All the above theoretical investigations have been confirmed by practical obsarvations. Thus the nebular hypothesis can, as I have already observed, explain many, if not all the nebular formation. Our present knowledge is undonbtedly inadequate ; but the outlook is quite hopeful.

TESTING A PHOTOGRAPHIC LENS.

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Most people possess a Camera with a lens but probably few have tested their lens, except perhaps by ordinary photographs, relying mostly on the salesmen's assurance that it would give "beautiful definition sharp as a needle." For those members who would care to investigate their lenses, this paper gives some simple experiments which are not difficult to carry out and do not require special apparatus.

As many members are aware astronomical lenses are tested by examining the images of star more especially by examining the pattern into which the light is distributed when the star is out of focus. This method can be applied to a photographic lens but it is more convenient to have an an artificial star. A pinhole in a thin metal plate with a light, even a candle, behind it will serve as an artificial star. Beyond this and a darkened room one only requires an eye-peice of medium power with which to examine images of the pinhole formed by the lens. A photographic lens is ordinarily required to produce pictures of distant objects; hence one should set up the camera as far away as the size of the room and the brightness of the light from the pinhole will allow.

The defects shown by a lens may be any or all of the following, which are here only briefly and non-technically defined, but more informations about them can be found on any book on Optics.

1. *Spherical aberration,* due to the image formed by the edges of the lens not coinciding with that formed by the centre.

2. *Comma,* when the image of the pinhole has a tail not unlike a comet.

3. *Astigmatism,* when the image of the pinhole is not a point but drawn out into a line, or rather into two lines at right angles into two different focal planes.

4. *Curvature of the field,* when the sharpest focus over the field of the lens lies on a curved surface instead of a flat hole.

5. *Distortion,* when equal distances on the objects are not represented by the equal distances in the image.

6. *Chromatic aberration,* when different colours have different foci.

Since a photographic lens consists of a combination of at least four lenses, it is important first to see that all the components are properly centered. To do this, look through the lens towards a bright light. A number of faint images due to reflection at the surfaces of the components of the lenses will be seen, generally six images. If by twisting the lens and moving the eye those faint images can be brought into coincidence the camponents of the lens is correctly centered, bnt if one or more persists in being out of position when the rest are in coincidence, at least one component is de-centered and the lens will never give good results. When a lens leaves the maker then centering is generally correct, but if it has been dropped, or taken apart and incorrectly assembled again, it may show centering errors.

Having examined centering of the lens, we can now proceed. Set up the camera as far as convenient from the illuminated pin-hole and point the camera directly towards the pinhole so that the image falls near the focussing screen or plate. Now remove the focussing screen or the camera back and focus the image of the pinhole by means of an eyepeice of not too small a magnifying power. It is important that the eyepeice should point directly towards the centre of the lens as otherwise the astigmatism due to the eyepeice will make the defects of the lens. By the character of the images seen in this eyepeice we can deduce many of the defects which are in the lens.

Even with a perfect lens, the sharpest image of the finest pinhole will be disc surrounded by alternate dark and bright rings which are small when the aperture of the lens is large. They may easily be made evident by stopping down the lens to a small aperture say F. 64, but they are still present at large apetures and can be seen with a sufficient magnifying power provided the light is not too faint. This disc is due to "Defraction" and is caused by the fact that the section of the waves which falls on the lens is used to form the image and not the whole of the spherical waves sent out from the artificial star. It is generally referred to as the "Defraction Image."

With a good lens the defraction image will be perfectly circular and symmetrical. If however the lens is strained in its mount as a result of a blow or a fall, or if the centreing is faulty the defraction image may be more extented in one direction than in another.

Comma may be seen to some extent in a fairly good photographic objective. It is however very evident if only the front or back combination of the lens is used. As the centre of the field of view of the lens, i. e,, with the camera pointed directly towards the pinhole the sharpest image obtainable will be seen to have a tail similar to a comet. Towards the edge of the field of view twisting the camera so that the lens does not point directly (which my be examined by at the pinhole) the Comma will become more exaggerated. Comma can be reduced by stopping down the lens and it can be seen easily how far it is necessary to stop down the lens to reduce the Comma to negligible dimensions.

So far as we have been examining the image in the best obtainable focus, but very valuable informations may be gained by examining the pattern in which the light is distributed when the pinhole is out of focus. Starting from the position of sharpest focus gradually push in the eyepiece either towards or away from the lens. As the eyepiece is moved rings will appear round and alternately bright and dark centre. With a perfect lens, the pattern seen inside the focus, will be exactly like that at an equal distance outside the focus. With such lenses as are obtainable however there will generally be a distinct difference between the patterns inside and outside the focus, and it is from this difference that many important conclusions as to the performance of the lens can be drawn.

If when inside the focus the inner rings (particularly the innermost) are abnormally faint and the outer (particularly the outermost) abnormally outer faint, thin spherical aberration is present. By reducing the aperture of the lens the spherical aberration can be reduced and a note should be made of the largest aperture at which there is no appreciable difference between the patterns inside and outside the focus. At apertures larger than this, the definition of the lens will be impaired. It may however happen that the lens gives patterns exactly contrary to that just-mentioned i. e. the central rings may be bright when the eyepiece is inside the focus. This denotes that the spherical aberration has been overcorrected. Generally such overcorrection has been made purposely by the maker in order to secure a compromise between one desirable quality and another.

If the sperical aberration has not disappeared when the lens is stopped down to F/16 the lens is not a good one. In one lens I have, belonging to a well known maker of hand camera, the spherical aberration is very reduced at F/13 and is practically not existing at F/16. In another I have, the spherical aberration concerned, becomes small at F/11 and entirely gone at F/13.

Another defect may possibly evidence itself in the out of focus patterns; viz there may be alternatives in the brightness of the rings intermediate between the centre and the outside. This defect is called zonal aberration. Another lens by the same maker of hand camera previously referred to shows one zone which has its focus outside that of the rest of the lens.

Generally, rings which have been noticed above will appear perfectly circular denoting absence of astigmatism in the centre of the field of view. When, however, the edges of the field of view round to axis perpendicular to the optical axis, the rings will unless the astigmatism has been completely corrected, be oval in form of the larger axis inside the focus being at right angles to the larger axis outside the focus; moreover it will be found also that the best possible focus will be obtained in two approximately straight lines which are at right angles to each other the one a little nearer the lens than the other. By gradually turning the lens so as to explore different distances from the centre of the field of view it can be seen how far from the centre the lens remains free from appreciable astigmatism. Astignatism cannot be reduced by stopping down the lens. With certain classes of lenses it will be much more in evidence than in others ; it will be very evident in "portrait lenses", present some extent in "rapid reclinations and small in anastigmats".

The out of the focus also give some information regarding the chromatic aberrations. Unless chromatic abberrations have been completely corrected (which of course can never be with lenses) there will be colour effect in the patterns. However their detection and interpretation are not quite so simple as those given above. Moreover the chromatic aberration has to be accepted by the uses of the lens as it cannot be improved by any simple device such as stopping down the lens. It will therefere not be discussed further at present except to remark that both front and back combinations of a photographic lens are corrected for the blue and yellow parts of the spectrum.

The method of out of focus images is not suitable for determining the presence of curvature of field. Curvature of the field is evidenced on the focussing screen of a camera when in focussing on a distant view, or on a flat wall, after obtaining the best focus at the centre of the screen, the screen has to be moved towards (generally) the lens in order to obtain the best focus at the edges. A simple way to examine far flatness of field (i. e. absence of curvature, is to place a sheet of squared paper, or even a newspaper, on a drawing board *titled* at an angle to the camera. Observing the image of the focussing screen a marked line is first of all sharpely focussed at the centre of the screen ; in another line (generally one nearer the camera) is in the focus than the marked line, the field of the lens is curved by an amount corresponding to the distance detween these lines. Curvature will be evidence on all lenses except so called "anastigmats" in whieh the focus at the centre of the field and at a point between the centre and the edge line in the same plane.

Distortion can also be detected by placing a ruler on the focussing screen along the images of the lines of the squared paper.

Any one who tries these experiments with his lens will learn a great deal as to its properties and limitations. He will not only be able to make the most of his lenses and to discern for what purposes and under what conditions it is as good as the most expensive lens, but should he be the happy possessor of an expensive lens he will be able to take full advantage of its qualities.