Comparison of HST and VLA Images at 0.1" of the Orion Nebula

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Abstract. We have compared the images of two compact sources near the center of the Orion Nebula obtained with the VLA and HST. When the Hα image is scaled to the radio continuum we see similar objects. The VLA shows higher concentration of flux, reflecting the better resolution (FWHM=0.13" versus 0.18"); but, does not show the extended cometary form of the sources due to the greater sensitivity of the HST.

The Orion Nebula has been the focus of radio observations of thermal radiation since the beginning of radio astronomy. In spite of the three centuries lead, radio astronomy rapidly caught up with groundbased optical observations in terms of resolution (Yusef-Zadeh 1990) and even passed it (Churchwell et al. 1991, Garay et al. 1991). Recent Hubble Space Telescope (HST) observations (O'Dell et al. 1993b) have closed the gap in resolution. The latter observations have the added diagnostic advantage of measuring atoms over a variety of ionization states, which can be very important in complex objects such as these.

The large region surveyed at the highest resolution with the VLA overlaps with our single 160"x160" HST field and contains two bright compact radio sources common to both studies. These two objects allow comparison of images of similar resolution but derived from interferometry, in the case of VLA, and direct imaging, in the case of the HST. The VLA data has a FWHM of 0.14"x0.13" and position angle of 5 degrees. The HST images are affected by the "spherical aberration" resulting from the mirror being tested with mis-spaced test optics (Burrows et al. 1991). They were corrected by use of a standard program of the Lucy (1990) type, with the important feature that it models the point-spread-function across the face of each detector and as a function of time. The resultant images have been used to determine the point spread function from four stars. The results are very consistent and shown in Fig. 1. The FWHM is 1.8 pixels, which corresponds to 0.18" at our scale size of 0.102"/pixel.

We have compared the HST images of the two objects in common with the revised analysis of the VLA data by Felli et al.(1992). That paper indicates that the 2 cm observations were made over a period of 90 minutes and achieved an rms deviation of 0.12 mJy/beam for the nebular background. The two most useful HST images are of Hα, with a 200 second exposure and the [OIII], 500.7 nm line, with a 300 second exposure. We have chosen to scale the HST results into radio units. The two sources compared are VLA 1(HST 1) at $5^h32^m50.23^s$,$-5°25'33.7"$ and VLA 4(HST 2) at $5^h32^m49.53^s$,$-5°25'30.2"$(O'Dell et al. 1993b).

Scaling of the optical observations is a straightforward matter for the Hα emission. We have assumed that the objects are optically thin at 2 cm, which is confirmed by their radio spectra, and have calculated that the ratio of emissivities is $I_{H\alpha}/I_\nu$

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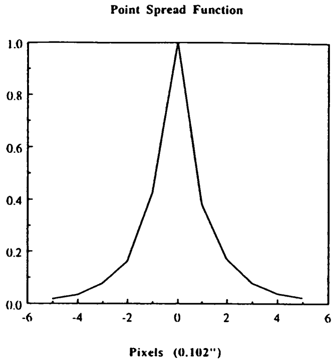

Fig. 1. The point-spread-function of the Lucy algorithim deconvolved HST images of four stars. The FWHM is 1.8 pixels (0.18").

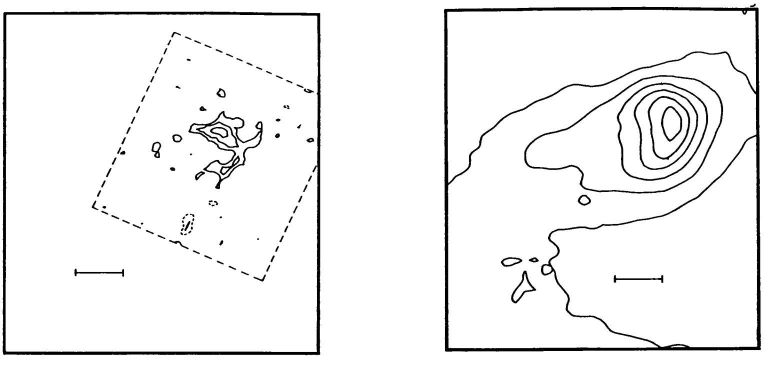

Fig. 2. Comparison of contour plots of VLA 1 (HST 1) showing positive values of the brightness in steps of 1.41 as solid lines, starting with 0.5 mJy/beam. The right hand plot gives the results of adding the Hα and [OIII] images and scaling to the central 2 cm image. The scale mark is 0.5" The straight dashed lines give the limit of the region covered by the VLA, with the nearly vertical line aligned with north.

$=1.33\text{x}10^{14}$ in cgs units, which would apply at the assumed electron temperature of 10^4 K. An uncertainty is introduced because of interstellar extinction at Hα. Extinction in Orion is quite variable and we have used the results of a recent study of the extinction (O'Dell et al. 1992) and adopted a logarithmic extinction value of $c_{H\beta} = 0.65$ for both sources. This translates to an Hα correction factor of 2.94. The resultant predicted total radio fluxes were both about a factor of two too high. This could indicate either that the extinction correction is too high, that the objects are actually optically thick (which is unlikely because of the shape of the radio spectra), or that the optical emission is enhanced by local reflection by the mechanism suggested by O'Dell et al. (1993a). Given this uncertainty, we arbitrarily scaled the predicted radio signals so that the brightest contours agreed in intensity. Before this scaling, the rms deviation of the predicted radio values of the nebular background was 0.006 mJy/beam.

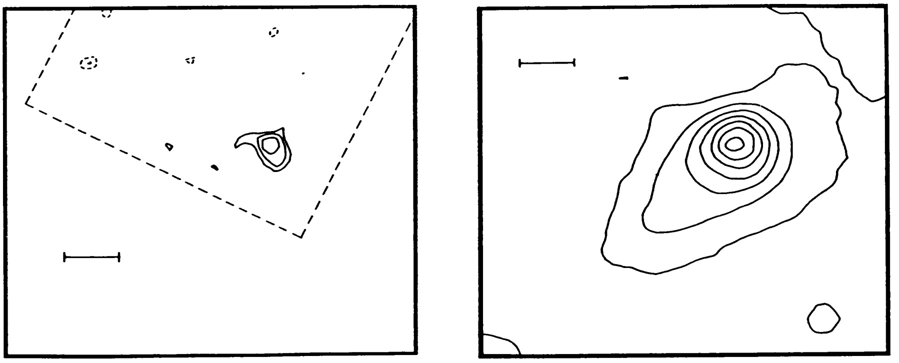

Fig. 3. Like Fig. 2 except for VLA 4 (HST 2).

Figures 2 and 3 give the results of these comparisons. The VLA images seem to show structure down to the FWHM and more concentration than the HST images. The HST images trace the objects to much greater size and reveal that they are cometary in form.

There is perhaps no surprise in these results in that the appearances only confirm the expectations of the separate, radio and optical, observers; however, this does provide a direct confirmation of the validity of the very detailed and refined image deconvolution schemes of these two approaches. From the point of view of scientists particularly interested in this type of source, we believe the edge lies with the optical approach because of the ability to easily image in atoms of varying degrees of ionization. In the study of similar objects in Orion but outside of the VLA high resolution field, we find that the apparent structure is very different in high ionization [OIII] and low ionization [NII], [OI], and [SII]. This touting of the optical approach is balanced by the note that we did not find any optical counterparts of the VLA compact sources within the field of view of the first HST observations of Orion (Hester et al. 1991), probably due to the sources suffering much higher extinction due to their lying within the Orion molecular cloud.

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