PhD Thesis proposal

Title: *Looking for thermality of Hawking radiation in an open channel flow*

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Location: Institut Pprime, POITIERS

Expected starting date: 01/10/24

Scientific context

Analogue Gravity follows the insight of Unruh that, since waves in moving media behave as if in an effective curved spacetime, we can investigate certain "gravitational" phenomena using these experimentally accessible analogue systems. In particular, the black-hole radiation predicted by Hawking (which links gravity to quantum mechanics and thermodynamics) can be investigated in a very different context, expanding the scope of existing theories and allowing us to gain confidence in them.

One such analogue system is provided by surface waves on open channel flows. These waves exist at the interface between water and air. Therefore, they live in an effective 2+1-dimensional metric, which can be reduced to 1+1 dimensions if the channel has a fixed width and varies only in the longitudinal direction (typically by placing an obstacle on the floor of the channel). In this context, an effective black-hole horizon is realized at another interface: that separating regions of subcritical and supercritical flow, the waves being able to escape the flow on one side while being inexorably dragged by the flow on the other. Such a horizon is associated with an analogue of the Hawking effect, whereby incident dispersive (short-wavelength) waves are scattered into hydrodynamical (long-wavelength) waves and amplified according to a thermal spectrum. The associated temperature is determined solely by the derivative of the total wave speed at the horizon, which plays the role of the effective "surface gravity".

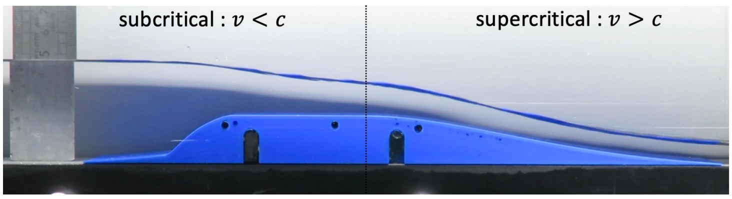

Figure 1: Transcritical flow over an obstacle. A black-hole horizon is realized where the flow passes from subcritical to supercritical.

Despite several important Analogue Gravity experiments in open channel flows [1-5] (many performed at Institut Pprime), the thermality of the Hawking effect associated with a transcritical flow remains observationally elusive. There is much scope for theoretical guidance on optimization, both in the experimental design and in the techniques used in the data analysis.

Project

The primary goal of the thesis will be to provide theoretical guidance on optimizing the observation of the thermal Hawking effect in a transcritical flow. This will cover the experimental design and the techniques used for data analysis. It will involve analytical treatments and numerical simulations, as well as the analysis of previously recorded data.

Of particular relevance will be the issue of how to ensure a large population of the ancestor waves, in order to achieve a suitably large signal-to-noise ratio. Two methods of exciting the Hawking effect should thus be considered and compared: that of stimulation by a suitably designed wave maker (as in [1,2,4]), and reliance on the scattering of noise that is naturally present in the system (as in [3,5]). To this end, the intrinsic noise should be analyzed and calibrated using old (and possibly new) data, and various observables should be tested as to whether they can be expected to reveal the presence of the Hawking effect. In parallel, the response of the water-air interface to different shapes of wave maker should be analyzed, to see whether the direct stimulation of the incident dispersive waves is feasible and can be expected to provide a sufficiently strong signal.

We will also consider the case of a transcritical white-hole flow, which is the time-reversed version of a black-hole flow. In this case, it is the hydrodynamical (long-wavelength) waves that are scattered into outgoing dispersive (short-wavelength) waves. In principle, then, the Hawking effect is easier to excite since hydrodynamical waves are more readily produced. However, the downstream side of a white hole is unstable against the formation of an undulation, which complicates the data analysis [5]. It will be necessary to provide some theoretical predictions for the behaviour expected in such a case, and to search for any tell-tale signs of the Hawking effect.

Candidate profile

- Comfortable with both analytical and numerical approaches to theoretical problems
- Some familiarity with Matlab and/or Mathematica is desirable
- Good level in English

References

[1] G. Rousseaux *et al.*, Observation of negative-frequency waves in a water tank: a classical analogue to the Hawking effect?, *New J. Phys.* **10**, 053015 (2008)
[2] S. Weinfurtner *et al.*, Measurement of stimulated Hawking emission in an analogue system, *Phys. Rev. Lett.* **106**, 021302 (2011)
[3] L.-P. Euvé *et al.*, Observation of noise correlated by the Hawking effect in a water tank, *Phys. Rev. Lett.* **117**, 121301 (2016)
[4] L.-P. Euvé *et al.*, Scattering of co-current surface waves on an analogue black hole, *Phys. Rev. Lett.* **124**, 141101 (2020)
[5] J. Fourdrinoy *et al.*, Correlation on weakly time-dependent transcritical white-hole flows, *Phys. Rev. D* **105**, 085022 (2022)