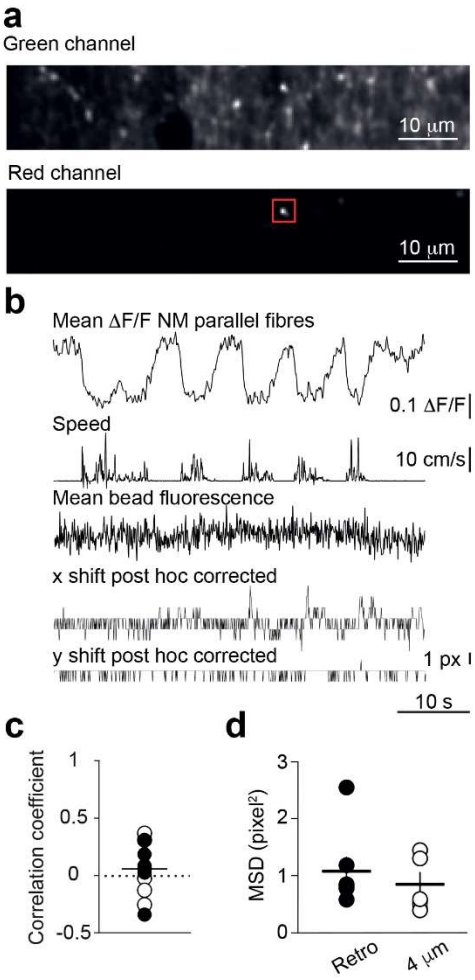
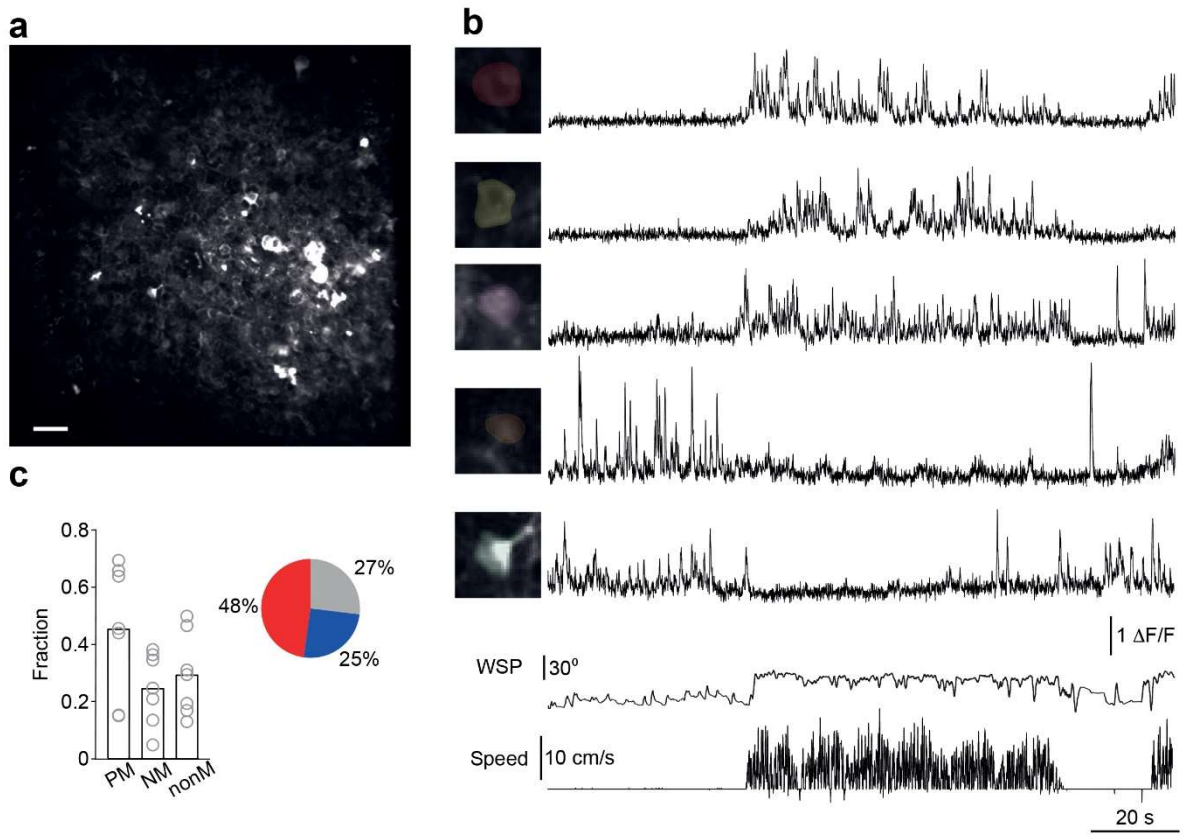
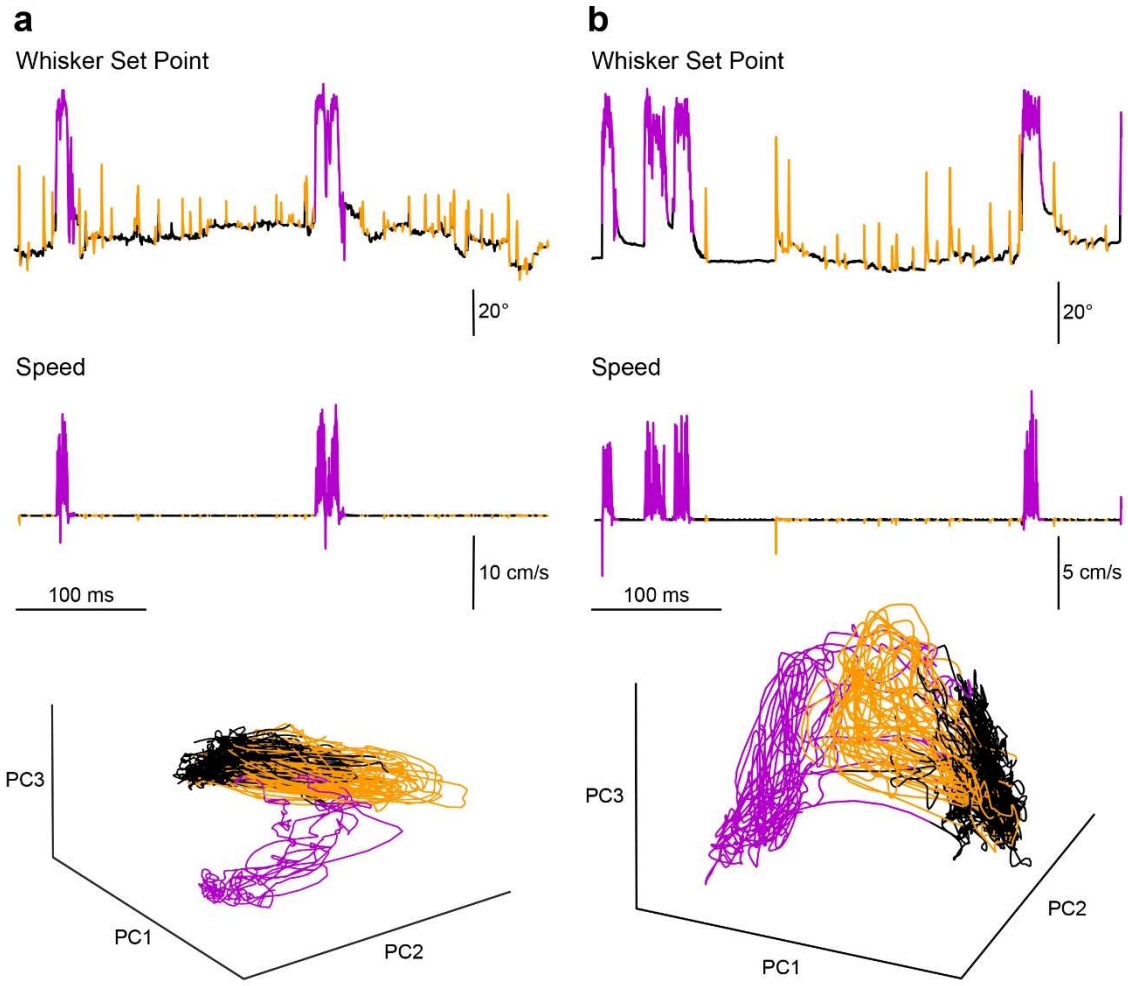
Supplementary Information file



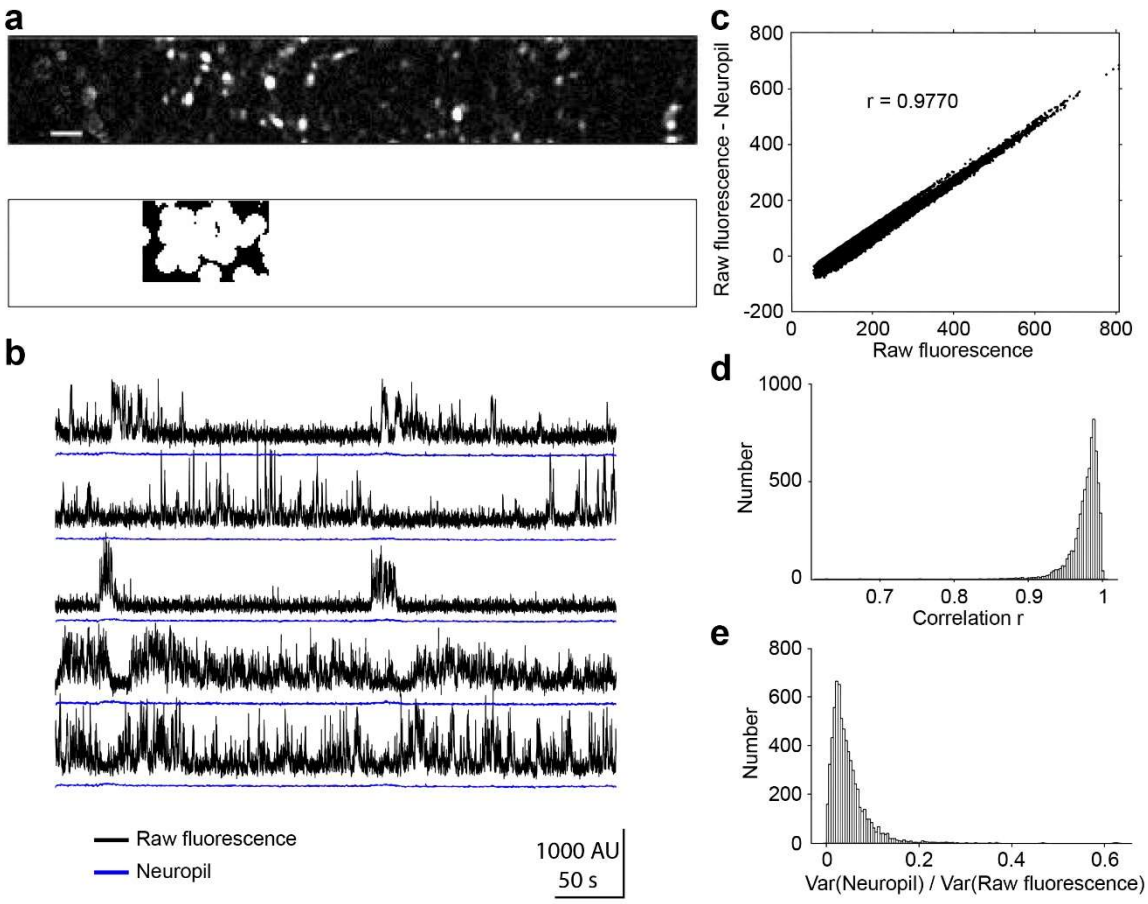
Supplementary Figure 1. Negatively modulated parallel fibres are not due to axial movement of the brain. (**a**) Example of an imaged patch showing varicosities expressing GCaMP6f in the green channel (top) and a retrobead (outlined in red) in the red channel (bottom). (**b**) Example mean ΔF/F for negatively modulated parallel fibres (top) locomotion speed (Speed), and mean fluorescence of the bead. Bottom two traces show the *post hoc* movement corrected shift in x and y (in pixels). (**c**) Correlation coefficient between the mean bead fluorescence and the mean ΔF/F for negatively modulated parallel fibres for each experiment (n = 13, N = 5). Experiments with online movement correction performed with retrobeads are shown in black, and those with 4 μm beads in white. (**d**) Mean square displacement (MSD) of bead images as a result of *post hoc* movement correction, shown for retrobeads (black symbols) and 4 μm beads (white) at the onset of locomotion, as in extended data 4a, after realtime movement correction (p = 0.53, two-sided Mann-Whitney test; retrobeads: n = 7, N = 3; 4 μm beads: n = 5, N = 2).



Supplementary Figure 2. Positively and negatively modulated responses in granule cell somatic recordings during the active state. (**a**) Image of GrC somas expressing GCaMP6f in the input layer of Crus I. Scale bar 20 μm. (**b**) ΔF/F example traces from GrC somas with whisker set point (WSP) and locomotion speed (bottom traces) from the recorded area shown in a. (**c**) Pie chart shows the percentage of positively modulated (PM; red), negatively modulated (NM; blue) and non-modulated (nonM; gray) GrC soma activity (n = 6, N = 4) for the entire population of recorded cells, quantified via correlation with locomotion compared to a shuffle test. Scatter plot shows the fractions of each subpopulation separately for each experiment.



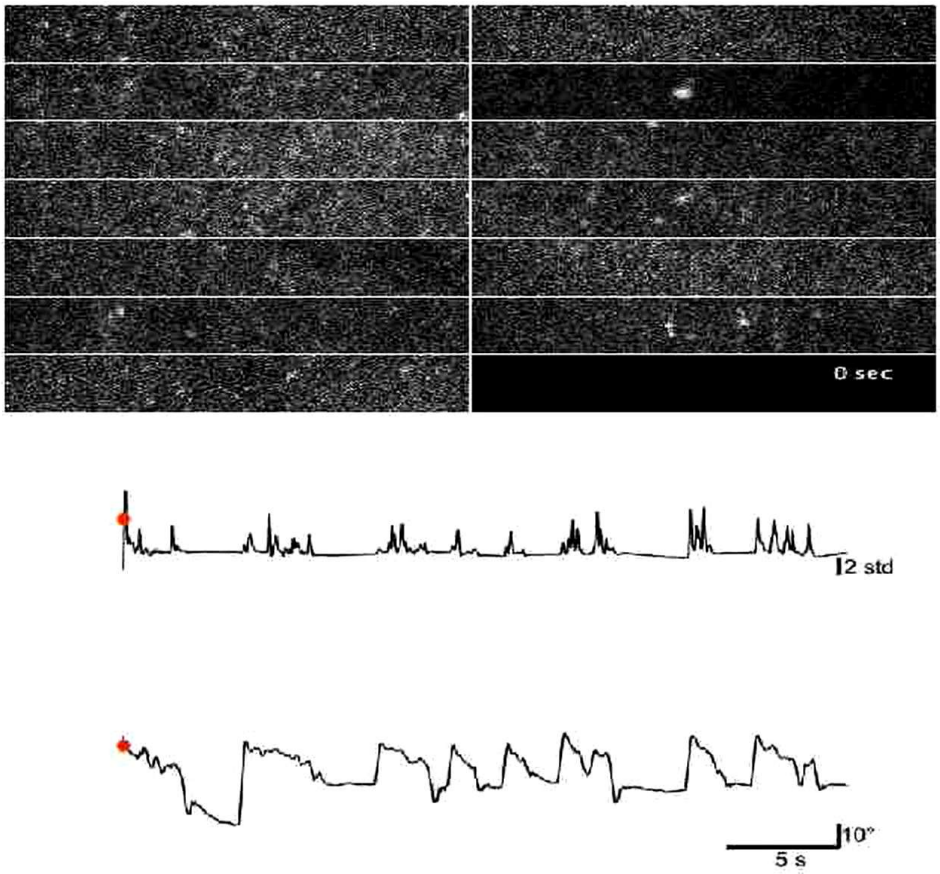
Supplementary Figure 3. Isolated whisk periods lie in a different region of the activity space. Examples of hand-labelled behavioural state segmentation for 2 mice (**a** and **b**) that engaged in occasional whisking without locomotion. Top traces: time series of whisker set point and locomotion speed hand-labelled as periods of active state (purple), quiet wakefulness (black) and periods of whisking without locomotion (orange). Bottom panels: first three principal components (PC) of parallel fibre activity for individual experiments in two mice color coded as a function of the state.



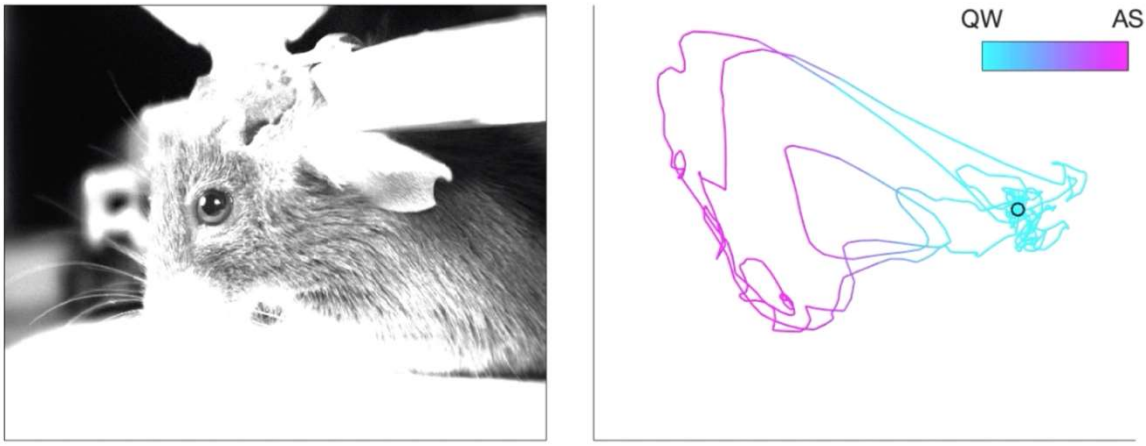
Supplementary Figure 4. Neuropil contains little signal. (**a**) Top: Correlation image of a patch in an example experiment. Scale bar indicates 5 μm. Bottom: Example neuropil mask (black), given by a 20 μm x 20 μm square while excluding all varicosities. (**b**) Raw fluorescence of five example varicosities (black), with corresponding neuropil fluorescence (blue). (**c**) Plot showing high correlation between raw fluorescence vs. neuropil-subtracted fluorescence for all varicosities in the example patch (a). (**d**) Histogram of correlations between F_{raw} and F_{raw} - $F_{neuropil}$ showing extremely high correspondence between raw signal and after neuropil subtraction (6854 varicosities over n = 13, N = 5). (**e**) Histogram of the variance of the neuropil fluorescence normalized by the variance of the raw fluorescence, var($F_{neuropil}$) / var(F_{raw}) (6854 varicosities, n = 13, N = 5).

Supplementary Table 1. Number of animals (N) and experiments (n) used for group data.

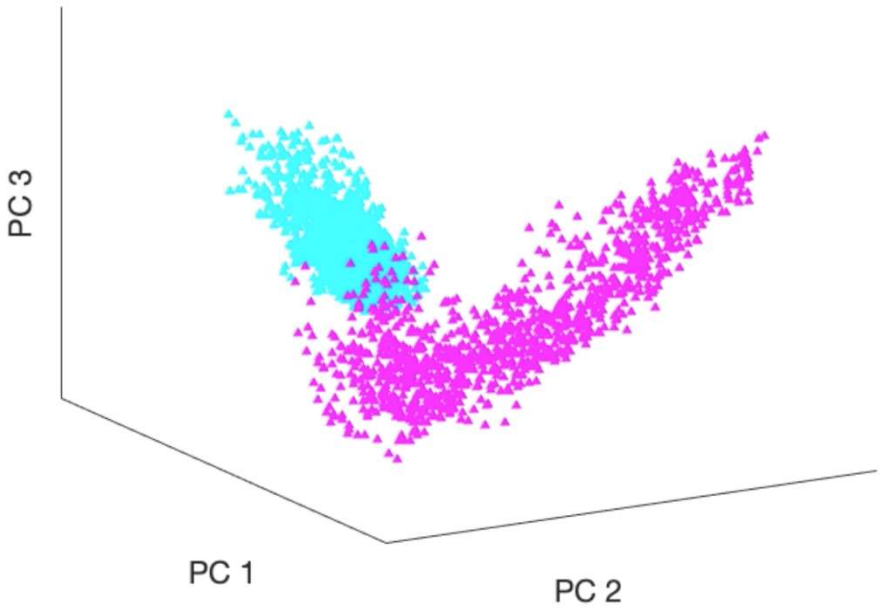
n	N	Figure panels	Reason for any exclusion
13	5	Figs. 1d, 2b,c, 3c,f, 4c, 5c-f, Extended Data Figs. 2a inset, 3a,b, 5b, 7b,c and Supplementary Figs. 1c, 4d,e	N/A
13	5	Fig. 3g (0th - 20th percentile)	For all Fig. 3g, datasets were removed if <100 axons were left after removing the most strongly modulated parallel fibres.
12	4	Fig. 3g (30th - 50th percentile)	(see above)
11	3	Fig. 3g (60th - 70th percentile)	(see above)
7	2	Fig. 3g (80th percentile)	(see above)
3	1	Fig. 3g (90th - 100th percentile)	(see above)
10	3	Fig. 6a,b (subsampling 300 axons)	For all Fig. 6, datasets were removed if the number of axons in the dataset is less than the number chosen for subsampling.
13	5	Fig. 6c (subsampling 100 axons)	(see above)
12	4	Fig. 6c (subsampling 150 - 200 axons)	(see above)
10	3	Fig. 6c (subsampling 250 - 300 axons)	(see above)
6	3	Fig. 6c (subsampling 350 axons)	(see above)
5	2	Fig. 6c (subsampling 400 - 450 axons)	(see above)
3	1	Fig. 6c (subsampling 500 - 550 axons)	(see above)
2	1	Fig. 6c (subsampling 600 - 650 axons)	(see above)
12	5	Extended Data Fig. 4c,d	One experiment was removed because no locomotion onsets were detected
6	4	Supplementary Fig. 2c	N/A (somatic data)
11	5	Extended Data Fig. 9a-d	Two experiments were removed because parallel fibre activity was unable to predict speed (unexplained variance over 100%)



Video S1. Acousto-optic lens 3D two-photon 'patch' imaging of granule cell axon activity in the molecular layer of an awake behaving mouse. Movie of 13 simultaneously imaged patches (14 x 68 μm) of granule cell axons (parallel fibres) expressing GCaMP6f located at different depths in the molecular layer of Crus I regions of the cerebellar cortex in a behaving mouse. Locomotion and whisker set point shown below. Data were acquired with real-time movement correction and images were *post hoc* corrected, as for all data used in this study. The acquisition rate was 15 Hz (30 s recording, speed 2x real time).



Video S2. Transitions between spontaneous behaviours captured in population activity. Left: Example movie of a mouse spontaneously switching between periods of active locomotion and whisking (active state, AS, magenta) and quiet wakefulness (QW, cyan). Right: 2D projection of population activity. Colour indicates projection onto the state dimension (Methods). The projection plane was chosen manually to show the separate transients for QW → AS and AS → QW transitions.



Video S3. Orthogonal representations of active state and quiet wakefulness. Movie showing rotation of active state (AS, magenta) and quiet wakefulness (QW, cyan) manifolds for an example experiment. Axes represent the first three principal components (PC1-3) of the full population activity.