ded we can calibrate the conversion of L_{1300} and L_{CO} into gas mass, both methods give the same result and should therefore be quite accurate. Second, the fundamental quantities R, β and κ – or at least their product times the Planck function – do not vary much from one galaxy to another. The last point becomes even more interesting when we realize that κ_{1300} is probably more or less constant because of the common origin of dust (old stars, supernovae) and the insensitivity to grain size at this wavelength.

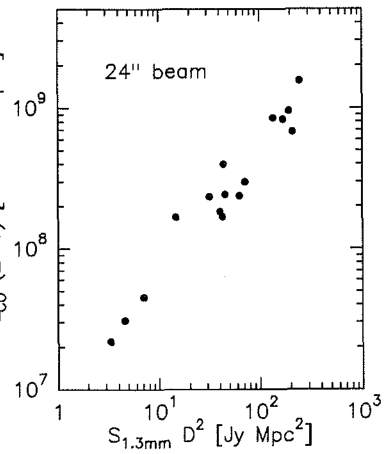

Figure 1: *The CO (2–1) luminosity L_{CO} vs. the luminosity at 1300µm L_{1300} for a sample of non-active spirals observed at SEST.*

8.2 The Stage of Activity – In Fig.2 we summarize the results concerning the ratio L_{IR}/M_{gas} for three classes of objects. We see that the luminosity itself is not an indicator of activity. For example, at luminosities from 10^{11} to $10^{12} L_\odot$, an extragalactic object may be a normal or an active galaxy or even a quasar. Put differently, out of a given gas mass one can produce significantly diverging luminosities. It is the efficiency of converting gas into luminosity, i.e. the quantity L_{IR}/M_{gas}, that determines the level of activity. Non-active galaxies are characterized by rather low values, of order 5. Active galaxies produce 20 times more luminosity out of the same reservoir of gas. The various L/M ratios reflect the vehemence of this process, extending from quiet star formation in galactic discs over explosive star bursts in galactic nuclei to quasars at the upper end of this sequence.

The high ratio L_{IR}/M_{gas} in Mkn galaxies may be explained within the framework of star formation by a combination of two effects. Either the star formation rate is enhanced compared to normal galaxies, i.e. more gas is transformed annually into stars (in the Milky Way $5 M_\odot yr^{-1}$), or the initial mass function (IMF) is biased towards massive stars of high luminosity. (The IMF describes the relation between the number of stars formed simultaneously in a certain volume and their mass.)

Undoubtedly, the star formation rate is high in active galaxies. To produce a steady luminosity of $10^{10} L_\odot$ with a normal IMF, one needs to convert $1 M_\odot$ of gas per year into stars. Therefore, activity has to end after at most 10^8 years

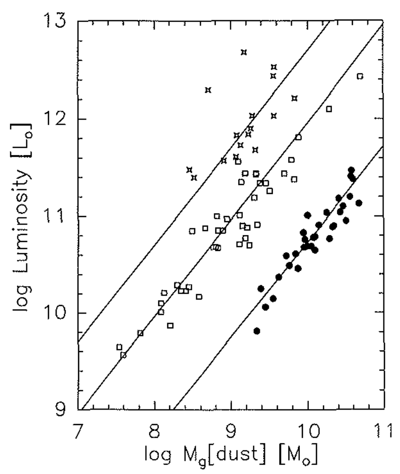

Figure 2: *IR luminosity L_{IR} vs. the gas mass M_{gas} for non-active spirals (•), active Mkn galaxies □ and radio-quiet quasars (⋆). The straight lines represent the loci of equal L_{IR}/M_{gas} with average values of 5 (normal), 100 (active) and 550 (QSO), in solar units.*

when all gas has been used up. It is a time limited phenomenon that occurs once or repeatedly in the nuclei of normal galaxies.

Most of their lifetime galaxies are located in the "non-active strip" of Fig.2, while occasionally they are excited to activity. The question arises what causes the transition from the quiet to the active phase. It has become clear that interaction and merging of galaxies and the subsequent transfer of gas into the nucleus plays an important role. The precise triggering mechanism is still debated. Our model computations show that under most conditions a gas-rich nucleus is intrinsically unstable towards star formation and a series of bursts (not just one) seems inevitable (Tutukov & Krügel 1995). They are based on the idea that the gas in the nucleus is supported against collapse by turbulent motions. As the turbulent energy is dissipated, the gas contracts and above some critical gas density star formation occurs. The following supernova explosions can replenish the turbulent energy so that the gas expands again. This cycle is repeated. If, for some reason, the turbulent energy of the gas is not sufficiently replenished by supernova explosions, gravity will pull the gas inwards and a catastrophic collapse towards a supermassive object ensues. This idea links star formation in galactic nuclei to quasars.

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Discovery of the first extra-galactic SiO maser, and the quest for more

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Red Supergiants (RSG) and stars at the tip of the Asymptotic Giant Branch (AGB) experience phases of heavy mass loss, which can reach values as high as $10^{-4} M_\odot$/yr. The physical conditions in the cool and dense circumstellar envelope (CE) allow dust to form: these stars may even be the main contributors of dust to the interstellar medium. Radiation pressure on the dust grains combined with collisional coupling between the dust and the gas drives the expelled matter away from the star.

The inner part of the CE is free of dust. How the matter is transferred from the stellar photosphere to the dusty part of the CE is not understood. The inner CE of cool evolved stars can best be studied through molecular lines. The most often used lines are the 43 GHz and 86 GHz masing transitions of SiO: SiO is highly depleted in the dusty regions but abundant closer to the star. From the observed SiO maser emission one can in principle derive the (variable) velocity structure of the inner CE.

Until recently, SiO maser emission had only been observed from stars in the Milky Way. Here we report the first extra-galactic detection: this opens the way to study the influence of metallicity on the structure of the inner CE.

In May 1995, new, more sensitive receivers were installed at the 15 m Swedish-ESO Sub-millimeter Telescope (SEST) at La Silla, greatly increasing its sensitivity. Shortly after the installation, we performed a search for SiO J=2-1 v=1 maser emission at 86 GHz by pointed observations aimed at a few cool evolved stars in the LMC that were expected to be good candidates for detection. As a first result we detected SiO maser emission from the best candidate amongst them, viz. the RSG PSC04553–6825. This star has thereby become the first known extra-galactic SiO maser.

The performance of the new 3 mm SIS receiver in combination with good atmospheric conditions resulted in a system temperature at 86 GHz of $T_{sys} \sim$ 120 K for elevations above 40°, and about 150 K at an elevation of 20°. After an on-source integration time of nearly 10 hours, corresponding to a total observing time of 26 hours we reached noise level of 63 mJy. We detected a feature at the expected wavelength, with a peak flux of 280 mJy. The line was resolved in velocity: the integrated emission profile reached a significance of 7 sigma (Fig. 1).

The SiO maser emission intensity from PSC04553–6825 is compatible with the observed ranges in SiO maser emission intensities from Milky Way RSGs. Compared to these, the total photon flux (assuming spherical symetry) is low but not extremely so. Some stellar properties (notably the long pulsation period of 930 days and the large volume of the inner CE) of PSC04553–6825 led to the expectation that the SiO maser in PSC04553–6825 could be as bright as the most luminous SiO masers in the Milky Way, but other stellar properties (a low pulsation amplitude) are more compatible with the observed moderate total photon flux emitted by the SiO maser in PSC04553–6825. From our first observations of a very limited sample of stars with one detection, and considering that SiO maser emission is known to be highly variable in both intensity and velocity line profile, we cannot conclude whether SiO maser emission from cool evolved stars in the LMC is different from that from similar Milky Way stars. A systematic difference would not be unexpected given the low metallicity of the LMC.

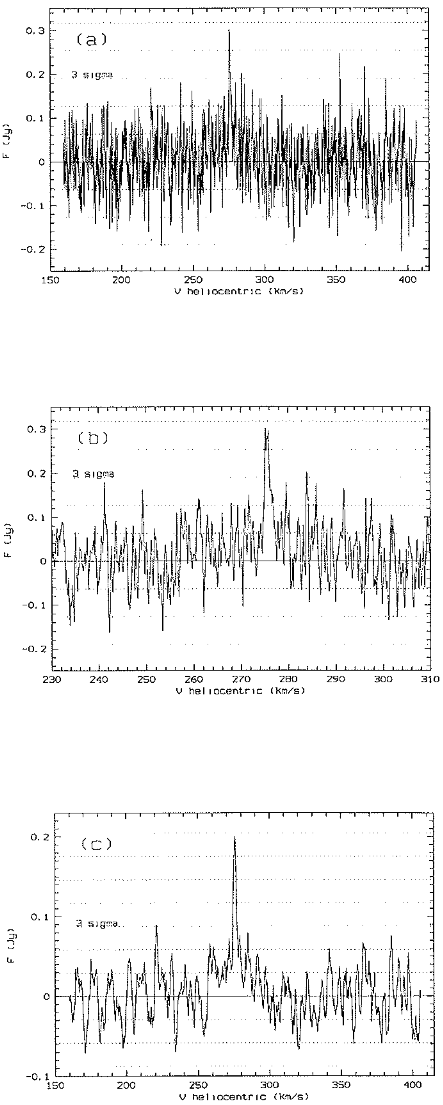

Figure 1: *(a) High resolution (HRS) spectrum around the* $SiO(2\text{-}1)_{v=1}$ *maser emission from PSC04553–6825. The velocities are heliocentric, and horizontal dotted lines are given per 1 σ (1 σ = 63 mJy). (b) Expanded section of the original HRS spectrum around the maser peak. (c) The HRS spectrum smoothed by averaging over 15 channels (=2.25 km s*$^{-1}$*). Now 1 σ = 29 mJy.*

Now that the observational capabilities have improved so much, we can raise the question whether it has become feasible to perform a comparison study of the SiO maser properties of cool evolved stars in and out of the Milky Way. It is clear that such a study would have to be limited to the nearby dwarf companions of the Milky Way. The brightest SiO maser emitters are the RSGs, and amongst the dwarf companions they are only present in the Magellanic Clouds. There are more than a dozen RSGs known in the LMC, which means that it is in principle possible to do a comparison of the SiO maser emission from those LMC RSGs and Milky Way RSGs. Taking the SiO maser emission from PSC04553–6825 as typical for LMC RSGs would mean that with a dozen stars and a full day of observing time per star it is possible to do a survey of SiO maser emission from cool evolved stars in the LMC that is sufficiently sensitive that non-detections bear flux upper limits that are lower than the average flux levels of detected Milky Way RSGs. This type of investigation will take on the order of two weeks observing time.

Extending such a study to AGB stars is more difficult. Average levels of detection for Milky Way AGB stars are such that we would expect to detect only the brightest SiO maser emitters amongst them at the distance of the Magellanic Clouds. Although such detections would yield important data for the study of individual stars, it would be difficult to use the non-detections for a comparison study.

In the near(?) future the study of the SiO maser emission from extra-galactic AGB stars could become easier. With the advent of millimeter arrays in the beginning of the next century the contrast between point source and sky will improve considerably, as well as the collecting area of the telescope. This will certainly yield a major breakthrough in the search for SiO masers in the Magellanic Clouds and perhaps some of the other dwarf companions of the Milky Way as well. It will then become possible to perform a statistical study of the properties of the SiO masers under different environmental conditions, to determine the metallicity dependence of the processes that take place in the inner CEs of cool evolved stars.

Another possibility would be to use the SiO J=1-0 v=1 maser line at 43 GHz which can be stronger by a factor of a few (sometimes even more than an order of magnitude) compared to the 86 GHz maser line. The relative strength of the 43 Ghz versus the 86 GHz line depends on the mass-loss rate and is an important additional parameter. At the moment. In the southern hemisphere only Parkes offers an (old) 43 GHz receiver. If such a receiver were available on the SEST, of comparable quality to the presently available receivers, together with the very good quality of the mirror shape and the La Silla site it would improve the SEST further as a unique facility for extra-galactic SiO maser research.