La $S(Q,\omega)$ di fluidi e regimi dinamici

Premise: in a scattering experiment characterized by the exchanged variables $\hbar Q$ and $\hbar\omega$ the dynamical processes (atomic motions) are probed over a length scale ~ $1/Q$ and over a time scale ~ $1 / \omega$.

Intuitively, one can attempt to identify different dynamical regimes by looking at the two limiting behaviours :

$$Q \to 0, \omega \to 0$$

"Large distances"
i.e. >> than
atomic spacings

The system is probed with a quasi-macroscopic step
Microscopic details are lost

"Long times"
i.e. >> than
collision times

Time scale over which too many microscopic events (free motion, collisions) occur, to be able to probe each of them in detail

"Looks like a continuum"

Hydrodynamic Theory
(Navier-Stokes equations)

$$Q \to \infty, \omega \to \infty$$

"Short distances"
i.e. << than
atomic spacings

"Short times"
i.e. << than
collision times

Probing the single *free* particle dynamics

i.e.

Over very short distances

AND/OR

"Initially" ($t \to 0$)

a particle is *unaware* of the other particles
Interaction effects are negligible

Motion is free

Kinetic regime
(ideal gas)

More precisely...

Different dynamical regimes, from the hydrodynamic to the kinetic one, are more correctly identified by comparing the time and length scales probed in scattering experiments, with a *characteristic* time and length *of the system*.

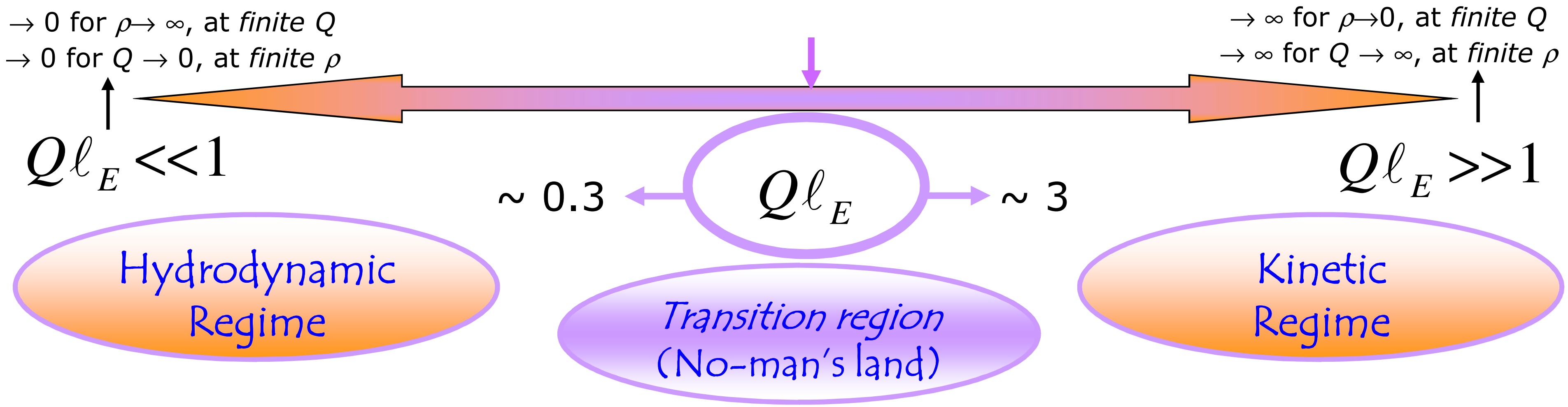
For instance, as a suitable "typical" length, one can take the ***mean free path*** ℓ defined in the kinetic theory for hard spheres of diameter **σ**:

$$\ell = \frac{1}{\rho\,\sigma^2\,\pi\sqrt{2}} \quad \propto 1/\rho$$

Even more appropriate is its generalization (Enskog kinetic theory) for ***dense*** hard-sphere fluids:

$$\ell_E = \frac{1}{g(\sigma)\rho\sigma^2\pi\sqrt{2}} = \frac{\ell}{g(\sigma)} \xrightarrow[\rho\to 0]{} \ell$$

So that dynamical behaviour can be more properly discriminated by looking at:



Dynamical regimes and $S(Q,\omega)$

Hydrodynamic Regime — *Transition region (No-man's land)* — **Kinetic Regime**

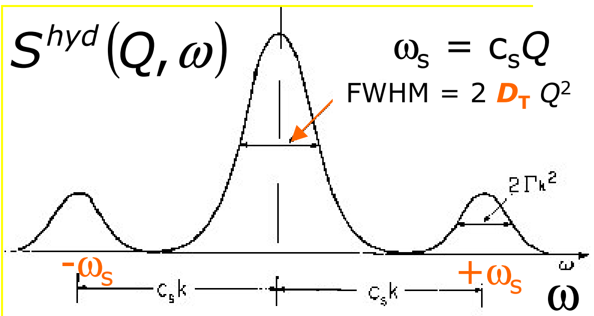
"Low-Q" coherent inelastic scattering (Brillouin scattering)

Collective properties

$S(Q,\omega)$

3 modes:
2 acoustic modes
1 non-propagating mode

Rayleigh-Brillouin triplet
3 lorentzians centred at



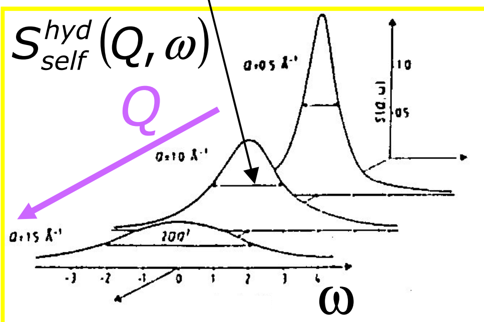
"Low-Q" incoherent quasi-elastic scattering

Single-particle "long-times" dynamics

$S_{self}(Q,\omega)$

Diffusive motion

Self-diffusion lorentzian
centred at $\omega = 0$
FWHM = 2 D Q^2



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Scattering on ideal-gas-like (low-density) systems

Deep Inelastic Neutron Scattering (High Q, high ω)

Impulse approximation

Single-particle kinetic properties
(momentum distribution, mean kinetic energy)

$S_{self}(Q,\omega)$

Single FREE particle dynamics

Ideal gas "gaussian"
centred at $\omega = \omega_r = \dfrac{\hbar Q^2}{2M}$