Supporting Information

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SI Text

We performed the tunneling measurements in a home-built variable-temperature scanning tunneling microscope that operates in the temperature range from 6 to 180 K. Lower temperature (2 and 4 K) measurements were performed on a low temperature scanning tunneling microscope.

The single crystal URu_2Si_2 samples used for this study were grown in an optical floating-zone furnace. Small, flat crystals were oriented along the crystallographic axes and cut into sizes suitable for scanning tunneling microscopy measurements ($\sim 2 \times 2 \times 0.2$ mm). The samples were cold cleaved on a surface perpendicular to the c axis at $T \sim 10$ K in ultrahigh vacuum and transferred in situ to the microscope head. Differential conductance (dI/dV) measurements were performed using standard lock-in techniques. The relative variation in $dI/dV(V)$ at a single point does not depend on the height of the tip and is therefore assumed to be representative of the local electronic density of states (DOS) within an overall normalization.

Identifying the Cleavage Planes. Multiple surfaces have been obtained after cleaving (Fig. S1 and Fig. 1). In ~55% of the cases, the topography is as shown in Fig. S1*A*. This 300-Å image of the surface (termed surface *A*) displays a square lattice ($a \sim 4.1$ Å) that corresponds to either the U or Si spacing (1). The Ru layer has a smaller interatomic spacing because it is rotated 45° with respect to the U layer (see Fig. 3*B*). The step size between equivalent surfaces (~4.8 Å) corresponds to half the unit cell. In approximately 45% of the cases, the topography is as shown in Fig. S1*B*. The surfaces in this 1,000-Å image show a "cigar-like" reconstruction (*Inset*) with a width of two lattice constants (~8.2 Å, surface *B*). The step height between the reconstructed surfaces (~4.8 Å) is also equivalent to half the unit cell.

Averaged spectroscopic dI/dV measurements on the different surfaces at $T = 4$ K are shown in Fig. S2. The spectra on the reconstructed surfaces do not necessarily resemble that of the bulk.

Fitting the *dI/dV* Spectra. Fig. S3 illustrates our fitting procedure for the electronic DOS shown in Fig. 2. The high temperature data (above T_{HO}) were fitted to the sum of a Fano line shape and a V-like background (*Dashed Lines* in Fig. S3). The background is obtained from a phenomenological fit to the highest temperature data (120 K) consisting of a linear spectrum with different slopes for hole and electron tunneling. The lower temperature data (below T_{HO}) were fitted to the same function multiplied by an asymmetric Bardeen–Cooper–Schrieffer (BCS)-like gap function (*Dotted Line*). The fitting functions were convolved with the Fermi function appropriate for the temperature. The results of the fits are shown as red lines both below and above the hidden order. The extracted hidden order gap magnitude is plotted in Fig. 4*C*.

Temperature Evolution of the Hidden Order Gap. To clarify the temperature dependence of the hidden order gap, and show that it evolves more rapidly than simple thermal broadening, we thermally broaden the data below T_{HO} all to 18 K. The divided raw and the artificially broadened gaps are shown in Fig. S4. Though the spectra (Fig. S4*B*) are smeared out due to the artificial broadening, they still show the opening of a gap already visible at 15 K. This confirms that the gap evolves with temperature rather than filling up due to thermal broadening.

Normalization Independence of the Onset Temperature. We see from the measured spectra that the hidden order gap is not seen in the raw spectra by $T = 18$ K. Accordingly, the spectra were normalized by the 18-K curve. To further verify that our results are independent of this choice of normalization temperature, we normalize the spectra by dividing them with a higher temperature data. Plotted in Fig. S5 are the averaged spectra of Fig. 2*B* below $T = 40$ K divided with the 40-K spectrum, which shows that the hidden order gap indeed opens below 18 K. Since the Kondo–Fano resonance has somewhat broadened at 40 K relative to 18 K, an additional background is produced by this choice of normalization temperature. However, the hidden order gap can be clearly distinguished from this weak background.

1. Palstra TTM, et al. (1985) Superconducting and magnetic transitions in the heavy-fermion system URu_2Si_2. *Phys Rev Lett* 55:2727–2730.

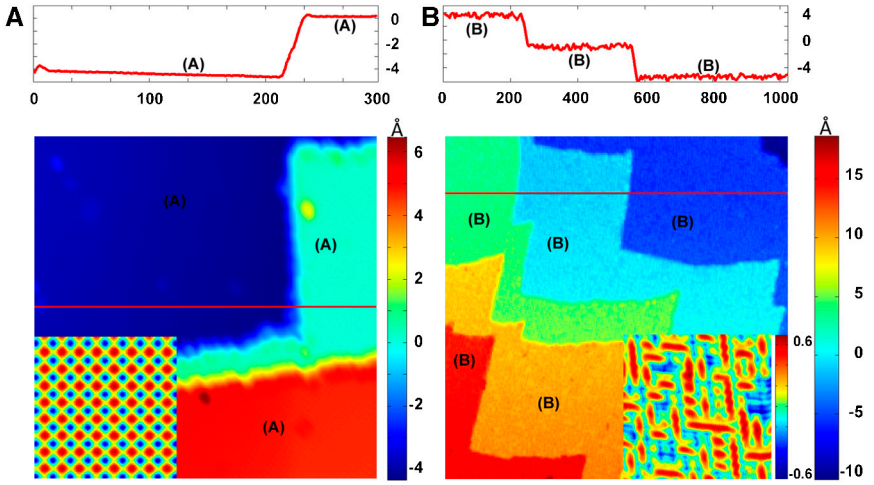

Fig. S1. (*A*) Constant current topographic image (−100 mV, 50 pA) over a 300-Å area of the atomic surface (surface *A*), showing atomic terraces. The Inset shows the magnification of the atomically ordered surface. (*B*) Constant current topographic image (100 mV, 80 pA) over a 1,000-Å area of the reconstructed surface (surface *B*). The Inset shows the magnification of a 100-Å area showing the reconstruction. In both panels step heights are ∼4.8 Å, corresponding to half the unit cell. The red lines show the locations of horizontal cuts through the data.

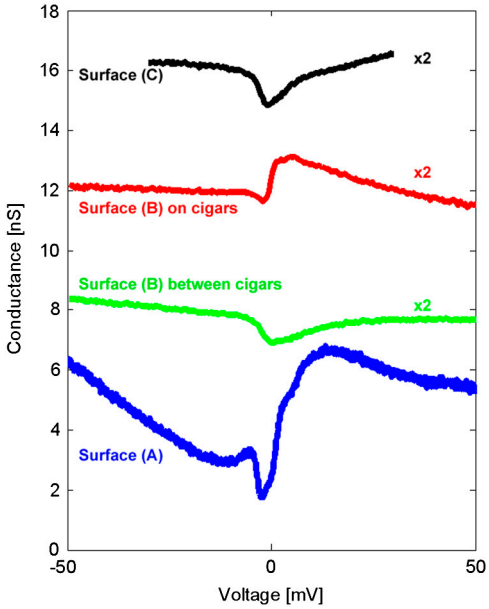

Fig. S2. Averaged *dI*/*dV* measurements on the different observed surfaces. The spectra on surface *B* strongly depend on the location. In between the cigars the spectra shows a gap-like feature similar to that of surface *C*. On top of the cigars the spectra show a resonance-like feature. The spectra are offset by 4 nS for clarity.

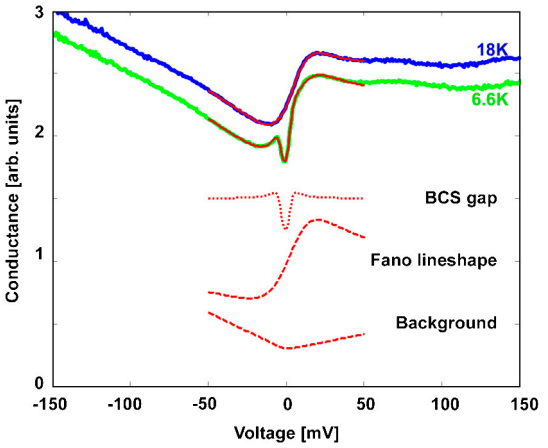

Fig. S3. Averaged dI/dV at 18 (*Blue*) and 6.6 K (*Green*). Above the hidden order temperature, the data are fitted to a Fano line shape and a V-shaped background (*Dashed Lines*). Below the hidden order temperature, the data are fitted with the same function multiplied by a BCS-like gap (*Dotted Line*). The red solid lines represent the fit to the data above (sum of dashed lines) and below (sum of dashed lines multiplied by the dotted line) the hidden order temperature.

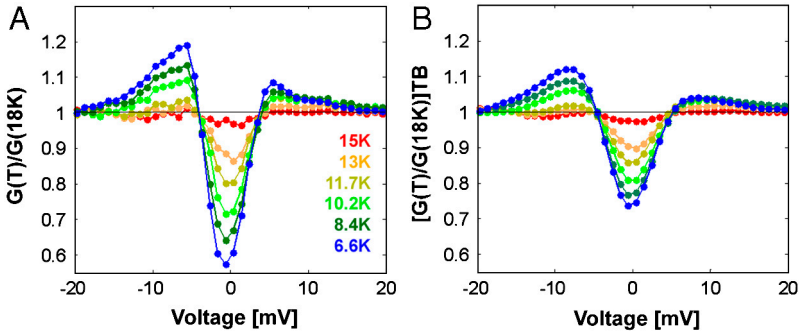

Fig. S4. (*A*) The experimental data below T_{HO} divided by the 18 K data showing the evolution of a gap in the DOS. (*B*) The same data as in *A* all thermally broadened to 18 K, which clearly demonstrates that the gap evolves with temperature more rapidly than simple thermal broadening.

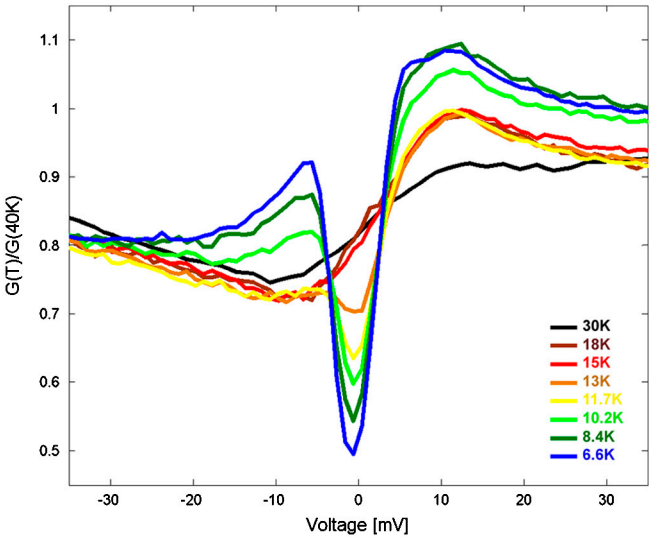

Fig. S5. The averaged dI/dV for $T < 40$ K divided by the $T = 40$ K data. The data show the development of a gap near the Fermi energy below 18 K. The spectra also display the residue of the asymmetric Fano line shape.