Simulations of the formation of Gould's belt-like structures

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ABSTRACT

We present numerical simulations of the collision of a gas cloud into the Milky Way's disk. The cloud is able to go through the disk, leaving behind a hole and high density ring qualitatively similar to Gould's belt.

1. THE MODEL

We performed 3D simulations of a cloud impacting an isothermal gaseous disk similar to the Milky Way using the RAMSES code (Teyssier, 2002) with a box of 32 kpc and a resolution equivalent to 1024^3 in the finer grid level. The disk starts in rotational equilibrium with a fixed halo+disk potential. Following Bekki (2009) for these early experiments, this setup is impacted by a $3\mathrm{x}10^7$ M_{sun} cloud, placed 2.5 kpc above the midplane. The density of the cloud follows a Plummer profile with 317 pc core radius. Initially, the cloud velocity is v_z = - 93 km s^{-1}, although we performed simulations with a variety of initial velocities. We also performed a simulation with a 10^5 M_{sun} cloud, similar to Smith's cloud, with a core radius of 47 pc so that both cases have the same central density.

3. SYNTHETIC *l-v* DIAGRAM

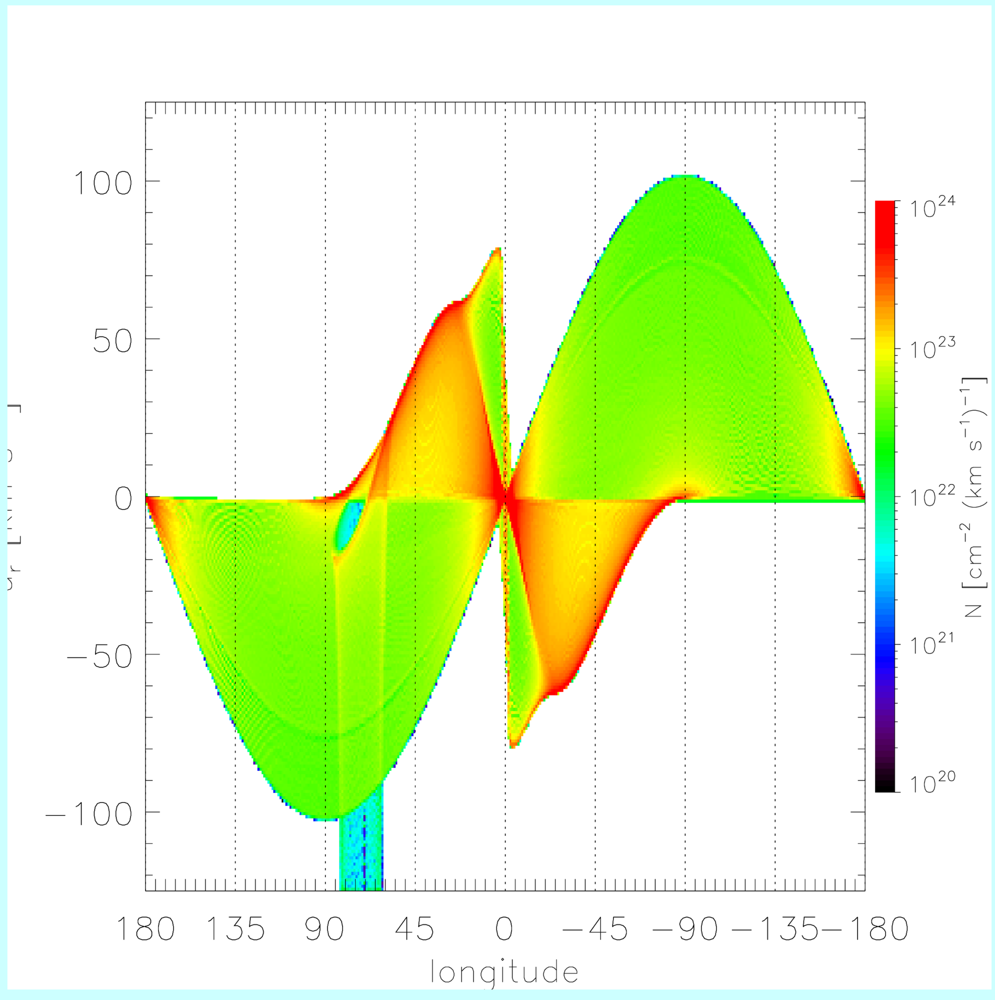

Figure 3: Synthetic *l-v* diagram for an observer placed outside the hole generated by the cloud. A beam size of 1^0 is assumed.

Figure 3 shows a synthetic *l-v* diagram assuming an observer placed 4 kpc upstream from the position of the hole in the disk, at a time of 20.9 Myr. The high velocities seen in fig. 2 are apparent as a large vertical extension around *l* = 70^0, although this gas is unlikely to remain neutral. Nevertheless, the abundance of holes near the midplane could be used as an estimator of the frequency of these events.

At this time, the vertical extension of the compressed gas is ~0.25 kpc, which means that the whole structure spans 3.5^0 in the observer's sky. So, it would be difficult to observe in low-latitude surveys.

2. TEMPORAL EVOLUTION

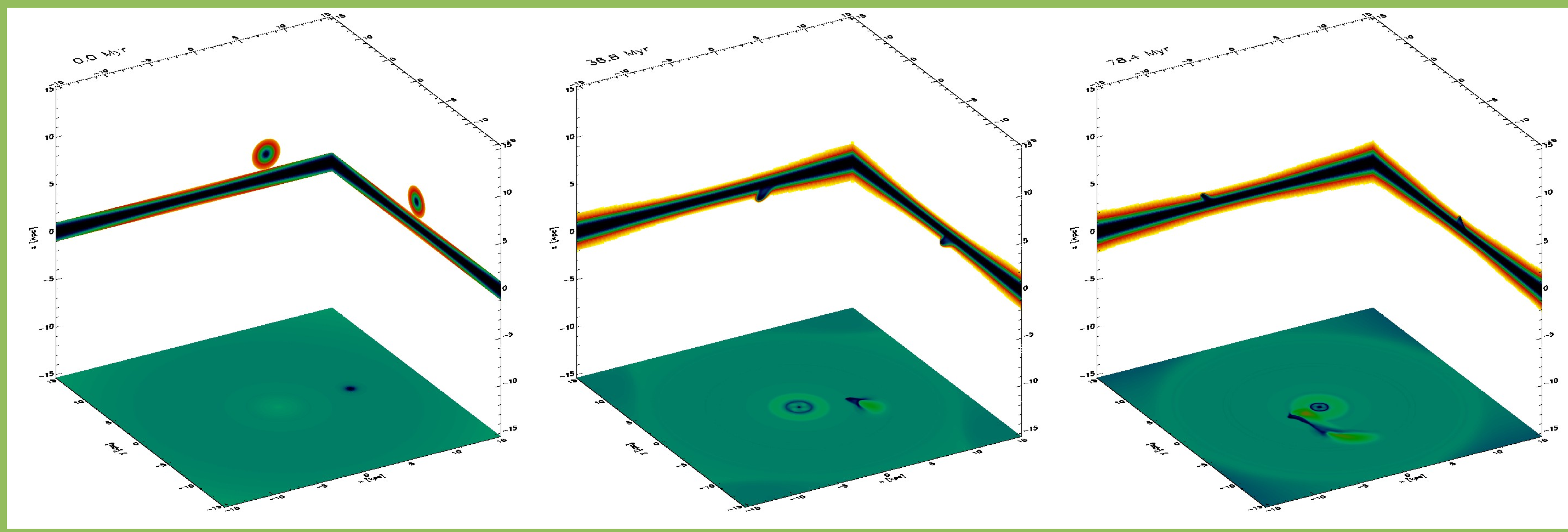

Figure 1: Projections of the simulation box at 0 (*left*), 36.8 (*middle*) and 78.4 Myr (*right*). Colors show the column density (in logarithmic scale, from 10^{18} to 10^{22} cm^{-2}).

Figure 1 shows the temporal evolution of the simulation. After the cloud impacts (some 10 Myr into the simulation), it is able to go through the disk, leaving behind an elongated hole. At 20.9 Myr, the hole has approximate dimensions 1.4 x 1.7 kpc in the midplane, and at 36.8 Myr, it measures ~2.3 x 2.9 kpc. If we consider gas with density >2.5 cm^{-3}, the dynamic ages of the structures at these times are 4.53 and 6.57 Myr, significantly smaller than the times elapsed since the cloud collided with the disk.

After going through the disk, the remnant of the cloud orbits back and collides with the disk ~40 Myr later. A tail of disk and cloud material falls into the disk also. This behavior is qualitatively similar if the cloud has an initial velocity equal to the disk's circular velocity. As it would be expected, the smaller cloud is unable to go through the disk and does not generate a similar hole in the disk.

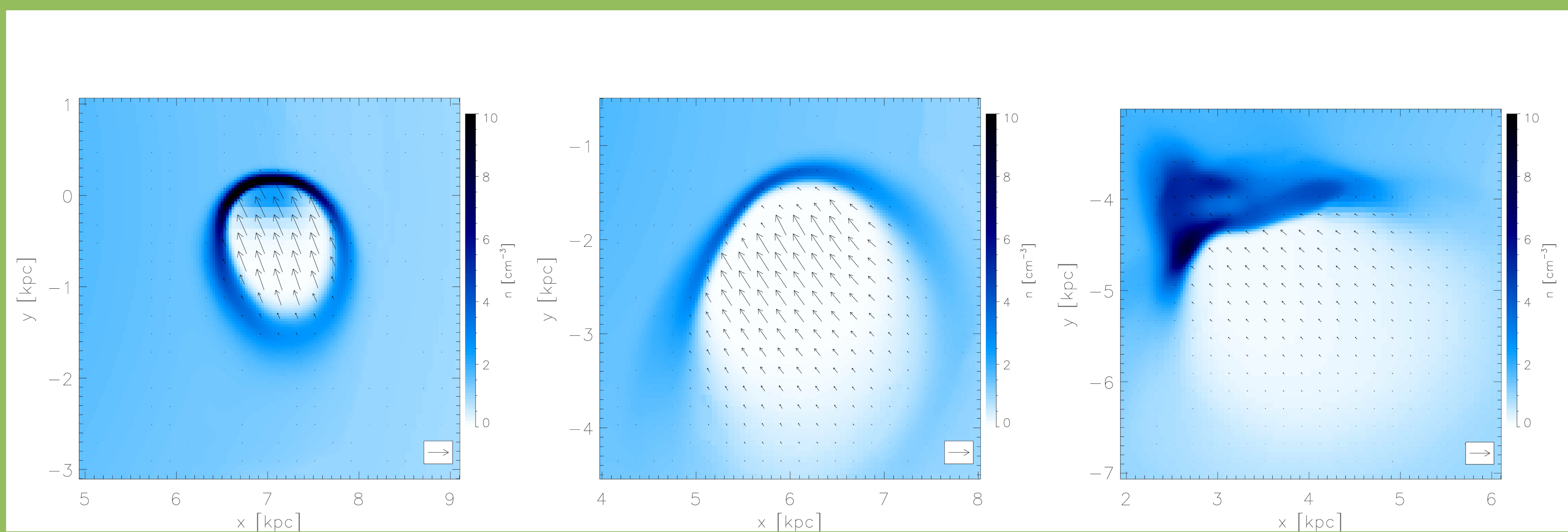

Figure 2: Density cuts at the z = 0 plane, 20.9 (*left*), 36.8 (*middle*), and 52.8 Myr (*right*) into the simulation. Arrows show the non-circular velocity of the gas, with the arrow in the lower right corner representing 200 km s^{-1}.

Since the cloud velocity is much smaller than the rotational velocity of the gas in the disk, a bow shock forms. The combination of the shock and the compression caused by the cloud itself implies that, the low density hole is surrounded by a very asymmetric high density ring, with the higher densities in the direction opposite to the galactic rotation. If we assume an observer placed inside this hole, this means that the induced star formation should be stronger in the negative longitude side of the ring, as is observed for B-stars in the Gould's belt (Poppel 1997).

4. SKY MAPS

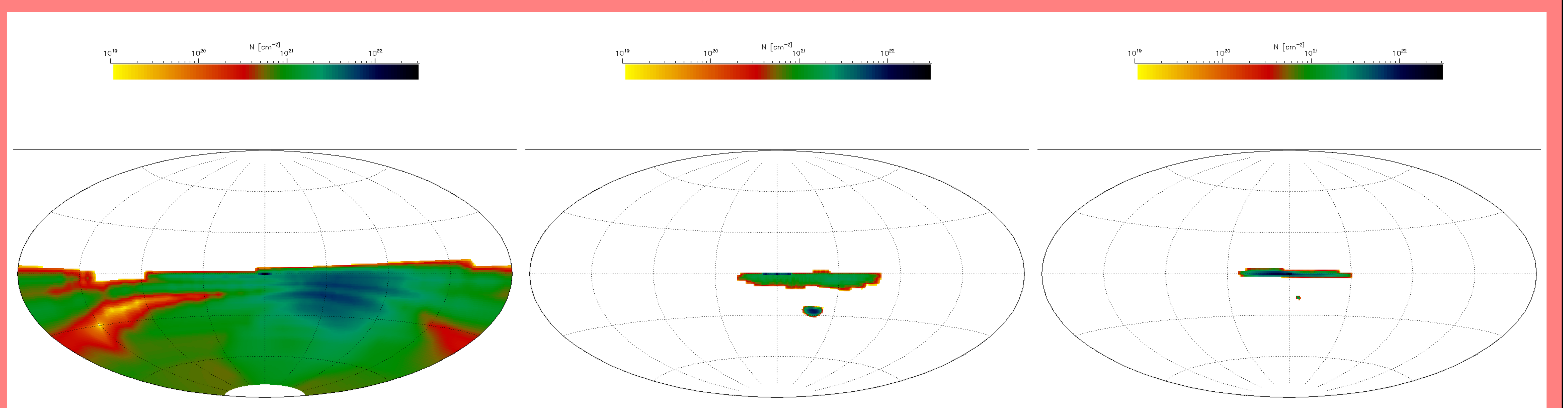

Figure 4: Sky maps for dense gas as seen from inside the hole in the galactic disk. The times are the same as in fig. 2. *l* = 0^0 is at the center of the diagrams, with longitudes increasing to the left.

The high density structure evolves quite rapidly, both because of the high velocity of the gas and the shear due to galactic rotation. While gas with density > 2.5 cm^{-3} fills the southern sky, the lower-z portion rapidly dissipates.

Bibliography

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