- HH 34 has a time offset distribution with a $\Delta\tau_0 = (8.9 \pm 17.3)$ yr width, which is not significantly different from zero. The velocity offset distribution has a $\Delta v_0 = (9.0 \pm 5.6)$ km s^{-1} width,
- HH 111 implies a time offset distribution with $\Delta\tau_0 = (27.7 \pm 20.5)$ yr and $\Delta v_0 = (10.9 \pm 5.8)$ km s^{-1}.

4. CONCLUSIONS

We have presented a simple, ballistic binary ejection model for interpreting the observed knot structures of quasi-symmetric bipolar outflows. In this model it is assumed that knots are ejected with small time ($\Delta\tau$) and velocity (Δv) offsets, which result in a slightly asymmetric propagation as the knots move away from the source. It is also assumed that these offsets have uniform distributions with mean values τ_0 and v_0 and half-widths $\Delta\tau_0$ and Δv_0 (for the time and velocity offsets, respectively). Under these assumptions, we show that the values of τ_0, v_0, $\Delta\tau_0$ and Δv_0 can be recovered from observations of the spatial jet/counterjet knot offsets $\Delta x = x_j - x_{cj}$ for a system of identifiable knot pairs.

We then apply this method to recent *Spitzer* observations of the HH 34 (Raga et al. 2011) and HH 111 (Noriega-Crespo et al. 2011) jet/counterjet systems. We find that the knots of the HH 34 outflow imply binary ejections with basically zero systematic jet/counterjet ejection times or velocities. The dispersion of the ejection times also lies below the errors due to small number statistics. However, the observed spatial distribution of the jet/counterjet knot offsets does imply a non-zero value for the width of the ejection velocity distribution [$\Delta v_0 = (9.0 \pm 5.6)$ km s^{-1}, see Table 1].

As noted by Raga et al. (2011), the good time coordination of the binary ejections of HH 34 imply that the triggering of the ejection events occurs in a compact region. Even though we are not able to obtain a well constrained value for the time-offsets between the jet and counterjet knots, we can take as an estimate either the value of τ_0 or of $\Delta\tau_0$ (both $\sim$5 yr, see Table 1). If we assume a (sound or Alfvén) wave propagation velocity $v_s \sim 3$ km s^{-1} for the jet formation region, this coordination timescale then implies a size $d \sim 3$ AU.

A clearly different result is obtained for HH 111. The jet/counterjet knot pairs of this system imply a clear bias towards one side, with the clumps in the W lobe being ejected on average a time $\tau_0 = (18.2 \pm 7.1)$ yr later and $v_0 = (6.5 \pm 2.6)$ km s^{-1} slower than the corresponding knots in the E lobe. The observations also imply non-zero widths for the ejection time and velocity distributions ($\Delta\tau_0 = (27.7 \pm 20.5)$ yr and $\Delta v_0 = (10.9 \pm 5.8)$ km s^{-1}, respectively, see Table 1).

For HH 111 we then conclude that an intrinsically asymmetric ejection is taking place, with one side producing faster and earlier ejections than the other. Such an effect is seen at least in one other YSO outflow: Curiel et al. (2006) present high resolution radio continuum maps at many epochs of the Cepheus A HW2 outflow, and they find that the knots are ejected $\sim$2 yr earlier in one of the two lobes. It appears that in HH 111 we are seeing a similar effect, but with a time-delay that is larger by one order of magnitude.

The systematic velocity offset ($v_0 \approx 6.5$ km s^{-1}, see Table 1) of the HH 111 jet/counterjet knots could actually be the result of a non-ballistic behavior of the motion. For example, if the knots along one of the outflow lobes were interacting directly with a denser medium, this interaction could lead to a lower velocity knot propagation velocity. However, as the knots are traveling into the wake of previous ejection episodes, such a direct knot/environment interaction seems unlikely. Also, the different velocities could in principle be the result of different orientations of the lobes with respect to the plane of the sky. However, the very small deviations from a straight path on the plane of the sky observed in HH 111 (see Noriega-Crespo et al. 2011) do not favor this scenario.

The asymmetries in the ejections of the HH 34 and 111 knots in principle provide constraints on the jet production model. However, in many cases it is not yet possible to apply these constraints because the present models for the production of outflows from young stars are either stationary (e.g., Salmeron, Königl, & Wardle 2011) or do not appear to incorporate the mechanism(s) that produce the knots observed along HH jets (e.g., Ramsey & Clarke 2011; Stute et al. 2010; Yamada et al. 2009). A recent analysis of models producing asymmetric ejections (as the result of the presence of a time-independent magnetospheric magnetic field with both a dipole and a quadrupole component) is given by Lovelace et al. (2010), who for some parameters obtain outflows that "flip-flop" with a period of $\sim$30 days. Given the fact that this predicted timescale is a factor of 10–100 times too small for explaining the asymmetries observed for the HH 34 and 111 knots, it is clear that if one is to rescue the ideas of Lovelace et al. (2010) it will be necessary to introduce other elements. A possibility would be the presence of a time-variability in the magnetospheric magnetic field, as explored by De Colle, García, &