R. Brent Tully: Research Highlights.

1974

Thesis study of velocity field of spiral galaxy M51 with an imaging Fabry-Perot interferometer. At the epoch, the most detailed two-dimensional study of motions in any galaxy and provided evidence favoring model of spiral formation driven by interaction.

1975

HI study of DDO dwarf galaxies (with J.R. Fisher). This program approximately doubled the number of galaxies observed in HI.

1976

Westerbork 21 cm observations of what became the smallest systems with detailed kinematic information (with L. Bottinelli, J.R. Fisher, L. Gouguenheim, R. Sancisi, and H. van Worden).

1977

Luminosity-line width relation for spirals (with J.R. Fisher). Subsequently referred to as Tully-Fisher relation. Still probably the most accurate way to measure the distances to large numbers of spiral galaxies beyond a few megaparsecs.

1981

HI observations data paper (with J.R. Fisher). Publication of results of observations of 1200 galaxies, again approximately doubling the number of galaxies observed in HI at the time.

1982

A description of the filamentary structure of the Local Supercluster.

A color-magnitude relation for spirals (with J.R. Mould and M Aaronson).

Model of galaxy infall toward the Virgo Cluster (with M. Aaronson, J.P. Huchra, J.R. Mould, and P.L. Schechter).

1984

A more elaborate model of galaxy infall toward the Virgo Cluster and on the angular momentum content of galaxies (with E.J. Shaya).

1986

Discovery of structure in the universe on a scale of 0.1c. Observed coincidence of the plane of the Local Supercluster and a plane delineated by Abell and less rich clusters in the Pisces-Cetus region.

1987

Publication of the 'Nearby Galaxies Atlas' (with J.R. Fisher) and the 'Nearby Galaxies Catalog'. Substantially the first attempt to map the structure in the distribution of nearby galaxies.

Compendium of nearby groups of galaxies selected by objective algorithm. Evidence for dark matter on a scale of 100 kpc around galaxies and lower limit for the density of the universe of 0.08 times the critical density.

1988

Distance estimates to galaxies in clusters (with M.J. Pierce) and in the field. Evidence that the Hubble Constant is approximately 85 km s^{-1} Mpc^{-1}.

First results with a new imaging Fabry-Perot interferometer (with J. Bland and G. Cecil). Studies of anomalous extended emission regions in nearby galaxies with active nuclei. Bipolar outflow from M82 mapped. Emission-line filaments demonstrated to be on outwardly accelerating surfaces of hot bubbles.

1990

Mapping of biconal outflow from the Seyfert galaxy NGC 1068 and the association with kiloparsec scale high excitation conditions (with G. Cecil and J. Bland).

1991

Dissection of the velocity field of the ultraluminous infrared collision object NGC 6240 into two discrete interacting disk components. A compact center was already known associated with one of these disks, but a 'dark' center with a 700 km s^{-1} velocity gradient was also identified with the second disk (with J. Bland-Hawthorn and A. Wilson).

1992

Linear non-parametric analysis of the velocity field of the Local Supercluster within 3000 km s^{-1} (with E.J. Shaya and M.J. Pierce). A value for the density of matter clumped on 1-10 Mpc scales of only $0.1\Omega_{crit}$ was found.

Further intriguing but inconclusive evidence is presented for coherent structure, possibly cyclic, on scales of 300 Mpc (with R. Scaramella, G. Vettolani, and G. Zamorani).

The velocity field of the galaxy NGC 4258 was mapped (with G. Cecil and A. Wilson). The well-known paired anomalous arms which emanate from the nucleus and are associated with ionized gas, radio non-thermal emission, and X-ray

emission are now shown to consist of braided strands. The phenomenon must be associated with a magnetohydrodynamic instability in the plasma jet outflow.

1994

NGC 3079 contains the most energetic bipolar outflow event seen in nearby galaxies with line-of-sight velocities ranging over 2000 km s^{-1}. A two-dimensional Fabry-Perot velocity field map reveals that, as with M82, the gas radiating visible lines is on a sheath around hot X-ray emitting plasma and the gas is accelerating outward. The stellar wind is driven by a starburst in the galaxy nucleus (with S. Veilleux, G. Cecil, J. Bland- Hawthorn, A. Filippenko, and W. Sargent).

1995

Least Action reenactment of orbits of galaxies in the Local Supercluster provide a plausible history of the formation of the structure that is seen and provides an estimate of the mass distribution. The density of matter distributed like the observed galaxies corresponds to 17% of closure density, with a standard deviation of 10% (with E.J. Shaya and P.J.E. Peebles).

1996

Evidence for bimodality of the surface brightnesses of spiral disks comes from optical–infrared photometry of a complete sample of galaxies in the Ursa Major Cluster. There may be 3 discrete formation states for spirals separated by (angular momentum?) thresholds: low surface brightness systems with exponential disks, high surface brightness systems with exponential disks, and high surface brightness systems with disks plus bulges (with M.A.W Verheijen).

1998

The extragalactic distance scale and expansion rate are reevaluated with an abundance of new data. Distances to individual galaxies are determined using the relation between luminosities and rotation rates. Samples are now much more extensive and complete, and cover more of the sky to greater distances. Photometry at B, R, I, and K' bands allows corrections for obscuration. Accurate distances from the cepheid method are available for 24 calibrator galaxies. It is now found that $H_0 = 77 \pm 8$ km s^{-1} Mpc^{-1} (95% prob.) (with M.J. Pierce).

2001

Observations with the wide field CCD cameras on CFH and Subaru telescopes and complementary HI observations with the VLA reveal significant variations of the faint end of the galaxy luminosity function in different environments. The ratio dwarf-to-giant is high in high density regions with short dynamical collapse

times and low in low density regions with long dynamical times. It is suggested that dwarfs were formed very early in regions with short dynamical times, so early that they formed, gas and dark matter together, before the epoch of re-ionization of the universe. In low density regions, dwarf dark halos collapsed after the epoch of re-ionization. The visible manifestations of galaxy formation were squelched in small halos since gas didn't collapse where the energy in the now ionized gas exceeded the gravitational energy associated with the dark halo potential well (with R.S Somerville, N. Trentham, and M.A.W. Verheijen).

2003

There is remarkably strong observational evidence for variations in the amount of blue light associated with dark matter in different environments. The most light (lowest M/L_B values) are found in group halos in the mass range $10^{12} - 10^{13} M_\odot$. Collapsed regions on larger mass scales have increasingly larger M/L_B values. The correlation is enhanced by a second parameter: groups or clusters with shorter dynamical times have larger M/L_B values. These correlations can probably be understood as the consequence of stellar aging, tidal disruptions, and thermalization of gas components. At smaller masses, there is evidently a cutoff in processes that lead to star formation. Groups in the mass range $10^{11} - 10^{12} M_\odot$ have very high M/L_B values, reaching values of several thousand. It is speculated that there may be completely dark halos. There may be astrophysical mechanisms that prevent gas accumulation and star formation in many low mass halos.

2005

Continuing observations of groups in the Local Supercluster with the wide field cameras on the Canada-France-Hawaii Telescope confirm that there are far fewer dwarf galaxies than the numbers of low mass halos anticipated by the current Lambda Cold Dark Matter galaxy formation paradigm. There is a broad range in the stages of development of the groups that have been observed. There are 'fossil' groups that collapsed early and where most of the intermediate sized galaxies have merged with the central dominant system. These places have high mass to light ratios and a relatively large number of dwarf ellipticals. Another interesting group has a core that is old and is marked by dwarf galaxies but there has been a relatively recent influx of additional galaxies upon this core. There are many transition dwarfs, systems experiencing a late and probably last stage of star formation (with N. Trentham and A. Mahdavi).

2006

An extensive campaign of observations with Hubble Space Telescope of nearby dwarfs is providing data on the colors and magnitudes of the stellar contents. Distances to the galaxies are determined based on the luminosities of the brightest red giant branch stars. It is found that the dwarf galaxies, like their brighter counterparts, are strongly clustered. There are groups of only dwarf galaxies. The masses of these groups are in the range $10^{11} - 10^{12}\ M_{\odot}$. These group masses are low but the light associated with the dwarf galaxies is very low so the mass to light ratios are extremely *high*. Evidently in these environments only a small fraction of the normal baryon component has been collected and resulted in star formation (with I. Karachentsev, L. Rizzi, D. Makarova, L. Makarova, S. Sakai, and E.J. Shaya).

2007

Peculiar velocities of galaxies are determined from an extensive catalog of 1800 distances within 3000 km/s. It is determined that our Galaxy and all its neighbors within 7 Mpc are in a filament with very low internal motions but the entire 'Local Sheet' is moving at 320 km/s with respect to adjacent structures. This motion is broken into components of 185 km/s toward the Virgo Cluster and 260 km/s away from the Local Void. Completely empty voids in the currently preferred cosmological model evacuate at 16 km/s/Mpc so, to generate a flow as large as seen, the Local Void must be at least 45 Mpc across and be very empty (with E.J. Shaya, I. Karachentsev, H. Courtois, D.D. Kocevski, L. Rizzi, and A. Peel).

2008

The region within the infall caustic around M81 has been surveyed with CFHT Megacam with a sensitivity that just resolves stars at the tip of the red giant branch. Observations lead to the identification of 22 new candidate members of the M81 group. Follow up using HST imagers confirm 14 new group members. With high confidence, all galaxies brighter than $M_R = -10$ within the M81 virial radius are now identified (with K. Chiboucas and I. Karachentsev).

2009

The Extragalactic Distance Database (http://edd.ifa.hawaii.edu) is released. One major component is a repository for HI profile information from observations with the Green Bank, Arecibo, and Parkes telescopes and reanalysis of material from archives. A second component is a repository for color-magnitude diagrams and tip of the red giant branch distance measures from Hubble Space Telescope imaging (with L. Rizzi, E. Shaya, H. Courtois, D. Makarov, and B. Jacobs).

2010

Keck spectroscopy of marginally resolved objects identified with Hubble Space Telescope imaging has uncovered a large population of Ultra Compact Dwarfs (UCD) near the center of the Coma Cluster. Velocity and metallicity correlations associate a large fraction of the UCD with specific dominant ellipticals. The evidence suggests that UCD are the remnants of super star clusters formed during discrete gas-rich mergers (with K. Chiboucas).

2011

Thousands of new galaxy HI profiles, surface photometry measurements, and color-magnitude diagrams are added to the Extragalactic Distance Database (with H. Courtois, B. Jacobs and many others).

2012

The Cosmicflows-2 program matures. The luminosity-linewidth (TFR) relation is recalibrated at I band and the calibration is extended to the mid-infrared with Spizer Space Telescope [3.6] photometry. Type Ia supernovae are calibrated resulting in a determination of the Hubble Constant of $H_0 = 75 \pm 3$ km/s/Mpc (with H. Courtois, J. Sorce and others).

2013

The data set of over 8000 distances and peculiar velocities, Cosmicflows-2, is published and used to reconstruct the development of structure on large scales using Wiener Filter techniques and on small scales with Numerical Action Methods. Flows extending to 200 Mpc are mapped. A coherent flow across the full range of the observations is seen, culminating in the Shapley concentration. At the other extreme of extragalactic scales, action orbits have been found that provide an explanation for the planar distributions of companion galaxies in the Local Group. These galaxies retain a memory of their formation in the wall bounding the expanding Local Void (with H.M. Courtois, S. Gottlöber, Y. Hoffman, B.A. Jacobs, I.D. Karachentsev, P.J.E. Peebles, D. Pomarède, L. Rizzi, and E.J. Shaya).

2014

Exploitation of the Cosmicflows-2 has lead to the definition to our "Laniakea" basin of attraction including the Pavo-Indus-Norma sheet, the Centaurus-Hydra complex, and the Ophiuchus and Virgo extensions. The nearest neighboring basins of attraction are identified: Perseus-Pisces, Coma, Hercules, Lepus, and especially the Shapley concentration. These separate entities are identified by separating local and tidal flows from the global flow inferred from the Wiener Filter analysis (with H.M. Courtois, Y. Hoffman, and D. Pomarède).

2015 Two papers are devoted to a consistent description of galaxy groups from the mass range of the halo of our Galaxy to the Virgo Cluster. Scaling relations between halo velocity dispersions, size, and mass are established in the first paper and these relations are exploited to define groups in a 2MASS sample in the second. In a separate study, the satellites of Centaurus A are tentatively identified to lie in two distinct planes.

2016 *Cosmicflows-3* is published, a compendium of 18,000 galaxy distances (with H.M. Courtois and J.G. Sorce).

2017 Two giant underdense regions have been identified following from the Wiener Filter analysis of Cosmicflows distances. The Dipole Repeller is anti-aligned with the direction of our cosmic motion with respect to the microwave background and is suspected to contribute roughly equally with attractors in causing our motion. The Cold Spot Repeller is coincident in direction with an anomalous negative fluctuation in the cosmic microwave background and possibly due to the integrated S-W effect, photon energy loss in passing throuugh a void in an accelerating universe (with Y. Hoffman, D. Pomarède, and H.M. Courtois).

Two publications have greatly enhanced our understanding of the structure and dynamics of the region known as the Local Supercluster. The first (with E. Kourkchi) analyzed the clustering characteristics of 15,000 galaxies within 3,500 km/s. The second (lead by E.J.Shaya and including Y. Hoffman and D. Pomarède) recovered physically plausible orbits for galaxies and groups within roughly the same volume. The dominant flow patterns are (i) a downward flow of all galaxies above the supergalactic equator out of the Local Void and its extensions, (ii) flows toward the Virgo Cluster giving good definition of the mass of the cluster, and (iii) a flow of the entire region toward the densest part of the Laniakea Supercluster.