tions. The method is very sensitive. By visual inspection, only flares of amplitudes larger than $0^{m}.6$ are found. Here it seems possible to decrease the limit to about $0^{m}.3$. The method also yields useful results for plates taken under non-photometric conditions; such plates, however, are rarely obtained at La Silla.

The flare candidates are stored in a "flare-file". This file contains also information about celestial coordinates, magnitudes of the images and density of the sky background. The last value is especially important for checking the reliability of a reported flare event, because a strong variable background, even when properly subtracted, can produce systematic exposure effects. Another problem appears for almagamated chains in regions of *high* star density. It occasionally happens that stars from the two chains merge into single images of higher brightness. This can occur at any position in the chain.

At last, the discovered flare events can be inspected in the form of tracings or digitized images of the chain. The images reveal only flare events with sufficiently large amplitudes, while the tracings clearly show also the fainter flares and the variations of the sky background. Two examples of flare stars are given in Figures 3 and 4.

The final part of the programme, which is under development, offers the user the possibility to combine results from *different* plates, in order to study the complete available history of all stars in the field. For flare stars, this means better confirmation, especially in cases of low amplitude flares of higher frequency, and thus higher sensitivity of the photographic flare search. Also, typical time scales for more frequent flares can be determined. Finally, other types of variables with longer periods can be detected.

Dust in Early-Type Galaxies

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Introduction

A brief historical review of the discovery and exploration of elliptical galaxies has been published by de Vaucouleurs (1987). We have made use of it to write this introduction.

The most widely used classification system for galaxies is that proposed by Hubble in 1926. The sequence of classification, as originally presented, consisted of a series of elliptical nebulae ranging from globular (E0) to lenticular (E7) forms, and two parallel series of unwiding spirals, normal (S) and barred (SB). The figure following the symbol E is equal to the ellipticity (a–b)/a with the decimal point omitted, a and b being respectively the major and minor axis of the galaxy.

Elliptical galaxies have been described by Hubble as highly concentrated objects with luminosity falling rapidly away from bright, semistellar nuclei to undefined boundaries; small patches of obscuring material are occasionally silhouetted against the luminous background, but otherwise these nebulae present no structural details.

No elliptical galaxies are known that are flatter than E7; galaxies which are flatter invariably show an outer region of low surface brightness which resembles a thin fundamental plane.

The transition from E7 to Sa appeared very abrupt. With accumulating data, and especially with the increasing number of good photographs taken with the 100-inch Mount Wilson reflector, numerous systems have been recognized as soon as 1936 by Hubble which are later (flatter) than E7, but which show no spiral structure. These galaxies fill the gap between E7 and Sa and are called S0 or SB0 (Sandage, 1975).

The S0 class has been described for the first time in 1961 by Sandage. S0 galaxies appear to form a transition between the E galaxies and the true spirals; the transition from E to S0 is smooth and continuous. The division between E and S0 is made on the basis of the presence or absence of an outer amorphous envelope or thin fundamental plane surrounding the nuclear regions. Some S0 galaxies exhibit a structureless envelope similar to that of the normal S0's, but a sharp, narrow absorption lane is found within the lens; the lane is in an arc concentric with the nucleus. These galaxies are called $S0_3$.

A more quantitative way to separate E from S0 has emerged from the study of the light distribution in galaxies. De Vaucouleurs (1959) has pointed out that elliptical galaxies have a single-component surface brightness distribution which follows closely the de Vaucouleurs relation:

$$\log I(r) \propto r^{1/4}$$

(r is the distance from the centre of the galaxy) while the surface brightness distribution for spirals and S0 galaxies show two main components: an inner spheroidal component which follows the de Vaucouleurs law, and an outer exponential component (disk) with:

$$I(r) = I(o) \times e^{-\alpha r}$$

This result has been confirmed since by a number of more recent works (see for instance: Freeman, 1970; Kormendy, 1977 a, b and c).

However, the classification of most galaxies has been made by visual inspection of photographic plates rather than by measurement of the brightness distribution leading to some misclassification especially when the galaxy contains dust.

Dust was clearly visible on a photograph of NGC 1316 taken in 1943 by Paraskevopoulos; but it was mistaken as plate defects by Shapley who could not believe that an elliptical galaxy could contain dust (Hodge, 1975). Probably because of the presence of this dust, NGC 1316 was called Sa pec by Sandage and Tammann (1981); however, Schweizer (1980) has shown that it is a typical Morgan D-type galaxy with an elliptical-like spheroid embedded in an extensive envelope.

In the course of a survey of bright southern galaxies, a pair of abnormal objects have been observed by de Vaucouleurs (1953) which shared most of the characteristic peculiarities of the bright radio galaxy NGC 5128 (Centaurus A), i.e. radio emissivity and dust; these galaxies are NGC 1316 (Fornax A) and NGC 1947, to which de Vaucouleurs added a northern galaxy, NGC 2537; however, at the time, radio positions were not accurately measured; the errors were of the order of 1°, and only NGC 1316 has been confirmed as a radio source; moreover, NGC 2537 is an Sc galaxy and of no interest here. NGC 1947 is indeed an early-type galaxy ($S0_3$ pec), but not a radio source (Möllenhoff, 1982).

Shobbrook (1963) has discovered a dust lane in the elliptical galaxy NGC 4696 and used it as an argument for the identification of this galaxy with a radio source now known as PKS 1245–41; this identification has since been confirmed.

Westerlund and Smith (1966) have identified the early-type galaxy NGC 612 with the radiosource PKS 0131–36 and noted the presence of a dust lane. The identification has been confirmed by Bolton et al. (1965).

In the meantime, it was shown that powerful extragalactic radio sources were always associated with elliptical galaxies rather than with spiral or S0 galaxies (Matthews et al., 1964), and therefore two ideas emerged: that elliptical galaxies could contain dust and that dusty ellipticals are more often radio sources than galaxies without dust.

Dust is now known to be frequent in E and S0 galaxies (see for instance Hawarden et al., 1981, and Ebneter et al., 1988); moreover, a number of early-type galaxies have been detected at 100 μm by the **I**nfra-**R**ed **A**stronomical **S**atellite (IRAS) (Neugebauer et al., 1984), and this far-infrared emission is attributed to thermal emission by cold dust (Jura, 1986).

We have made a study of a complete volume limited sample of 78 early-type galaxies, looking for the presence of dust in order to check if there is any correlation between the presence of dust and that of radio or far-infrared emission.

The Observations

The revised Shapley-Ames Catalogue (Sandage and Tammann, 1981) contains 47 ellipticals and 29 S0 galaxies at declination $\delta < +20°$, with

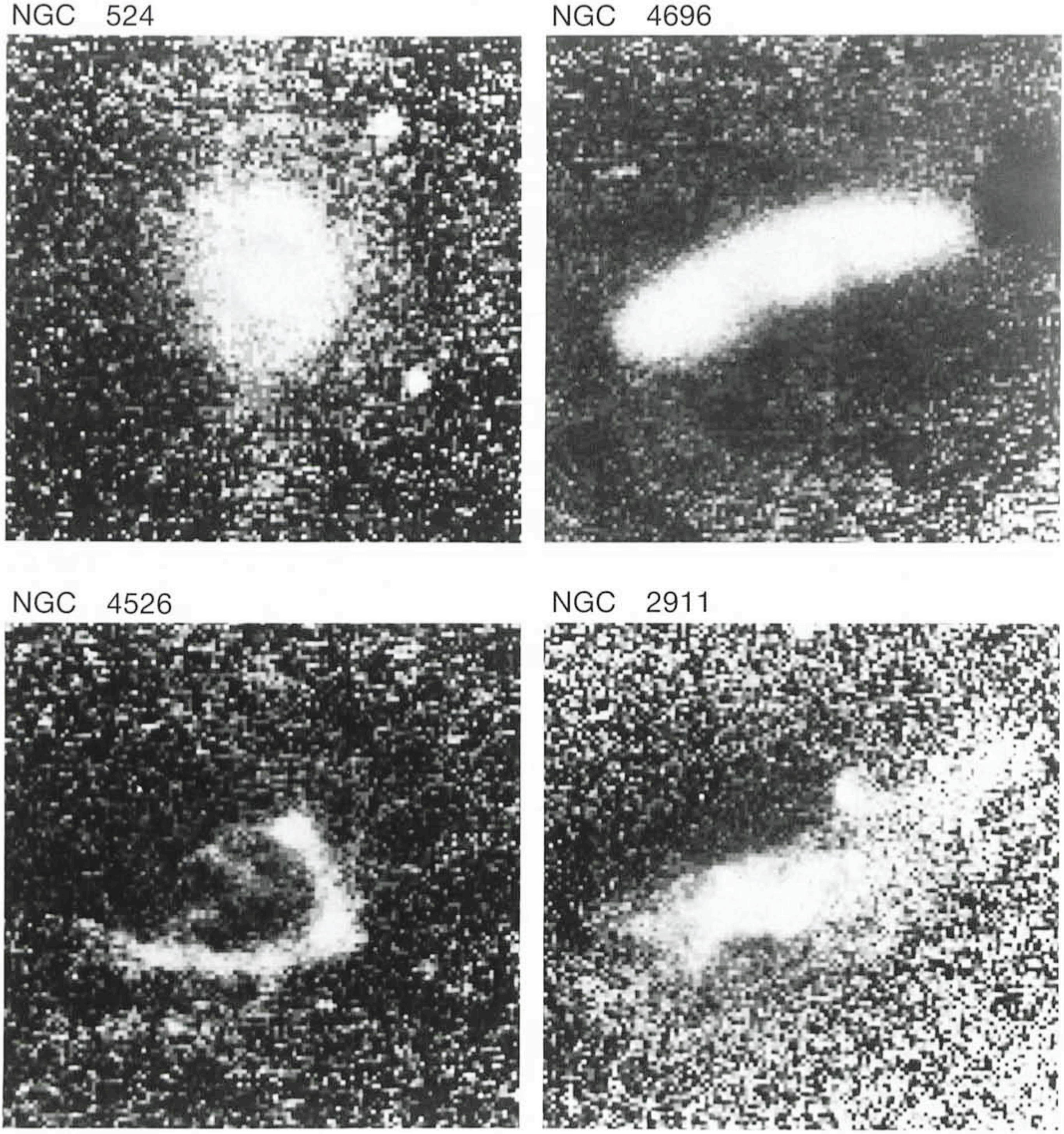

Figure 1. *This figure shows the ratio of the B to the z images for four of the galaxies with obvious dust clouds. Red, i.e. dust, shows up in white. In NGC 524, the dust appears to form an almost face-on disk; in NGC 4526, the dust is a very regular disk or torus seen almost edge-on; in NGC 4696, there is a thin filament of dust first discovered by Shobbrook in 1963; while in NGC 2911, the dust is in a very irregular cloud.*

a galactocentric radial velocity $V_o < 3{,}000$ km s^{-1} and a blue total absolute magnitude $M_B < -21$. If the RSA catalogue was complete to $m_{pg} = 12.9$, this would constitute a volume limited sample; however, according to Sandage and Tammann, at $m_{pg} = 12.9$, the completeness of the RSA catalogue is only 28%. Two other galaxies, NGC 1316 and 7213, classified as Sa by Sandage and Tammann, have been added to the sample; as we have seen above, NGC 1316 is a Morgan D-type galaxy while, according to Phillips (1979), NGC 7213 is a pole-on S0.

In the course of four observing runs at La Silla (October 1984, February and June 1985 and September 1987), we observed 69 of the galaxies with the 2.2-m telescope. For each galaxy, we have obtained two ten-minute direct images through a Johnson B and a Gunn z filter (Schneider et al., 1983) with a thin, back-illuminated RCA CCD having 512×320 30μm pixels. The scale of these images is 0."36/pixel.

In addition, on January 24, 1988, one of the sample galaxies, NGC 2911, was observed with EFOSC (Dekker et al., 1988) at the Cassegrain focus of the 3.6-m telescope. The detector was a thin back-illuminated RCA 15×15μm pixel CCD used in the 2×2 binned mode; the effective scale corresponds to 0."675 per 30μm pixel. The exposure time was 6 minutes with each of the B and z filters.

In the near-infrared, fringes on the RCA CCD chip are very prominent; to remove them, we have obtained flat-fields during each observing run, by taking three sky images in a field almost void of stars, the telescope being moved by a few arcseconds after each exposure; comparison of the three exposures (with the routine FCOMPARE of IHAP) allows the removal of the stars and results in a flat-field which removes almost perfectly the fringes.

The sky level, estimated from the corners of each frame, was removed from each image and then, for each galaxy, we have divided the B by the z frame.

The presence of dust was detected by visual inspection of these images in 16 galaxies (four examples are given in Fig. 1) to which one can add NGC 1316, 5018 and 5128 for which we have no observations, but which are well known to contain dust.

Elliptical and S0 Galaxies

Of the 19 galaxies with dust, 6 are ellipticals, 12 S0 and one Sa (according to Sandage and Tammann, 1981), suggesting that dust is more frequent in S0 than in E galaxies (there are 47 E's and 29 S0's in the complete sample). However, as we have seen above, galaxies may have been misclassified and, more specifically, E galaxies with dust may have been called S0, just because for a long time it was believed that there is no dust in ellipticals. For instance, Sandage and Tammann have classified NGC 6868 as an E3/$S0_2$ and NGC 7196 as an E3/$S0_3$, suggesting that they are elliptical with dust.

A careful study of NGC 5266, classified as an $S0_3$ pec by Sandage and Tammann, has shown that it is an E4 galaxy, without trace of disk (Varnas et al., 1987). Similarly, van den Bergh (1976) has concluded that NGC 5128 is an E0 galaxy. NGC 1316 is an Sa pec according to Sandage and Tammann (1981), however, the brightness profile established beyond doubt that it is essentially an elliptical (Schweizer, 1980).

It is therefore necessary to measure the brightness profile of all the dusty galaxies to determine without ambiguity if they have a disk or not and find out the fraction of ellipticals and S0s which contain dust.

Dust and Radio Sources

Out of the 78 galaxies studied, 17 have a 5000 MHz flux density larger than 0.1 Jy. At the level of detection, 31% (6/19) of the dusty galaxies are radio sources, while 19% (11/59) of the non dusty galaxies are radio sources. There is therefore no strong evidence in our data for early-type radio galaxies to preferentially contain dust.

Dust and Infrared Emission

Jura (1986) has found that at least a third of all early-type galaxies are detected in the far-infrared by IRAS. The infrared emission is strongest at 100 μm and quite often the far-infrared luminosity is in excess of 10^8 $L_\odot$; the infrared flux most probably results from dust reprocessing of starlight (Jura, 1982).

Of the 78 galaxies in our sample, one has no IRAS coverage (NGC 3078) and 21 have been detected in the infrared (Lonsdale et al., 1985). Among the 21 galaxies detected by IRAS, 14 contain dust visible on the direct images, while of the 19 galaxies with dust, 14 have been detected by IRAS, all at 100 μm.

In our sample of 78 galaxies, 21 have been detected in the infrared. Let us assume that there is no correlation between the presence of dust as seen on direct images and the detectability at 100 μm. We have found 19 galaxies with dust; we expect five of them to be detected at 100 μm while there are 14. The probability to find 14 or more galaxies with dust in the IRAS subsample is about 10^{-6}; this is a strong indication that the assumption that dust and infrared emission are independent is not valid and that, therefore, the infrared emission of early-type galaxies is indeed due to thermal emission by cold dust.

One of the brightest galaxies at 100 μm is NGC 7213; however, in this galaxy, the presence of dust has been suspected (Phillips, 1979) but has still to be confirmed. It is a Seyfert 1 (Filippenko and Halpern, 1984) and, in this case, the infrared emission could be related to the activity of the nucleus rather than due to cold dust. Jura et al. (1987) have detected NGC 4486 at 12, 60 and 100 μm; this infrared spectrum is rather "hot", and unlikely to be due to cold dust; it could rather be associated with the optical jet discovered by Curtis in 1918. A good photograph of this jet has been published by Nieto and Lelièvre (1982).

Conclusions

The two main conclusions we have reached are that:

1. There is no clear evidence that radio galaxies more often contain dust than radio quiet galaxies.
2. Galaxies detected at 100 μm by IRAS are those which show clear evidence for dust on direct images, indicating that the infrared emission is most probably due to thermal emission by this dust. However, galaxies with an active nucleus and showing no evidence for dust may have a detectable far-infrared flux, in which cases this infrared emission would be associated with the activity of the nucleus.

References

van den Bergh, S., 1976, *Astrophys. J.* **208,** 673.

Bolton, J.G., Clarke, M.E. and Ekers, R.D., 1965, Australian *J. Phys.***18,** 627.

Curtis, H.D., 1918, *Publ. Lick Obs.* **13.**

Dekker, H., D'Odorico, S. and Arsenault, R., 1988, *Astron. Astrophys. J.* **189,** 353.

Ebneter, K., Djorgovski, S. and Davis, M., 1988, *Astron. J.* **95, *Astron.*** 422.

Filippenko, A.V. and Halpern, J.P., 1984, *Astrophys. J.* **285,** 458.

Freeman, K.C., 1970, *Astrophys. J.* **160,** 811.

Hawarden, T.G., Elson, R.A.W., Longmore, A.J., Tritton, S.B. and Corwin, H.G., 1981, *Monthly Notices Roy. Astr. Soc.* **196,** 747.

Hodge, P.W., 1975, *Sky and Telescope* **49,** 354.

Hubble, E., 1926, *Astrophys. J.* **64,** 321.

Hubble, E., 1936, *The realm of Nebulae,* Yale University Press.

Jura, M., 1982, *Astrophys. J.* **254,** 70.

Jura, M., 1986, *Astrophys. J.* **306,** 483.

Jura, M., Kim, D.W., Knapp, G.R. and Gahathakurta, P., 1987, *Astrophys. J.* **312,** L11.

Kormendy, J., 1977a, *Astrophys. J.* **214,** 359.

Kormendy, J., 1977b, *Astrophys. J.* **217,** 406.

Kormendy, J., 1977c, *Astrophys. J.* **218,** 333.

Lonsdale, C.J., Helou, G., Good, J.C. and Rice, W. 1985, "Catalogued galaxies and quasars observed in the IRAS Survey", JPL publication D. 1932.

Matthews, T.A., Morgan, W.M. and Schmidt, M., 1964, *Astrophys. J.* **140,** 35.

Möllenhoff, C., 1982, *Astron. Astrophys.* **108,** 130.

Neugebauer, G. et al., 1984, *Astrophys. J.* **278,** L1.

Nieto, J.-L. and Lelièvre, G., 1982, *Astron. Astrophys.* **109,** 95.

Phillips, M.M., 1979, *Astrophys. J.* **227,** L121.

Sandage, A., 1961, *Hubble Atlas of galaxies,* Carnegie Institution of Washington Publication 618.

Sandage, A., 1975, in *Galaxies and the Universe,* Sandage, A., Sandage, M. and Kristian, J. eds. University of Chicago Press; p. 1.

Sandage, A. and Tammann, G.A., 1981, *A revised Shapley-Ames catalog of bright galaxies,* Carnegie Institution of Washington Publication 635.

Schneider, D.P., Gunn, J.E. and Hoessel, J.G., 1983, *Astrophys. J.* **264,** 337.

Schweizer, F., 1980, *Astrophys. J.* **237,** 303.

Shobbrook, R.R., 1963, *The Observatory,* **83,** 36.

Varnas, S.R., Bertola, F., Galletta, G., Freeman, K.C. and Carter, D., 1987, *Astrophys. J.* **313,** 69.

de Vaucouleurs, G., 1953, *The Observatory,***73,** 252.

de Vaucouleurs, G., 1959, *Handbuch der Physik* **53,** 311.

de Vaucouleurs, G., 1987, IAU Symp. 127, p. 3.

Westerlund, B.E. and Smith, L.F., 1964, *Australian J. Phys..* **17,** 340.

Long-Term Walraven Photometry of Cataclysmic Variables

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During the last seven years we have been observing cataclysmic variables (CV's) with the Walraven photometer behind the 90-cm Dutch telescope at La Silla. An advantage of this photometric system for strongly variable blue sources is that it allows simultaneous detection in five passbands, extending from the optical (5400 Å) to the ultraviolet (3200 Å). We have observed these CV's by monitoring them for several hours, and reduced the measurements differentially with respect to nearby comparison stars.

Results obtained so far include measurements of changes in the rotation periods of accreting white dwarfs in CV's, quite strong upper limits to secular changes in optical brightness of dwarf novae (DN) between outbursts, and the recognition that accretion instabilities similar to DN outbursts also occur in systems not classified as such.

Introduction

Cataclysmic variables are close binary stars consisting of a white dwarf and a low-mass ($< 1\ M_\odot$) near-main-sequence companion. This "secondary" star fills its so-called Roche lobe, i.e. the critical equipotential surface, outside which matter is no longer bound to the star (see Fig. 1). At the point on the line through the two stellar centres, where the Roche lobes of the secondary and the white dwarf touch each other, matter from the secondary can easily fall into the gravitational potential well of the white dwarf.

Such matter, flowing from the secondary star, has angular momentum with respect to the white dwarf, due to the orbital revolution of the binary. It will therefore settle into a more or less Keplerian orbit around the white dwarf. It is generally believed that viscous processes give rise to exchange of angular momentum, by which an initially formed ring spreads and forms a flat disk-like configuration, the accretion disk, around the white dwarf. Matter transferred from the secundary gradually spirals inward along quasi-Keplerian orbits. During this diffusion of the particles, the other half is radiated away.

This radiation from the accretion disk generally dominates the optical and UV luminosity of cataclysmic variables. The kinetic energy of the inflowing material is eventually dissipated close to the white dwarf surface, e.g. in a transition region from the accretion disk to the white dwarf surface.

Based on observational characteristics, cataclysmic variables have been divided into several groups. During our observing project, we have paid most of our attention to the following types of cataclysmic variables:

Dwarf Novae

In the dwarf-nova systems the accretion rate onto the white dwarf changes in a spasmodic way. Long time intervalls of the order of months of a low accretion rate (and therefore luminosity) are interrupted by outbursts, lasting for a few days to about two weeks, during which the accretion rate increases by a large factor (see Fig. 2).

Intermediate Polars

In these cataclysmic variables the white dwarf has a magnetic field that is strong enough to dominate the motion of the inflowing matter within a certain distance from its centre. Within this "magnetospheric radius" the matter is channeled onto regions near the magnetic poles of the white dwarf. Inside this magnetosphere an accuration disk cannot exist; what fraction of the accretion disk remains depends on the size of the magnetosphere, relative to that of the Roche lobe around the white dwarf.

Brightness Variations

Most cataclysmic variables with an accretion disk show brightness variations with the orbital period, which are

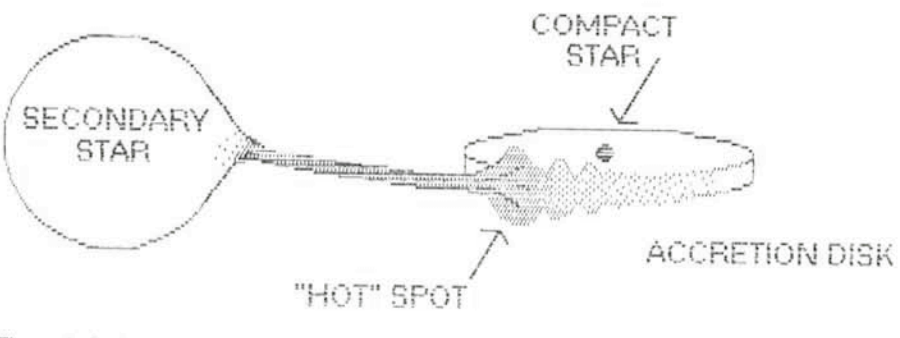

Figure 1: *A sketch of the structure of a cataclysmic binary. Matter from the secondary falls into the potential well of the white dwarf and hits the accretion disk at the bright or "hot" spot.*