A Comparisson of Distance Measurements to NGC 4258

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Abstract

The accurate measurement of extragalactic distances is a central challenge of modern astronomy, being required for any realistic description of the age, geometry and fate of the Universe. The measurement of relative extragalactic distances has become fairly routine, but estimates of absolute distances are rare.[1] In the vicinity of the Sun, direct geometric techniques for obtaining absolute distances, such as orbital parallax, are feasible, but heretofore such techniques have been diffcult to apply to other galaxies. As a result, uncertainties in the expansion rate and age of the Universe are dominated by uncertainties in the absolute calibration of the extragalactic distance ladder[2]. Here we compare previous distance measurements to the galaxy NGC 4258 from both an estimate of Hubble's constant and a direct measurement of orbital motions in a disk of gas surrounding the nucleus of this galaxy to a direct measurement using a model of constant rotational velocity and galactic spiral morphology. The results of the comparisson help validate methods of direct measurement of spiral galaxies to much greater distances.

Burbidge et al[3] and Herrstein[4] et al have both reported independant distance meaurements to NGC 4258. Burbidge reports a distance estimate of 7.8 Mpc using a Hubble constant of 75 Kps per Mpc and Herrstein reports a measurement of $7.2 \pm .3$ Mpc. which is inferred from a direct measurement of orbital motions of a disk of gas surrounding the nucleus of the galaxy. NGC 4258 is one of 22 nearby AGN known to possess nuclear water masers and Herrstein has used this property of NGC 4258 to obtain a direct measurement. We present another direct measurement of the galaxy's distance using a combination of the galaxy's rotational profile and it's spiral morphology. This method was first used by the author in making a distance measurement to NGC 3198[5]. Since we have a second independant and direct measurement to

NGC 4258, we are able to compare results and add to the verification of these methods.

Burbidge used a slit on an image at the prime focus of the 82" telescope at the McDonald Observatory of NGC 4258 in three areas of the galaxy. Spectral line displacement was measured and a rotation profile obtained. The central section of the galaxy and either ends were measured separately. The middle section appears to have a rotation profile which is linear from about 297 Kps to about 800 Kps, or from -40" to +54" seconds of arc, from the centre of the galaxy. Burbidge reports a mixture of different stellar spectra in the central region and a model of constant rotational velocity would explain this profile. The spectra of receding stars would combine with the spectra of approaching stars to create interference in measurements across the central region of the galaxy. This would result in a non-horizontal linear profile in the central region. The spectral lines on either end of the galaxy would thereby be free from the interference phenomena described as a mixture. The ends of the rotation velocity profile show a distinct constant velocity along the ends of each galactic arm. Furthermore, from examining a digital photograph of the galaxy produced by the Hubble Space Telescope it appears there is a cloud of interstellar dust in our galaxy that blocks observation of the southeast side given by the position angle of the digital photograph.

From the velocity profile we infer a rotation velocity of 241 ± 10 Kps. We feel this allows for an adequate degree of error. Using 1600 times magnification and calculating the length in pixels of clearly defined positions in the galaxy, we report a separation of $1.8 \pm .008$ minutes of arc between galactic arms across the major axis of the galaxy. This was using a digital photograph across 15 minutes of arc centred on the galaxy and having a pixel to angular displacement ratio of 0.016854. A second digital photograph was later obtained from the Hubble Space Telescope of the galaxy with slightly different pixel to angular displacement ratio, namely 0.017007, and identical results of the angular displacement between galactic arms were obtained.

Knowing the rotational velocity of the stars in the galaxy and using a model of a constant rotational velocity profile, the absolute distance between spiral arms can be calculated.

$$r = \frac{2\pi\theta}{(v/c)} \tag{1}$$

which is the equation describing a spiral in polar coordinates matching the morphology of the galaxy as described in the measurement made of NGC 3198. Here r is in light years and θ is in radians. From this we can determnine the distance to the galaxy by:

$$\Delta r = \frac{2\pi^2}{(v/c)}$$
$$d = \frac{\Delta r \times 360 \times 60}{4\pi\alpha} \qquad (2)$$

where Δr is the distance between spiral arms along the major axis of the galaxy in light years, α is the angular separation between spiral arms along the major axis of the galaxy in minutes of arc, v is the rotational velocity of stars in the galaxy, c is the speed of light and d is the distance to the galaxy in light years.

We thereby report a distance measurement of $7.16 \pm .034$ Mpc. This is well within the parameters of the distance measurement reported by Herrstein et al. and is a further validation of distance measurements using a model of a constant velocity profile with angular measurements of the spiral morphology of galaxies compared to measurements of the behaviour of nuclear water masers.

Furthermore, we note that NGC 4258 has been reported as a barred spiral from observations in the Hα wavelength in 1960. We have applied geometric transformations to the pixels of a digital photograph of NGC 4258 to view an image of the galaxy from a position directly above it. This is shown in figure 2. Here we can clearly see that there is no bar present in the galaxy and suggest new observations be made and if necessary a reclassification to a spiral, rather than barred spiral, may be in order.

Also, with the distance and rotational velocity measurements reported here and an angular size of 8.3 arc minutes, or 126,000 ly, we calculate a linear density of 8.7×10^{20} kg/m giving a mass of 1.04×10^{42} kg or 5.22×10^{11} solar masses and angular momentum of 2.5×10^{47} J-s.

Figure 1: NGC 4258. [6]

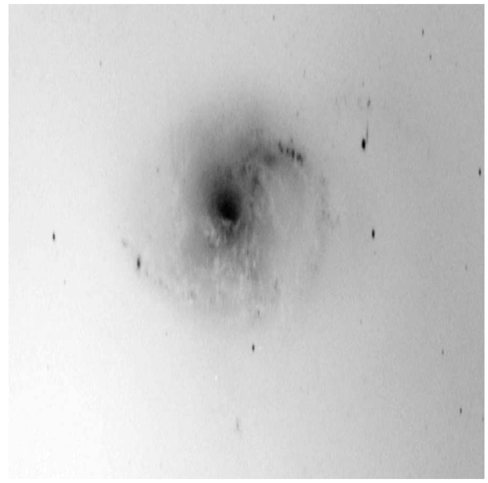

Figure 2: NGC 4258 with the positions of stars adjusted through a geometric projection algorithm in order to view the galaxy from a reference point directly above the galaxy.

References

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[4] J. R. Herrnstein, J. M. Moran, L. J. Greenhill, P. J. Diamond, M. Inoue, N. Nakai, M. Miyoshi, C. Henkel, A. Riess, *A 4% geometric distance to the galaxy NGC 4258 from orbital motions in a nuclear gas disk*, arXiv:astroph 9907013v1, Jul 1999.

[5] Rout, B., *The Spiral Structure of NGC 3198*, viXra:0909.0007, Sept, 2009.

[6] Digital Photograph courtesy Digital Sky Survey, Hubble Space Telescope.