# TAURUS OBSERVATIONS OF THE EMISSION-LINE VELOCITY FIELD OF CENTAURUS A (NGC 5128)

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ABSTRACT

Using TAURUS - an Imaging Fabry Perot system in conjunction with the IPCS on the AAT, we have studied the velocity field of the Hα emission line at a spatial resolution of 1.7" over the dark lane structure of Centaurus A. The derived velocity field is quite symmetrical and strongly suggests that the emission line material is orbiting the elliptical component, as a warped disc.

## 1. OBSERVATIONS

Recently much interest and speculation has centered on the origin and dynamics of the gas and dust which constitute the dark lanes across the giant elliptical radio galaxy Centaurus A. In an attempt to clarify the nature of this structure we have used TAURUS - an imaging Fabry Perot system (Taylor 1978, Taylor and Atherton 1980, Atherton et al 1982) to study the velocity field of the Hα emission over the central 9 x 5 arc mins.

The Fabry Perot etalon was used at a finesse of 25 in the 332nd order of interference to study the Hα line, thus giving us a velocity resolution (FWHM) of 36 km $sec^{-1}$ and a Free Spectral Range of 903 km $sec^{-1}$ An integration time of 2 hours yielded approximately $3.10^3$ independent velocity determinations over the surface of the dust lane, with an internal consistency of ∿ 6 km $s^{-1}$ r.m.s. Indeed our data is in excellent agreement with Graham's spectroscopic velocity determinations. However we see not a simple ring of HII regions, as claimed by Graham (1979), but instead a very symmetrical S-shaped envelope of emitting regions, similar in shape to the picture developed by Tubbs (1980) from theoretical considerations. Our spatial coverage agrees well with the map of HII regions derived by Dufour et al (1979) from UBV photometry, giving the velocity of almost all the region presented by them, and also showing the presence of an underlying diffuse component.



*E. Athanassoula (ed.), Internal Kinematics and Dynamics of Galaxies, 331–334.*

Perhaps the most striking characteristic of the velocity field of the excited gas is its symmetry about the centre of the underlying elliptical component. The velocities of the warped regions in the NW and SE are farily constant, consistent with material rotating differentially about the centre of the elliptical component. Across the centre of the object the velocity field shows a steep gradient, probably induced by the deep potential well of the elliptical, consistent with a highly inclined rotating gaseous disc. The central hole in the observed Hα emission prevents measurement of this gradient in the innermost regions and the steepest measured gradient is 170 km sec$^{-1}$ kpc$^{-1}$ at a radius of 0.5 kpc (D = 5 Mpc), which leads to a Keplerian estimate of $10^{10}$ $M_\odot$ inside 1 kpc.

## 2. KINEMATIC MODELS

We have approached the problem of interpreting this wealth of kinematic data by attempting to fit simple geometrical models suggested by the appearance of the isovelocity contours, shown on an unsharp-masked print of Cen A (courtesy of David Malin, AAO), in Figure 1.

By deprojecting an expanding/rotating circular anullus of varying radius onto the data we are able to identify the centre of rotation of the system to an accuracy of < 2 arcsec which coincides to within measurements error with the position of the radio point source, IR and X-ray nucleus. Furthermore the derived heliocentric systemic velocity of 544 ± 4 km s$^{-1}$ is in excellent agreement with Graham's value. Most striking is the azimuthal continuity of the velocity data for each annulus indicating that despite the ∿ 70° orientation (β) of the rotation axis with the line of site, we are seeing emission material at the far side of the disc. Using however the orientation parameters used by

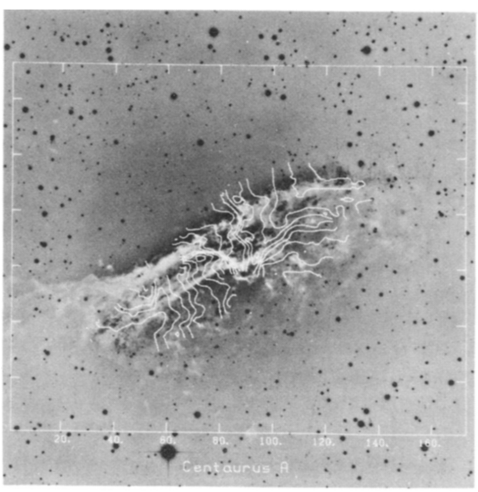


Figure 1. 25km/s isovelocity contours beginning at 330km/s (SE)

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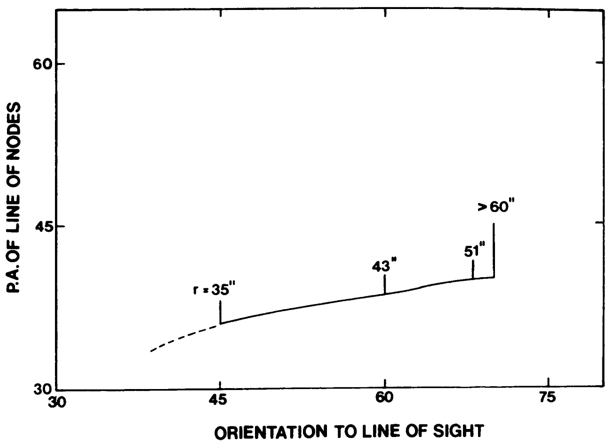


Figure 2. Trend of orientation parameters with radius

Graham (1979) we consistently obtain a significantly non-zero expansion component to the kinematic model, indicating either strong non-circular motions or an incorrect value for the PA of the line of nodes ($\alpha$).

Prompted by a change in the apparent expansion term with radius we attempted to optimise the two orientation parameters $\alpha$, & $\beta$ at each radius for a model which allowed for no expansion term. The results are uncertain for radii < 30 arcsec but outside this we were able to see a clear change of orientation of the disc with radius. This result is depicted in Fig. 2 from which it can be seen that despite the visible appearance of the dust lane, the warp of the disc is most prominent in the orientation parameter, $\beta$.

## 3. THE KINEMATIC WARP

The slight change in P.A. of the line of nodes is in the wrong sense to account for the warped appearance of the outer dust lane in Cen A, and we take this as evidence that the appearance of a warp is a result of viewing a spiral disc-like geometry nearly edge-on, so that the trailing arms seen to wrap around the elliptical component of Cen A. However the main change is seen in $\beta$ which indicates that the tumbling of the elliptical component seen in the absorption lines along its major axis is duplicated in the inner dust lane.

Independent of these considerations however is our result that the predominant value of $\alpha$, the kinematic P.A. of the line of node is 130° ± 2° contrary to the visible dust lane which lies at 120°. This difference is reinforced by the fact that the inner radio lobes, the inner optical filaments and the diffuse X-ray structure all are orthogonal to the kinematic $\alpha$ rather than the angle of the visible dust lane. Of course the X-ray jet is even further from the visible dust lane orien-

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tation (i.e. orthogonal to 143°). This suggests that all but the most recent activity represents ejection along the rotation axis of the inner disc, a view which may include the ejection of the X-ray jet if we assume a gradual precession of the disc.

The reason for the descrepancy between the kinematic $\alpha$ and that implied from the visible appearance of the dust lane may have to do with the possibility that the disc is not uniformly populated with gas but posesses a spiral-type geometry suggested also by the apparent warping of its outer contours.

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DISCUSSION

SCHWEIZER : I would like to point out that three models have recently been proposed for NGC 5128, each involving a slightly different mechanism. The first and best known model is by Tubbs (Astrophys. J. 241, 969, 1980), who modeled the aftereffects of the infall of a small gas-rich galaxy into NGC 5128 by studying the behaviour of an inclined disk of non-interacting test particles in a fixed, prolate potential. Differential precession at various radii leads to a strongly distorted disk that can be made to resemble the observed gas-dust disk of NGC 5128. However, in a detailed comparison with all existing observations, G. Simonson (Ph.D. thesis, Yale Univ. 1982) has shown that the Tubbs model errs on which is the "upper" side of the disk that we see, and that it cannot be made to agree with the observations. (We see the south pole of the disk in NGC 5128). He improved on the Tubbs model by introducing cloud-cloud collisions in the model disk, which lead to "viscous" damping and a flat central disk that grows outward as time elapses. He places the transition region between this damped central part and the still precessing outer parts at about r = 4 kpc, where Graham observed a ring of HII regions. Simonson's model reproduces many observations in considerable detail. Finally, a third and very different model has been proposed by van Albada, Kotanyi, and Schwarzschild (Monthly Notices R. Astron. Soc. 198, 303, 1982), who studied the equilibrium deformation of a gaseous disk in the potential of a slowly tumbling triaxial galaxy. However, unpublished measurements of the rotation of the NGC 5128 spheroid by Danziger and collaborators suggest rotation in the sense opposite from that required by the model. If confirmed, these measurements would seem to rule out any steady-state model as an explanation for the observed disk warp. The beautiful new observations presented here by M. Marcelin and K. Taylor ought to be compared with the Simonson model, which for the moment seems to be the most detailed and promising for NGC 5128.