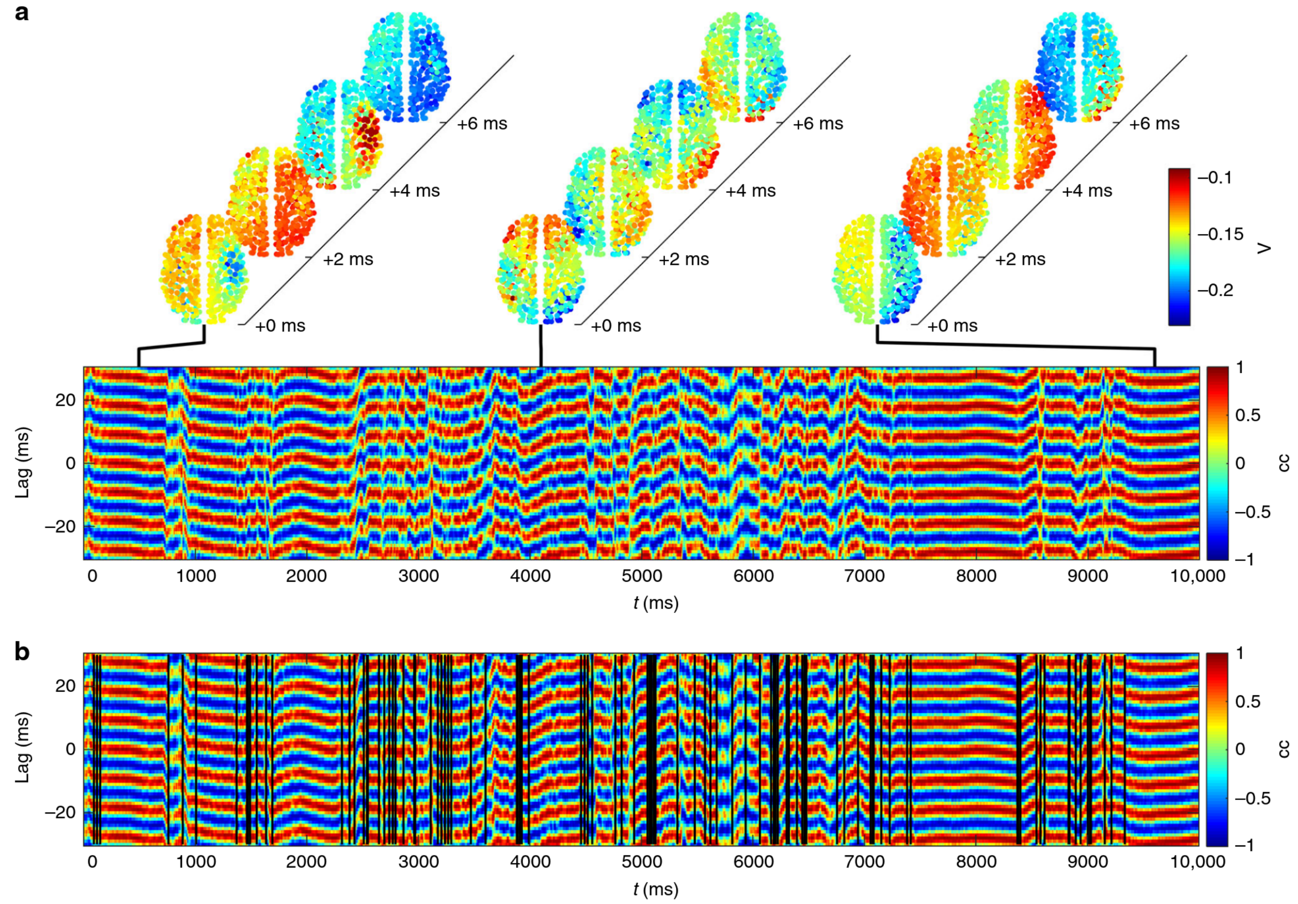

Fig. 3 Metastable transitions. **a** Each pattern has a signature in the interhemispheric cross-correlation, with transitions between different patterns revealing a brief period of desynchronization. **b** Vertical lines depict instances of low values of the interhemispheric cross-correlation function, corresponding to wave transitions. These results are for strong coupling $c = 0.6$ and short delay $\tau = 1$ ms, as in Fig. 1

The bimodal nature of the speed distribution (Fig. 2b) suggests that slow and fast regions partition into two somewhat distinct clusters.

To place this in terms of the classic functional networks, we assigned brain regions to 12 subnetworks according to a broadly used functional subdivision of the brain[50] (Supplementary Fig. 2). The top ten fastest nodes lie in the somatomotor hand, auditory, default mode, fronto-parietal, and ventral attention networks. The top ten slowest nodes lie also in the default mode (thus indicating a wide diversity in its wave speeds), plus memory and visual regions.

Metastable transitions. The observed diversity of types of wave patterns (i.e., traveling waves, rotating waves, and sources and sinks) occurs for a fixed set of parameters—the dynamics shown in Fig. 1 transition spontaneously between different patterns (Supplementary Movie 4). The system dwells in a single wave pattern for many repeats of a particular wave oscillation, then exhibits a relatively rapid reconfiguration into the next pattern. These are spontaneous transitions that occur in the absence of noise or other external inputs. This rules out multistability as a mechanism for the transitions, which requires the application of a perturbation to kick the system between attractors[2,51]. Instead, what we observe is metastability, a form of winnerless competition whereby the system's orbits visit multiple patterns in sequence and no single pattern endures[51].

To quantify these metastable transitions, we use the fact that any particular wave pattern is composed of specific phase relationships that vary relatively smoothly across space and time. The waves we observe have long wavelengths on the whole-brain scale; thus, signals averaged over a large area of cortex typically do not cancel out, as would be expected if short incoherent wavelengths dominated. To capture a metric of these patterns, we hence partition the brain into the two hemispheres and calculate the instantaneous coherence within each hemisphere (see Methods). We then calculate the sliding-window, time-lagged cross-correlation between these two intrahemispheric coherences. We term this the interhemispheric cross-correlation function.

As a particular wave pattern propagates across the brain, this pattern of correlated phase lags between the hemispheres is relatively constant. To see this, notice that during a metastable pattern (Fig. 3a), the same signature (alternating blue and red as a function of lag) persists on the time scale of hundreds of milliseconds, varying relatively slowly in time within any individual pattern (as shown by the way the blue and red stripes evolve slowly). At the time of a metastable transition, the large-scale wave pattern breaks up and disorganized short wavelengths dominate. Thus, the metastable wave signatures are separated by narrow periods of time with relatively low correlation between the hemispheres. That is, metastable transitions exhibit a brief desynchronization during which wave patterns reconfigure.

Here we used an interhemispheric partition, but any partition can be used in principle. We additionally tested partitions along the anteroposterior and dorsoventral axes, and found that they also capture the transitions (Supplementary Text, Supplementary Fig. 3).