4.6 The quest for photographic magnitudes from focal images

The Astrographic Congress of April 1887 had one very beneficial influence. Suddenly astronomers had to find ways of measuring photographic magnitudes for millions of faint stars to magnitude 11, yet it soon became evident that there was no clear picture of how to undertake this photometry. There was no agreed definition of a photographic magnitude scale and very few stars had been measured visually to such faint limits. Even the exposure time to reach magnitude 11 was uncertain. At the second congress in 1889 Prosper Henry had maintained that increasing the exposure time by a factor of 2.5 resulted in stars one magnitude fainter being recorded, and after much discussion it was therefore decided that the *Catalogue* plates should be exposed 6.25 times longer than required for stars of visual magnitude 9 [86]. At this time no-one challenged the reciprocity law on which this resolution was based. Both Janssen at Meudon [87] and Lohse at Potsdam [88] before the first congress had strongly asserted its correctness.

By 1891 the reciprocity law had been challenged by several workers. The first doubts came from Edward Pickering at Harvard [42, 45] followed in quick succession by Pritchard [89], Scheiner [90, 91] Abney [92, 93], William Pickering [48] and Dunér [94, 95].

All these observers found that progressively fainter stars required increasingly longer exposure times to record them than predicted by the Pogson 2.5 factor per magnitude. For example, Scheiner estimated an exposure 2.5 times as long gained only between 0.5 and 0.75 of a magnitude [90]. The hopes of defining a scale of photographic magnitudes based simply on the validity of the reciprocity law, as had been proposed for example by Dunér at the 1891 Congress [96], were therefore dashed.

Table 4.1. *Empirical formulae for magnitude m vs image diameter d*

m	=	$A - B\sqrt{d}$	W. H. M. Christie	[97]
			H. H. Turner	[99]
m	=	$A - B \log d$	C. Pritchard	[89]
m	=	$A - B \log d$	C. V. L. Charlier	[100]
d	=	$a + b(m_0 - m)$	J. Scheiner	[101]
d	=	$-a \log m + b$	C. Pritchard	[102]
m	=	$A/(d + B)$	J. C. Kapteyn	[62]
m	=	$A - Bd + Cd^2$	K. Schwarzschild	[103]

To confuse the issue, some observers continued to publish results confirming that the reciprocity law was satisfied by their data, among them the Astronomer Royal, Sir William Christie [97]. Even when the evidence was overwhelmingly against the reciprocity law, the Henry brothers and their French colleague, Charles Trépied (from the Algiers Observatory), were stubbornly insisting on its validity and usefulness as a basis for photographic photometry [98].

From the outset the first Astrographic Congress had resolved to record focal images of stars, which renders the stellar images as nearly point-like. Magnitudes were to be obtained from the measurement of diameters, no doubt as a result of the influence of Gill and Kapteyn and their work on the *Cape Photographic Durchmusterung*. The relationship between image diameter and visual magnitude therefore became a matter of considerable interest, and many observers proposed different empirical interpolation formulae that could be used, so it was claimed, to convert image diameters to stellar magnitudes. Bond in 1858 [18] and Kapteyn for the CPD [55] had both adopted empirical formulae for stellar image diameters. Table 4.6 lists some of the formulae proposed at this time.

The question of the relationship between image diameter and exposure time is a related problem, but not identical in view of departures from the reciprocity law. This property of photographic plates was also explored in detail (see Table 4.2). One of the most thorough of these investigations was that of Carl Charlier (1862–1934) at the Lund Observatory in 1889. This work was published to celebrate the Pulkovo Observatory jubilee and was cited by many of those who subsequently entered the same field [100] – see also E. S. Holden [109] for an English summary.

Charlier adopted the $m = a - b \log d$ relationship between magnitude m and diameter d. In addition he found that the diameter increased with