

# Supplementary Materials for

## **Direct visualization of the quantum vortex lattice structure, oscillations and destabilization in rotating $^4\text{He}$**

Charles Peretti<sup>1</sup>, Jérémy Vessaire<sup>1</sup>, Émeric Durozoy<sup>1</sup>, Mathieu Gibert<sup>1\*</sup>

<sup>1</sup>Univ. Grenoble Alpes, Institut Néel - CNRS UPR2940, 25 rue des Martyrs, BP 166, 38042  
Grenoble Cedex 9, France.

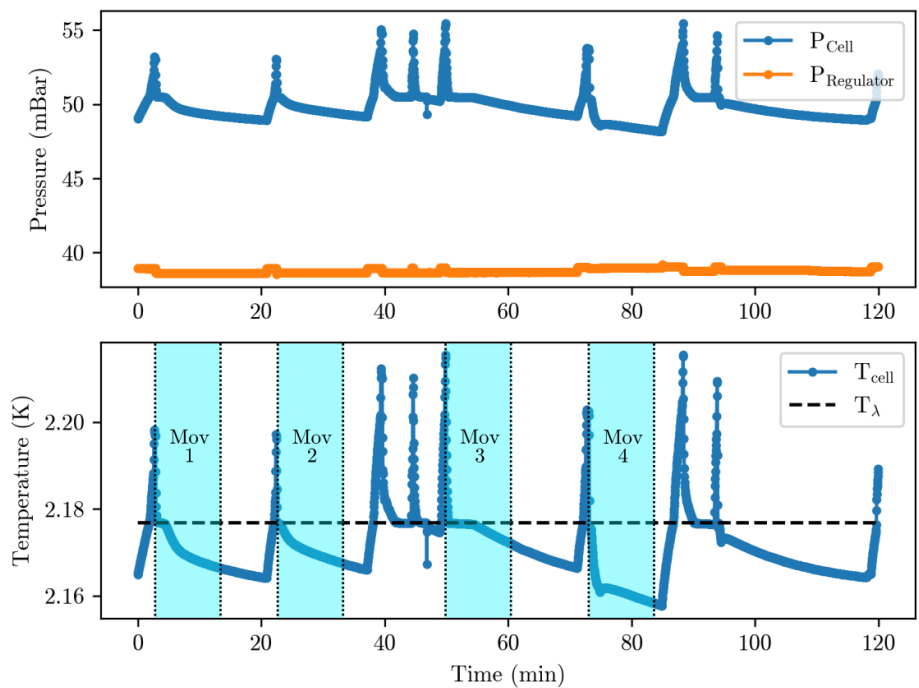
Corresponding author: [mathieu.gibert@neel.cnrs.fr](mailto:mathieu.gibert@neel.cnrs.fr)

### **The PDF file includes:**

Figs. S1 to S5  
Table S1

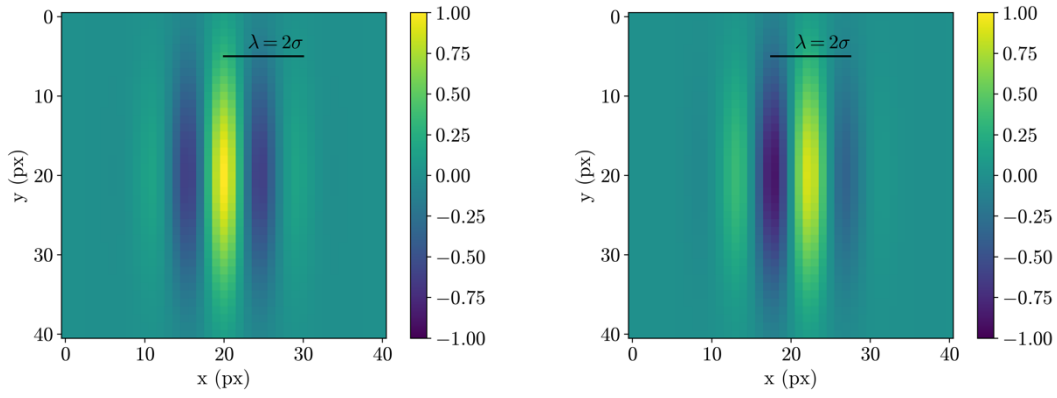
### **Other Supplementary Materials for this manuscript include the following:**

Movies S1 to S2



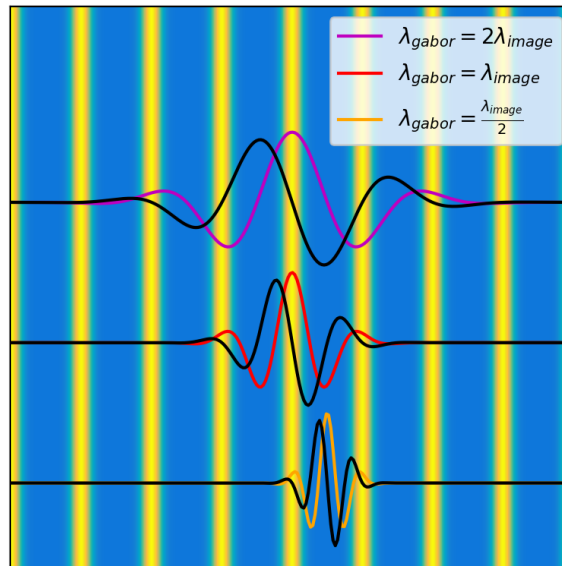
**Fig. S1: Pressure and temperature during time.**

Representation of pressure and temperature during an experimental session. The temperature is dropped by reducing the pressure in the cell (at vapor saturation). Each run starts by injecting  $H_2$  in the cell just above  $T_\lambda$  and then opening the regulator valve to allow pumping through it. It can be seen that  $P_{Regulator}$  is slightly lower as the valve is opened, but remains constant during a run. Movies are acquired for 10 to 20 minutes. The next movie has to be taken after re-injecting  $H_2$  as the particles float up and do not stay indefinitely in the region of interest. As seen in the temperature graph, the temperature is not constant during a run, however, the maximum drift is of order 0.7% of the minimum temperature during a run.



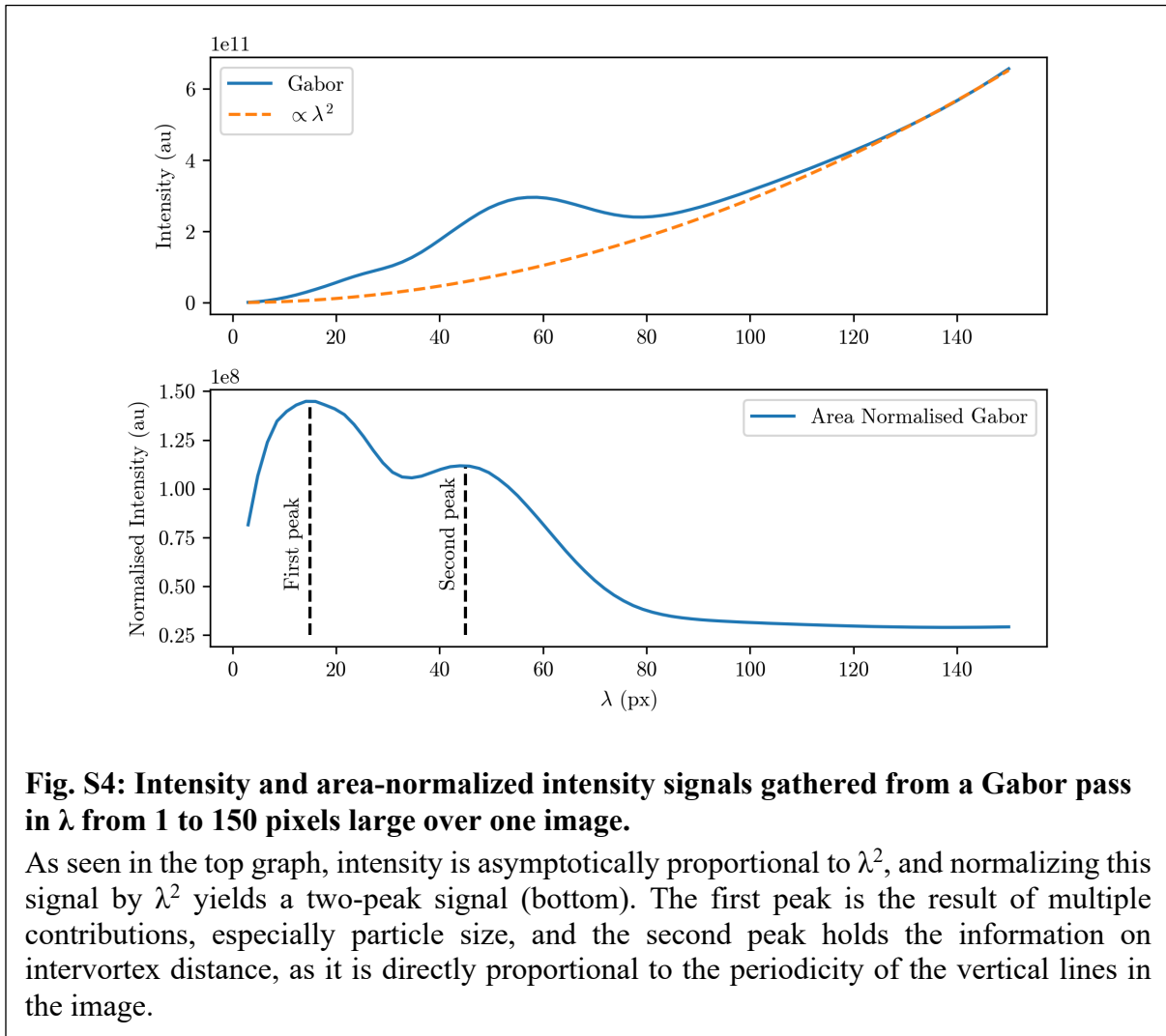
**Fig. S2: Real and imaginary parts of the Gabor kernel.**

2D representations of the numerical real (left) and imaginary (right) parts of the Gabor kernel. The colorbar represents the intensity of the colored pixels. The horizontal scale bar has a length of  $\lambda$ , the spatial period of the sine and the cosine parts of the Gabor function, which is equal to 2 times  $\sigma$ , the standard deviation of the gaussian part of the Gabor function. The kernel is a square of length  $L = 1+2\text{ceil}(4\sigma)$ . In this example,  $L = 41$  pixels,  $\lambda = 10$  pixels and  $\sigma = 5$  pixels.



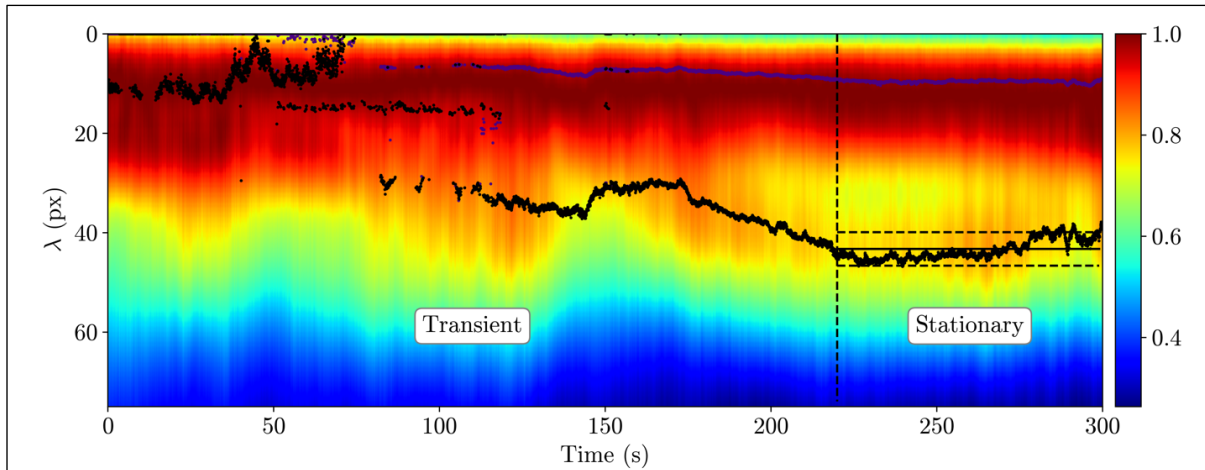
**Fig. S3: Superposition of a synthetic image with three Gabor kernels.**

The lines in black represent the imaginary part of each kernel.  $\lambda_{gabor}$  is the  $\lambda$  discussed in the text and  $\lambda_{image}$  the one of the perfect synthetic image that we intend to measure.



**Fig. S4: Intensity and area-normalized intensity signals gathered from a Gabor pass in  $\lambda$  from 1 to 150 pixels large over one image.**

As seen in the top graph, intensity is asymptotically proportional to  $\lambda^2$ , and normalizing this signal by  $\lambda^2$  yields a two-peak signal (bottom). The first peak is the result of multiple contributions, especially particle size, and the second peak holds the information on intervortex distance, as it is directly proportional to the periodicity of the vertical lines in the image.



**Fig. S5: Time dependent colored representation of Gabor kernel and image convolution intensity.**

The normalized intensity (Figure S4 down) is colorcoded and represented as a function of time. The vertical dashed line corresponds to the end of the transient state due to the particle injection scheme. The purple (respectively black) dots are the values of the first (respectively second) peak found at a given time by the bimodal fit we used. The horizontal black line is the average value of the intervortex spacing that we measure, and the horizontal dashed lines represent the standard deviation around it, obtained over the entire stationary dataset at 5RPM.

**Table S1: Intervortex spacing (Gabor convolution second peak)**

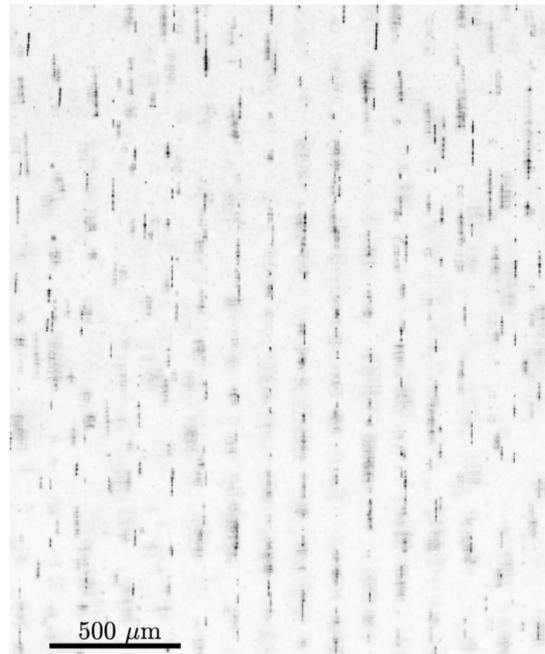
Mean intervortex distance and standard deviation reported for the explored angular velocities.

$\Omega$ (RPM)	$\Omega$ ( $\text{rad} \cdot \text{s}^{-1}$ )	$\delta$ ( $\mu\text{m}$ )	$\Delta\delta$ ( $\mu\text{m}$ )
1	0.1047	671.6	203.2
2	0.2094	444.6	26.6
3	0.3142	353.3	8.5
4	0.4189	309.1	23.9
5	0.5236	275.8	21.6
6	0.6283	279.9	4.7
8	0.8378	213.1	44.6
10	1.0472	175.8	9.0
12	1.2566	173.7	7.8
16	1.6755	151.2	4.4

## Movie S1.

### Stability of the vortex lattice

This movie is acquired at a frequency of 25Hz, and is played 4X faster while the cryostat spins at 10RPM. The average velocity of the particles is  $20\mu\text{m/s}$  upward. One can also visualize oscillations that have an amplitude of  $\sim 50\mu\text{m}$  due to the motion of the He II container with respect to the camera (both on the spinning table). This parasitic motion comes from a misalignment of order  $1\mu\text{m}$  between the principal axis of the pumping feedthrough and the axis of rotation of the experiment. This tiny default (when compared to the experiment sizes) is amplified by the 1m lever arm between the body-fixed point of the pumping feedthrough where the HeII container is soldered to the cryostat and our region of interest. These oscillations are deterministic and periodic. This movie demonstrates the stability of the quantum vortex lattice that we observe.



## **Movie S2.**

### **Vortex/Vortex interaction and spinning counterflow**

This movie is acquired at a frequency of 100Hz with a high-speed camera (20 $\mu$ m pixel size) while the cryostat spins at 10RPM, and is played back 4 times slower. We switch on the surface heater at the bottom of the channel with 15mW, corresponding to 37.5 W/m<sup>2</sup>. Shortly after, one can visualize a few hundreds of vortex/vortex interaction events. It is important to stress that these events are triggered by the heating and that the initial condition is well defined. After these strong events characterized by strong accelerations, the particles appear to move mostly upward in a rotating counterflow. Their motion needs to be further characterized in order to search for signs of their interactions with the polarized quantum vortex tangle (out of scope of this paper).

