on the way in which the rotation curve behaves at large distances from the centre while the mass distribution with radius near the centre depends on the detailed behaviour of the rotation curve. Consequently both these quantities are poorly known for the galaxy.

The Andromeda Nebula is important because it resembles our galaxy, because it subtends a large angle in the sky, and because radial distances can easily be measured. M31 has been studied using optical techniques and the 21 cm line. For such a distant object the optical methods have an advantage because the angular resolving power of radio telescopes is low. Individual stars in M31 are faint and so the Doppler shifts of HII regions—bright clouds of ionized gas around young hot stars—are measured. Vera Rubin and Kent Ford of the Department of Terrestrial Magnetism of the Carnegie Institute of Washington have recently made a detailed study of the rotation curve of M31 (*Astrophys. J.*, **159**, 379; 1970). Kent Ford has been one of the pioneers of the application of image tubes to astronomical spectroscopy.

The gain in speed of the image tube over photography has enabled them to determine the Doppler shifts of 67 HII regions between 3 and 24 kpc from the centre of M31 with an accuracy of ± 10 km/s^{-1}. These emission regions were mapped several years ago by Arp and Baade. Inside 3 kpc there are no individual HII regions but instead there is a diffuse background of emitting gas. Rubin and Ford have used this to define the rotation curve inside 3 kpc.

Ford and Rubin's rotation curve for M31 is well defined and exhibits a complicated structure. Inside 3 kpc the situation is complicated by non-circular motions which they interpret as being caused by gas which has been ejected from the nucleus of M31. Subtracting out these radial motions, they conclude that the nucleus is rapidly rotating, with a maximum velocity of 225 km s^{-1} at $R=400$ pc. The rotation curve falls to a deep minimum at $R=2$ kpc and then rises to 270 km s^{-1} at $R=11$ kpc, after which the rotation velocity falls off gradually. Rubin and Ford deduce a total mass for M31 out to 24 kpc, the last measured point, of $1{\cdot}85 \pm 0{\cdot}1 \times 10^{11}$ solar masses. On this basis M31 is about 20 per cent more massive than the galaxy. The rapidly rotating nucleus has a mass of $6 \pm 1 \times 10^9$ Suns with a mean density of 4,000 solar masses per cubic parsec inside $R=400$ pc. (This can be compared with a mean density of 0·1 solar masses per cubic parsec in the solar vicinity.)

The final implications of Rubin and Ford's work will require further theoretical study. For example, in their model the mass density falls to zero near $R=1$ kpc, which is physically unreasonable. But theirs is the most complete study yet made of the rotation of a galaxy, and it will form a solid foundation for future investigations of the dynamics of a typical spiral galaxy.

TRIBOLOGY

On the Interface

from a Correspondent

EARLIER this month, Manchester was the scene of the latest phase in industry's war with friction. With its symposium on profit from tribology, the Ministry of Technology, in association with the National Centre of Tribology (NCT), Risley, the Institution of Mechanical Engineers and the Confederation of British Industries, sought to inculcate in local industry some idea of the potential rewards from the application of tribology—the science and technology of interacting surfaces in relative motion.

On March 9 an exhibition and film were directed at senior management from more than 200 companies. Lord Delacourt-Smith (Minister of State, Ministry of Technology) recalled that in 1966 the Jost Report estimated industry's frictional losses as £500 million per year. He pointed out that this seemed an underestimate, the true figure now being nearer £1,200 million per year, of which £500 million could easily be saved by applying existing tribological expertise. In the NCT, the industrial units for tribology and the universities, Britain had this capability. Referring specifically to the NCT, he noted the pioneering work on plastic gas-bearings. These promise to be cheap, efficient, free of contamination (being greaseless) and silent.

On March 10 a technical meeting was aimed at engineers from the same companies. Dr J. F. Archard (University of Leicester) maintained that at present "the economics of tribology is more important than the science of tribology". Valuable knowledge was available, the problem was to disseminate it.

Four reasons for this under-utilization were suggested: tribology was new, it was interdisciplinary, academics were not problem-oriented, and industrialists were scared to ask too many simple questions. The obvious savings, like energy, manpower, lubricants and increases in mechanical efficiency, he said, were typically only one-eighth of the total saving tribology could provide.

The major benefits derived from consequentials such as less maintenance and longer machine life. These factors, it was claimed, sat squarely on the interface between management and technology. This interface "must not become a barricade".

Dr D. Summers-Smith (lubrication adviser, ICI Ltd) emphasized that the process industries put a high premium on reliability, since a single pump-bearing failure could shut a complete modern integrated chemical works for days and cost many thousands of pounds in lost production, whereas to replace a part could cost only shillings.

But to duplicate each component would incur a vast capital cost. Where should the line be drawn? A tribological understanding aided the choice of the cheapest bearing design commensurate with an acceptable component lifetime. In other cases, techniques like noise spectrum analysis of vibrating bearings permitted replacement weeks before failure occurred. Britain's oil industry spends several million pounds per year on research and development, maintains advanced technical services departments, and will even give companies detailed assistance with machine design.

Mr B. E. Hurley claimed (British Petroleum Ltd) many companies still adopt a costly *ad hoc* approach to lubrication problems. Dr W. H. Roberts (NCT), however, discussing case histories of problems overcome at his centre, gave some examples of huge savings achieved through the thoughtful application of tribological knowledge.