The opacity of spiral galaxy disks.
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Synthetic Dust Models

The dust dimming used in the synthetic fields in this thesis assume a grey uniform screen. The numbers of distant galaxies in any given field can then be modelled as:

\[ A = -2.5C \log \left( \frac{N}{N_0} \right) \]  
(C.1)

in which C and \( N_0 \) depend on field characteristics, not on the properties of the dust screen. This was the approach of González et al. (1998) and since they could not find much difference in using as Galactic Extinction Law or a completely grey one, the grey extinction law was used from the outset in this thesis. However, the lack of an inclination dependence and the constant colour of the background galaxies indicated that the dust was distributed in clumps.

To model the disk of a foreground galaxy, this is a very simplistic approach but a uniform screen and a field of opaque clumps have the same average effect on background light. This is the limiting case in Natta and Panagia (1984) for a clumpy distribution and the average optical depth of the field is then:

\[ \tau = -\ln(1 - f) \]  
(C.2)

in which \( f \) is the filling factor of the clouds in the field. The filling factor is the sum of the cross sections of the clouds in the field, or the product of their number and their average cross-section:

\[ f = \frac{\Sigma_i a_i}{\Omega} = \frac{N \times \bar{a}}{\Omega} \]  
(C.3)

where \( \Omega \) is the solid angle for which the average extinction is made.

It is immediately obvious that for a given filling factor, one could be looking at a range of possibilities for the number of clouds and their average cross section. As long as their effect on the numbers of distant galaxies stays the same as the uniform grey screen. To test this assumption, simulations can be made using some distribution of dark clouds equivalent
in average opacity as the grey screen used so far. In fact the grey screen itself is an extreme of this model: there are very many clouds but their cross-sections are much smaller than the pixelsize in the field.

There is one problem with combining the counts of many fields of different galaxies. The apparent cloud sizes in these disk may vary strongly due to different distances. Therefore the best field to test the effects of clumpy dust is an uniform one of a single galaxy.

Figure C.2 shows the profiles of synthetic fields of NGC1365 made with different cloud cross sections. Of course there is a distribution of cloud sizes but from equation C.2, one can approximate the effect by using N clouds of the average size. Cloud cross-section radii of 0.5, 1, 2, 25 and 100 pixels are used.

In Figures C.1 and C.2 the relation between average opacity of the fields and the number of synthetic galaxies identified changes with the cloud size used in the clumpy simulations. The simulations using a cloud size of 0.5 or 1 pixel mimic the uniform screen well. However, larger clouds of dust display a much shallower relation between number of synthetic galaxies and opacity.

At the distance of NGC 1365, the example data in the above plots, the linear scale of a pixel in the disk is about 4 pc. (D = 17.95 Mpc., pixelscale = 0′′05). From observations of our own Galaxy, we know that this is a reasonable cloud size.

The discrepancy between cloud size models can be interpreted in two ways. Either the dust is indeed predominantly clumped in very small clouds. In this case the assumption of a smooth screen in the construction of the synthetic fields is fine. Or one assumes that large cloud complexes are predominantly filling the image and opacity values are grossly underestimated by the number of galaxies or there is a structural discrepancy between the counts in the science fields and the synthetic fields.

However, the opacities from counts of distant galaxies correspond very well to the values found with the occulting galaxy method. This does point to a clumpy distribution of small clouds as the predominant culprit for the opacity of the spiral disk.

Much more realistic clumpy simulations can of course be made using a certain dust cloud size distribution and not one single cloud size. This can more easily be done for a single disk at one fixed distance, not a composite of several disk at varying distances. For now, the smooth screen is a good model for the effects of the dust clouds on the numbers of distant galaxies.
Figure C.1: The fits to the number of synthetic distant galaxies from simulations using different cloud sizes and a smooth screen (points). These are the simulations for NGC 1365, the Wide Field no. 2 chip. The simulations using very small clouds (0.5 and 1 pixel radii) are very similar to the smooth screen while the bigger cloud screens show much more shallow relation between number of galaxies and average opacity.
Figure C.2: Same as in Figure C.1 but for the Wide Field no. 3 chip. The same effect is present under different crowding conditions.