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The Impact of External Tidal Fields on the ISM of Dwarf Spheroidals

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Abstract. It was found that for three dwarf spheroidal galaxies — Sculptor, Tucana, and Cetus — there is a correspondence between the distribution of associated HI gas and the projected tidal axis direction. Numerical hydrodynamical simulations confirmed the following scenario: SN Ia explosions remove most of the interstellar medium beyond the tidal radius of the dwarf galaxy, with most of the mass being in clouds moving along the principal tidal axis.

1. Observational data

Figure 1 shows the HI distribution integrated over certain intervals of velocities for three dwarfs spheroidal (dSph) galaxies — Cetus, Sculptor, and Tucana. The HI data have been obtained with the Australia Telescope Compact Array (Sculptor and Tucana, with the Tucana data presented by Oosterloo, Da Costa, & Staveley-Smith, 1996), and the Parkes Multibeam System (Cetus). Monte-Carlo simulated projections of the principal ("stretching") tidal axis are shown as vertical lines. One sigma error ellipses are shown for the apparent location of points on the tidal axis, located at spatial distances r_t, $2r_t$, $3r_t$, ... from the center of the galaxy (r_t is the tidal radius.) Tidal tensor components were assumed to be constant within the dSph, and included contributions from all Local Group members. The images (Figure 1) were rotated and rescaled to make 1) their projected principal tidal axes vertical, and 2) their projected tidal radii

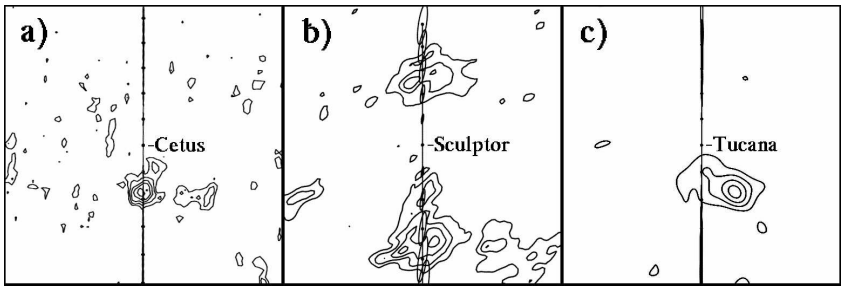

Figure 1. HI distribution (contours) and projection of the principal tidal axes (vertical lines) for three dwarf spheroidals

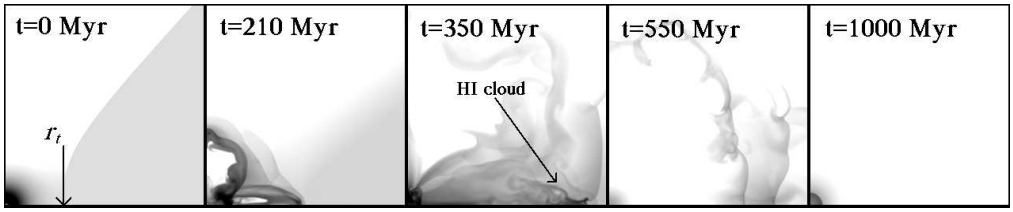

Figure 2. Results of 2D hydrodynamic simulations. The center of the dwarf galaxy is at the lower left corner. A dense extratidal HI cloud moving along the principal tidal axis (bottom horizontal line) is evident for $t = 210$ Myr and $t = 350$ Myr.

equal. Normalized in such a way, neutral hydrogen maps manifest one common feature — the associated HI gas appears to follow the tidal "stretching" axis direction.

2. The model, and discussion

To test the intuitive idea that fragments of expanding HI shells resulting from supernovae type Ia explosions in dwarf spheroidals are removed from the galaxy preferentially along the strongest tidal force direction, 2D hydrodynamic simulations have been conducted. The evolution of the interstellar medium (ISM) in a dSph galaxy has been followed with the ZEUS-2D hydrodynamical code (Stone & Norman, 1992). Figure 2 shows the density distribution (logarithmic scale; black corresponds to the densest gas) obtained for a few time steps. (One quarter of the whole distribution is shown). The box size is 5 kpc. The axial symmetry with the axis of symmetry directed along the strongest tidal force direction (horizontal in Figure 2) has been adopted. The parameters of the dSph model and of the tidal field correspond to the Sculptor galaxy. Initially the hydrostatic gas with a mass 2×10^5 $M_\odot$ and a temperature T=500 K was perturbed by 10 supernova type Ia explosions occuring in the center of the galaxy at random moments of time over the interval of 1 Gyr. The assumed spatially distributed mass input from red giants was 1.65×10^{-5} $M_\odot yr^{-1}$. Radiative cooling was taken into account. The energy and mass inputs from the SNe was 10^{51} erg and 1.4 $M_\odot$ per SN.

The simulations showed that repeated SNe Ia can completely expel the ISM from a dSph with most of the mass being removed as relatively dense clouds along the tidal axis direction. This is in accordance with the observed HI distribution in three Local Group dwarf spheroidals. The results obtained emphasize the impact of the tidal field on the evolution of dwarf spheroidal galaxies (even for relatively "isolated" systems such as Tucana and Cetus), and might shed some more light upon the complex star formation history of dSphs.

References

Oosterloo, T., Da Costa, G. S., & Staveley-Smith, L. 1996, AJ, 112, 1969
Stone, J. M., & Norman, M. L. 1992, ApJS, 80, 753