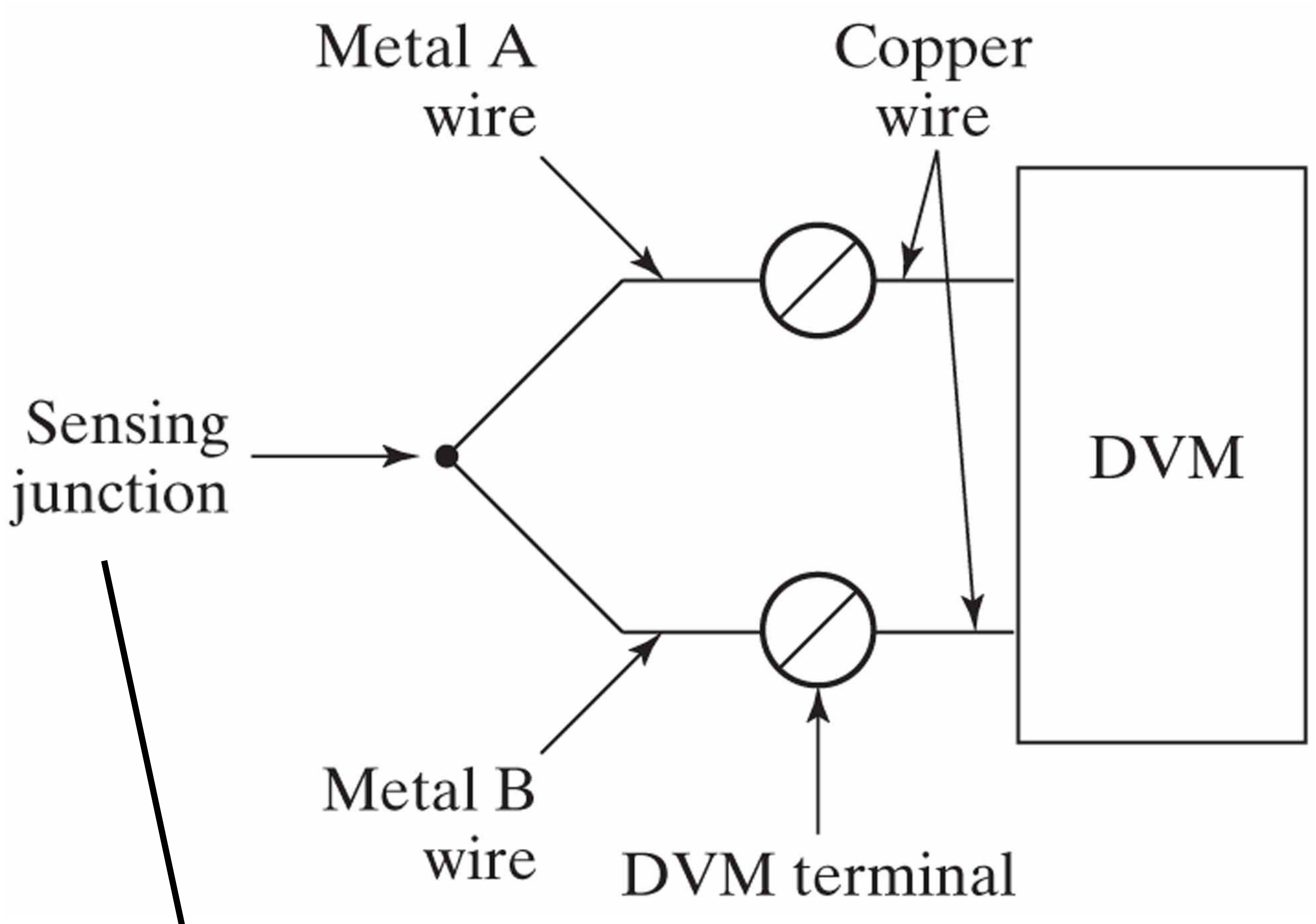
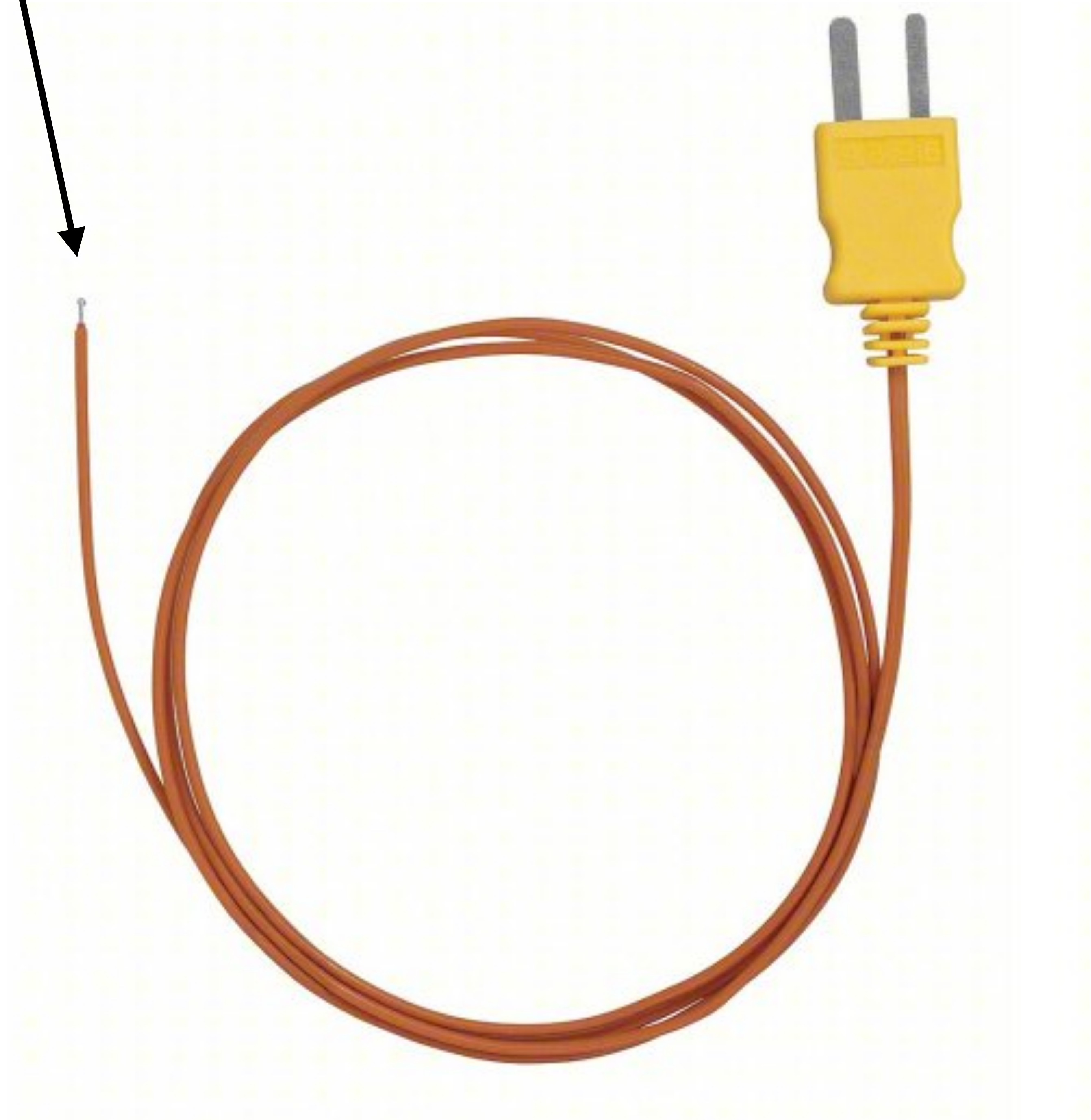
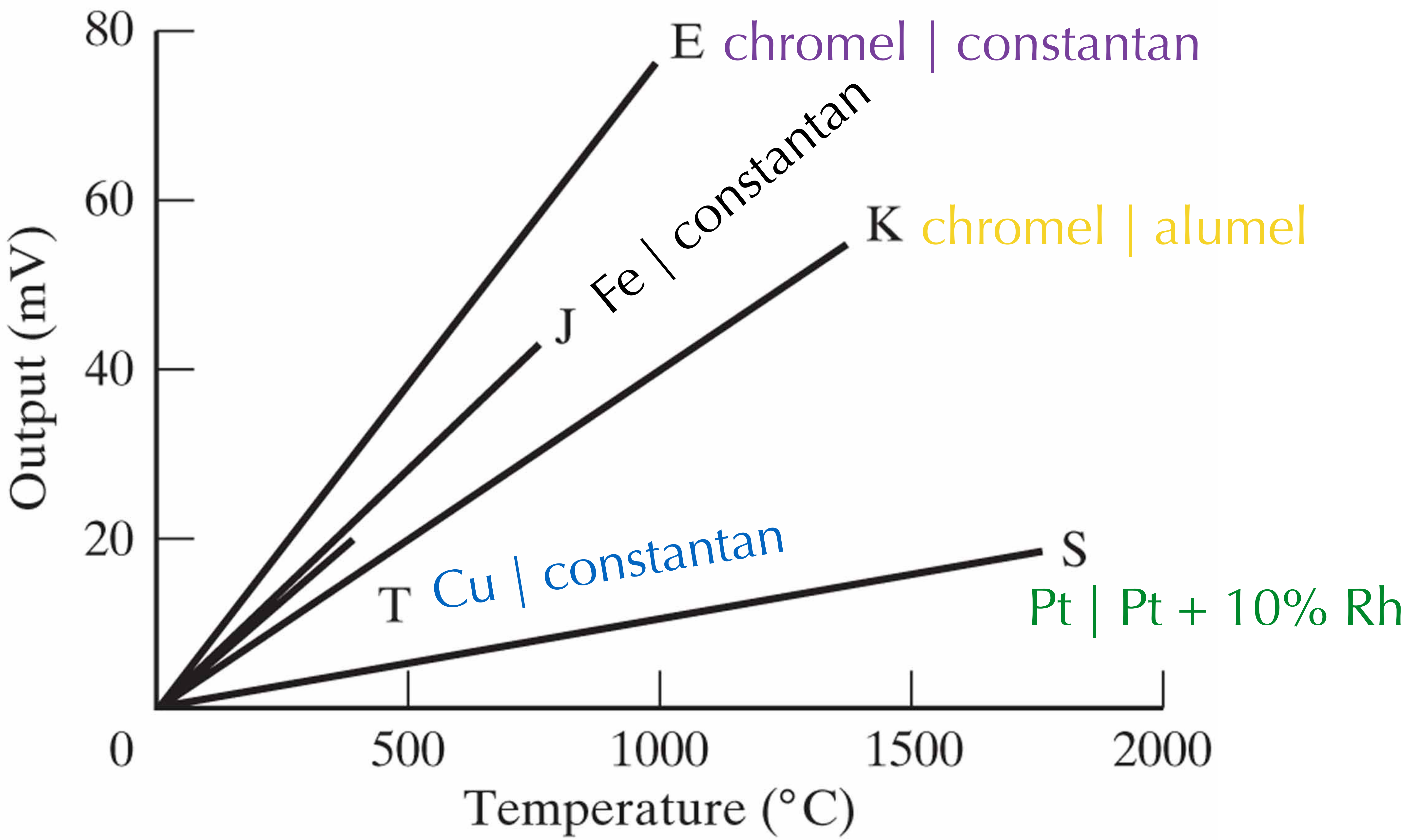
Thermocouples





- Where two metals touch, a voltage is developed that is proportional to temperature (Peltier effect).
- Different proportionality for different metals.
- Lead wires of same (or compatible) metal



Radiation thermometers / thermal cameras

- All objects radiate always!

$$E = \epsilon \sigma T^4 = \epsilon \int_0^\infty \frac{C_1 \lambda^{-5}}{e^{\frac{C_2}{\lambda T}} - 1} d\lambda$$

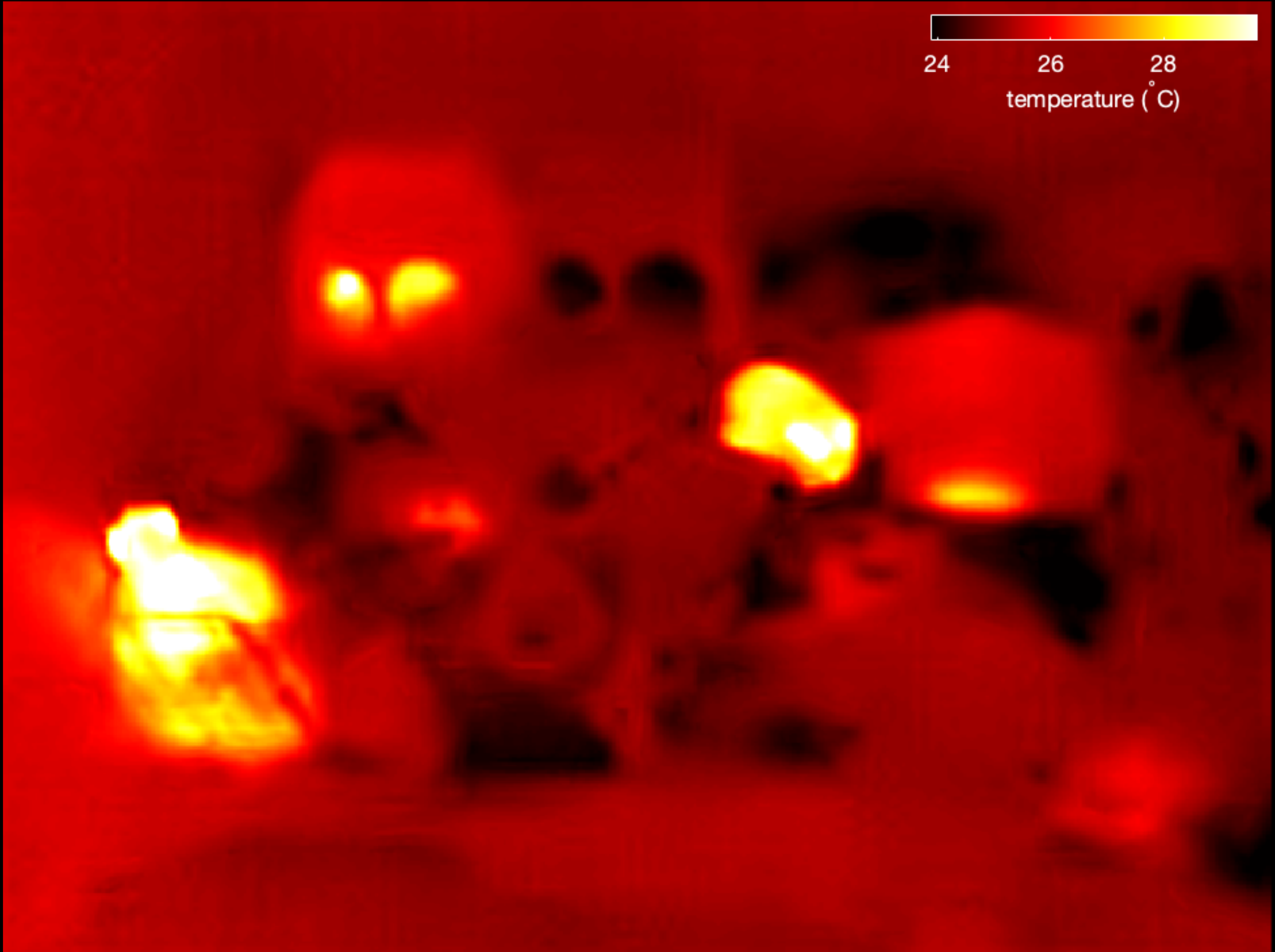
radiation power (E), emissivity (ϵ), temperature (T), Stefan-Boltzmann constant (σ), wavelength (λ)

$\sigma = 5.669 \times 10^{-8}\,\mathrm{W m^{-2} K^{-4}}$

$C_1 = 3.743 \times 10^8\,\mathrm{W} \cdot \mu\mathrm{m}^4/\mathrm{m}^2$

$C_2 = 1.4387 \times 10^4 \mu\mathrm{m} \cdot K$

- $\epsilon = 1$ for ideal black body, $\epsilon = 0.018$ for shiny metals
- Common to measure E at two or more wavelengths, estimate T from ratio.


24
26
28
temperature (°C)

A philosophy of captions

- Start with a brief and literal statement of what the figure shows (e.g., "Distributions of normalized resistance for different vascular arrangements.").
- Give the reader all information necessary to understand what you're plotting and how: colors, plot symbols, math symbols, acronyms, etc. But information that is self-evident in the plots, e.g. because it's on legends or labels, need not be repeated.
- End the caption with a brief statement of the take-home message (e.g., "Though all distributions overlap with the observed normalized resistance, the hexagonal pseudorandom perturbed arrangement gives the closest match").
- Don't write "A figure showing…" or "Plots of …" because that's obvious.
- In the body text, avoid writing about colors or symbols; just write about the quantities.
- Keep details about the methods that produced the plots and the analysis of the results in the body text, not the caption…
  - … unless you're writing with a tight word limit on body text (e.g. *Nature* or *Science*) and must therefore pack words into captions.

FIGURE 1. Schematic of the experimental set-up (*a*) and the UDV Sensor positions for (*b*) the axial velocity and (*c*) the chord velocity measurements. (*d*) Photograph of the experimental set-up without sidewall insulation in place. Image credit: Y. Xu (UCLA).

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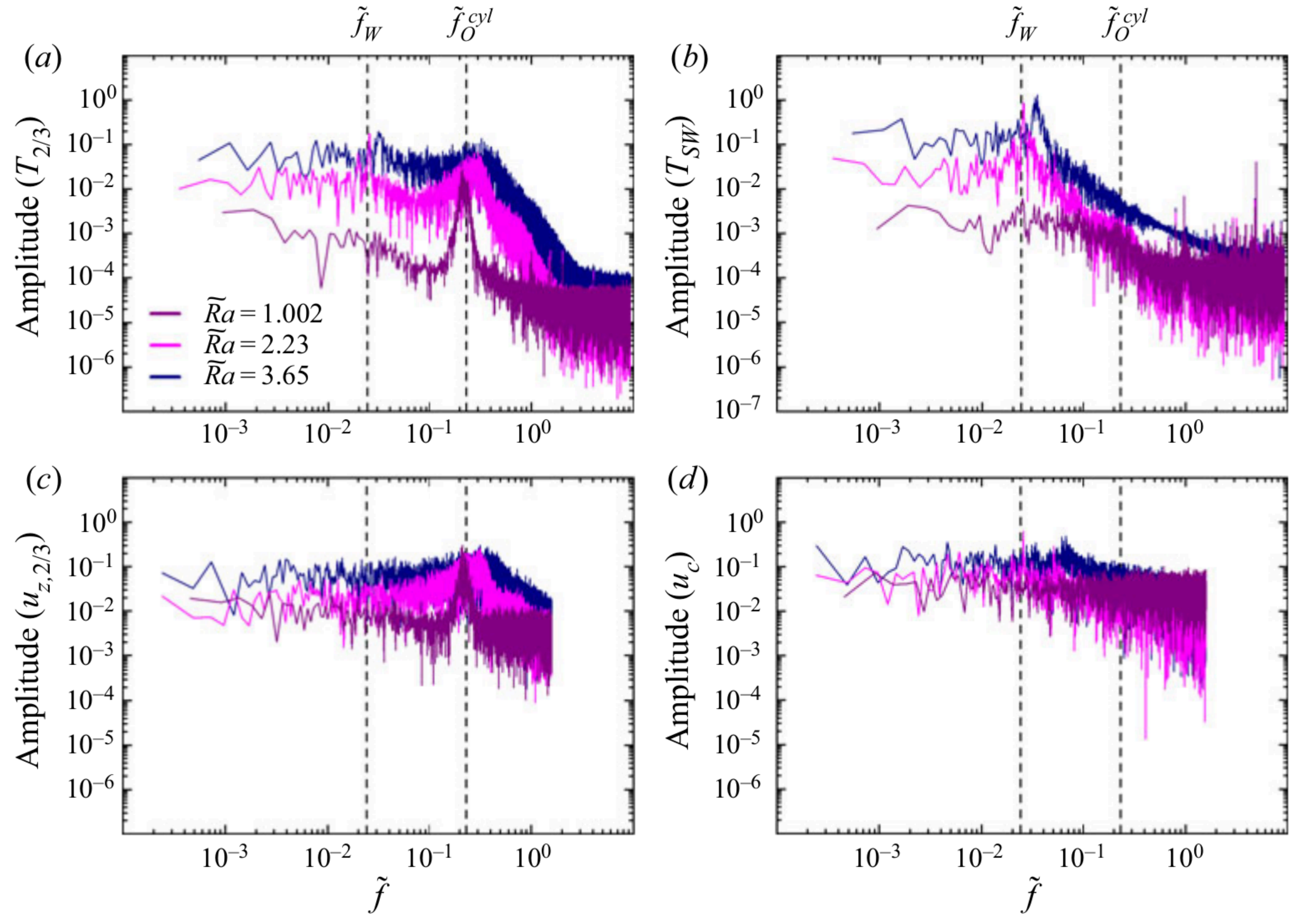

FIGURE 7. Amplitude of the Fourier transforms of temperature and velocity signals versus normalized frequency $\tilde{f} = f/f_\Omega$. The Ekman number is $Ek = 5 \times 10^{-6}$ and the supercriticality $\widetilde{Ra}$ is indicated by the line colour. All spectra are evaluated on the midplane, $z/H = 1/2$. (*a*) Temperature spectra measured with a thermistor situated within the fluid bulk at $r/R = 2/3$. (*b*) Temperature spectra measured on the cylindrical tank's outer sidewall at $r/R = 1.05$. (*c*) Vertical velocity spectra measured at $r/R = 2/3$. (*d*) Chord velocity spectra evaluated in the vicinity the the sidewall. Vertical dashed lines indicate the onset frequency for wall modes $\tilde{f}_W = 0.024$ and bulk oscillations $\tilde{f}_O^{cyl} = 0.274$.

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Writing an abstract

An abstract is a one-paragraph summary of your report.

- Basic introduction to the broad topic, readable by any colleague (1-2 sentences)
- Detailed motivation for solving the specific problem at hand, readable by engineers (2-3 sentences)
- Problem statement (1 sentence)
- Statement of your findings (e.g., “Here we show…”) (1 sentence)
- Implications of the result for the specific problem at hand (1-2 sentences)
- Broader implications for possible future problems, readable by any colleague (1-2 sentences)

Abstract: Oscillatory thermal-inertial flows in liquid metal rotating convection

We present the first detailed thermal and velocity field characterization of convection in a rotating cylindrical tank of liquid gallium, which has thermophysical properties similar to those of planetary core fluids. Our laboratory experiments, and a closely associated direct numerical simulation, are all carried out in the regime prior to the onset of steady convective modes. This allows us to study the oscillatory convective modes, sidewall modes and broadband turbulent flow that develop in liquid metals before the advent of steady columnar modes. Our thermo-velocimetric measurements show that strongly inertial, thermal wind flows develop, with velocities reaching those of non-rotating cases. Oscillatory bulk convection and wall modes coexist across a wide range of our experiments, along with strong zonal flows that peak in the Stewartson layer, but that extend deep into the fluid bulk in the higher supercriticality cases. The flows contain significant time-mean helicity that is anti-symmetric across the midplane, demonstrating that oscillatory liquid metal convection contains the kinematic components to sustain system-scale dynamo generation.

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