

THAT WAS THEN, THIS IS NOW; ON TO THE FUTURE!

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Abstract: In this short paper I reflect on the progress of solar physics over the past 50 years, and identify five major issues that still plague us.

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1 FIFTY YEARS AGO

Fifty years ago, J.T. Jefferies, F.Q. Orrall and I recorded the visible spectrum of the corona and chromosphere during the total solar eclipse of 7 March 1970, and we presented two papers on this research at the AAS Conference in 1971 (Jefferies, Orrall and Zirker, 1971a, 1971b). The abstracts for these two papers are shown below in Figure 1.

2 MAJOR ADVANCES OF THE PAST FIFTY YEARS

In the following 50 years, major advances in spectroscopy were made from space, using narrow band filters in the EUV and XUV. Thus, for example, four simultaneous EUV images were obtained from the SOHO satellite (171 Å Fe IX, 195 Å Fe XII, 284 Å Fe XV and 304 Å He I) each corresponding to different EUV temperatures, probing the chromospheric network to the lower corona. Similarly, observations of magnetic structures with the Hinode satellite have clarified their behavior. At the time, these were considered very useful basic building blocks for tackling the longstanding problems in solar physics.

Using this, we have been able to set a firm lower limit to the chemical abundances and to find a somewhat less firm determination of the abundances themselves.

The Spectrum of the Chromosphere and Corona from $\lambda 3000$ to $\lambda 7000$ on March 7, 1970. J. T. JEFFERIES, F. Q. ORRALL, and J. B. ZIRKER, *University of Hawaii*. – During the total Solar Eclipse of March 7, 1970, we obtained spectra of the inner corona simultaneously at all position angles around the limb from $\lambda 3000$ to $\lambda 7000$. We were in all respects fortunate since conditions at the site in Nejapa, Mexico were ideal and the spectra are well exposed, focused and standardized. Fifteen spectra were made at different exposure times to record the corona, prominences and chromosphere. The linear dispersion was 36 Å/mm and 18 Å/mm in the first and second orders, and the solar image size was 1 cm. The f/4.8 spectrograph is the same one that we used in 1965 and 1966 and has been described by Dunn (1966, *Trans. Inst. Soc. America* 5, No. 2).

No strong coronal condensation was present on the limb at eclipse time, although the yellow line [$\lambda 5694$ Ca XV] was observed over a wide region on the west limb. Twenty-five emission lines are present on the spectrograms, particularly in the violet.

But that was then, and this is now. Although I am no longer active as a solar physicist, I still take a great interest seeing the slow but steady progress being made. Nonetheless, many of the same problems that I tried to tackle over the last 50 years still remain to be solved. I have always been frustrated by the lack of detailed data from the Sun's magnetic fields, making any theories I studied to be speculations based on 'fuzzy' data. For instance, do nanoflares exist?

3 FUTURE DIRECTIONS

In particular, five major issues still plague us. We anticipate that these physical problems are tightly coupled, making them even more difficult to resolve:

(1) How does the Sun's dynamo generate and emit energy from the radiative zone, through the chaotic tachocline layer, and into the churning convective zone? Modeling the dynamo, particularly the dynamics of the tachocline, where magnetic field is twisted, has become feasible. One can ask whether the tachocline is the primary site of twisting? What role does the convection zone play?

Coronal Models and Coronal Chemical Abundances. J. T. JEFFERIES, F. Q. ORRALL, J. B. ZIRKER, *University of Hawaii*. – Consistent intensity measurements have now been made of the continuum and numerous forbidden emission lines in the inner solar corona at four total eclipses (1952, 1965, 1966, 1970). Calculations are available for the state of ionization under coronal conditions for a number of chemical elements (Jordan, C., 1969 *Monthly Notices, R.A.S.* 142, 501) that take account of dielectronic recombination, and a rather complete determination has been made of the state of excitation of these ions (Zirker, J. B., 1970 *Solar Phys.* 11, 68). These factors make possible a new analysis of the physical state of the inner corona which, in turn, can lead to improved determination of the coronal chemical abundances.

One of the most promising methods of analysis of coronal intensity data has been to study coronal structures that appear to have some special simple geometry or symmetry, but a full application of this method requires higher spatial resolution than has yet been obtained. Lacking this, self-consistent models have been constructed in which one assumes several different components in the line of sight, each at a different temperature and density. Since this is somewhat arbitrary we have, for the moment, abandoned these geometrical approaches and have found it possible to determine a non-geometrical temperature distribution.

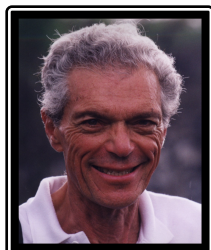
Figure 1: Jack Zirker's abstracts from the first SPD, joint with John Jefferies and Frank Orrall.

- (2) How are magnetic fields modified by twisting, looping, shearing, and reconnecting as they erupt toward the surface?
- (3) How is the corona heated to millions of degrees? Do nanoflares really exist and play a role in heating the corona? How do the magnetic field and currents carry the energy from the surface into the corona? What role do currents play?
- (4) How is the eleven-year solar activity cycle generated? Why eleven years? Why are there periodic maxima from cycle to cycle?
- (5) How are different types of solar holes generated?

We look forward to fresh data from the Parker Solar Probe and from the European Solar Observatory. The Parker Solar Probe will be close enough to record the structure and dynamics of the coronal plasma and magnetic fields. Maybe it will be able to answer my questions about nanoflares. Maybe it will be able to provide enough insight into the turbulent energy flows that heat the corona and create the solar wind. Maybe it will even provide the data that allow future solar physicists to understand the 11-year solar cycle. On to the Future!

4 REFERENCES

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Dr Jack B. Zirker was born in 1927, and served in the U.S. Army from 1945 to 1947. He then studied Biomedical Engineering at City College of New York, and completed an MSc at New York University in 1953. The following year he went to Sacramento Peak as a summer student, and 1956 received a PhD from Harvard University for a thesis on the temperature structure of the chromosphere and corona. He then worked at Sacramento Peak Observatory from 1956 to 1964, before moving to a Chair in Astronomy at the University of Hawaii. In 1976 Jack returned to Sunspot as Director of Sacramento Peak Observatory and in the early 1980s played a key role in the formation of the National Solar Observatory, where he was the Director until his retirement.

Jack's research interests included mechanisms of coronal heating, the physics of prominences and their fine structure, flare mechanisms and energy distribution, and the use of non-redundant arrays for high-resolution imaging. Over the years he published more than one hundred research papers, and the following books: *Total Eclipses of the Sun* (Princeton University Press, 1984), *Journey From the Center of the Sun* (Princeton University Press, 2002), *Sunquakes: Probing the Interior of the Sun* (Johns Hopkins University Press, 2003), *An Acre of Glass: A History and Forecast of the Telescope* (Johns Hopkins University Press, 2005), *The Magnetic Universe: The Elusive Traces of an Invisible Force* (Johns Hopkins University Press, 2009) and *The Science of Ocean Waves: Ripples, Tsunamis, and Stormy Seas* (Johns Hopkins University Press, 2013).

Jack was retired and aged 93 when he wrote this short paper for the 50th Anniversary celebrations of the AAS's Solar Physics Division.

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