SUPPLEMENTARY FIGURE LEGENDS

Supplementary Figure 1. Overview of the steps involved in the computation of the comodulogram map. To compute each entry of the comodulogram map, first the LFP (top left) is band-pass filtered into two frequencies: a phase-modulating frequency (8 Hz in this example, second panel from top) and an amplitude-modulated frequency (80 Hz in this example, bottom panel). The instantaneous amplitude (thick red line, bottom panel) and phase time series (third panel) are extracted from the filtered signals and used to compute a phase-amplitude distribution-like plot (middle bottom panel), which shows the mean 80 Hz amplitude distribution over 20^{o} phase bins of the 8 Hz oscillation. The modulation index (MI) for this frequency pair (8 Hz, 80 Hz) is then computed; the MI is simply a measure of divergence of the amplitude distribution from the uniform distribution (Tort et al., 2010). This procedure is repeated for several frequency pairs, and the MI values are expressed in a bidimensional pseudocolor map. The bottom right panel depicts a phase-amplitude plot obtained for the pair (16 Hz, 80 Hz), which has lower levels of cross-frequency coupling. (The example signals and comodulogram map shown in this figure were obtained from an actual CA1 recording during 300 seconds active exploration).

Supplementary Figure 2. CFC patterns within electrodes are stable over multiple days. Comodulogram maps from three CA1 electrodes in a 4x8 array across 7 days of recordings. On each day, 180 seconds of REM sleep data were analyzed.

Supplementary Figure 3. Theta-HG and theta-HFO coupling levels are positively correlated with theta power. The different rows investigate the correlation between CFC strength and theta power using different parameters for the sliding windows, as labeled. These results were obtained from the analysis of the same electrodes as shown in Figure 2 and are representative of other electrodes.

Supplementary Figure 4. HG and HFOs are not correlated at zero-lag. (A) Linear correlation between the amplitudes of HFOs, HG and theta oscillations (four representative animals are shown). For each animal, pairwise correlations between HFO- and HG-electrodes were obtained during 60-s periods of high theta activity (see C); bar graphs represent the mean correlation coefficient over all electrode pairs. (B) Same as in A, but for electrodes presenting mixed CFC patterns (inset) in a representative rat. The rightmost bar represents the mean correlation coefficient between HG and HFO activities recorded from the same electrode. (C) Representative time-frequency power spectrum of a 60-s epoch of high theta activity used in A and B.

Supplementary Figure 5. Time-frequency amplitude distributions time-locked to the theta peak for three electrodes in a bundle (different rows). The top electrode was the most superficial; the middle electrode was located in *stratum oriens-alveus* near the pyramidal cell layer; the bottom electrode was located at *stratum lacunosum-moleculare* near the hippocampal fissure. The left column shows the theta-triggered amplitude distribution obtained when local theta oscillations are used as reference signal. The right column shows the distribution obtained when

the theta signal from the bottom electrode is used as reference. Three hundred seconds of active exploration were used in these analyses.

Supplementary Figure 6. Different CA1 layers have different CFC patterns (second example). Top: left traces show LFPs (black) and theta-filtered signals (gray) obtained from 4 electrodes in a bundle (1st, 2nd, 3rd and 5th electrodes). The estimated location of the electrodes is shown on left. a – *s. alveus*; o – *s. oriens*; p – *s. pyramidale*; lm – *s. lacunosum-moleculare*. Notice higher theta amplitude and theta phase reversal in the electrode located at *s. lacunosum-moleculare*. The middle and right traces show 0.5 – 8 KHz and 100 – 250 Hz filtered signals, respectively. Notice characteristic multiunit activity and ripple oscillations in the pyramidal layer. Peak theta power and theta phase difference (with respect to the first electrode) are shown at the top right panels. Bottom left panels: theta coupling strength (top row) and theta phase-amplitude distribution (bottom row) for HG (red) and HFOs (blue) in each electrode (local theta used as reference). Bottom right panels: Mean theta-HFO (blue) and theta-HG (red) coupling in each electrode (top panel), along with their respective comodulogram maps (bottom panels). Three hundred seconds of active exploration were used in the CFC analyses, as well as to compute mean theta power and mean theta phase differences.

Supplementary Figure 7. Nissl-stained histology of a multielectrode array (top) and an electrode bundle (bottom).