authors on scientific papers, with the font size denoting the number of common co-authorships. Aside from the number of collaborators, what is most strking about this diagramme is that it is not just a few names that dominate; many collaborators share a similar-sized representation on the diagramme, reflecting Michael's interest in working with new people. He was

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**Fig. 1** A word cloud created from the titles of research papers on which Michael was a co-author (ADS)

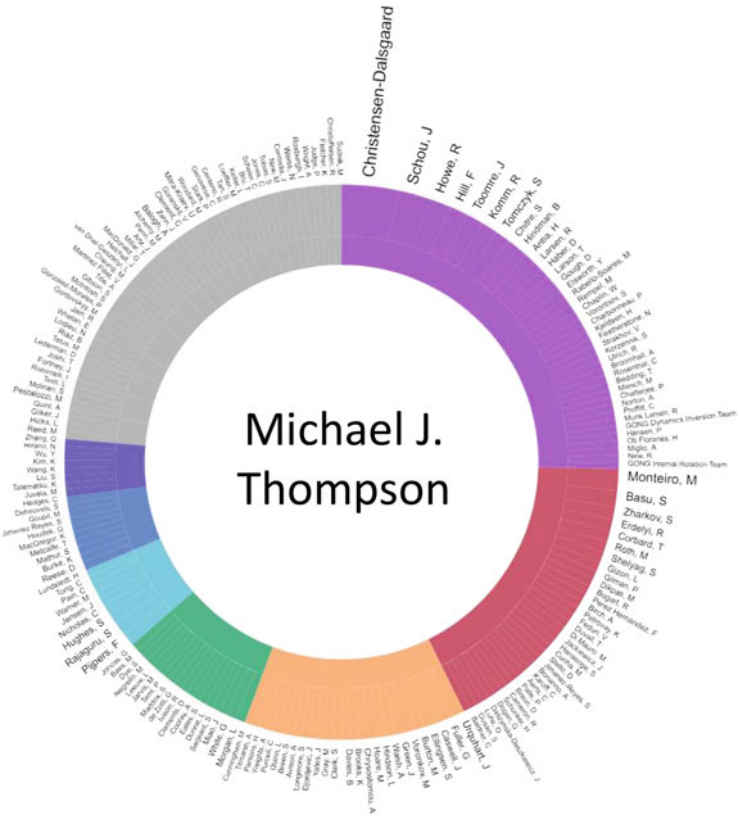


**Fig. 2** A visual representation of Michael's network of research collaborators. The diagramme shows co-authors on scientific papers, with the font size denoting the number of common co-authorships (ADS)

always encouraging, particularly with younger colleagues, and treated everyone the same, irrespective of their position and standing.

Michael was an unfailing supporter of theoretical investigations of the solar interior. He was a strong advocate of research excellence, believing implicitly that long-term understanding could only arise through a sound theoretical underpinning.

Michael took his undergraduate degree at Cambridge from 1978 to 1981. Following a brief period in industry, he returned to Cambridge to complete a Certificate of Advanced Studies in Mathematics (Part III Mathematics) in 1984. He is remembered as an outstanding student, who won the Tyson Medal and Prize for his scholastic achievements. He excelled in exams, including one in particular that would shape the future direction of his career: astrophysical fluid dynamics, taught by Professor Douglas Gough. Michael was convinced he had performed badly in the exam to the extent that he aired his frustrations and resolved never to speak to Douglas again, although he had in fact come top by some margin. Michael was so taken by the course that he decided to pursue research in this field. Wanting also to stay in Cambridge, he approached Douglas to supervise and a life-long friendship and working relationship developed from there, and so Michael added his name to a prestigious academic family tree (Fig. 3).

For his PhD research Michael worked with Douglas in the nascent field of helioseismology. This was a time when helioseismology, the study of the Sun's interior through observation of its oscillations, was becoming established as a field in its own right. Michael's research developed around using seismology as a tool to further understanding of the internal structure and physics of stars, the Sun being a focus throughout much of his career.

After completing his PhD, in 1987 Michael began a postdoctoral fellowship at Aarhus University, working with another former student of Douglas, Jørgen Christensen-Dalsgaard. He then joined the High Altitude Observatory (HAO) in Boulder in 1988, where one day he would become its Director. During this period he began building a body of work on investigating the internal rotation of the Sun, the research topic he is probably best known for (see Fig. 4 for a photo from this period). It is fitting that Michael's first lead-author paper [4] in a refereed journal reported results on an inversion for rotation, which he performed using data from Ken Libbrecht's instrument at the Big Bear Solar Observatory.

Michael was a theoretician, but displayed a strong interest in developing the techniques needed to analyse data. Indeed, he was in the forefront of developing so-called inverse analysis techniques—which had been used in the Geophysics community—for application to helioseismic data, allowing the Sun's internal rotation and structure to be inferred in great detail. After Michael moved to Queen Mary University of London in 1990—initially as a Science and Engineering Research Council Fellow, and as a member of the faculty from 1992—he worked with Frank Pijpers on major improvements to the Optimally Localized Averages (OLA) method of inversion.

As its name suggests, the technique utilizes optimal combinations of sensitivity kernels of individual modes to produce so-called averaging kernels that isolate information on the structure within a specific layer or region of the stellar interior. In

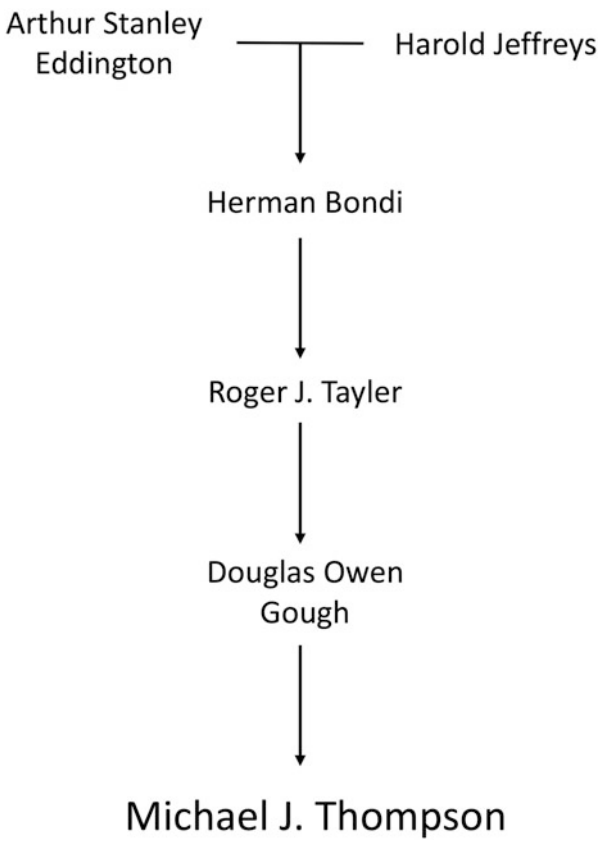


**Fig. 3** Michael's academic family tree

the usual approach, one minimizes the integral of the square of the kernel multiplied by some "cost function" that penalizes the kernel having significant amplitude away from the target radius: hence multiplicative OLA, or MOLA. This calculation can be computationally expensive, and Michael and Frank proposed an alternative, more efficient approach [2]. Here, the trick was to instead compare the integral with some desired target function (e.g., a Gaussian), implying a subtraction in the minimization rather than a multiplication, hence Subtractive OLA or SOLA. In a second paper, they then discussed how to choose a suitable width for the target function depending on the location in the interior [3].

The year 1996 marked an important landmark for the growing field of helioseismoloy, with the publication of a topical edition of Science Magazine, carrying first-light papers on results from the Global Oscillations Network Group (GONG). Tellingly, and a testament to the leadership he had established in the field, Michael was the lead author of the paper on inference on the rotation and dynamics of the interior [5]. Its results revealed with greater clarity than before the differential

**Fig. 4** Michael (right-hand side, in the blue check shirt) and colleagues listen intently at the IAU 121 "Inside the Sun" conference, Versailles, France 22–26 May 1989

rotation of the convective envelope, the pronounced rotational sheer at the base of the envelope, in addition to shear in the near-surface layers.

Results on rotation did not fit with prevailing theory. Whilst they showed that the pattern of differential rotation observed at the Sun's surface—with equatorial regions rotating more rapidly than the poles—penetrated the Sun's convective envelope, the patterns failed to match those predicted by models. Deeper down the rotation was observed to transition across a thin layer called the tachocline to that expected of a solid body, again a surprise, and one that continues to challenge models today. Michael would continue to publish key results in this area. This included further work on the tachocline [1], and studies of the variations of rotation in the outer envelope over time [7]. These variations were revealed to carry signatures of the Sun's activity cycle and have provided important observational constraints for those working to model the internal evolution of the Sun's global magnetic field, which has far-reaching implications for understanding the influence the Sun has on the Earth (what we now call "space weather").

In 2003, it was fitting that Michael was approached to lead a review in the prestigious Annual Reviews of Astronomy and Astrophysics on the then state-of-play of knowledge on the internal rotation and dyanamics of the Sun [6].

Whilst researches in rotation were a common theme throughout his career, it is important to recognise Michael's contributions across a range of different areas of solar and stellar physics. There was work on the physics of the solar interior. Important examples included: the impact of introducing diffusion and settling into stellar evolutionary models of the Sun, which brought the models into better agreement with observations from helioseismology; and constraining overshooting at the base of the convective envelope from subtle differences in the frequencies that

carry signatures of the change in stratification at the base of the convective envelope. Michael performed important calculations on the internal structure and physics of the Sun, and on evaluating different ways of performing local helioseismology (which carries many similarities with terrestrial seismic studies). Later in his research career, Michael also worked on transferring helioseismic techniques to other Sun-like stars, notably using data from the NASA *Kepler* Mission, where the reduced quantity and quality of data present additional challenges.

In 2001 Michael moved to Imperial College, London, to take up a professorial Chair. Michael's professional interests went much wider than physics and astronomy, and in 2004 he moved to the University of Sheffield to take on his first major administrative role. There, he led the successful creation of a new School of Mathematics and Statistics.

Throughout this period Michael maintained strong links with HAO, including regular research trips, and in 2003 he became a National Center for Atmospheric Research (NCAR) affiliate scientist at HAO. In 2010 those links became more permanent when Michael moved with his wife Kate to Boulder to become the Director of HAO and Associate Director of NCAR. In 2013, he was named Deputy Director and Chief Operating Officer of NCAR and interim Director for thirteen months in 2015/16.

Very recently Michael had been in the process of becoming research active once more, and was leading an international project to provide timely updates on the Sun's internal rotation. That work will be completed, under the supervision of friend and colleague Jørgen Christensen-Dalsgaard. The results will serve as a fine testament to Michael's research legacy.

Michael will be much missed by all who knew him.

**Acknowledgments** The author expresses his thanks to Robin Thompson, Jørgen Christensen-Dalsgaard, Steve Tobias, and Rachel Howe, and to the organizing committee of the conference for the opportunity to share memories of Michael's notable achievements.

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# Michael Thompson in Sheffield

**Rekha Jain**

**Abstract** Michael Thompson gave huge contributions to the field of Helioseismology and inspired many young researchers in the discipline with his insight and new ideas. He spent six years in Sheffield after being appointed as the Head of Applied Mathematics Department in the University of Sheffield (UK) where colleagues hold fond memories of him, both as a committed academic and a very effective leader. His hard work and sincere approach was infectious to all those who worked around him. This tribute is an opportunity to share a little part of his work and life during his time in Sheffield.

## 1 As a Head

Michael Thompson was appointed as the Head of Department of Applied Mathematics in 2004 at the University of Sheffield. Over the next four years, he led the change from three separate Departments, Applied Maths, Pure Maths and Probability and Statistics each with very different cultures into the single School of Mathematics and Statistics (SoMaS) becoming its first head in 2008. The event marking the launch of SoMaS was organized on May 21, 2008 where distinguished external speakers from other Universities, Michael Atiyah (Edinburgh), Douglas Gough (Cambridge), Jon Keating (Bristol) and Terry Lyons (Oxford), were invited to present their life-long academic work in their respective field. Figure 1 shows Mike Thompson introducing the meeting on the Launch day of SoMaS on what one imagines as one of the busiest and happiest days for Mike. Figure 2 shows him enjoying the occasion with the dignitaries.

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**Fig. 1** Michael Thompson: presenting the vision for SoMaS on May 21, 2008. Source: http://www.maths.dept.shef.ac.uk

## 2 Opportunity for All

As the Head of School of Mathematics and Statistics (2008–2010), Mike believed in participation and progress done through forming various official committees and groups. Colleagues felt Mike was a very patient listener, always providing staff members with the opportunity to speak up.

He supported staff in acquiring various skills encouraging their training through various workshops in and outside Universities. On his recommendation, I also attended one such session run by the University and gained huge benefit from it. He was particularly keen to involve staff members in the decision-making process and train the young upcoming staff for Leadership roles. One of my colleagues Professor E. Winstanley had this to say about Mike:

**Fig. 2** Michael Thompson with Fields medallist and Abel prize winner Sir Michael Atiyah, then President and Vice-Chancellor of UoS Prof. Sir Keith Burnett CBE, FRS, FLSW, on May 21, 2008; source: http://www.maths.dept.shef.ac.uk

> He was always extremely kind, supportive and encouraging to me as a younger colleague when he was Head. I am very grateful for his support and encouragement, and also for the opportunities he gave me to be involved in decision-making within the department and school, which was invaluable experience. Mike set an example in leadership which one should strive to emulate!

## 3 Good Citizenship

One of the greatest aspects of Mike's leadership was his belief for staff to be engaged with SoMaS and not just hide in their offices doing their own teaching and research. Mike was himself a good citizen and expected everyone to be so. My colleague, Prof. D Applebaum from Probability and Statistics mentioned to me that

> he has never forgotten this thinking of Mike's. Mike valued being a good citizen so much that when we were considering promotion of academic staff, he would always ask "is he/she a good citizen?" meaning does he/she do their bit for the school.

## 4 A Committed Academic

As is well known, Mike was a dedicated researcher and was remarkably driven; his contribution to the field of Helioseismology will always be recognized around the world. Mike gave great credit to his PhD students, postdocs, collaborators and research visitors with whom he had scientific discussions on a daily basis. As reseachers and academics ourselves, we all know that to be able to work so

efficiently and fruitfully with folks of different personalities and abilities requires a very special skillset, one that Mike certainly had!

Although as the Head of SoMaS, he had many important and time-consuming administrative tasks, he was a teacher at heart. He took his fair share of teaching duties and taught large undergraduate classes. He somehow found time to meet his tutees several times during the semester to check their progress and to sort out their problems, and took support for his PhD students very seriously. It demonstrated to staff around him that he indeed practiced what he preached. His seminal work on Helio and Astero-seismology is discussed by many in this proceedings so I will not repeat those but I will briefly mention some of the work that he involved me in during the supervision of his PhD student Kara Burke at the University of Sheffield.

His expertise in analytical method was obvious to me when I saw the process of his supervision to Kara Burke who submitted her PhD thesis in 2011 to the University of Sheffield. The thesis work was about the investigation of the Effects of Rotation on the Frequencies of Stellar Oscillations by treating rotation as a perturbation to the non-rotating star. They derived the rotational splitting coefficients, correct to second order in rotational velocity and added to the non-rotating frequencies (see Burke [1]).

$$\omega_{nlm} = \omega_0 + \omega_1 + (2I\omega_0)^{-1} \langle\, \xi_0^* \cdot \left(\mathcal{N}_0 - \mathcal{L}_\Omega - \rho_\Omega P_2 \omega_0^2\right) \xi_0 \,\rangle$$
$$- \frac{\omega_1^2}{2\omega_0} - \frac{\omega_1}{I} \langle\, \rho_0 \xi_0^* \cdot \mathcal{M}_0 \xi_1 \,\rangle + \frac{1}{2I\omega_0} \omega_1 \langle\, \rho_0 \xi_0^* \cdot \mathcal{M}_0 \xi_0 \,\rangle \qquad (1)$$

Here, the subscripts '0' and '1' denote the equilibrium and perturbed quantities respectively. $\xi$ is the displacement (eigenfunction) with $^*$ denoting the complex conjugate. $\omega_0$ is the frequency of the non-rotating case, $\omega_1$ is the correction due to the first order perturbation theory and $\rho_0$ is the equilibrium density. $I$ is an integral involving the spherical harmonic and $P_2$ is a Legendre function. $\mathcal{M}_0 \xi_{0,1}$ contains all the first order rotation terms. Similarly, $\mathcal{L}_\Omega$ denote the remaining perturbed terms in the linearized momentum equation. The new terms arising due to second order rotation effects are contained in $\mathcal{N}_0$ and are quadratic in velocity $u_0$. The subscript $\Omega$ denotes the perturbed quantity due to rotation.

The corresponding perturbations to the eigenfunctions were also calculated. These were then implemented in the EVOLPACK stellar evolution and adiabatic pulsations package and splitting coefficients of various models calculated. The splitting coefficients were found to converge with increasing radial order for solar-like models, regardless of the mass or evolutionary stage of the star. They also concluded that a comparison of eigenfrequencies correct to first and second order in $\Omega$ revealed that for first order frequencies the splitting is uniform with the multiplet evenly spaced with the $m = 0$ mode in the middle and that the spacing between the modes increases with rotation rate. The second-order frequencies are evenly spaced at low rotation rates where the first order rotation effects are dominant, however as rotation rate increases the effect of centrifugal distortion causes the shape of the star to change from spherical to that of an oblate spheroid. By comparing the observations

of other stars it was concluded that without rotation it is more difficult to constrain the models.

Another project where he showed his interest in bold application to Helioseismology was through numerical simulations. We jointly worked with Pedro A. González-Morales who tested the suitability of FLASH code for simulating subphotospheric wave motions in helioseismology (see, Gonzalez-Morales et al. [2]). In order to check the capability of this code for different sources of waves, Pedro implemented a non-magnetic plane-parallel atmosphere with the energy source as suggested by Rast [3]. The plan was to analyse the numerically generated data using the same methods as used in local helioseismology. However Mike's move to Boulder during the project made it difficult to be completed.

A good researcher also has ability to work with observational data and Mike's knowledge on observations and his ability to formulate a mathematical problem using them was quite unique. He obviously was an excellent mathematician and so solving the resulting equations and interpreting the solutions in the context of these observations made him a successful allrounder Helioseismologist.

He was very much respected and admired by his postdocs as well. When I asked Sergei Zharkov for his memory of Mike, this is what he had to say about Mike

> Mike was a uniquely successful solar physicist and mathematician, an English gentleman of highest personal integrity and a great sense of humour, somebody who believed in Science above individual interest, somebody you can trust. The last time we met was at NAM held at Hull a couple of years ago—he invited me to a dinner with his wife, it was amazing that even with his outstanding career and success he would find time for very personal approach, listening and offering advice and support. I suspect, he was a great family man—he was close with his wife and he talked a lot about his son and was so proud of his son's achievements.

## 5 A Musical Talent and His Love of Carols

Mike was a great admirer of classical music and he himself was a good pianist. He would play the piano and sing Christmas carols in the annual Christmas celebration of the Applied Maths Department, as we see in Fig. 3 pictured by his postdoc. Daniel Rees.

In addition to this, Mike was also the pianist for the New Year's Day sing in their home village of Grindleford near Sheffield. My colleague Dr Frazer Jarvis, another caroller who took over as pianist on Mike's recommendation after he left Sheffield, has prepared a DVD featuring Mike singing in a number of the carols. Figure 4 shows the back cover of the DVD that was presented to Kate and Robin. Here is an excerpt from the commentary Frazer provided for the DVD:

During his time in Sheffield, Mike was a regular at "Sheffield Carol" events, generally taking place in pubs where the repertoire was singing carols local to the area, and often joined by Kate and Robin.

**Fig. 3** Michael Thompson playing keyboard at a Christmas party. Source: Daniel Rees


**Fig. 4** Back cover of the DVD containing Mike's Carols

Some of the video recordings of Mike:

1. BBC The Truth About Christmas Carols (2009)
   A segment from the Blue Ball pub in Worrall, with both Mike and Kate.
2. BBC Songs of Praise (2010)
   Another segment from the Blue Ball, this time broadcast as part of another BBC programme.

3 and 4. Festival of Village Carols 2008
   Every two years since 1994, a festival has taken place in Sheffield to celebrate the tradition of the pub carols. Mike first attended in 2008—here are the carols "Tinwood" and "Egypt" from that year. After Mike left for Boulder in 2010, he returned to Sheffield to sing in the festival in 2012, 2014 and 2016.

5. Grenoside: at The Old Red Lion "Top Red" (2014)
   A pub sing just before the 2014 Festival, with Robin joining Mike, singing "Hark, Hark".
6. Mike's last festival in 2016 with Robin
   Here are Mike and Robin in part of "Jesu lover of my soul".
7. 2013 Foolow village tour
   Most carol sings take place in pubs, but there is a small village a little west of Sheffield called Foolow, a village with only about 60 houses, but with the largest collection of unique carols in the UK. Every Christmas evening, there is a village tour, where the singers visit a number of houses, and sing the Foolow carols to the local villagers. Mike, Kate and Robin joined this tradition on a number of occasions during Mike's time in Sheffield. This short clip is from 2013, when they were in the USA, but it gives some idea!

8 and 9. 2014 Festival with Foolow
   Mike had a ticket for the 2018 festival also, but died before it took place. Robin was able to come, and tributes were paid to Mike at the festival. These clips are from the 2014 Festival, where Mike and Robin appeared as part of the Foolow group. You will see Robin–Mike is beside him, but obscured by someone in front. The carols are "Once More" and "Farewell", the latter being sung at the end of every house visit in Foolow on Christmas evening.

10. Mike's last festival in 2016 with Robin
    The carol "Merry Christmas".

In short, Mike created a flourishing and more efficient unit in SoMaS. The ex-head of Applied Maths department, Prof. Lucy Wyatt summed Mike's tenure as:

> It was not without difficulties. Like most University Departments we have our big egos and feifdoms and Mike had to cope with those sometimes successfully, sometimes not so well. No doubt he was glad to leave those battles behind when he went to the USA in 2010 and recently, managing to find a bit more time for research before his untimely death in 2018.

Even after Mike left, his legacy is felt across SoMaS and we reflect upon the great loss our School, Sheffield and the Solar physics community of the world has suffered.

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# Michael J. Thompson: A Remarkable Scientist, Leader, and Friend


**J. W. Hurrell**

The international research community lost a shining star on October 15, 2018. It was on that day that many were shocked and deeply saddened by the news that Michael J. Thompson passed away unexpectedly. Michael was an outstanding solar physicist, known for his exceptional accomplishments in advancing the understanding of the structure and dynamics of the solar interior. Michael was an internationally recognized leader in the field of helioseismology, in large part for his pioneering efforts in developing inversion techniques and applying them to modern data to advance understanding of the physics of the Sun. His many noteworthy achievements as a research scientist were celebrated in September 2019 with the workshop that these proceedings document. Dynamics of the Sun & Stars: Honoring the Life & Work of Michael Thompson was a wonderful gathering of Michael's family, friends and colleagues to discuss the science that was his passion and to commemorate his many professional achievements.

Michael had a wide-ranging influence on essentially all aspects of helioseismology. A hallmark of his research was its extremely high quality, which he always presented with great clarity. His colleagues knew that they could safely rely on his results. Arguably, his best-known and most important contribution was in measuring the rotation profile throughout most of the solar interior. In order to achieve a high level of confidence in his results, Michael devoted considerable attention to developing a framework for understanding and reconciling the properties of different helioseismic inversion techniques. Other contributions in this volume document his scientific achievements in detail. Michael achieved eminence in his field. His intellectual reach was exceptional.

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