Dynamic Sound Localization
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**Problem**
- What binaural dynamic cues are available to the human sound localization system?
- How do they break the notorious circle (tori*cones) of confusion?
- Derive a localization algorithm for a mobile robot based on these principles.

**Mathematical Analysis and Results**
- Sound pressure at ear is a complex function of frequency (amplitude and phase), governed by Helmholtz eqn. (for time harmonic source).
- Solution for spherical head is expansion in Zonal Spherical Harmonics (ZSH) which are invariant under SO(2) rotations.
- Interaural functions (IPD,ILD) have same symmetry: can statically localize source only up to rotations about interaural axis.
- Polar (horizontal) rotations act by derivation of amplitude and phase as so(2) representation.
- Comparison of derivatives of amplitude and phase at each ear give IPD’ and ILD’. They break the confusion symmetry by generating different flow on ILD/IPD plane for different source locations! (Fig. 1)

**Localization Algorithm:**
1. Define metric between four interaural localization functions (ILD,IPD,ILD’,IPD’) for source and test directions.
2. Choose test direction for which metric has minimum (zero).

Dynamic (derivatives) information gives unique global minimum -- no confusion. (Fig 2-3)

**Background**
Humans rely on several cues to infer the location of a sound source:
- Binaural information due to diffraction (mostly) about the head -- comparison of sound amplitude and phase between ears (IPD,ILD).
- Direction dependent spectral filtering by Pinna (external ear) and canal.
- Echoes and reverberations from environment for range estimation.
- Dynamic (binaural) information due to rotation of head relative to source -- shown experimentally but, so far, not understood theoretically.