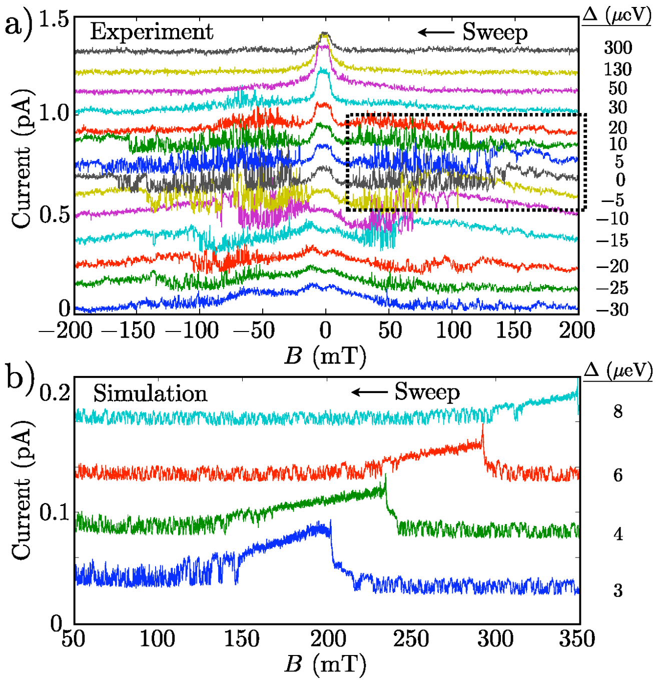

FIG. 4: Current during magnetic field sweep $dB/dt < 0$. a) Experimental field sweeps for several values of Δ, see Eq.(1), in the regime described in Ref.7, Fig. 3d ($\Delta = 0$ could only be approximately located experimentally). Curves are offset by 0.1 pA for clarity. b) Simulated field sweeps in the field regime indicated by the dotted box in panel a), showing bistable current similar to experiment. In both cases, the threshold for noisy to quiet current moves to higher field with increasing detuning. To treat the case of $B \approx 0$, a 5×5 formulation akin to that of Ref.17 must be used.

for parameters. For dots of unequal sizes, $N_L \neq N_R$, the flow (6) is asymmetric with respect to s_L and s_R. In particular, the rates (3) and (4) favor spin flips in the smaller of the two dots due to the increased hyperfine coupling per nuclear spin. As a result, the system can follow an arc-shaped trajectory like that shown in Figures 1b and 3c, in which polarization passes through the insensitive region $s_L \neq s_R$ during its build up, eventually returning to a steady state $s_L \approx s_R$ where polarization fluctuations result in large fluctuations of current.

Slow fluctuations with a power spectrum close to $1/f^2$, see Fig.2c, are indicative of diffusion, which may be driven by nuclear dipole-dipole interactions, as discussed in Ref.8, or by current as described above. Unlike other sources of steady-state spin fluctuations, the shot-noise mechanism is intrinsic to spin-blockade and its intensity can be controlled by current. Alternative mechanisms can thus be distinguished through the current-dependence of the underlying diffusion coefficient.

Experimentally, current was also measured during slow sweeps of magnetic field (see Fig.4a). These data were obtained in the same regime as that of Fig.3D in Ref.7, with a small change in tunnel coupling. At large Δ, current displays a simple peak at small magnetic fields arising from mixing of the triplet levels with the $(1,1)$ singlet by the random hyperfine field[17]. However, when detuning is comparable to the tunnel coupling (dotted box), the traces show diminished zero field peaks flanked by noisy regions exhibiting large fluctuations and stable regions of high current at higher fields. The boundary between noisy and stable high current systematically moves to higher field as detuning is increased, and is hysteretic in the sweep direction.

By including a time-dependent external field in the simulation, we produced the field sweep traces shown in Fig.4b. The low-field boundary between noisy and quiet regions depends on detuning in a similar manner to that observed in the experiment, while on the high field side we find an additional current-step not observed within the range of available experimental data. Based on the corresponding behavior of DNP in the simulations, we thus interpret the transition from noisy to stable current in the experiment as an indication that the polarization quasi-fixed point, $\dot{s}_{L,R} = 0$ in Eq.(6), moves away from the sensitive region $s_L \approx s_R$.

IV. CONCLUSIONS

The mechanism described above, based on spin dynamics driven by electron shot noise, provides a natural explanation for the systematic observation of regions of stable and strongly fluctuating current. We propose that regions of high, stable current, see e.g. $\Delta = -10\,\mu$eV, $B > 60$ mT in Fig.4, indicate that the system tends to an asymmetric fixed point with a sizable difference between the hyperfine fields in the two dots. As recently demonstrated, such states can be used to perform controlled manipulations of the double dot electron spin states[21].

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Appendix A: Simulation Parameters

The main text describes the microscopic model used to generate the simulated current and polarization traces in Figures 1-4. The behavior exhibited by the model is sensitive to a number of parameters, many of which are not well characterized for the experimental system. While on the one hand the existence of many parameters makes direct comparison to experiment more difficult, it can also be seen as a necessary consequence of the fact that such a wide variety of complex phenomena have been observed in this system. To this end, we have attempted to include the minimum number of ingredients necessary to produce the phenomena of slow quiet transients followed by steady state fluctuations. We chose parameters with plausible values for realistic systems, see table I, which