

ASTRONOMY

Software Cloud Counting (SWCC) in NGC 224 Distance Estimation, I

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Abstract. About 41770 dark clouds were identified through a C++ program [software cloud counting, SWCC] developed to study the dust content in NGC 224 (M31). The clouds were sorted out according to their opacities and then their areas. An old procedure developed by Issa [1,2] was used to study the apparent radius distribution function of dark clouds. The distance of NGC 224 deduced from this method is 0.685 Mpc.

Introduction

A method to estimate dust content by counting dark clouds in galaxies was developed by Issa [1,2]. As a side product of this method, the size distribution function of dark clouds (DC) was used to have an estimate of the distances of galaxies. The method was applied later on H II-Regions (H II) [2,3] and on globular clusters [4]. Table 1 contain the distances of some galaxies obtained by this method. For the sake of comparison the last two columns give the distances (in Mpc.) of these galaxies, mostly on the long distance scale (LS) taken from the reference cited in the last column.

Method

Earlier Issa [1,5] measured visually (Eye + magnifier + reseau) areas of dark clouds in some galaxies to have an estimate of the dust content in galaxies. This proce

Table 1. NGC numbers for some galaxies using dark clouds

NGC	DC	H II	LS	LS
224*	0.73	0.76	0.71	4
253	2.06		3.4	10
300		2.67	3.3	11
598		0.755	0.85	12; pp.153
2404		2.02	3.25	8
2841	8.07		11.5	4
5194	9.92		9.72	4
SMC		0.089		4
LMC		0.043		4

ture was subjected to some uncertainties. In the present work a C++ program (Software Cloud Counting, SWCC,) was developed to distinguish dark clouds according to the 256 gray levels. These 256 gray levels were first averaged into seven gray levels. Level 0 corresponds to bright regions (galactic core, H II- regions or globular clusters etc..). Level I corresponds to least opaque clouds; level II corresponds to the next opaque clouds; and level VII is the darkest clouds (or background starless sky). This is similar to the 6-opacity classes introduced visually by Lynds [6]. The galaxy image of NGC 224 taken from Hubble Atlas [7; pp. 18-19], photographed with the 48"-Schmidt telescope (enlargement 2.5 with a scale print of 25.7 arc sec/mm). Using a transparency adapter (ENV 24 Pro) the galactic image was scanned with a resolution of 450 dpi. Taking above factors into account, it was found that

$$n(R) = n_0 e^{-KR} \quad (2)$$

The program was written in such a way that the darkening of a certain cloud is to be compared with the 7-averaged gray levels for opacity determination and then to read out the number of pixels in each cloud as soon as identified. Clouds of the same opacity were given the same colour as indicated in figures 1 (a, b & c). A cloud was considered as separate if appeared alone as one pixel or as a block of pixels, or if appeared connected corner to corner or side to side. Structures in the internal areas were counted as dark clouds, although it shows the same darkening as the sky background but display structures. At this stage an idea about the procedure followed earlier, Issa [5] and references therein has to be mentioned. Dark clouds in four galaxies, nearly face on, were identified visually and measured, using a reseau (divided so as to give areas in units of 0.25 mm²) and a magnifier to count the number of the units and fractions of it were

used. Table 2 shows the results of that study.



Fig. 1a. NGC 224 as scanned in 256 gray levels.

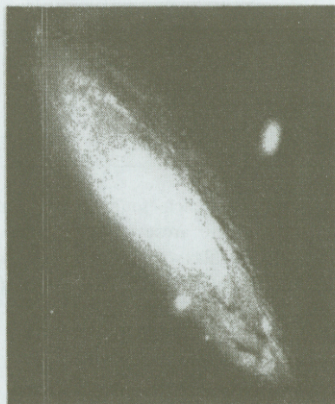


Fig. 1b. NGC 224 averaged into seven gray levels.

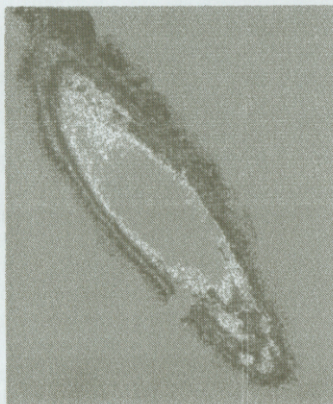


Fig. 1c. NGC 224 after painting and omitting the background.

Table 2. NGC numbers, type, magnification, etc. measured in each galaxy

NGC No.	Type	Magnification	Scale "/mm	Distance MPc	No. of DC measured
3031	Sb	3.0	3.69	2.63	298
5128	E _a p	3.5	3.16	2.71	74
5194	Sc	4.8	2.3	5.52	271
5457	Sc	2.1	0.92	2.51	258

The area of each cloud in each galaxy was measured, transformed through the plate scale into square arcseconds. Angular radii are then easy to deduce. Knowing the distance of the galaxy the linear radius of each dark cloud in each galaxy was determined. The linear radius distribution function $n(R)$ was studied for each galaxy. This resulted in four equations of the form:

$$n(R) = n_0 e^{-KR} \quad (2)$$

Where R is the linear radius of the dark cloud in parsecs, n_0 is constant depending on the galaxy and K is found to be constant (independent of the galaxy type). Its average value from the four galaxies is 0.05 pc^{-1} . Substituting for $(R = d \theta \tan 1'')$ in Eq. 2, taking logarithms and solving for the distance (d), we get Eq. 3.

$$D = - \frac{\ln[n_1(\theta_1'')/n_2(\theta_2'')]}{K(\theta_2'' - \theta_1'') \tan 1''} \quad (3)$$

Table 3 gives the number of dark clouds (n) as a function of θ in arc seconds. Counts were stopped at $\theta'' = 69.6$ because the numbers were getting small. Figure 2 shows the natural logarithm of the number of dark clouds (n) as a function of the apparent radius θ'' . The plot shows two curved parts corresponding to the smallest and largest radii and linear portion in between. For the same reasons mentioned in earlier works the numbers corresponding to small and large radii were neglected in the distance analysis but not in the dust content analysis. Relying on the linear portion of the distribution lying between $8.8 \leq \theta'' \leq 32.8$. The least square solution for 16- points containing 4029 clouds led to:

$$\ln n = - 0.166 \theta'' + 8.186 \quad (4)$$

The distance of NGC 224 (M31) deduced by this method is 0.685 MPc, which fits well in the long distance scale Sandage & Tammam of 0.679 Mpc [8]. This is an improved result of the study done by Issa [9] using as small number of H II regions to get a

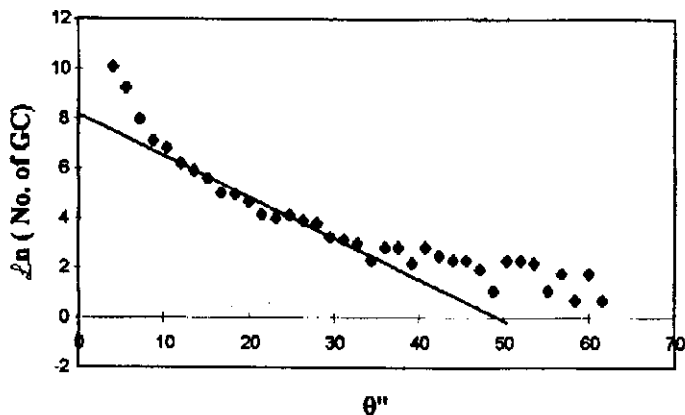


Fig. 2. The relation between the natural logarithm of the number of dark clouds and the apparent radius of the clouds.
distance of 0.44 Mpc.

Table 3. The first column shows the apparent radius (in arc seconds) of dark cloud classes and the number of clouds in each class

θ''	No.	θ''	No.	θ''	No.
4	23984	26.4	50	48.8	3
5.6	10590	28	45	50.4	10
7.2	2945	29.6	26	52	10
8.8	1219	31.2	23	53.6	9
10.4	932	32.8	20	55.2	3
12	492	34.4	10	56.8	6
13.6	369	36	17	58.4	2
15.2	263	37.6	17	60	6
16.8	152	39.2	9	61.6	2
18.4	145	40.8	17	63.2	5
20	106	42.4	12	64.8	3
21.6	64	44	10	66.4	0
23.2	55	45.6	10	68	3
24.8	63	47.2	7	69.6	1

The likely errors in this SWCC are not considered to lie in the program. The 256 gray levels in the software are wide enough to contain all the eye possibilities.

Conclusion

Using SWCC program have increased the counted numbers of dark clouds and reduced to minimum the personal errors, especially for small clouds. This can help to have an accurate estimate of the dust content in galaxies (in preparation). The distance of NGC 224 as determined in the present work and by others is 0.685Mpc. Accordingly, the method can be used to calibrate some primary and secondary distance indicators. It is less affected by absorption than photoelectric methods and no assumptions are needed apart from a universal distribution function of dark clouds.

It should be mentioned that, the present work is a preliminary trial to test this new approach of treatment, on a galaxy when distance is well known.

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عد السحب بين النجمية في مجرة المرأة المسلسلة NGC 224
بواسطة البرمجة الآلية (SWCC): (١) تقدير المسافة

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(أستلم للنشر في ١٤١٨/٦/٢٠هـ؛ وقبل للنشر في ١٤١٨/١٠/٢٠هـ)

ملخص البحث. تم التعرف على ٤١٧٧٠ سحابة بين نجمية معتمة من خلال برنامج ++C (برنامج عد السحب SWCC) لدراسة كمية الدخان (الغبار) في مجرة المرأة المسلسلة (NGC 244 (M31)). قسمت السحب بعد هذا طبقاً لعمتها ومساحتها. واستخدمت طريقة قديمة للدراسة دالة توزيع أنصاف الأقطار الظاهرية للسحب. ثم استنتجت مسافة المجرة وكانت ٦٨٥٠، ميغا بارسك، وهذه تتفق مع مسافتها التي قدرها ساندج وتامان.