(DRAFT): Historical Records of Australian Science.

W.H Bragg & J.P.V.Madsen: 1905-1911 Collaboration & Correspondence (update to 1981).

Rutherford's nuclear atom 1911.

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Abstract: In November 1981 H.R.A.S published a paper "W.H.Bragg and J.P.V.Madsen: Collaboration and Correspondence, 1905-1911" authored by Professor R.W.Home. Significantly, two further documents relevant to Sir Ernest Rutherford's 1911 theory of the structure of the atom have recently been located comprised of a letter from Madsen to Bragg on 24 July 1910 and a press account of a discourse "The scattering of cathode rays" given by Madsen on 12 January 1911 to the Physics Section of the A.A.A.S, (Australasian Association for the Advancement of Science) not published in the Association handbook, but reported in the Sydney Telegraph and also the Sydney Morning Herald the following day, Friday 13 January 1911. Remarkably John Heilbron (1934-) at Berkeley has been able to comment on this paper and has indicated that the "single most interesting point is an agreement between Madsen's atom, as reported in the Sydney Daily Telegraph in January 1911, and the initial drafts of the nuclear atom, which Rutherford announced the following March."

Introduction.

The recent discovery by digital search of Trove, of Madsen's discourse to the A.A.A.S dealing with the structure of the atom analogous to a solar system with the electrons as comets was given two months prior to Rutherford's first public disclosure of his nuclear atom theory in Manchester on 7 March 1911 to the Literary. & Philosophical Society.(Lit & Phil) The indication of this is that Madsen had independently arrived at a similar model to Rutherford's and one which was quite different to the "plum pudding" model of J.J.Thomson. Many experiments, including Madsen's own, had been performed in recent years to form some picture of the atom.

In the course of preparing this paper it became evident that Madsen's 1909 assumption that his original stream of beta rays was, more or less, homogenous needs to be clarified in the light of the 1927 experiments by Ellis & Wooster at the Cavendish showing that the distribution curve of Beta particles from Radium E ranged up to 1.0 mil volts and was positively skewed to the right such that approximately 20% of the Beta particles have an energy twice that of the mean. This resolved a long outstanding contentious issue proving that the single energy level of the Alpha particles and the continuous Beta particle levels are not the same.

On reading John Heilbron's 1967 paper "The scattering of Alpha & Beta particles & Rutherford's atom" it seems desirable to elucidate the detail which Home refers to in his 1981 paper to better understand Madsen's role in Rutherford's 1911 paper which otherwise seems to be incidental. Heilbron maintains that the single collision Beta data from Madsen's 1909 experiment was crucial to Rutherford's thesis that the same rules of scattering applied to both the Alpha and Beta particles which in turn was the basis of his nuclear theory.

Arising from Madsen's description in the 24 July 1910 letter to Bragg concerning his efforts with the German Light-Quantum, reference is made to subsequent developments on the properties of the electron and Chadwick's discovery of the neutron in 1932, comprised of a proton and electron.

The balanced apparatus technique Madsen used for his 1909 experiment is in parallel with the techniques used by J.J.Thomson in 1897 for his discovery of the electron and J.A.Crowther's 1907 experiment using uranium to investigate Beta ray scattering which Madsen was to further investigate using Radium.

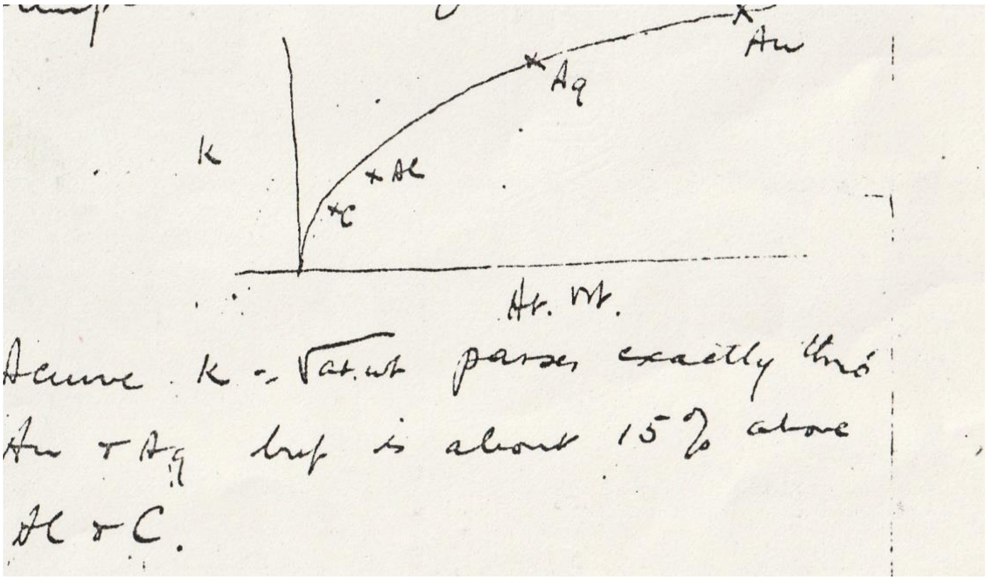
In retrospect Madsen observed that he & Bragg obtained very good results with Radium when in England Radium was thought to have been "all played out"'

Two new documents. It became apparent to Home in writing his paper that not all the letters in the exchange between Bragg & Madsen had been found in England at the Royal Institution (R.I), although the letters from Bragg appear to be complete from Madsen's records. The letters from Madsen to Bragg on 10 July 1909, c. 1 September 1909 & c. 13 January 1911 are missing, however a letter of 24 July 1910 to Bragg has surfaced subsequent to Home's paper. (Appendix XII attached).

The method of compiling scientific bibliographies in Australia does not include the listing of papers read, but not published in a journal and it has only been through a search of digital newspaper records (Trove) that a transcript of Madsen's discourse to the Physics Section of the A.A.A.S in Sydney on 12 January has been found, Madsen himself surprisingly never having kept a copy in his own records. (Appendix XIII attached). This discourse two months prior to Rutherford's public announcement to the Manchester Lit. & Phil. is significant in that Madsen had a definite theory to explain his own and other's experimental results on Beta and Alpha scattering in terms of a structure of the atom as a type of solar system in which electrons behaved like comets, and this model was not at all unlike that of Rutherford at that time.

Heilbron in 2022 notes that: "Rutherford at first could not decide whether the nucleus was positive or negative; here Madsen did not hesitate, although he made the central charge out of several circulating electrons".

An indication of the work that Madsen was doing in January 1911 was his calculation of the number of scattered rays deflected by only small amounts which he said varied for atoms by their atomic weights, over a large range,and was proportional to the product of the atomic weight and its square root for any element. It appears that by November 1911 he found this to be correct for the heavy metals gold and silver, but at a 15% variance for the lighter elements, aluminium and carbon.



Heilbron's 1967 paper. John Heilbron's paper in 1967 (which Madsen unfortunately was not aware of prior to his passing in October 1969) gives a vastly different insight into Rutherford's May 1911 paper with only its single reference to Madsen (which at times is obscured by printer's error or mistaken for "Marsden"). Rutherford states in his paper (p.685): "The experiments of Madsen on scattering of Beta rays, although not made with quite so small a thickness of aluminium as that used by Crowther, certainly support such a conclusion (ie. that single scattering is present). Considering the importance of the point at issue, further experiments on this question are desirable".

Rutherford in his paper quite extensively refers to the work of Crowther on Beta scattering, however Heilbron in his investigations found that the Thomson-Crowther approach at Cambridge was suspect to Rutherford at Manchester, and also to Bragg at Leeds, not only because of the implications of Geiger's work, it also conflicted with results of exceptional importance on the scattering of Beta particles by thin foils, precisely its field of competence, which had been published in Phil. Mag. December 1909 by J.P.V.Madsen.

Madsen's paper seems not to have attracted much attention at the Cavendish, perhaps because its author was a Lecturer in Electrical Engineering at the University of Adelaide. However something that Madsen always bitterly remembered was that in November 1908 the Editor of Nature issued an ultimatum at the end of a letter Madsen wrote to the journal concerning the nature of gamma rays, that the correspondence **must cease** as the subject was deemed to be more suitable to a special journal in physics. Madsen held that Nature was precisely the place his material should be published. In retrospect Madsen may have been able to publish his ideas on the structure of the atom in 1910, rather than just at the A.A.A.S in January 1911.

The ratio of large to small scattering for the thinnest foils was found by Madsen to be practically constant and this data is evident from the following table reconstructed by the author from the published graphs, in the absence of the original experimental notebooks.

J.P.V.Madsen Thin Foils 1909 Beta Scattering.

AL (13)-Aluminium

Density Gm/Cm^3: 2.7 — Atom Diam: 250 pm

Foil	Gm/Cm^2	mm thick	Atoms	Scatter Ratio A/B
1	0.005	0.0185	74074	1.33
2	0.01	0.037	148148	1.3
3	0.018	0.0667	266667	1
4	0.028	0.1037	414815	0.86

Au (79).-Gold

Density Gm/Cm^3: 19.3 — Atom Diam: 280 pm

Foil	Gm/Cm^2	mm thick	Atoms	Scatter Ratio A/B
1	0.003	0.0016	5551	1.111
2	0.007	0.0036	12953	1
3	0.01	0.0052	18505	0.8883
4	0.013	0.0067	24056	0.8451

It is in America, with Heilbron's 1967 paper and the reference by Lawrence Badash in his biography of Rutherford for Princeton University in 1974 that the significance of Madsen's single scattering by Beta rays has become known outside of Australia..

Heilbron understands the key role that Bragg played in his submissions to Rutherford on Madsen's behalf in supporting the reliability and confidence in his work. Heilbron specifically identifies a letter Bragg wrote to Rutherford on 8 February 1911 from Leeds referring to a single encounter of one Beta particle being evident in Madsen's & Schmidt's work. In this letter Bragg describes a model of an atom he showed at an R.I discourse and which he said he could modify to suit Rutherford's preference for a big positive or negative centre, when Rutherford gives his permission.

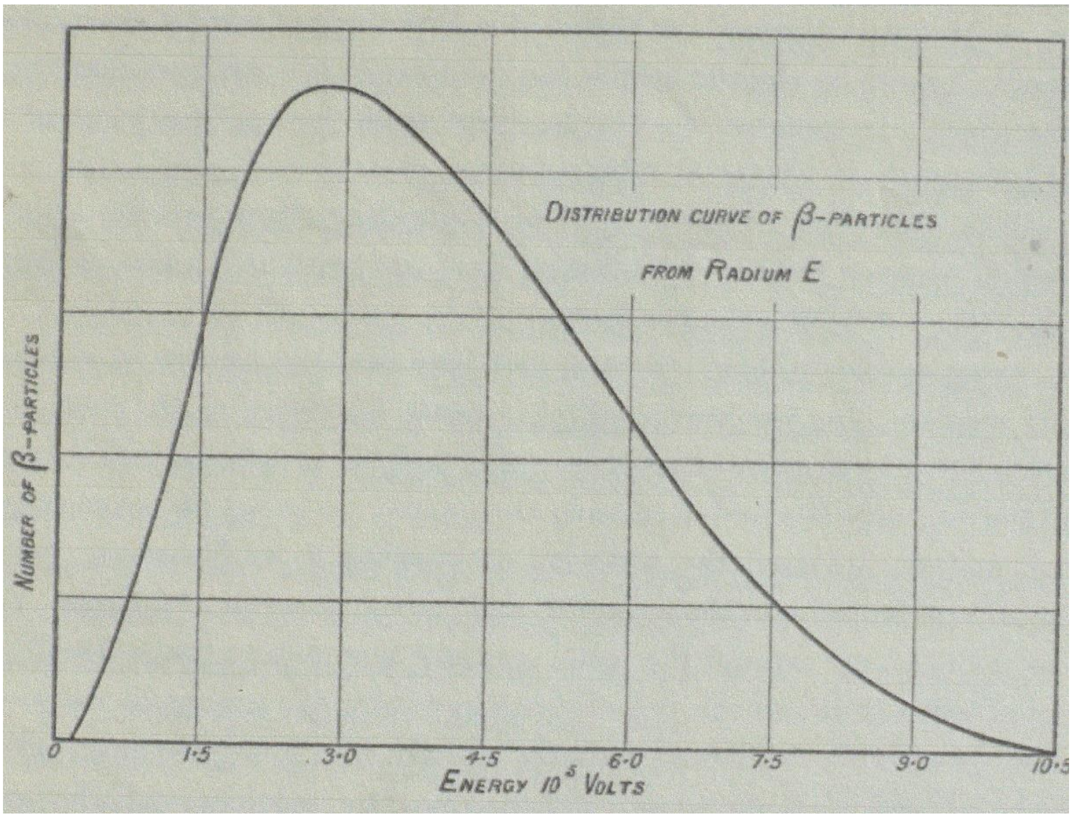
Heilbron identifies from the Bragg-Rutherford correspondence that on 12 February 1911 Bragg responded to Rutherford's request that Bragg should write down his objections to Crowther's paper of 1910 ("on the scattering of homogenous Beta rays and the number of electrons in the atom")- Bragg responded with a grand slam at Crowther and gave a re-affirmation of the theory of single scattering. He stated that Madsen's original experiment on the scattering of Beta rays (Phil.Mag. December 1909) showed quite clearly that the distribution of scattered rays amongst themselves was not at first a function of the thickness of the plate, for these well deflected. I have always held that the meaning of that was they suffered but one deflection that counted and this makes everything much clearer as well as more interesting.

Heilbron maintains that finally in his May 1911 paper, that Rutherford can say little in print about his feelings about Crowther's experiments and points out that two tests fail to discriminate between the theories and that the peculiar bend in the Thomson-Crowther curve conflicts with the extrapolations from Madsen's results. From Heilbron's investigations into Rutherford's letters and discussions when Rutherford first refers to his new theory it appears that from 14 December 1910 & over the ensuing few weeks Rutherford first told B. Boltwood and then Bragg. This of course would not have given time for word to get to Sydney for Madsen's discourse on 12 January 1911.

Balanced Experiments & Disintegration energy of Radium. The design of Madsen's balanced chamber apparatus to achieve great accuracy followed a similar earlier balanced experiment in 1907 by Crowther using Uranium in two identical chambers but one with a shutter to achieve a compensation method of obtaining accurate Beta ray scattering data for thin foils.

The essential feature of J.J. Thomson's 1897 electron experiment was to mathematically equate the electric & magnetic forces applied to the cathode rays such that they are counterbalanced to fluoresce on the centre of a scale on the outside glass.

In Madsen's 1909 paper an important consideration was the original stream of rays being more or less homogeneous and that the current may be taken approximately as a measure of the number of beta particles which enter the chamber. It was known at this time that the energy of Alpha particles & Gamma rays did not vary with their source and a similar situation was thought to apply to Beta particles, but this view remained contentious for many years until 1927 when, at the Cavendish, Ellis & Wooster carried out an investigation under Rutherford's auspices, to resolve the issue. Using two separate methods (ionisation & calorimetry) with Radium E, which was very difficult to obtain, but had the property of only emitting Beta rays, they found a wide distribution of energies ranging up to 1.0 mil volts where 20% of the Beta particles have an energy of approximately twice the mean value (graph from the 1927 Ellis & Wooster paper).



It is not clear what the implications are for Madsen's "uniform bundles" or for his proposal that the scattered Beta rays are proportional to the square root of the atomic weight. (Rutherford in his May 1911 paper states that "Bragg has established for Alpha particles that the stopping power of an atom for an Alpha particle is proportional to the square root of its atomic weight" and perhaps Madsen thought the same or similar would apply to the Beta particles). It is of interest also to consider from Madsen's 1909 paper his remarkable observation that the maximum value of curve C (the rays moving directly forward) is very nearly the same for all substances tested. For Aluminium & Gold the maximum value is at the same thickness of 0.01 gm/cm^2 & may represent all the high energy rays passing through the foils.

Light quantum & subsequent electron developments. In Madsen's letter to Bragg on 24 July 1910 he states: "I tried hard to follow out the light-quantum but the German was too much for me so I started work with a German here & have kept hard at it for the last two months". There is no indication of how Madsen may have used the quantum theory in his thinking but evidently he was on the right track of what was to become a further revolution in the development of the structure of the atom with Bohr's model in 1913 of electron shells using the Hydrogen spectrum and the subsequent work by H.G Moseley (1913-periodic table spectra), L.De.Broglie (1924-electron wavelength), W.Pauli (1925-electron sub shells), G. Uhlenbeck & S. Goudsmit (1925-electron spin).

In 1919 Rutherford published his account of work done since 1917 on the proton being the Hydrogen nucleus but it was not until 1932 that James Chadwick at the Cavendish with his Berrylium and paraffin wax experiment was able to prove the existence of the neutron consisting of a proton and electron, which as a neutral particle provided a powerful means of getting into the positively charged atomic nucleus of atoms.

J.P.V. Madsen & subsequent research. In 1926 Madsen conceived of a plan, to return to research, for Radio Research to be carried out by universities in Australia under the auspices of the newly formed C.S.I.R which was adopted with the dual idea of a National Standards Laboratory. Madsen was Chairman of the Australian Radio Research Board from inception through to 1956 and between 1931 -1939 the R.R.B published 14 Reports consisting of 45 papers by 16 researchers. Some of these papers of considerable merit were also published by the Royal Society, with Rutherford's willing assistance. The program of work which was adopted by these investigators was very much governed by Madsen's ideas on which research areas should be investigated with a view to Australia establishing a pre-eminence in the southern hemisphere in radio work, which in fact became the case.

APPENDIX (following the sequence of the 1981 H.R.A.S paper).

XII. Madsen to Bragg, 24 July 1910.

Sydney, July 24, 1910.

My dear Prof,

I have put off writing lately in the hope of having some work to tell you of but I have not been able to push things on as rapidly as I hoped. We started with a very heavy year in El.Eng about 18 men in third year & a dozen in fourth so that it has taken all we could do to keep them going. However I am glad to say that part of the work is well in hand now so that I can go on with other things. Six of the final men are going on with small investigations & seem very keen on their work. The Gaede pump has just arrived & its results seem very good so that I may be able to clear up the work on scattered cathode rays during the next vacation. Thanks very much for sending the Al. foils- they will be very useful. It is very interesting to see that J.J is realizing the existence of neutral doublets even if not in the form of fast moving rays. I should think there might be a chance of getting something from a measurement of the rate of diffusion of those doublets which Bunte seems to have obtained as a result of ring discharges.

I tried hard to follow out the light-quantum but the German was too much for me so I started work with a German here & have kept hard at it for the last two months. There seems a possibility of the B.A being invited out here- the Federal Govt has put 1,000 pounds on the estimates on the understanding that if it is passed 10,000 pounds will be available to meet the expenses, so we may be able to see you out here again if only for a short visit. I was glad to hear that Duffield had obtained a post. My brother -in-law who has just come back after a couple of years work at home has been getting me interested in the medical side of the ray work. A lot of this work can be simplified considerably in the light of our own experiments so I have fixed up a suitable electrometer for the work.

I am giving a lecture to the Brit. Med.Asoc in a few weeks so feel that at any rate I have not become entirely an engineer yet. I am glad to hear you have got over most of the initial work of organization etc. We are all very well here. I hope the same of your family.

With kindest regards to you all.

Yours very sincerely

J.P.V.Madsen.

XIII. Physics Section, Thirteenth Meeting of the Australasian Association for the Advancement of Science. Sydney 1911."14. The Scattering of Cathode Rays" J.P.V.Madsen.

The paper by Dr J.P.V. Madsen is listed in the A.A.A.S handbook for Thursday 12 January 1911 but is not printed in the handbook so the article in the Daily Telegraph, Sydney Friday 13 January 1911 & also in the Sydney Morning Herald are the only remaining record of what was said.

The Daily Telegraph Sydney article was headed "Radium's Beta rays-Atoms like solar systems-Beta rays the Comets"

A demonstration on "The scattering of the Beta Rays of Radium" was given before the Physics Section by Dr J P V Madsen, P N Russell Lecturer in Electrical Engineering of the Sydney University.

Introducing his subject, Dr Madsen stated that the discovery of the beta rays emitted from Radium was made almost simultaneously in 1899 in Germany , France & Austria . It was subsequently found that these rays carried a negative charge of electricity and moved at a high velocity, that they were subject to deflection in a magnetic field, produce fluorescence & photographic action & could penetrate considerable thickness of matter & that when such matter was gaseous, measurable ionization was produced as a result of their passage. The rays proceeding from Radium could by the aid of a magnetic field could be spread out into a spectrum. This showed that rays of different velocities were present. They were identified as being similar to the cathode rays observed in the same mass but moved with far greater velocity. The absorption of these rays by matter has been the subject of much investigation. The Laws of absorption appeared at first to be very simple, approximating to the well known exponential form which would result from each ray being brought to rest as the result of a single definite collision. In this case the number of rays stopped in a small thickness would be proportional to the thickness, the total number of rays projected & a quantity known as the "absorption coefficient" of each material. One half millimetre of glass, mica or aluminium absorbs about the same number of rays as a sheet of lead of one nineth the thickness & all these screens would absorb about 50 percent of the bundle of rays falling on them.

This simple theory of absorption, however said Dr Madsen has been found lacking in many respects & fails to explain many observations. Experiments by Crowther at Cambridge & by the author show clearly that for very thin screens of material in fact an appreciable absorption has been effected with scattering taking place. In the case of elements of large atomic weight a considerable number of rays are found to be completely turned back. Experiments by other investigators showed that although turned back, these rays have lost very little energy & move at very nearly their original speed. In the case of lighter atoms the number of rays turned back is not so great .About each atom we might in fact describe diagrams showing the number of rays deflected in any given direction when the different atoms were placed in the path of the same bundle of beta rays.

From many experiments which have been performed in recent years, continued the Lecturer, it is possible to form some picture of the structure of the atom. The atom would appear to be similar in some respects to a solar system the centre or nuclei being electrons possessing some form of orbital motion, their negative charge being compensated for by corresponding positive charges occupying the whole extent of the atom or else concentrated in individual masses, small compared to the size of the whole atom, but large compared to the electrons. The passing of a beta ray through such a system with a given velocity would be similar to the movement of a comet. Such comets proceeding into a solar system with a given velocity are deflected more the nearer they approach any one of the centres of the system. In the special case when the approach is very close, the collisions may result in the complete absorption of the comet. In general however a large number of comets passing at random through the system will suffer little deflections; a smaller number will have their direction of motion almost reversed.

For any one system or atom it should be possible to construct a polar diagram to represent these effects. The present investigation has enabled portions of such diagrams to be drawn in the case of aluminium, silver & gold. It has also been possible to show that apparently a measurable deflection of the incident beta rays can occur without the atom being in any way damaged as a result. Very frequently the atom will be disturbed that it ejects a slow speed electron, thus giving rise to the well known phenomenon of ionisation.

The scattering power of the atoms of some substances which can be obtained in sufficiently thin sheets has also been obtained. In the case of the rays which have been deflected from their original motion by only small amounts, the number of such rays scattered from a uniform bundle appears for atoms, which vary in atomic weight over a large range, to be proportional to the product of the atom’s weight & its square root for any element.

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(20 December 2022, email to R.W.Madsen from Berkeley "J P V Madsen & Rutherford's Atom 1911".)

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