Chapter 7

Summary and Outlook

7.1 Summary

This thesis presents first 1.2 mm continuum survey in the Magellanic Clouds. The observations were performed with SIMBA at the SEST, which is currently the only submillimeter telescope in the Southern Hemisphere. The MCs have been observed at four ESO and two Swedish observing runs, totaling about 160 h of integration time on MC sources. The data reduction of the 1.2 mm measurements was performed by using the MOPSIS software package. This study comprises star forming regions with CO detections extracted from Israel et al. (1993) and Johansson et al. (1998), respectively, the first and the seventh part of the ESO-SEST Key Programme: CO in the Magellanic Clouds.

Johansson et al. (1998) mapped the central part of the 30 Doradus nebula and the southern HII regions N 158C, N 159 and N 160. From their 50 CO sources, 38 have been investigated for dust continuum emission. For 20 of them one or more positive detections have been obtained totaling 21 observed dust sources.

Israel et al. (1993) observed CO towards 92 positions in the LMC and 42 in the SMC. In the LMC, four of the brightest sources from those not located in the 30 Dor complex were selected. In the N 44 (two positions), N 113 and N 214 nebulae, a total of 12 dust sources have been revealed.

In the SMC, the observations coordinates were based on Israel et al. (1993) and oriented towards selected regions located in the SW Bar, in the northern Bar and in the Shapley Wing. The spatial distribution of the star forming regions was chosen in order to get an idea of the cool dust across this dwarf galaxy. From the eight studied star formation sites four presented dust detections. Three of them are located in the SW part of the Bar, while further out of this part of the optical bar only one HII region with dust detection was found (N 88). As expected, the two brightest CO sources included in this study (N 12, N 27) have associated dust sources.

In the SMC seven dust sources have been obtained, distributed through four mosaics. Together with the ones shown in the eight mosaics of the LMC, the survey resulted in a total number of 40 (sub)millimeter sources for the two galaxies. All of them are new detections. The SMC sources have on average smaller sizes than those of the LMC.
Comparing the 1.2 mm integrated fluxes of the LMC sources with those of the SMC sources, it is clear that the former are, on the average, considerably higher. This result is expected as the SMC has a lower metallicity and a higher radiation field.

From the detected dust sources several properties were obtained. As at 100 μm and 1.2 mm the grains are in thermal equilibrium with the interstellar radiation field these wavelengths, which were respectively taken with IRAS and SIMBA, were combined to find the dust temperature. The 1.2 mm emission might be not entirely due to thermal dust emission, with the possibility that synchrotron and/or free-free emission make up a non-negligible contribution. By taking radio fluxes into consideration, the synchrotron emission contribution always showed up to be negligible unlike the contribution of the free-free emission. The inferred temperatures for the different regions range from 17 ± 1 K to 24 ± 5 K in the LMC and 17 ± 1 K to 20 ± 2 K in the SMC, with an average value of about 21 K and 18 K, respectively, in the LMC and in the SMC. The derived dust masses range from 50 ± 26 M⊙ to 3700 ± 1800 M⊙ in the LMC and from 42 ± 9 M⊙ to 350 ± 80 M⊙ in the SMC.

The virial theorem was used to obtain the gas mass from the associated CO detections. In some of the sources the dust and CO cloud sizes are different. In the two cases of the highest calculated gas-to-dust mass ratio R in the LMC the gas to dust cloud size ratio is also highest. The calculated and the estimated R values show a high dispersion through the individual regions in the LMC as well as in the SMC. The variations in the ratio R show a east-west asymmetry in the 30 Dor central complex, a north-south asymmetry in the 30 Dor southern HII regions, a bimodal behavior in the N 44 complex and a correlation with the cloud size in the N 113 and N 214 regions. In the SMC, the two mapped intense and compact HII regions located in the SW Bar have similar R values, while the other areas show different molecular gas-to-dust ratios.

The IRAS 12, 25 and 60 μm data were used together with IRAS 100 μm and SIMBA 1.2 mm to obtain the FIR luminosity. The ratio L_{FIR}/M_g is defined in this work as star formation efficiency. The 30 Dor A region has the highest average star formation efficiency among the investigated areas in the MCs with the individual sources indicating a moderate (10 L⊙/M⊙ ≤ SFE < 20 L⊙/M⊙) to powerful starburst (SFE ≥ 20 L⊙/M⊙), another evidence that it is a site of ongoing massive star formation. In the 30 Dor B region as well as in the southern HII regions (N 158, N 159 and N 160) several sources are present with SFEs that suggest a moderate starburst. Unlike the LMC, all regions studied in the SMC show low SFEs (SFE < 4 L⊙/M⊙). This result is in agreement with other studies for the SMC.

7.2 Outlook

It is desirable to enlarge the present data set, as the observations were only carried out for selected star forming regions in the LMC and in the SMC. So, the analysis presented in this work can be considered as a basis for further investigations in the (sub)millimeter wavelength range, in these two dwarf irregular galaxies.

As the SEST has been closed, research using SIMBA is no longer possible. Therefore, the MCs survey with this instrument is considered completed. Further research will be possible in the near future with APEX (Atacama Pathfinder EXperiment) and, later on, with ALMA
CHAPTER 7. SUMMARY AND OUTLOOK

(Atacama Large Millimeter Array). APEX is a submillimeter telescope with a diameter of 12 m. In international collaboration, the MPIfR (Max-Planck-Institut für Radioastronomie in Bonn, Germany), the AIRUB (Astronomisches Institut der Ruhr-Universität Bochum, Germany), the ESO (European Southern Observatory) and the OSO (Onsala Space Observatory, Sweden) have started this project. APEX, as implied in the name, will serve as a pathfinder for ALMA, finding target sources for the future interferometer array. On APEX will be installed a new bolometer array (LABOCA: LArge BOlometer CAmera) with 313 channels for 870 μm wavelength, which is being built through a Bonn/Bochum/Jena collaboration. As this new bolometer will have a larger field of view than SIMBA and also a higher spatial resolution, the observing efficiency will be increased. The idea is in the future implement APEX in the ALMA array. Both APEX and ALMA will be built at the best suited site for submillimeter observations, on the Chajnantor Plateau in the Chilean Andes at an altitude of 5000 m, because of its location in the dry Atacama desert and because of its high altitude. APEX operations are expected to start this year. ALMA will be an array comprising 64 (sub)millimeter antennas, each with a diameter like the APEX, with baselines extending up to 10 km. Its receivers will cover the range from 70 to 900 GHz. ALMA will be the largest ground-based astronomy project in the current decade, coming into operation by the end of it. It will only be comparable to the VLA (Very Large Array), which is used at radio wavelengths, offering an incredible increase in spatial resolution if compared with the SEXT.

So subsequent studies will improve the understanding of how the local ambient conditions influence the dust clouds, the molecular gas-to-dust ratio and the star formation efficiency. The systematical survey in the LMC and the SMC will provide a good statistical knowledge between the several local parameters and the properties of the dust clouds. A better determined gas-to-dust ratio $R$ for the MCs will help to better establish the distance of galaxies at high redshifts.