cannot exclude that boxy E's just represent extreme examples of enivronmental evolution at early phases of galaxy formation. The physical state of the hot interstellar medium, which is present in many of these objects, is certainly of importance for the understanding of formation and present-day evolution of boxy ellipticals.

In summary, the isophotal shape analysis offers a new methodology/tool for a complete revision of the classification of early-type galaxies and our understanding of the underlying formation mechanisms/conditions, provided it is applied to a significant and statistically meaningful sample of objects (in the same way the Hubble classification scheme was applied before). This revision obviously requires a huge research project.

Our key-programme is an attempt to collect all the observational and theoretical expertise to coordinate the efforts toward an effective solution of the problem outlined above. As a first step of the project, we aim to investigate the occurrence of faint stellar disks in E galaxies, their properties, origin, significance, and relation to their analogues in S0's. Surface photometry will be supplemented by kinematical analyses in order to investigate the kinematical behaviour of the spheroids and the distribution of their specific angular momentum. Narrow-band images will be used to study the properties of the interstellar medium and relate the gas properties to the other galaxian parameters (shape of potential, X-ray emission, etc.).

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PROFILE OF A KEY PROGRAMME

Gravitational Lensing

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Prior to Professor van der Laan's enquiry, in the March 1988 issue of the *Messenger,* on the general interest among astronomers from the European community to possibly participate in Key Programmes (KPs) at the European Southern Observatory, at least three distinct groups (including more than half of the above authors) were already involved in the study of "gravitational lensing" effects (see box on pages 10–11). Observations were being performed with the help of various telescopes on La Silla as well as at other observatories (VLA, CFHT, Palomar, Kitt Peak, etc.).

A general feeling existed that our individual work was progressing very slowly, the number of effective nights that were allocated to our programmes being modest, also very much dependent on unknown weather and/or seeing conditions, on possible instrument failures as well as on the sometimes unpredictable decisions of the programme committees. We all knew that there was a total absence of coordination between our independent programmes and that, of course, we could not avoid duplicating observations of similar objects. Furthermore, each or our teams was hoping very much to broaden its observational interests: those studying "highly luminous quasars" wished to look also at distant "radio galaxies", and vice-versa, but this would remain a mere dream until . . . it became really possible for our present team to submit an ESO Key Programme entitled "Gravitational lensing: quasars and radio galaxies". We do feel very fortunate to-day since our programme has been generously allocated 54 nights with the ESO 3.6-m and/or NTT telescopes, 48 with the ESO/MPI 2.2-m telescope and 9 effective nights with the 1.5-m Danish telescope during the next three years, starting effectively during period 43 (April 1–October 1, 1989). We should like to describe briefly hereafter the main goals of our programme and say a few words about the different instruments and techniques that we intend to use.

The Importance of Gravitational Lensing Effects

Following the discovery of the first example of a multiply lensed quasar (Walsh et al., 1979), there has been increasing evidence that gravitational lensing perturbs, to a significant extent, our view of the distant Universe (see Nottale, 1988 for a review on the subject). Gravitational mirages are indeed being identified among QSOs, especially among highly luminous quasars (Surdej et al., 1987, 1988a–c; Magain et al., 1988; Meylan and Djorgovski, 1989), among distant 3C and 4C radio galaxies (Le Fevre et al., 1987, 1988a–b; Hammer et al., 1987; etc.) and as giant luminous arcs lensed by individual foreground galaxies and/or their associated cluster(s) (Soucail et al., 1987a–b, 1988; Lynds and Petrosian, 1986, 1988; Hammer et al., 1988).

Highly significant statistical effects of "gravitational amplification" have also been reported for various samples of extragalactic objects. For instance, the case of anomalous quintets – as well as other tight groups – of galaxies has been accounted for by the lensing of quartet haloes on background galaxies (Hammer and Nottale, 1986a). Good evidence for gravitational amplification by intervening matter (stars, galaxies, clusters, etc.) has been set forward for the Brightest Cluster Galaxies (Hammer and Nottale, 1986b), for quasars with the richest absorption line spectra (Nottale, 1987) and for a selected sample of flat-radio spectrum quasars (Fugmann, 1988). Furthermore, it has been suggested that the variability of some eruptive quasars such as 0846+513, 3C446, etc., is a direct consequence of gravitational lensing by stars or compact objects located in galaxy haloes (Nottale, 1986). These so-called "micro-lensing" effects had been predicted by Chang and Refsdal (1979, 1984). Finally, speculations have been made that the second observed rise in the comoving density of quasars from $z \approx 2.45$ up to at least $z = 3.8$ (Véron, 1986) could be due to statistical gravitational lensing effects by foreground objects near the lines-of-sight.

A Quest for New Observations

The answer to the question "what fraction of extragalactic objects are gravitationally lensed?" is very closely related to that of "how do the visible and dark matter distributions look at different scales in the Universe?". It turns out that any prediction made for the expected number of gravitationally lensed quasars, radio galaxies, etc. is bound to be very model dependent. We conclude that it is essential to carry out a systematic observational search and study of gravitational lensing effects in order to better understand the luminosity function of quasars, distant radio galaxies, etc., their observed number counts, their apparent cosmic evolution and the basic physical mechanism(s) powering these energetic objects. The proposed observations will also allow us to determine the Hubble parameter (Refsdal, 1964, 1966; Borgeest and Refsdal, 1984; Gorenstein et al., 1988) as well as galaxy masses (Borgeest, 1986) on account of the expected time delay between the brightness variations of multiply lensed QSO images. More generally, we shall obtain information on the distribution of luminous and dark matter at various scales in the Universe. Furthermore, information on the size and structure of quasars should be derived from the observation of micro-lensing effects (Grieger et al., 1986, 1988).

Our Choice of Gravitational Lens Candidates

We do consider that the apparently ($m_v < 18.5$) and intrinsically ($M_v < -29$) highly luminous quasars (hereafter HLQs) as well as the distant ($z > 1$) powerful ($P(178\,MHz) > 10^{28}$ W/Hz) radio sources (hereafter DPRSs) constitute the best extragalactic candidates to search for the presence of gravitationally lensed images at arcsec./sub-arcsec. angular scale resolutions and/or for a brightness amplification due to an excess of foreground objects (galaxies, clusters) in the vicinity of the relevant targets. The technical arguments leading to this assumption may be found in Surdej et al. (1988c). High angular resolution imaging of selected HLQs and DPRSs with the ESO/MPI 2.2-m telescope (plus direct CCD camera/DISCO or digital speckle camera) under optimal seeing conditions (FWHM < 1".2) is likely to give important clues on our understanding of lensing effects by galaxies, clusters and/or any other class of unknown massive objects. Recent systematic searches for lensed QSO images with the 2.2-m telescope have already led to the discovery of three new cases of multiply lensed HLQs: ESO GL1 = UM 673 (Fig. 2a), ESO GL2 = H1413+117 (Fig. 2b) and ESO GL3 = UM425 (Fig. 2c). Similarly, several multiple DPRSs have been identified among the distant 3C radio sources at Mauna Kea using the CFH telescope; strong arguments supporting the mirage hypothesis have been obtained for one of them: 3C324 (Le Fevre et al., 1987). Of special interest is that a detailed comparison between CCD frames obtained for a sample of 30 distant 3C radio sources with $z > 1$ and randomly selected fields indicates a significant excess of bright foreground galaxies and Abell/Zwicky clusters near the 3C sources (Le Fevre and Hammer, 1989). It seems that gravitational amplification by foreground galaxies and rich clusters is at least partly responsible for the observed radio and optical luminosities of the bright 3C sources.

Further Proposed Observations

We intend to monitor under very good seeing conditions (FWHM < 1".2) the three ESO gravitational lens systems mentioned above plus the Einstein cross 2237+031 (Huchra et al., 1985). UM 673 (cf. Fig. 2a) constitutes our best candidate to attempt an independent determination of the Hubble constant H_o, and hence to set an upper limit to the age of the Universe, while 2237+031 appears to be the most ideal object for detection of micro-lensing effects. It will be imperative to monitor each of the four proposed targets about once a week with the ESO 3.5-m NTT and/or ESO/MPI 2.2-m and/or 1.5-m Danish telescopes through a B filter. We wish to thank in advance, for their comprehension, all observers at La Silla with whom we shall routinely share observing nights during some 90 minutes.

Furthermore, because one expects most of the multiply lensed QSO images to have angular separations of less than 0".5 (e.g. Turner et al., 1984), we wish to image approximately 50 HLQs with speckle masking. We recall that speckle masking is an interferometric imaging method that yields diffraction limited images with 0".05 resolution in spite of image degradation by the atmosphere

Figure 1a: *Sunset from La Silla (16 November 1988).*

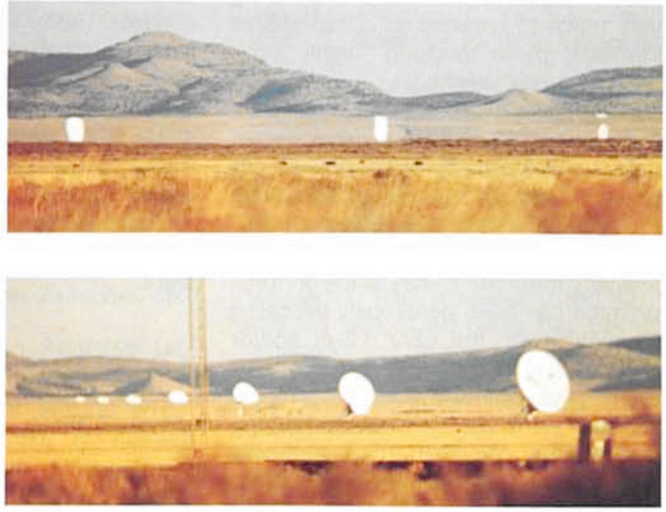

Figure 1b: *Two different views of the VLA as seen in the early morning of 17 January 1989 (Socorro, New Mexico).*

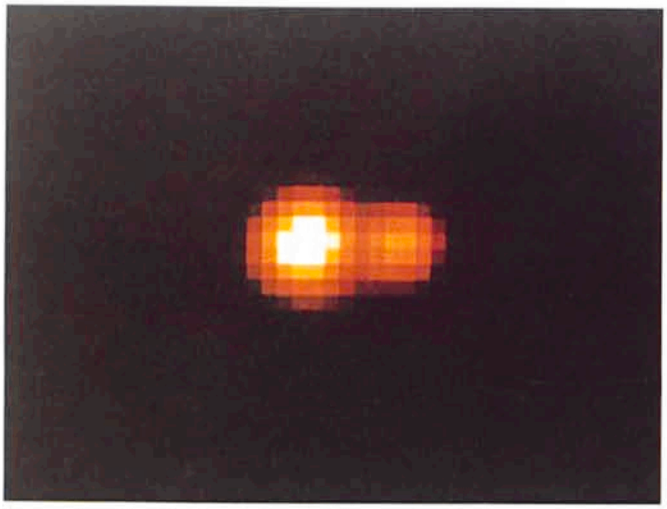

Figure 2a: *The double quasar ESO GL 1 = UM 673* (Nature **329** *695).*

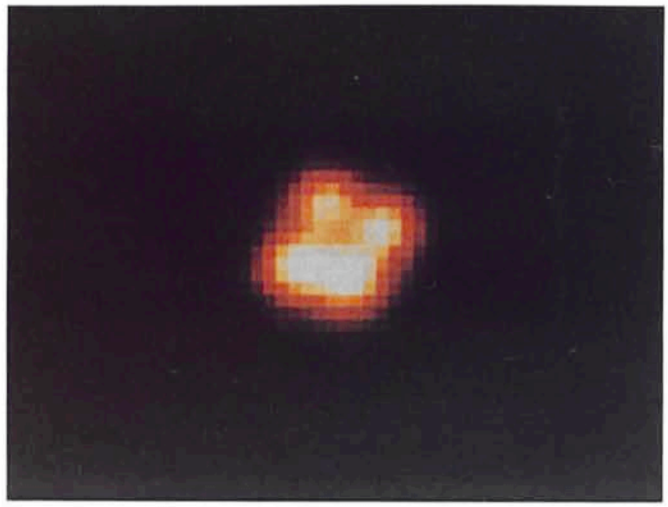

Figure 2b: *The Clover-leaf ESO GL 2 = H1413+117* (Nature, **334,** *325).*

Gravitational fields in the Universe may act on light rays emitted by distant sources in a way very similar to the refraction properties of our atmosphere, or to the way lower air layers act on objects located near the horizon (cf. the Sun in Fig. 1a or the Very Large Array or car lights at night in Figs. 1b–c).

Fig. 1d gives a schematic representation of the light ray paths when the ground turns out to be somewhat hotter than the ambient air (cf. around noon on a sunny day). Because the refraction always bends light rays towards regions of colder air, a second lower, inverted and somewhat deformed–image of the source (a palm-tree in this case) may result. Such a multiplication, deformation and also amplification of different source images are readily seen in Figs. 1a–c.

Since the total solar eclipse of 1919, when astronomers observed for the first time an apparent displacement in the positions of stars near the limb of the Sun, it was recognized that light beams can be bent, not only in air layers having different densities or in optical systems, but also in gravitational fields. As a matter of fact, this effect was predicted by Einstein within his General Theory of Relativity. Bending of light is also observed when the light from a distant quasar,

and by telescope aberrations (Weigelt and Wirnitzer, 1983).

In addition, since gravitational amplification of a compact or extended source by large-scale foreground inhomogeneities (cf. rich galaxy clusters, etc.) may very well occur without multiplication of images, a detailed comparison of the count number of field objects (galaxies, clusters) will be made between the R CCD frames taken for the HLQs, the DPRSs and randomly selected fields. This unprecedented statistical study combined with the observed frequency of detecting multiply lensed images versus their angular separation should enable us to quantify the importance of lensing effects as a whole.

We also plan of course to perform detailed photometric and spectroscopic studies of the immediate surroundings and projected intergalactic medium near known, suspected and expected new ESO gravitational lens systems.

Acknowledgements

Our recognition naturally goes to Prof. van der Laan for having promoted so convincingly the idea of the ESO Key Programmes in the European community. Our thanks are also due to the Observing Programmes Committee and to the external referees for their patient (and somewhat hidden) work. We specially thank Jacques Breysacher and Christa Euler, for gently orchestrating the non trivial task of scheduling all our

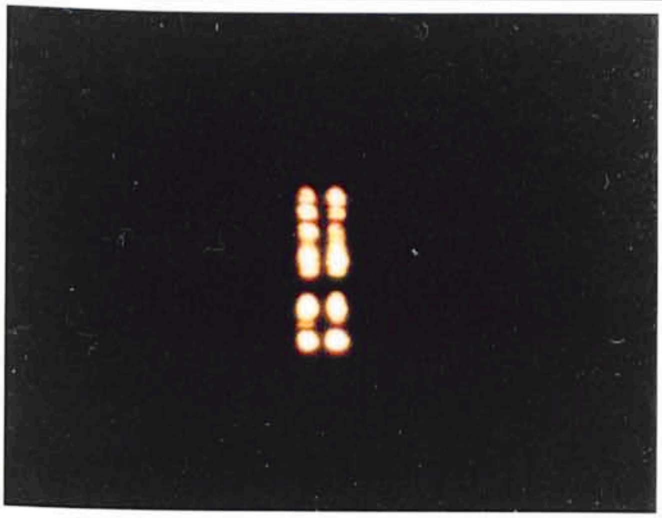

Figure 1c: *Lights from a distant car on the national road between Magdalena and Datil (New Mexico, 16 January 1989).*

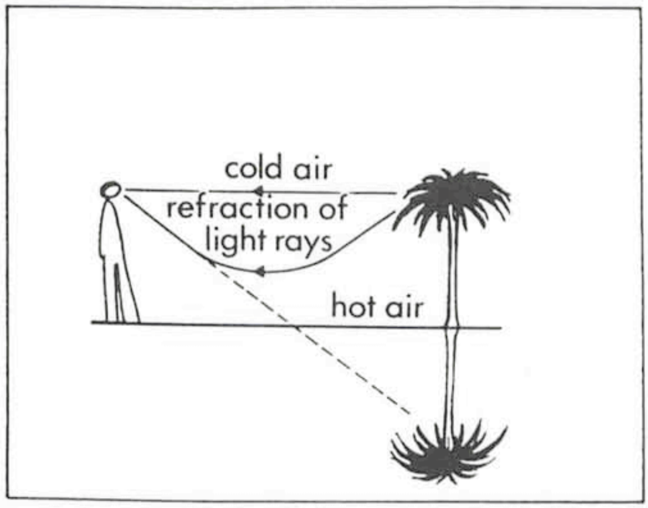

Figure 1d: *Explanatory diagram: formation of terrestrial mirages.*

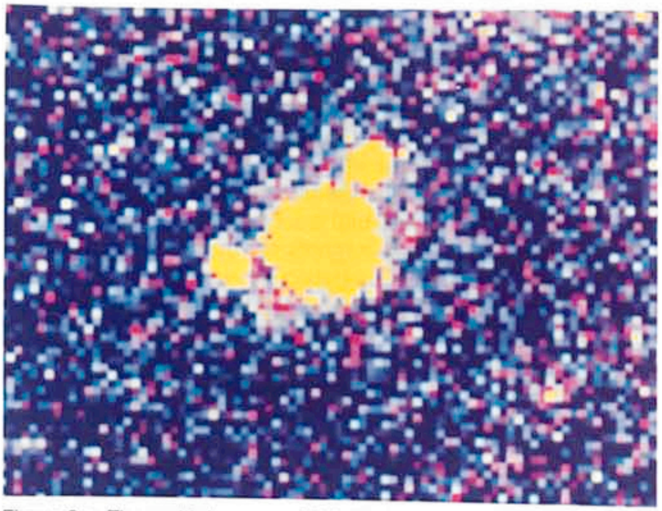

Figure 2c: *The multiple quasar ESO GL 3 = UM 425* (Ap. J. *Letters, in press).*

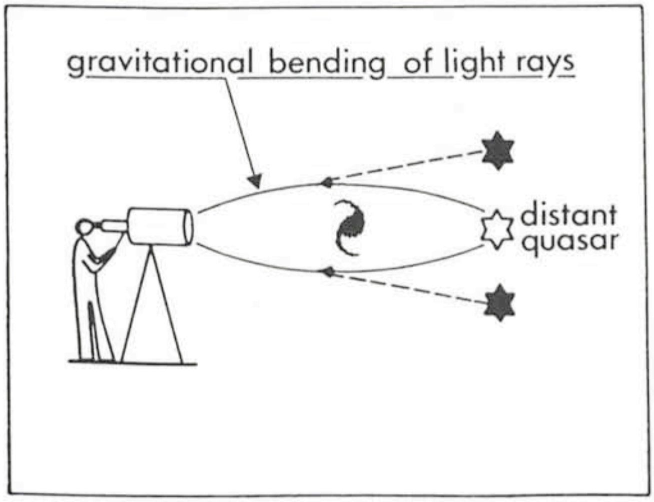

Figure 2d: *Explanatory diagram: formation of gravitational mirages.*

galaxy or any other astronomical source passes close by one or more massive objects on its way to us. Such objects may be individual galaxies (cf. Fig. 2d), clusters of galaxies or even larger structures in the Universe. This effect is referred to as the so-called "gravitational lensing". Depending on the intensity and form of the gravitational field, the light from the quasar may not only be bent into multiple images, but some of these images may become brighter than the quasar itself would have appeared in the absence of the gravitational lens (cf. Figs. 2a–c). This is referred to as "light amplification". Due to the amplification effect, we may be able to observe gravitationally lensed images of very distant quasars, galaxies, etc. which would otherwise have been too faint to be detected with present telescopes. Gravitational lenses may therefore act as giant telescopes, allowing us to investigate otherwise inaccessible, very remote regions of the Universe. It is partly in order to evaluate the extent to which our view of the distant Universe corresponds to a still unveiled mirage, and not to the real Universe, that we have proposed to perform the studies summarized in the present article.

requested observations.

Finally, we apologize for not having quoted in this short note the works of all scientists having contributed to the progress of our knowledge in the field of gravitational lensing; they are simply just too numerous!

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The New Research Student Programme of the European Southern Observatory

H. VAN DER LAAN, Director General, ESO

For many years ESO has appointed young astronomers as Fellows to work one to two years at Headquarters or on La Silla. The HQ Fellows spend the greater part of their efforts on personal research, the Fellows on La Silla split their time roughly 50/50 between their research and support astronomy duties. The ESO Fellowship programme has successfully contributed to the development of young scientists from member states into mature research astronomers. It has also promoted the interaction among investigators from many places and traditions, interactions that continue long after the collaborators have left their ESO posts. This postdoctoral Fellowship programme continues undiminished.

Henceforth ESO is also offering Studentships, about 8 appointments per year, equally shared between Garching and La Silla. This article introduces this new predoctoral Studentship Programme.

Selection and Studentship Conditions

ESO aims at having sixteen such graduate students in the Organization's establishments at any time. The programme will be semi-annually announced in the *Messenger* and by the circulation of announcements in member states' institutes. Applicants have to make use of a form designed for the purpose and available upon request from Personnel and General Services at Headquarters. Deadlines for application will be May 1st and December 1st. Appointments can commence throughout the year.

Students whose duty station is the Garching Headquarters, will be required to spend at most 25% of their official working time on duties in support of Visiting Astronomers (users of measuring machines, of computers with the IHAP and MIDAS data reduction systems, and astronomers using the Remote Control Observing Facilities). Students on La Silla will normally be part of the team in the La Silla astronomy department that provides introductions and observational support to Visiting Astronomers. Typically, half their official working time will be occupied by these duties.

Students are appointed for one year, normally renewable by a second, final year. During their studentship term, they may have diverse forms of support from their home institution. ESO will supplement these to a maximum, total stipend of DM 2200/month during the first year.

For many years young astronomers and engineers from France, called coopérants, have worked on La Silla in national service, which is an alternative to military duty. More recently Belgium and Italy also offer such "coopérant" programmes. Henceforth ESO will require coopérants, whether at HQ or on La Silla, to meet at least the same requirements as candidates for studentships. Coopérants are normally preselected by national selection committees and then proposed to ESO. Some coopérants already have a doctor's degree and are then regarded as Fellows. Where they are selected by studentship criteria the coopérants will henceforth be counted as part of the contingent of 16 students.

Selection Criteria – Necessary Conditions

- Candidates must be registered postgraduate students at a recognized university in an ESO member state.
- Candidates must have at least an outline of their Ph.D. dissertation programme and a professor who accepts responsibility for that programme and the student's supervision.
- The candidate must have fulfilled the normal course- and examination requirements for the Ph.D., except the dissertation research.
- The candidate's programme must be such that it can be successfully pursued at ESO HQ or on La Silla, because of its affinity with work going on there and facilities available for the student.
- The candidate's university must guarantee the conditions necessary for the student to complete her/his dissertation after the tenure of the ESO Studentship.
- An ESO staff member must be prepared to be the student's local supervisor and mentor, notwithstanding the continuing responsibility of the student's university supervisor.

From this list it should be obvious that ESO in no way seeks to play the role of a degree-granting institution. The programme means to provide opportunities, circumstances and facilities which enhance the participating universities' postgraduate programmes and enrich selected students' early research experience. The conditions listed above are necessary. From among applicants potentially capable of meeting them, ESO will select those whose talents and circumstances are best attuned to the programme's goals.

Groups Where Research Students May Work

There is a brochure in preparation, available in a few months, which will describe the programme in some detail.