Guest Comment

Ronald Gordon Giovanelli died on 27 January 1984 following a long and debilitating illness which he fought with great courage and determination. It was these qualities allied with the keenest physical insight that made him one of the outstanding solar physicists of the post-war era.

Throughout his long career at CSIRO he championed astrophysical research, particularly solar optical research, in Australia. He left his mark in every field of solar physics and his personal influence was felt everywhere that a critical and challenging approach to basic problems was appreciated.

As a tribute to his achievements, his many friends contributed to colloquia held at the two places which were the focus of his life and work in recent years. The first took place in Sydney on 26–29 November 1984 and was devoted to a review of past progress in solar and stellar atmospheric physics, to which Giovanelli had contributed, and to future developments, which he had actively fostered up until his death. The second was in Tucson on 17–18 January 1985 and took as its theme current controversies in solar magnetic fields. Giovanelli had poured his boundless energy into this topic over the last decade, a decade which has seen a revolution in our appreciation of the significance and structure of magnetic fields throughout the Sun.

Ron Giovanelli's own work on solar magnetic fields culminated in a radical rethinking of the workings of the solar cycle, the processes underlying the presence of magnetic fields in the Sun. Here he drew together many aspects of his profound knowledge of both observation and theory. He was preparing this work for publication at the time of his death and it is highly fitting that these two final papers should be included in this commemorative volume (see pp. 1045 and 1067). They exemplify his characteristically novel and physically intuitive approach to complex problems, but have not had the benefit of critical revision in the light of the referees' scrutiny. However, it is their common judgement that the ideas represent a challenging legacy to the scientific community and the papers are published here essentially as he left them.

It is not the purpose here to present an appreciation of Ron Giovanelli's work—that is to be found in the following pages. Nevertheless, the picture drawn from the recollections of Jacques Beckers (p. 769) and Bill Livingston (p. 775) would be incomplete without reference to Giovanelli's contribution to the theory of radiative transfer. John Jefferies found time from his onerous duties to recall this work at the Sydney meeting and the following account is drawn from his notes.

Ron Giovanelli was one of the pioneers who confronted the difficulties of treating correctly the formation of spectral lines in the outer layers of the Sun. The computational simplicity and adequacy of the assumption in the lower atmospheric layers had led to the universal adoption of local thermal equilibrium. However, in 1948, Giovanelli demonstrated that, under the conditions postulated in the solar chromosphere, the lowest ten atomic levels of hydrogen could not be expected to be populated as in local thermal equilibrium. He then progressed in 1949 from a simplified treatment of the excitation balance, assuming the region to be optically thin, to a fully self-consistent study in which the radiation transfer in the lines and

Lyman continuum was taken into account. An improved formulation was produced jointly with Jefferies in 1954 and led to a realistic prediction of the strength of the chromospheric Hα line. This work laid the basis for the interpretation of a vast amount of material utilizing Hα filter observations of the chromosphere.

This work was subsequently greatly extended, mainly under the influence of another pioneer, Dick Thomas, whilst Giovanelli turned to another of his lifelong preoccupations—the influence on light of non-uniformities in media. Characteristically, he concluded his 1949 paper on the hydrogen spectrum by attempting to assess the effect of the chromospheric fine structure. But he recognized that the treatment of radiative transfer was important to a wide range of problems, from the prediction of the colours of paints to inferring the properties of giant molecular clouds. His starting point was the general problem of reflection from diffusing or scattering materials. In 1955 he tackled the calculation of the diffuse reflectivity of a semi-infinite material with a discontinuous change in refractive index at the surface. To make progress on such a general problem in an age of mechanical computing, it was necessary to introduce approximate methods and these he found in the Eddington approximation, which underlay all his work and whose accuracy was fully adequate for the applications envisaged. Subsequent papers in 1956 generalized the study to the case where the incident radiation was not of uniform intensity across the surface. He and Jefferies also took up the problem of transfer in diffusers with non-uniform structure, investigating composite media of simple geometrical shape illuminated by, or containing, non-uniformly distributed sources.

Giovanelli returned to this problem in 1957 and 1959. Using now his three-dimensional generalization of the Eddington approximation, he evaluated the effects of small periodic fluctuations in the absorption, scattering and source parameters of a gaseous medium. He then drew attention to the fact that the theory predicted a critical size, in the sense that physical parameter fluctuations of smaller scale would be confused by structural effects in the emergent radiation. Other solar physicists are still coming to grips with multi-dimensional transfer.

In John Jefferies' words: 'Ron's contributions were not in the field of mathematical techniques although he could handle those with the best of them. What he brought to the problem and what delighted and inspired his students was his ineffable sense for physics, his overwhelmingly fertile mind, and his driving need to understand at the basic level the natural world, especially and above all the Sun, whose secrets he spent a lifetime unfolding to the delight and edification of us all.'

It remains only for me to record our thanks to the organizers of the two meetings, Peter Wilson and Bill Livingston, for their dedicated efforts. But the meetings were dominated by Ron Giovanelli. He was an intangible presence—not only during a screening of a videotape in which he spoke about magnetic reconnection, yet another subject that he influenced decisively, but throughout the presentations and discussions. These topics had been enlivened by him for so many years; he was sadly missed.

C. J. Durrant
University of Sydney
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Contributions by R. G. Giovanelli to Solar Instrumentation*

Jacques M. Beckers

Advanced Development Program,
National Optical Astronomy Observatories,
Tucson, AZ 85726, U.S.A.

Abstract

R. G. Giovanelli and his co-workers at CSIRO have contributed in a major way to the renewal in solar instrumentation which has occurred since the nineteen fifties. I review here some of their contributions.

1. Introduction

As Chief of the CSIRO Division of Physics, from 1958 to 1974, R. G. Giovanelli directed a significant part of the effort of the Division towards the advancement of solar instrumentation. Since the study of an astronomical object such as the Sun requires the very best of spectroscopic instrumentation, that meant a program of state-of-the-art, innovative optical instrumentation. Many in the Division collaborated in these efforts and share therefore with Giovanelli the credit for the very productive output of the Division. These included scientists such as R. Bhavilai, R. Bray, C. Coulman, D. Hall, J. Jefferies, R. Loughhead, M. McCabe, J. Ramsay, R. Smartt, J. Winter and W. Steel, as well as many on the engineering and technical staff such as R. Abel, H. Gillett, H. Kobler, E. Mugridge, G. Norton, E. Tappere and J. deVries. I was also privileged to be a research fellow with the Division from 1959 to 1962 during which I became familiar with the exciting frontiers in optical instrumentation.

The present paper summarizes the work of Ron Giovanelli and his staff in astronomical instrumentation. It does not include his work in optics which preceded his astronomical interest. This earlier work at the National Standards Laboratory centred around photometry and the observational and radiation transfer aspects of diffusing media. The paper is divided into sections dealing with narrow band tunable Lyot filters (Section 2), narrow band tunable Fabry–Pérot etalons (Section 3), telescopes (Section 4) and solar eclipses (Section 5).

2. Narrow Band Tunable Lyot Filters

The construction of a 1/8 Å widely tunable (± 8 Å) Lyot filter for the Hα line was without doubt the largest step forward in the development of Lyot filters since

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their invention (Lyot 1944). Fig. 1 shows the optical layout of this filter, as published by Steel *et al.* (1961). This filter included state-of-the-art technology in Lyot filter design and construction, incorporating the split element concept invented by Evans (1949) and the tunability by element rotation invented by Lyot. The advance in the 1/8 Å filter came as a result of a bandwidth four to eight times narrower than any existing filter and in the degree of tunability (±8 Å), which required the rotation of as many as seven elements at the expense of substantial mechanical complexity. The narrow bandwidth was needed to allow a detailed study of the hydrogen Hα line, which itself has a width of about 1 Å. Tuning of the filter through the Hα line resulted in a scanning through the solar atmosphere over a height of 3000–5000 km, as well as in the imaging of small scale structure within the solar atmosphere with different Doppler shifts.

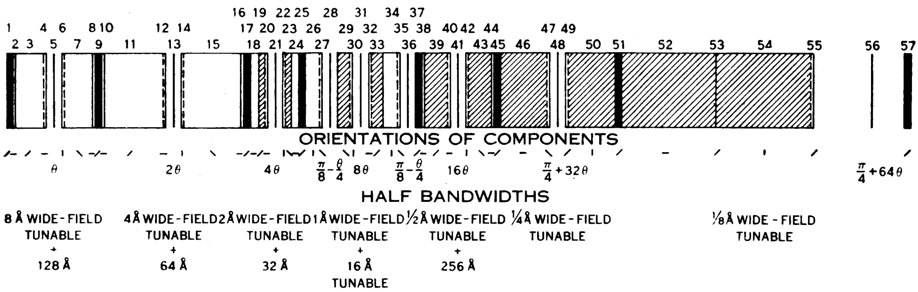

Fig. 1. Optical design of the 1/8 Å filter, showing a scale drawing of the layout of the various optical components. For ready identification, calcite components are hatched and polarizers are in black; half- and quarter-wave plates are shown schematically, and windows before component 1 and after component 55 are omitted. [From Steel *et al.* (1961).]

No previous attempts had been made to construct Lyot filter elements as narrow as 1/8 Å. Optical elements were required which were made out of calcite of thicknesses close to 9 cm. One of the hurdles to overcome in making these elements was to compensate for birefringence inhomogeneities inside natural calcite crystals by local figuring of the surfaces of the calcite elements (see Figs 3 and 5 in Steel *et al.* 1961) and by adding non-birefringent elements to compensate for the optical aberrations introduced by the locally figured calcite elements. The tolerancing of the filter elements was done with the help of Jefferies in the early 1950s (Giovanelli and Jefferies 1954).

I was given the opportunity to apply the filter for the first time to solar observations. This included the integration of the filter with one of the Fleurs 5-inch solar telescopes and the commissioning of the telescope/filter system, carried out with the invaluable assistance of Graham Norton. Solar observations resulted which formed the basis of both my thesis (Beckers 1963, 1964) and that by Bhavilai (1965). At that time, the tuning of the filter was done manually, and then later motorized and moved to computer control (Bray and Winter 1970).

3. Narrow Band Tunable Fabry–Pérot Etalons

With the completion of the 1/8 Å birefringent filter for Hα, Giovanelli's attention turned to filters which could be tuned over a much wider wavelength region (e.g.

the entire visible spectrum) and which have a narrower bandwidth. I shared similar interests and developed eventually, with C. Zeiss in West Germany, the so-called universal birefringent filter (Beckers *et al.* 1975), which in many respects was an extension of 1/8 Å filter technology. Ramsay and Giovanelli (Ramsay *et al.* 1971) decided to pursue an entirely different route using three air-spaced Fabry–Pérot etalons in tandem.

Each of the Fabry–Pérots was tunable over at least one order. Their parallelism was controlled by means of a servo-loop which used white light optical metering at the edge of the etalons. The transmission bands of the etalons themselves were spectrally coaligned by means of another servo-loop utilizing mechanically parallel small Fabry–Pérot etalons. The tandem arrangement of three etalons is required to provide both for a narrow bandpass and for a large separation of adjacent major transmission maxima.

Fabry–Pérot etalons have two major advantages over Lyot filters, as well as two major disadvantages. On the one hand they have a linear aperture larger by a factor of 2–4 and a higher transmission (by a factor of ~ 3). Lyot filters, however, have a larger angular aperture (by a factor of 3–4) and a better sideband rejection. Because of this combination of advantages and disadvantages, the relative merits of Fabry–Pérot and Lyot filters is still a highly debatable issue.

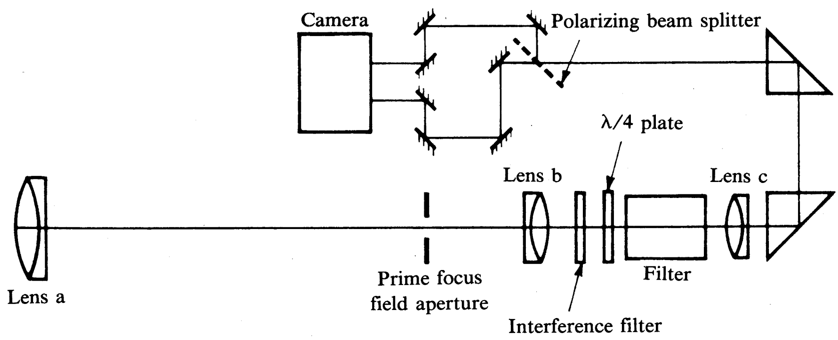

Fig. 2. Schematic diagram of the Culgoora magnetograph. [From Ramsay *et al.* (1971).]

Giovanelli wanted to use the Fabry–Pérot filter primarily for a solar magnetograph. At first he tried to incorporate a thin plate of mica in the Fabry–Pérot cavity giving the filter two transmission bands separated by a range of wavelength which depended on the retardation of the mica plate. This would have allowed observation of solar images composed of a combination of left-handed circularly polarized light in the blue wing of a line with right-handed polarization in the red wing. By electro–optical means, this image could then be switched to opposite circular polarizations in the two line wings. Any change in intensity would result from magnetic fields. This attempt failed, however, because of a decreasing sensitivity resulting from the mica plate. Eventually the magnetograph took the form shown schematically in Fig. 2 in which left- and right-handed circularly polarized images were simultaneously recorded at one wavelength (in the blue or red wing) only.

Recently this Fabry–Pérot filter has been rebuilt to allow fully automated tuning over almost the entire visible spectrum by rotating the small reference interferometer attached to each main interferometer (Winter 1984). A tunable dye laser is used for laboratory calibration.

4. Solar Telescopes

Giovanelli was among the first to realize the importance of removing building and other environmentally generated effects from optical telescopes. The Fleurs photoheliograph and 1/8 Å filter telescopes were therefore placed in the open with the protective building completely removable during daylight observations. The telescope itself was shadowed by a sunlight shield kept at ambient temperatures by drawing air through its perforated front end. The photospheric and chromospheric images were as a result frequently limited in resolution only by diffraction on the edges of the 5-inch telescopes.

The second generation of solar telescopes developed by the CSIRO Division of Applied Physics (now 8 and 12 inches in aperture) were placed on top of towers at Culgoora. Tower and telescope building design again took into account possible deteriorating seeing effects by the local environment. The Culgoora protective shielding therefore completely folded out of the way during solar observations.

5. Solar Eclipses

Unlike some solar astronomers, Ron Giovanelli could not be called an 'eclipse hunter'. Rather than 'collecting' solar eclipses Giovanelli only carried out an expedition when an eclipse was required to carry out a specific scientific investigation. I had the pleasure of collaborating with him in one such experiment at the 1974 eclipse in Western Australia. In a combination of three experiments, we were to measure the electron density N_e, electron temperature T_e and proton temperature T_p at many points in the solar corona. Two rockets launched north of Perth were to record the coronal Lyman-α line profile to give T_p. A white light coronograph on the S.W. coast at Point D'Entrecasteaux was to record the white light coronal image, yielding N_e, and the Giovanelli experiment at Walpole was to record T_e by means of the width of the very much thermally broadened H and K lines in the K corona. Unfortunately, this experiment joined the ill fate of many other eclipse expeditions because of bad weather and rocket failure.

6. Conclusions

This short overview of Giovanelli's contributions to solar instrumentation is undoubtedly very much coloured by my own experiences while working with him. Not all instrumental efforts were published, especially since not all of them were always successful. My overview is therefore highly biased towards the years during which I worked with Giovanelli (1959–62, and during the 1974 eclipse) and towards his published record. Giovanelli was an innovator not only when it came to instrumentation, but also in the theoretical treatment of radiation transfer and in the methodology of interpreting solar observations. I owe him much of my training in solar research, especially in the area of advanced solar instrumentation.

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