The Sequence of Events that led to the 1963 Publications in *Nature* of 3C273, the first Quasar

Cyril Hazard[1],
David Jauncey[2,3], W. M. Goss[4]
and David Herald[5]

1: Institute of Astronomy, Cambridge
2: CSIRO Astronomy & Space Science
3: Research School of Astronomy & Astrophysics, ANU
4: National Radio Astronomy Observatory
5: International Occultation Timing Association

We would also like to thank Maarten Schmidt
for many valuable discussions

It is good that people now are sorting out
the complex histories of our times.
The professional historians often have a
difficult time sorting it all out, because
so much depends on technical details.

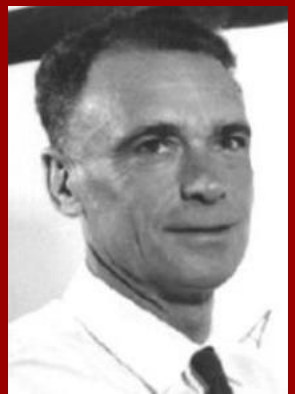
Martin Harwit June 2015

3C273: the cast

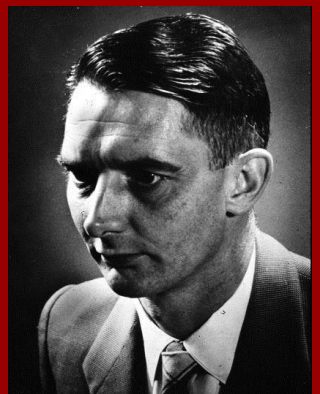
Cyril Hazard

W. Nicholson

Taffy Bowen



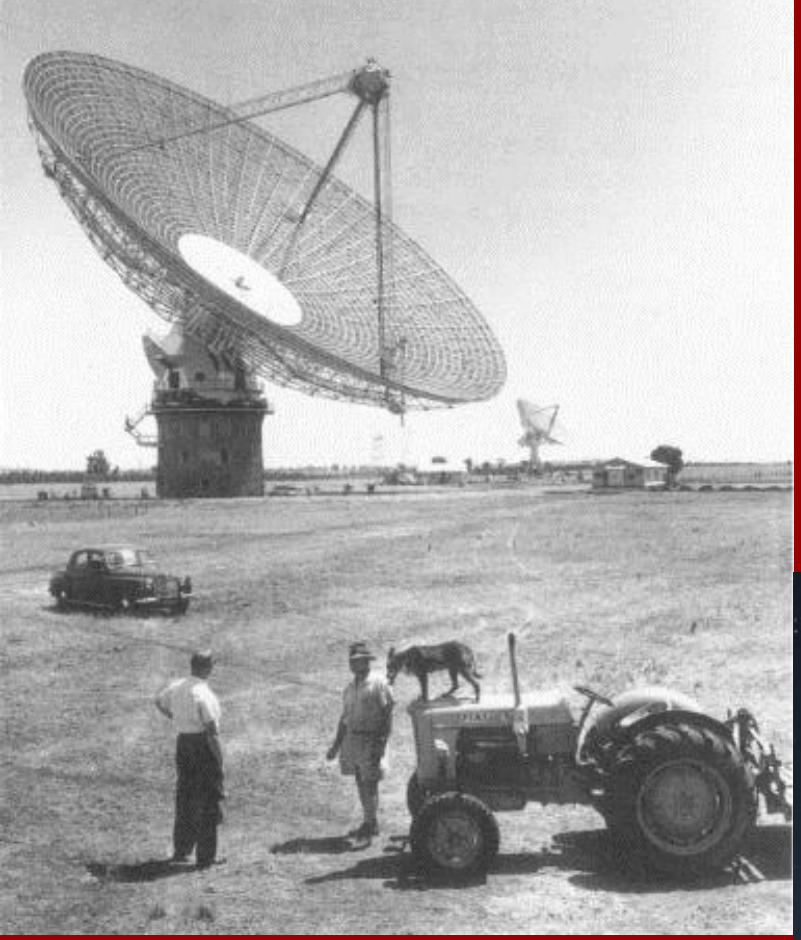
John Bolton



Maarten Schmidt

Tom Matthews

the telescopes



Parkes

OVRO

Palomar

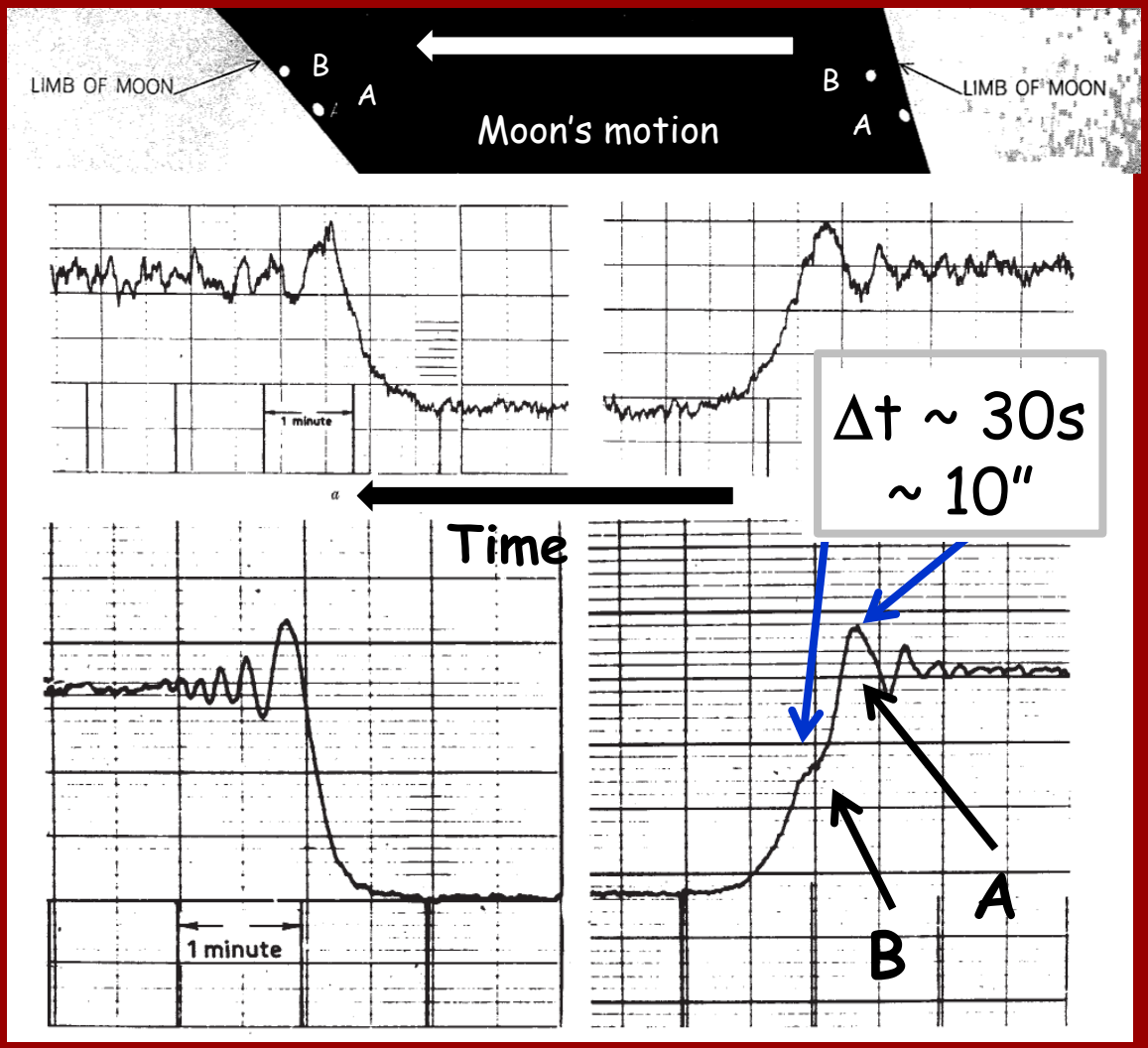
1962 and the three Parkes Occultations

- In 1962 Parkes could not track the moon, only the source
- May 15 at 410 MHz saw the first ever diffraction fringes
- August 5 at 136 and 410 MHz, disappearance and reappearance
- October 26 at 410 and 1420 MHz, disappearance only
- concentration on August and October

Between May and August John Bolton "attacked" the Dish, but that's another story…… it proved unnecessary anyway……

What's the distance between Fleurs and Parkes……..

August 5, 1962 occultation



3C273 is clearly a double source at 410 MHz, aligned so that both components disappear separately but reappear together along P.A. 45 degrees

Therefore separation between A and B has to be ~ 20″

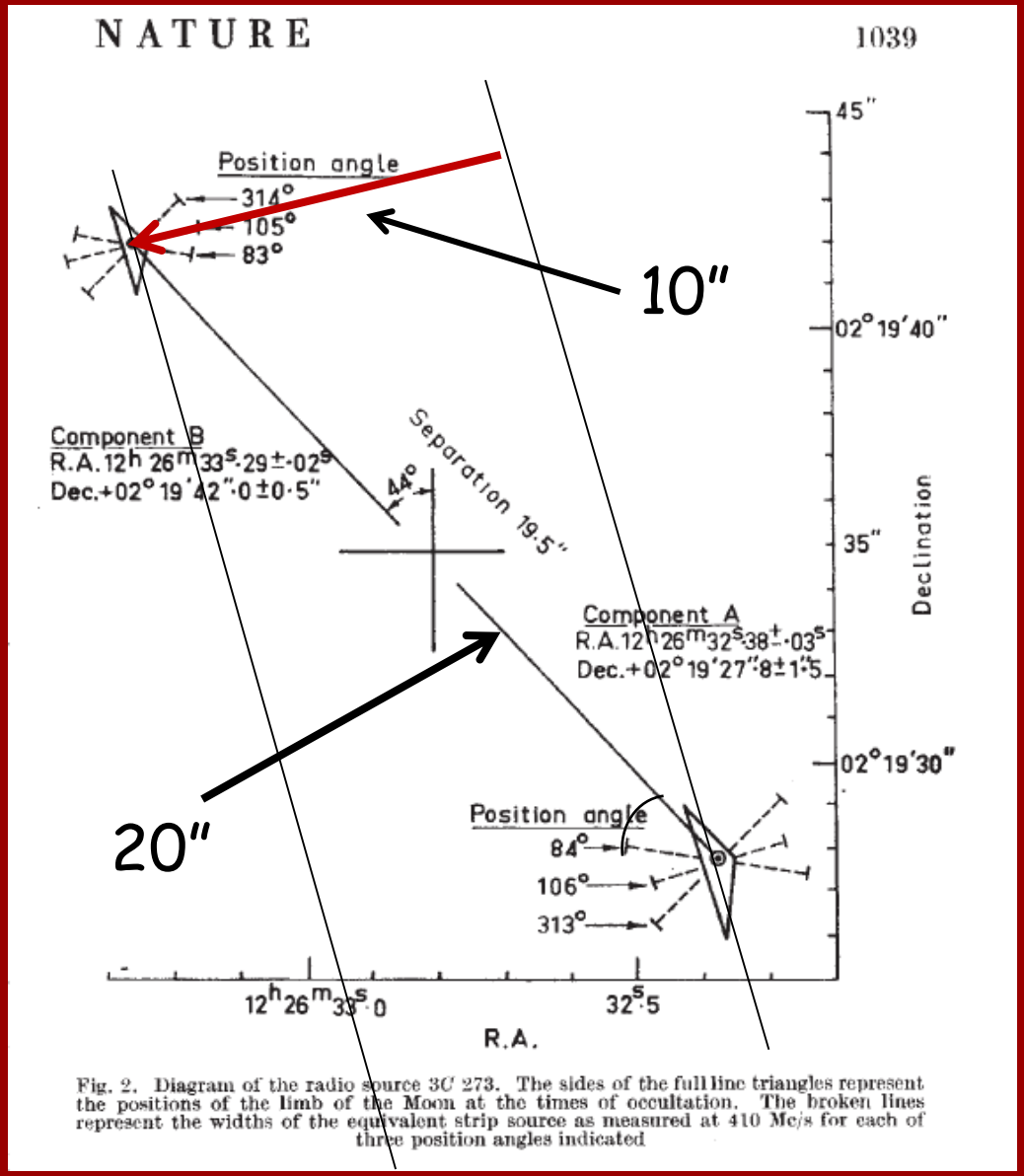


Fig. 2. Diagram of the radio source 3C 273. The sides of the full line triangles represent the positions of the limb of the Moon at the times of occultation. The broken lines represent the widths of the equivalent strip source as measured at 410 Mc/s for each of three position angles indicated

Hazard's published reduction of the structure and position

telegram

On August 20 John Bolton wrote to Maarten Schmidt, and as a "by the way" noted the following coordinates for 3C273 (giving no reference as to their origin…)

(a)	12^h	29^m	$32^s.1$	$\pm 0^s.1$
	02°	$19'$	$30''.1$	$\pm 0''.2$
(b)	12	29	$32^s.5$	$\pm 0^s.1$
	02	19	$37''.3$	$\pm 0''.2$

With a postscript……

The position of 273 is subject to arithmetic errors as yet undetected!

……subject to arithmetic errors as yet undetected!

This letter raises many questions:

- Where did Bolton get the position from?
- Where did his error estimates come from?
- Why was the occultation not mentioned?
- Why was Hazard not copied, and not informed of the letter?
- What was Maarten Schmidt to make of this position?

Remembering that 3C273 was inaccessible to him until the end of the year…

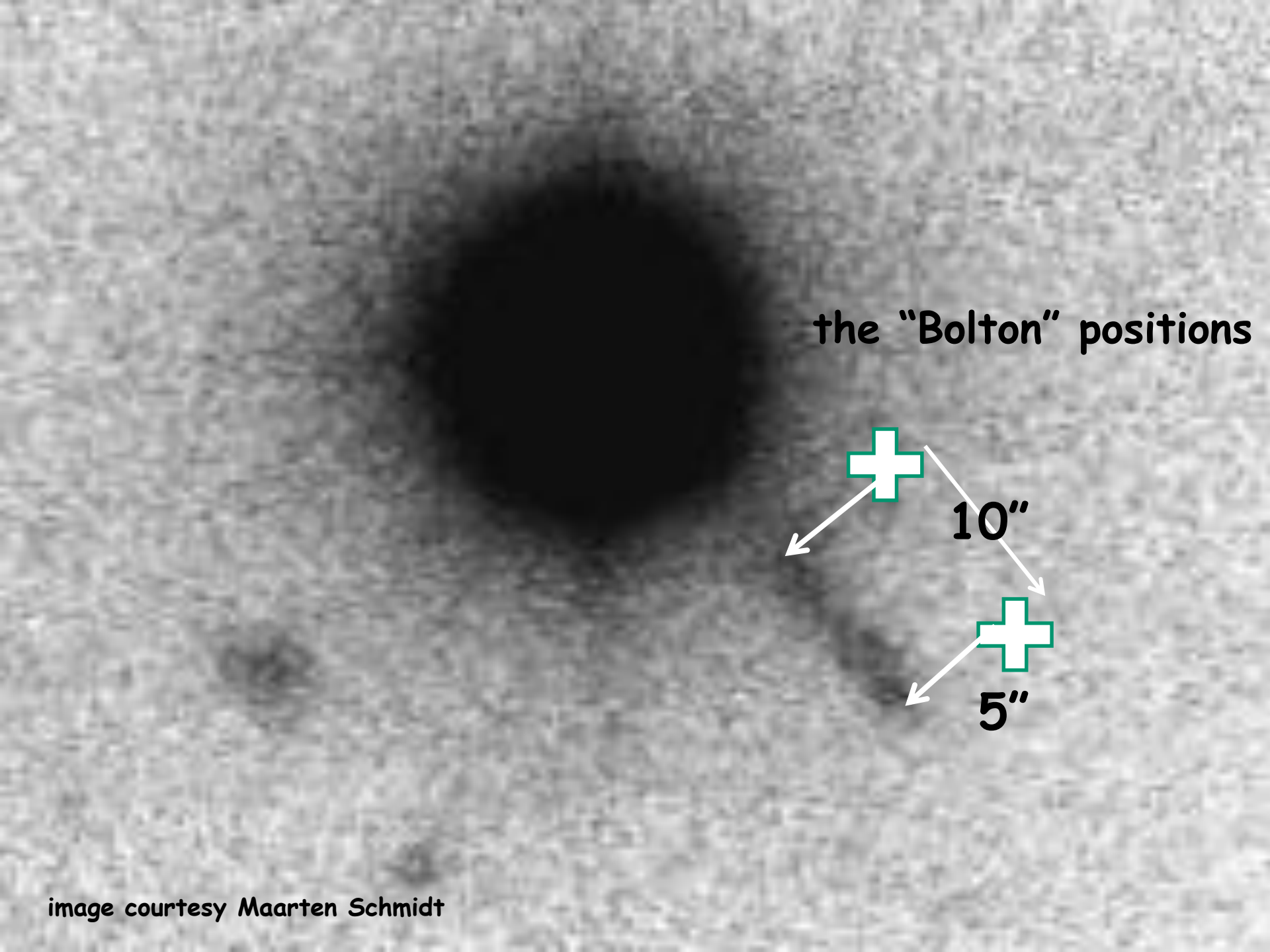
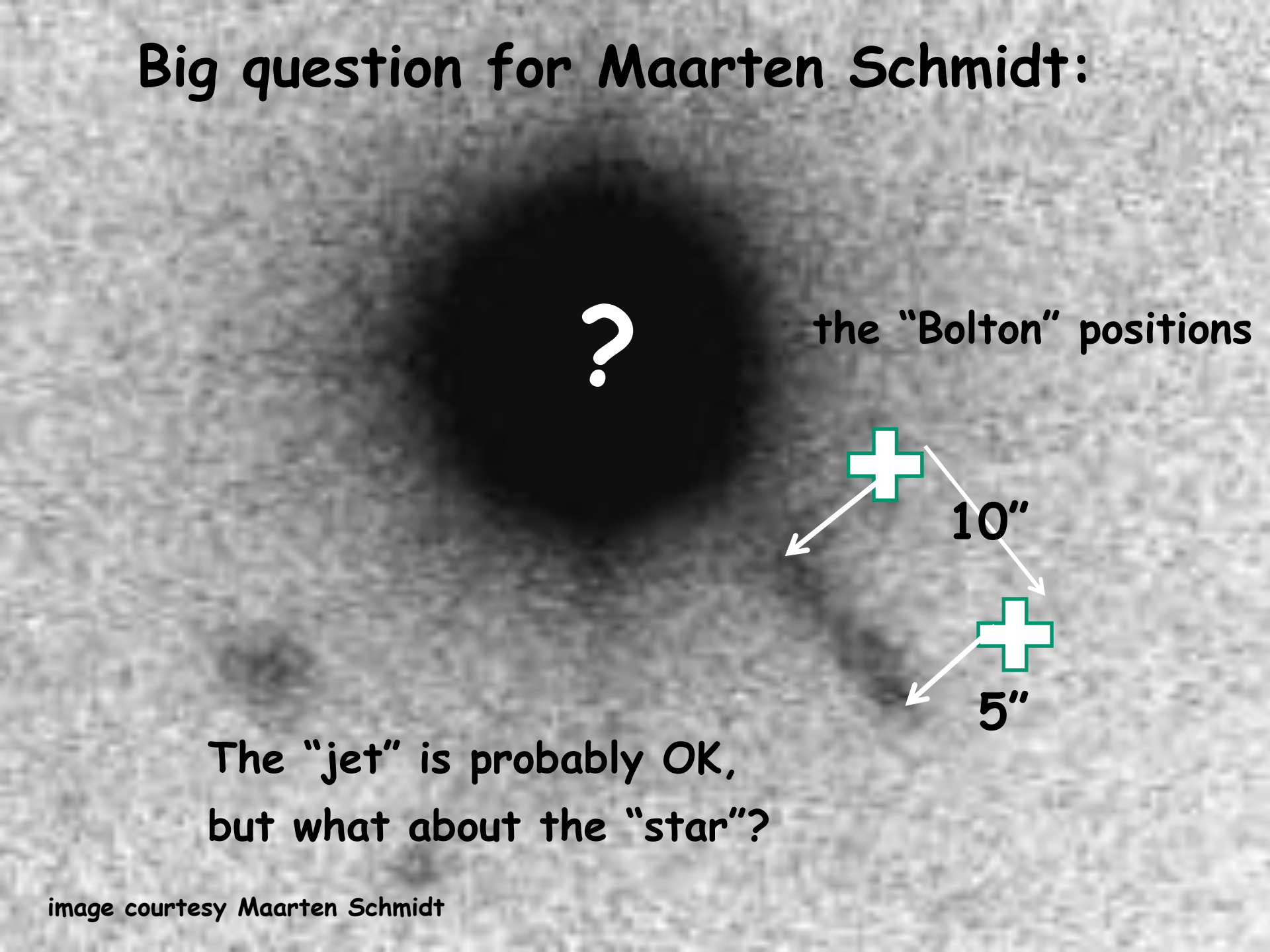


image courtesy Maarten Schmidt

Big question for Maarten Schmidt:



The "jet" is probably OK,
but what about the "star"?

image courtesy Maarten Schmidt

How could John Bolton have gotten this position?

Could he have miss-read the numbers? Possibly??

Could he have given the centroid for B? Possibly??

At 136 MHz component B has effectively disappeared.
At 410 MHz the separation was ~20", so a possible "solution" could be to put B half way between the 410 MHz positions.

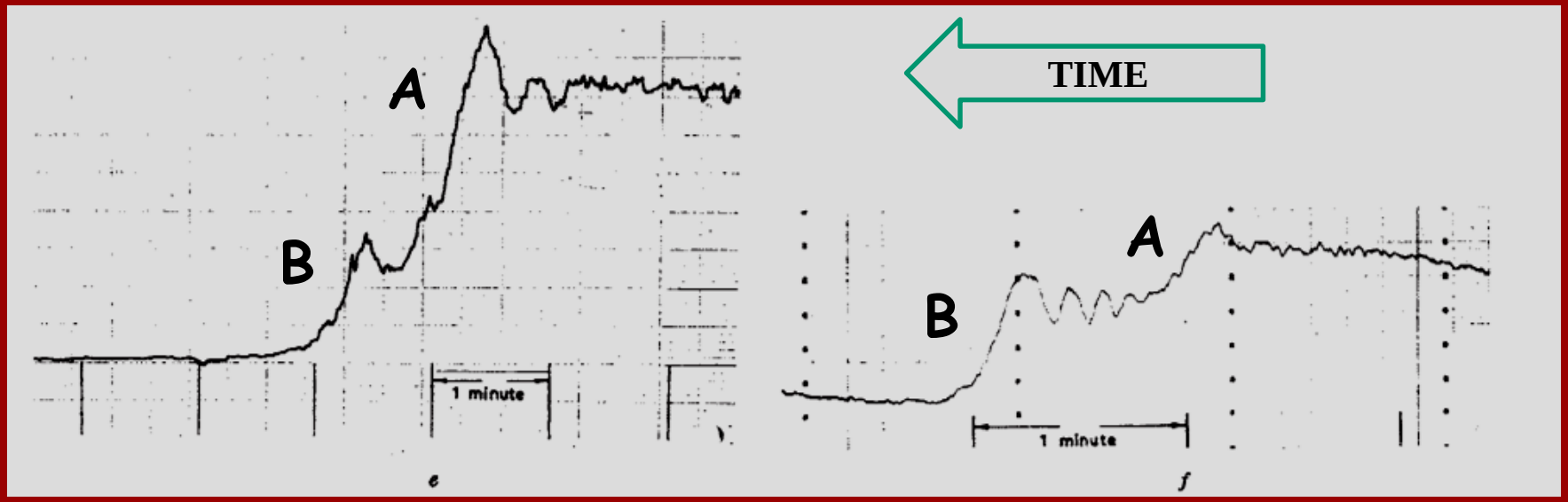
Could "half-way" just be an interim solution? Possibly??

Did Hazard mistake the 10" offset? Possibly??

Where did Bolton's error estimates come from? ????

This is just two weeks after the observations, and was the first time fringes had been analysed. There was insufficient time for Hazard to have communicated with Nicholson.

The Occultation of October 26 1962, disappearance only



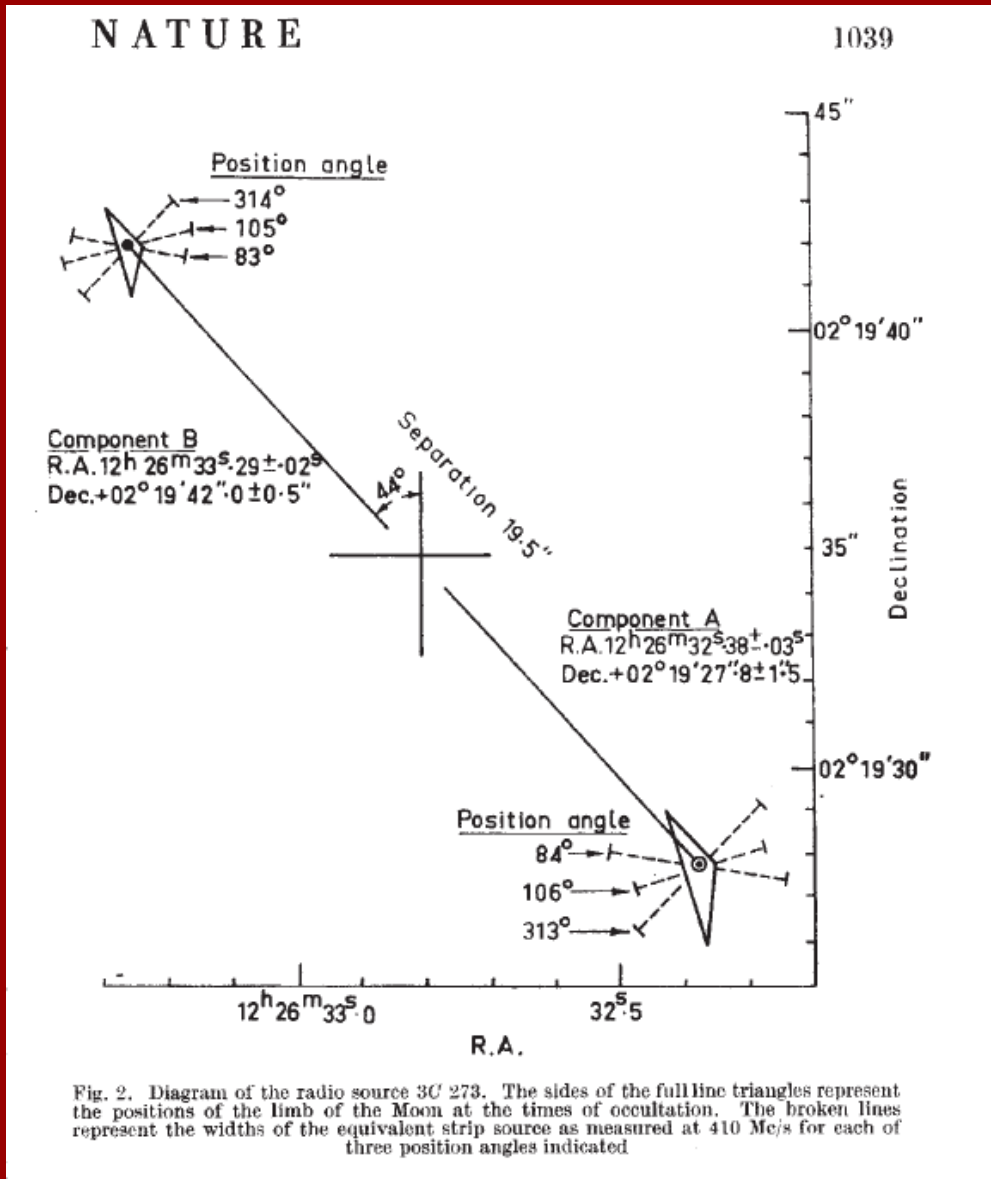
410 MHz 1420 MHz

What is interesting at 1420 MHz is the change in the flux density ratio of the two components with frequency. The spectral index of component B, the more compact, is flat at 0.0, whereas that of component A is steep at -0.9. Examination of the August '62 record shows component A totally dominates at 136 MHz and is ~95% of the total.

For both August and October 1962, Hazard's 3C273 analysis had revealed a "core-jet" structure

January 31st 1963 Hazard wrote to Schmidt with the correct occultation positions for A and B, and suggested a joint publication.

This core-jet radio structure now coincided very closely with the optical image. Component B is now clearly the bright STAR!



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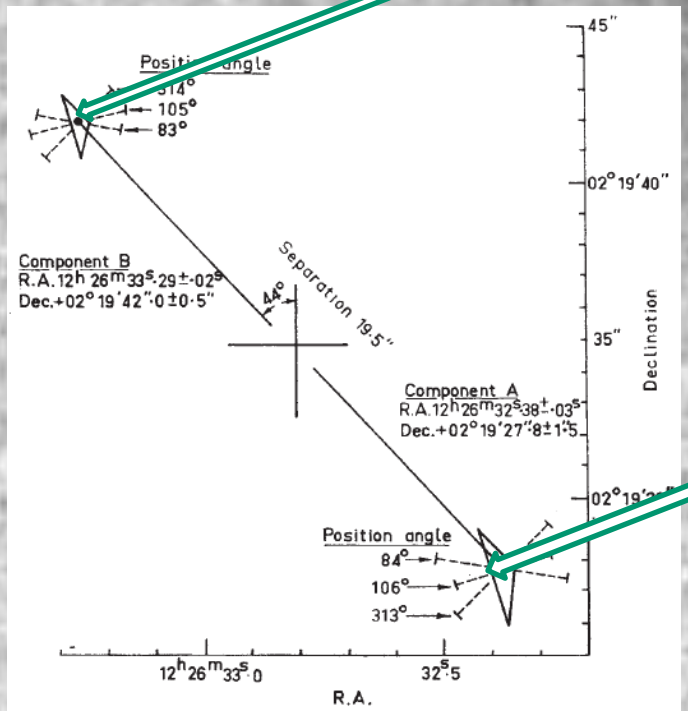
Component B



Component A

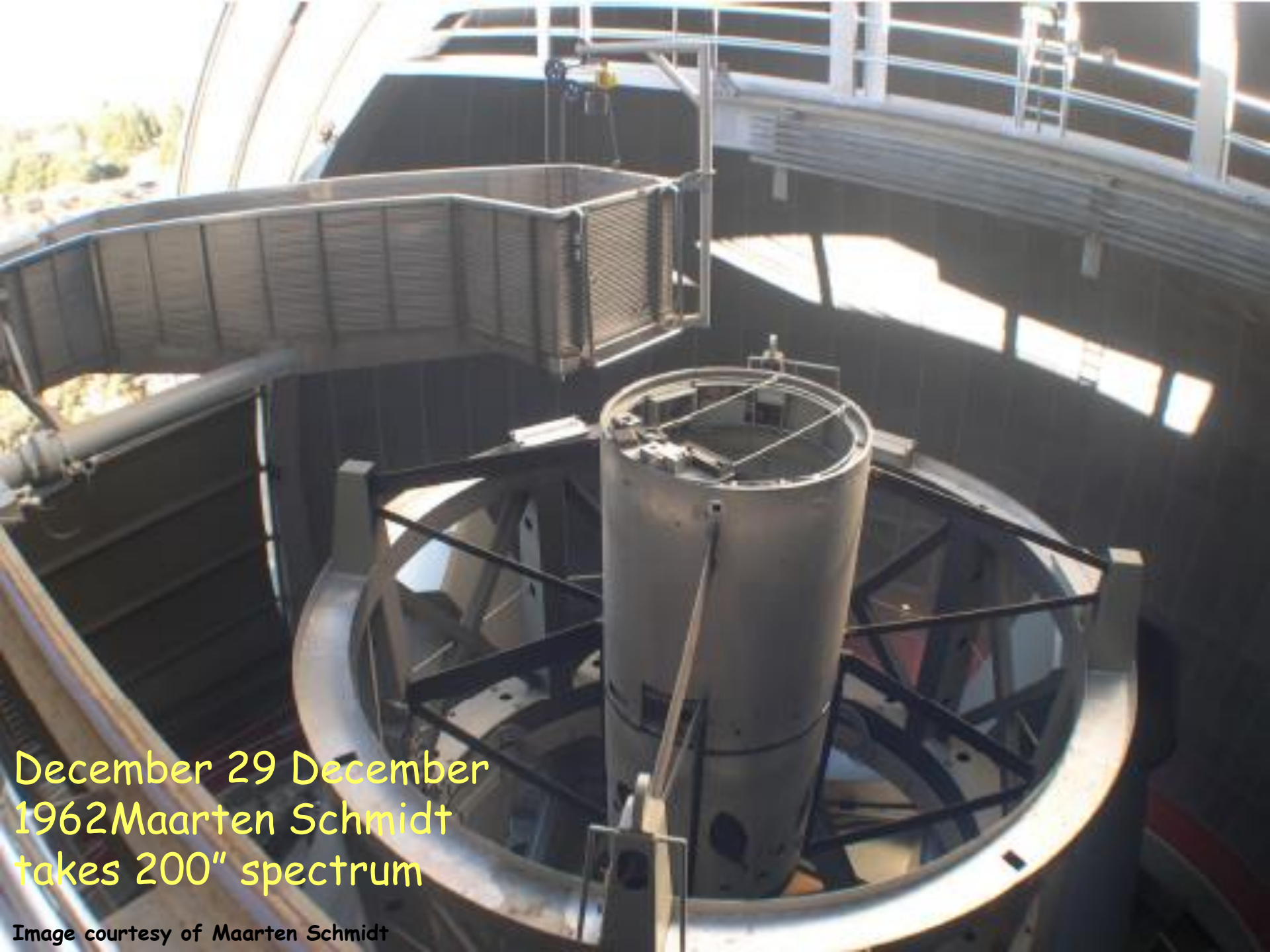
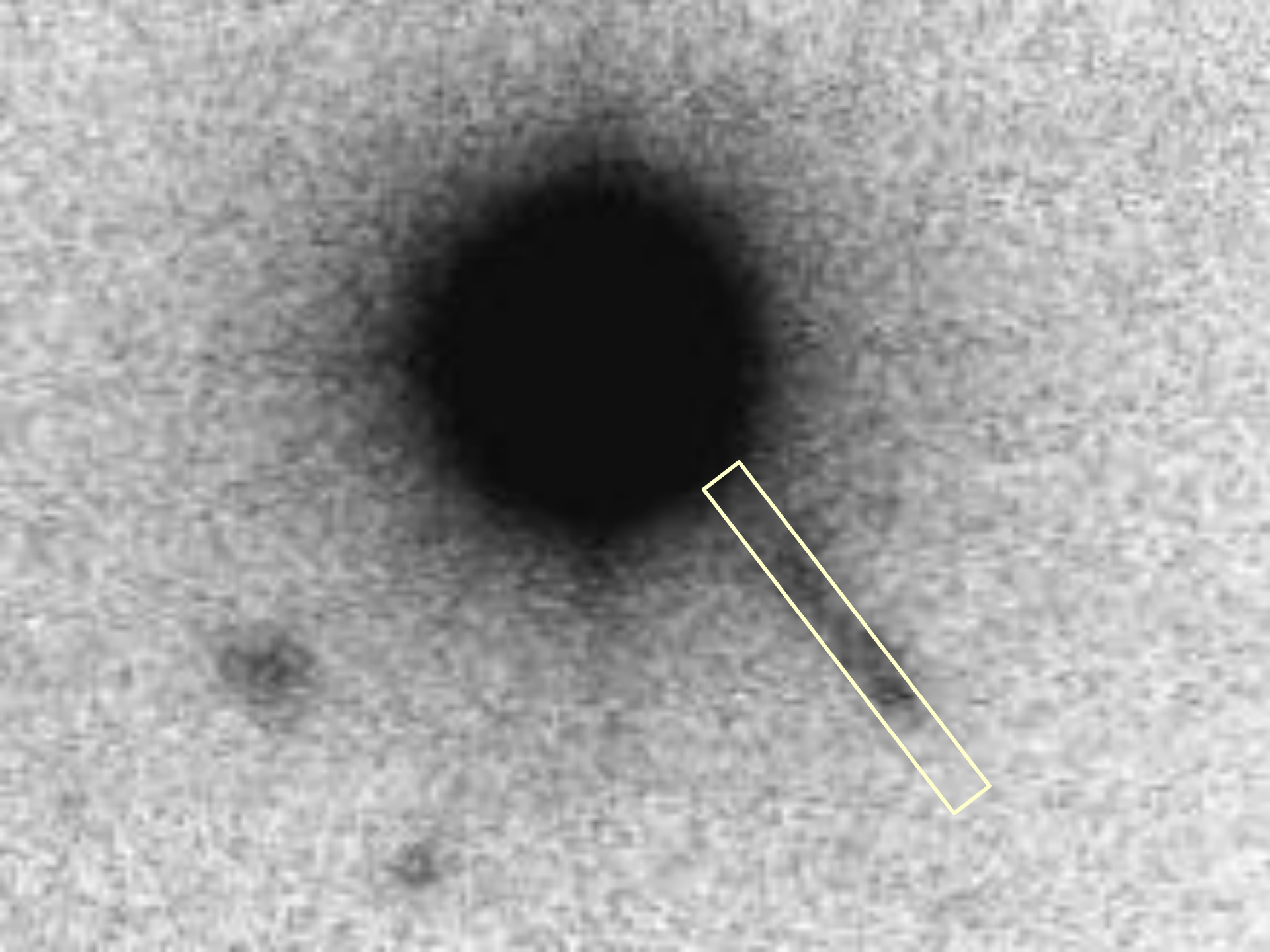


Image courtesy of Maarten Schmidt



Maarten's 200" spectrum taken December 29 December 1962

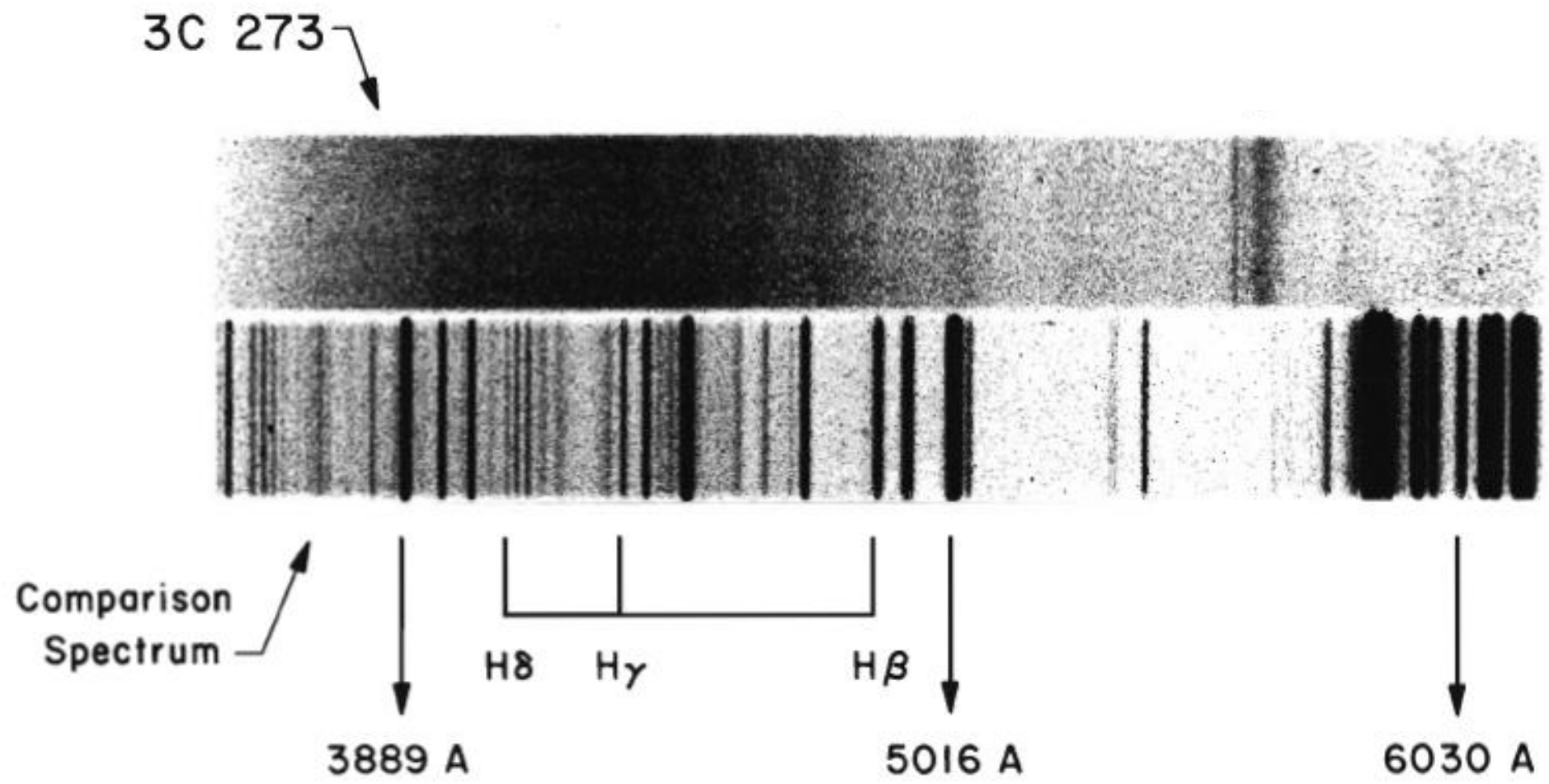


image courtesy Maarten Schmidt

He'd been puzzling over it. But on February 6

$z = 0.16$

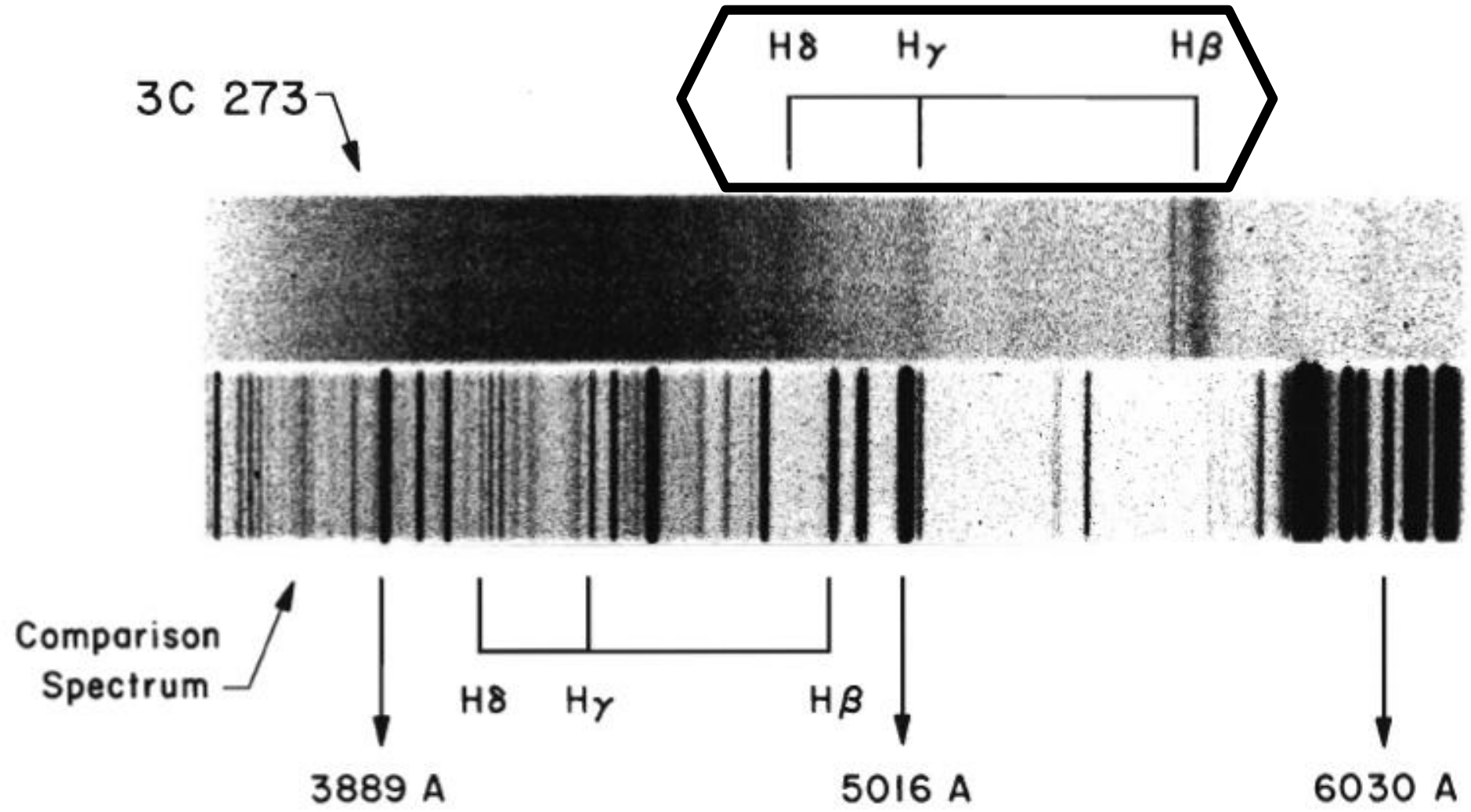


image courtesy Maarten Schmidt

It happened on 6 February 1963. In response to Hazard's letter I decided to have another look at the spectra…..

For reasons that I don't remember I tried to construct an energy-level diagram. When the energy levels did not come out regularly spaced, I was annoyed….. To check on the regularity of the observed lines, I decided to compare them with the Balmer lines of hydrogen….

Specifically, I took for each line in 3C 273 the ratio of its wavelength over the wavelength of the nearest Balmer line. The first ratio was 1.16, the second was…..also 1.16.

It suddenly struck me that I might be seeing a redshift. When the third and fourth ratios were also close to 1.16, it was abundantly clear that I was seeing in 3C 273 a redshifted Balmer spectrum.

Maarten Schmidt, Proc. Amer. Phil. Soc., 155, 145, 2011

No. 4872 March 16, 1963 NATURE 1037

INVESTIGATION OF THE RADIO SOURCE 3C 273 BY THE METHOD OF LUNAR OCCULTATIONS

By C. HAZARD, M. B. MACKEY and A. J. SHIMMINS
C.S.I.R.O. Division of Radiophysics, University Grounds, Sydney

THE observation of lunar occultations provides the most accurate method of determining the positions

spond to spectral indices for components A and B of $-0{\cdot}9$ and $0{\cdot}0$ respectively. The spectral index of A is a

3C 273 : A STAR-LIKE OBJECT WITH LARGE RED-SHIFT

By DR. M. SCHMIDT
Mount Wilson and Palomar Observatories, Carnegie Institution of Washington, California Institute of Technology, Pasadena

THE only objects seen on a 200-in. plate near the positions of the components of the radio source 3C 273 reported by Hazard, Mackey and Shimmins in the preceding article are a star of about thirteenth magnitude and a faint wisp or jet. The jet has a width of 1″–2″ and extends away from the star in position

Table 1. WAVE-LENGTHS AND IDENTIFICATIONS

λ	$\lambda/1{\cdot}158$	λ_0	
3239	2797	2798	Mg II
4595	3968	3970	Hϵ
4753	4104	4102	Hδ
5032	4345	4340	Hγ
5200–5415	4490–4675		
5632	4864	4861	Hβ

With the discovery of the first quasar our knowledge and understanding of the Universe changed forever.

3C273:

- The first Quasar
- The first radio Jet
- The first inverted spectrum radio source
- The first sub-arcsecond radio position
- The first sub-arcsecond radio structure
- The first radio-optical reference frame tie
- The first radio and optical variable extragalactic source
- The first black hole

IDENTIFICATION OF TWO SOUTHERN QUASI-STELLAR OBJECTS*

By R. D. Ekers† and J. G. Bolton‡

A number of possible quasi-stellar objects have been found from a search of the Palomar Sky Survey plates for identification of radio sources in the Parkes catalogue (Bolton, Clarke, and Ekers 1965). Confirmation of the identification of two of these sources, 1327—21 and 2115—30, has now been obtained from both precise position measurements and photoelectric observations. As quasi-stellar objects generally are of very small radio diameter, the optical positions can be used as primary calibration points for southern radio telescopes.

Aust. J. Phys., 1965, **18**, 669–70

Ron and John Bolton were amongst the first to start Making optical identifications with colour selection for Blue stellar objects.

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THE observation of lunar occultations provides the most accurate method of determining the positions of the localized radio sources, being capable of yielding a positional accuracy of the order of 1 sec of arc. It has been shown by Hazard[1] that the observations also provide

spond to spectral indices for components A and B of $-0{\cdot}9$ and $0{\cdot}0$ respectively. The spectral index of A is a representative value for a Class II radio source; but the flat spectrum of B is most unusual, no measurements of a comparable spectrum having yet been published. If the

OF THE RADIO SOURCE 3C 273 BY LUNAR OCCULTATIONS

By C. HAZARD, M. B. MACKEY and A. J. SHIMMINS
C.S.I.R.O. Division of Radiophysics, University Grounds, Sydney

But that's another story, too……

School of Physics of the University of Sydney.

C. Hazard

School of Physics, University of Sydney.

M.B. Mackey

A.J. Shimmins

Radiophysics Laboratory, CSIRO, Sydney, Australia.

School of Physics of the University of Sydney.

C. Hazard

School of Physics, University of Sydney.

M.B. Mackey

A.J. Shimmins

Radiophysics Laboratory, CSIRO, Sydney, Australia.

School of Physics of the University of Sydney.

C. Hazard

M.B. Mackey*

A.J. Shimmins*

* Radiophysics Laboratory, CSIRO, Sydney, Australia.

Intensity Interferometer,
Narrabri. N.S.W.

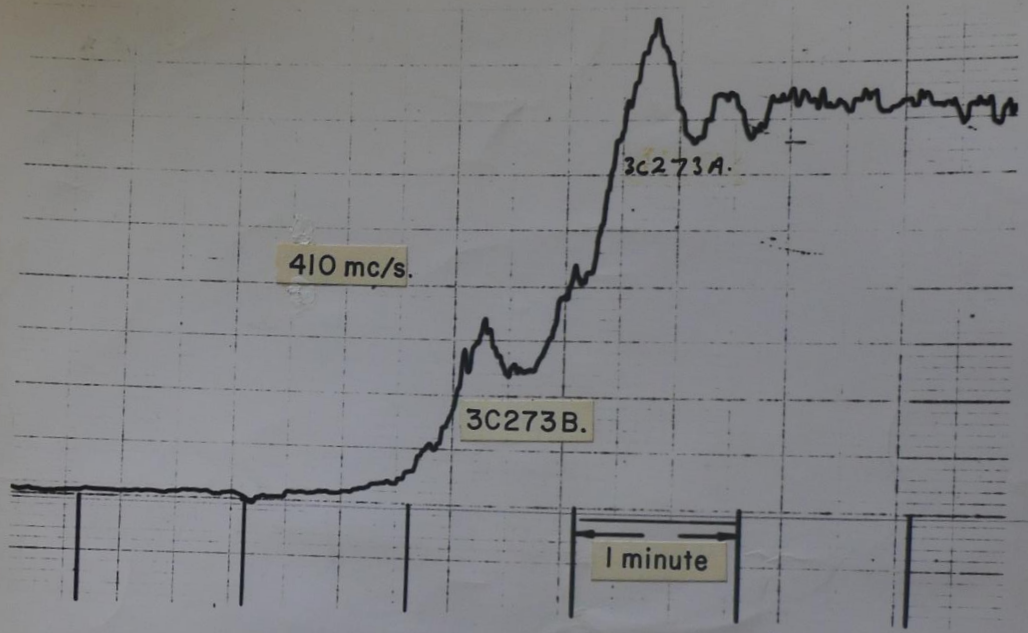
DR. MINKOWSKI

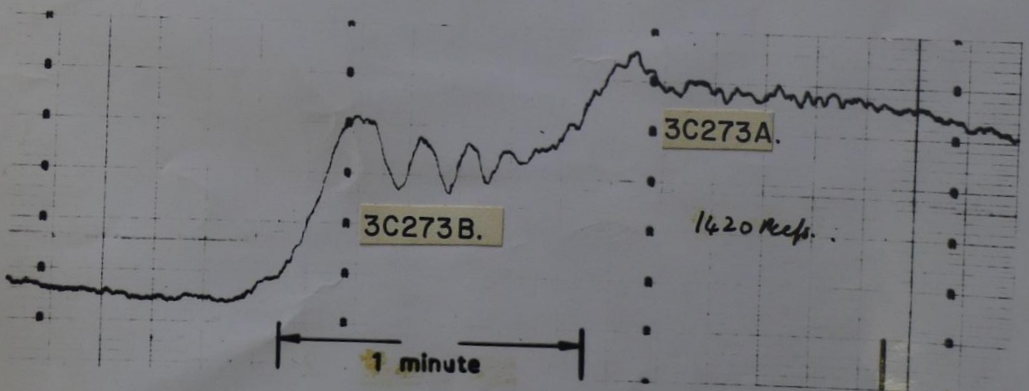
MOUNT STROMLO OBSERVATORY
CANBERRA.

OCCULTATION SUCCESS SOURCE DOUBLE COMPONENTS THREE SECONDS PROBABLY ELLIPTICAL SEPARATED TEN SECONDS POSITION BEING CALCULATED.

HAZARD

CH/AW. 9/8/62


3C273A.
410 mc/s.
3C273B.
1 minute


3C273A.
3C273B.
1420 Mcs.
1 minute

Slide notes:
Slide 1: alternative title could be “the anatomy of a discovery.

Slide 2: Martin Harwit is the author of Astrophysical Concepts
Slide 3: Hazard was already using occultations to determine accurate radio source positions, as he had realized that this was the only means at the time to achieve the required arcsecond accuracy.
Schmidt had recently taken on the optical spectroscopy program at Cal Tech on the retirement of Rudolph Minkowski.
Slide 5: Fleurs vs Parkes for the Almanac Office predictions. Fleurs is two and a half degrees to the east of Parkes. The source/moon rises and sets at Fleurs well before doing so at Parkes.