# New Visualization Technique of High-Spin Level Schemes: Double Helix Level Scheme of $^{171}$Yb

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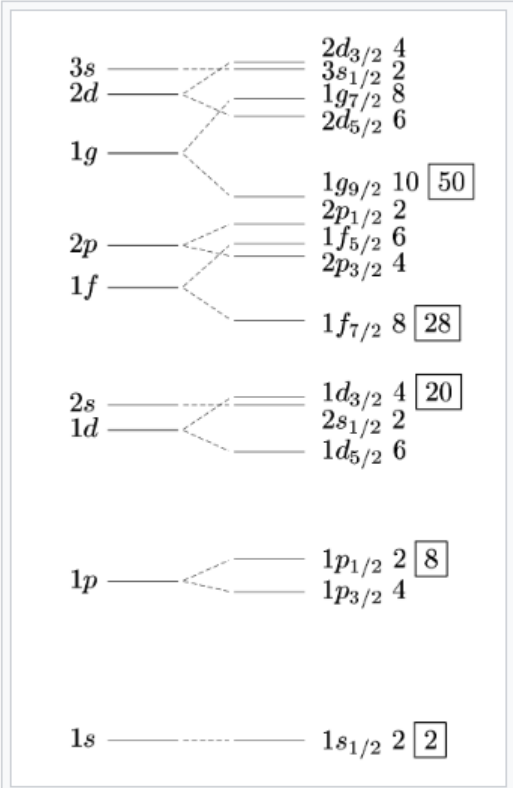
# Microscopic (Shell Model)

# Mesoscopic

# Macroscopic (prolate/oblate)




https://en.wikipedia.org/wiki/Nuclear_shell_model

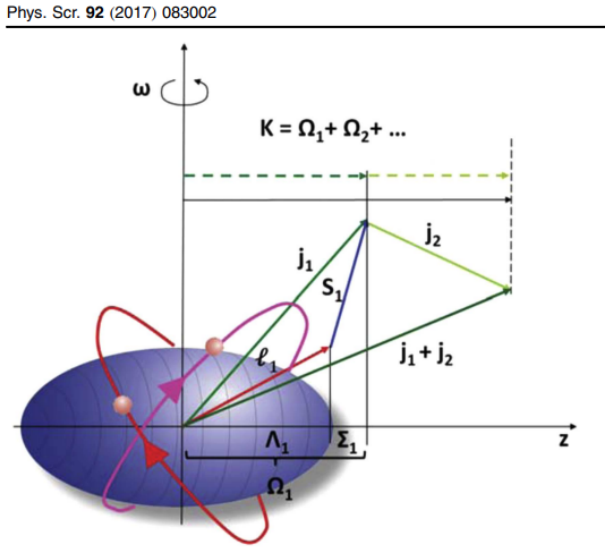


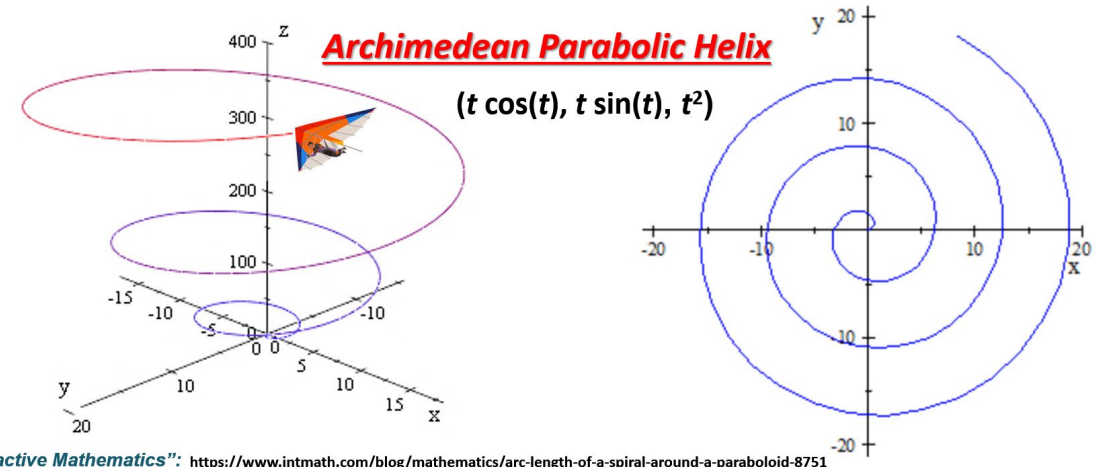

**Figure 8.** Definition of the $K$ quantum number as the total projection of the sum $j_i$ of the spin of the nucleon $S_i$ and the orbital angular momentum $\ell_i$ of all excited 2-quasi-particle states onto the symmetry axis of the nucleus.

# Correspondence Principle: Classical to Quantum Mechanics

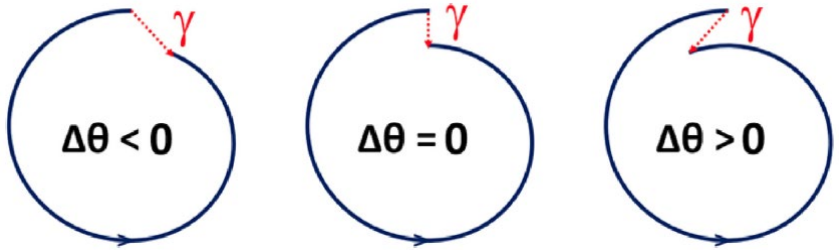
## a) Classical: Attenuated Rotational Motion
## (progressive continuous decrease of energy and ang. momentum)

**Archimedean Parabolic Helix**

$(t\cos(t), t\sin(t), t^2)$




From "Interactive Mathematics": https://www.intmath.com/blog/mathematics/arc-length-of-a-spiral-around-a-paraboloid-8751




$$\mathbf{I} = mvr = mr^2\frac{v}{r} = \mathcal{J}\omega, \quad \text{with } \mathcal{J} = \frac{Mass_A}{\pi r}r^2 = \frac{Mass_A}{\pi}r \text{ and } \omega = const$$

$$\mathbf{I} \sim r$$

*Angular Momentum Space is mapping with Metric Space*

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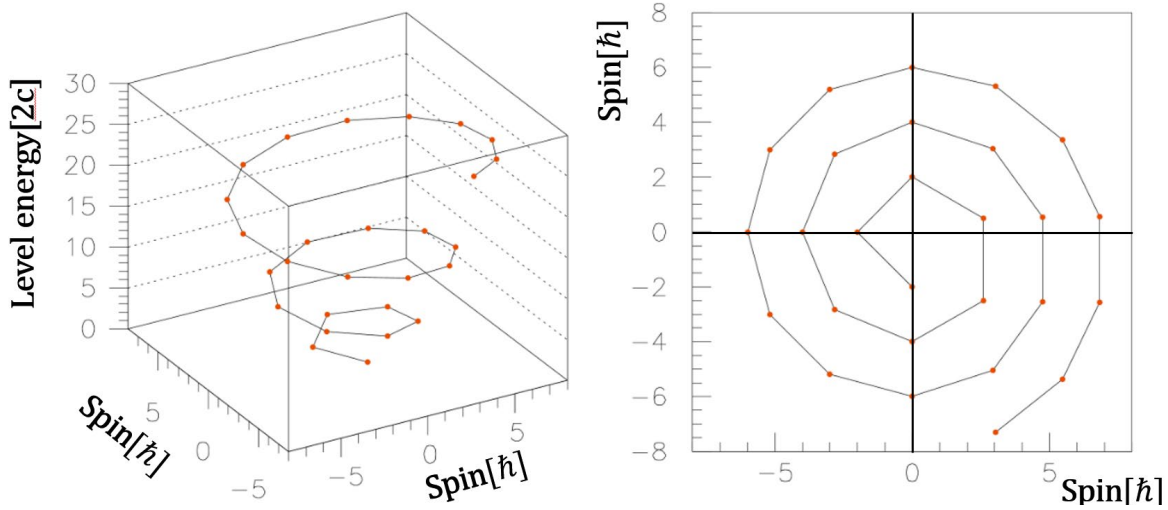
# Correspondence Principle: Classical to Quantum Mechanics

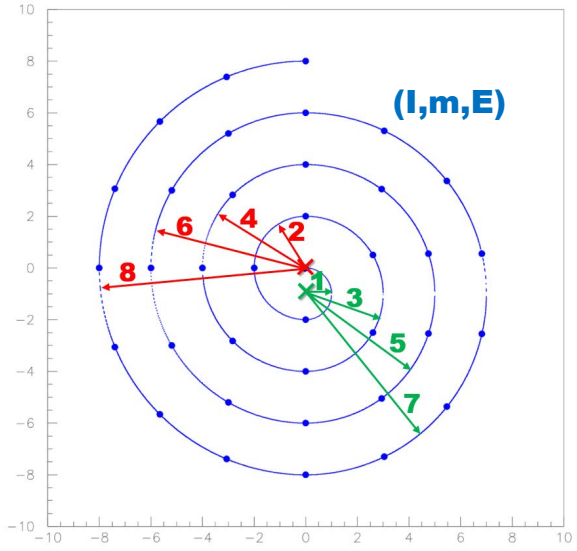
## b) Quantum: Attenuated Rotational Motion
## (progressive discrete decrease of excitation energy and spin)




## Quantum Helix: Attenuated Rotational Motion
## (progressive decrease of excitation energy and spin)

- *The fact that quantum angular momentum is expressed by integer values implies that the radii of the quantum helix are also integers*
- *This implies that the quantum helix is composed of a series of alternating odd-even radii semicircles*
- *This also implies that unlike the classical helix, the quantum helix has two centers:*

1. *(0,0) center for even integer radii for even-I semicircles on the left*
2. *(0,-1) center for odd integer radii for odd-I semicircles on the right*



# Double-Helix for even-A and odd-A Nuclei

## Double Helix:
## Geometrical Locus
## of the complete set of *(I,m,E) Rotation -Correlated States*
## that defines the *Meta-Trajectory*
## followed by the *Rotational Motion of Nuclear Matter*

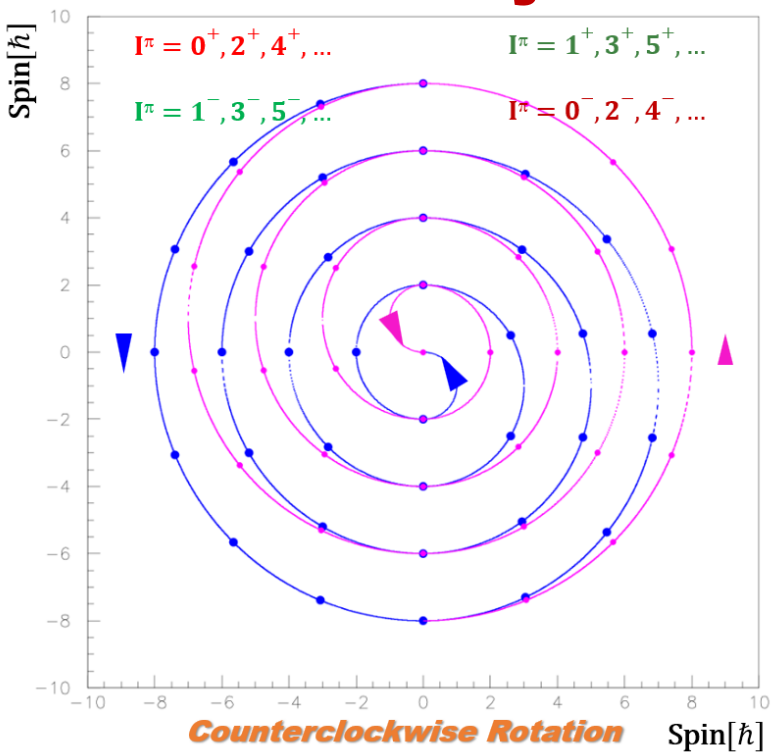



Fig. Set of 2 helixes for integer spins

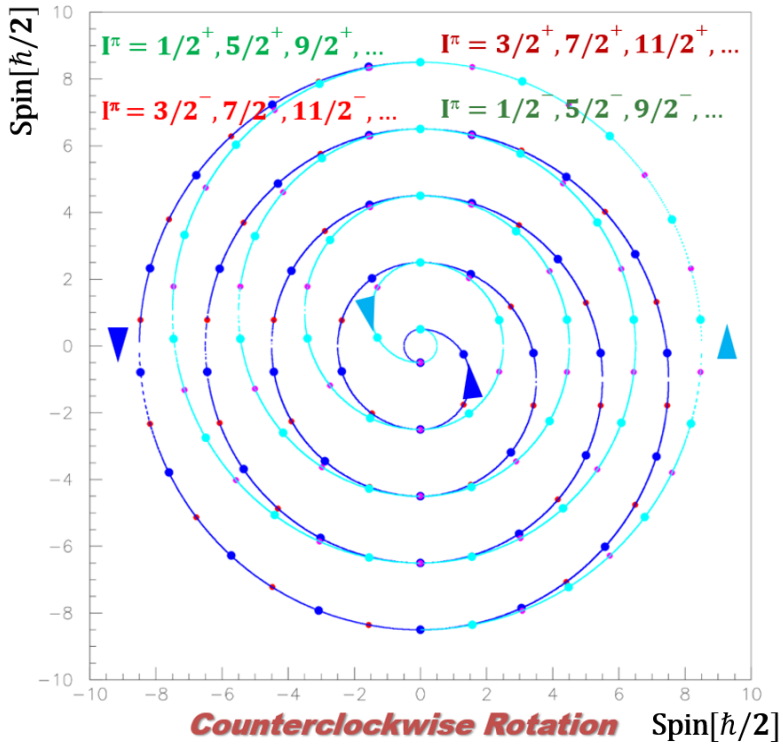



Fig. Set of 2 helixes for half-integer spins

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# Case study: $^{171}$Yb nucleus high spin rotational bands

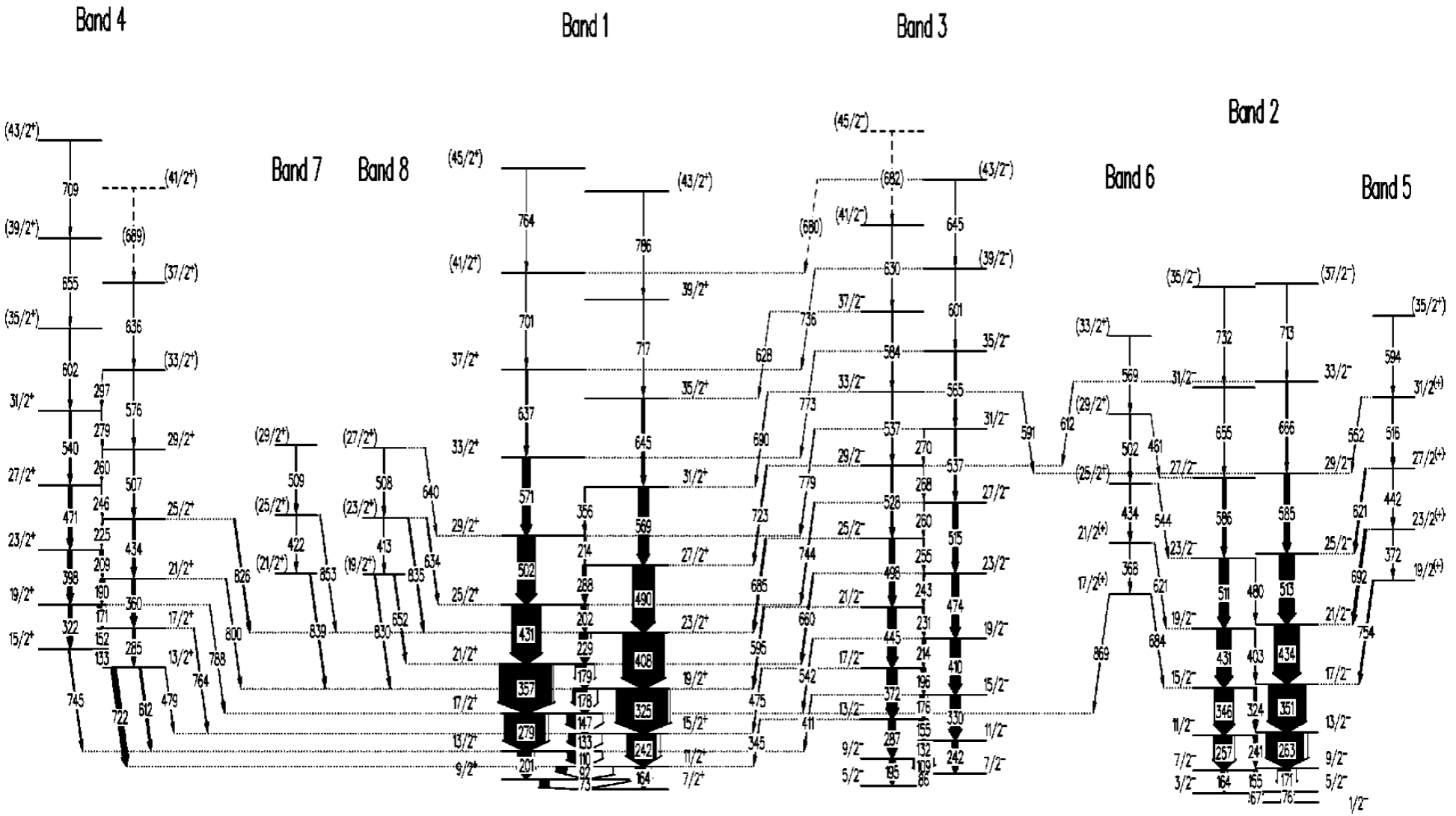


FIG. 5. Level scheme for $^{171}$Yb.

D.E.Archer *et al*, Phys.Rev. C57, 2924 (1998)

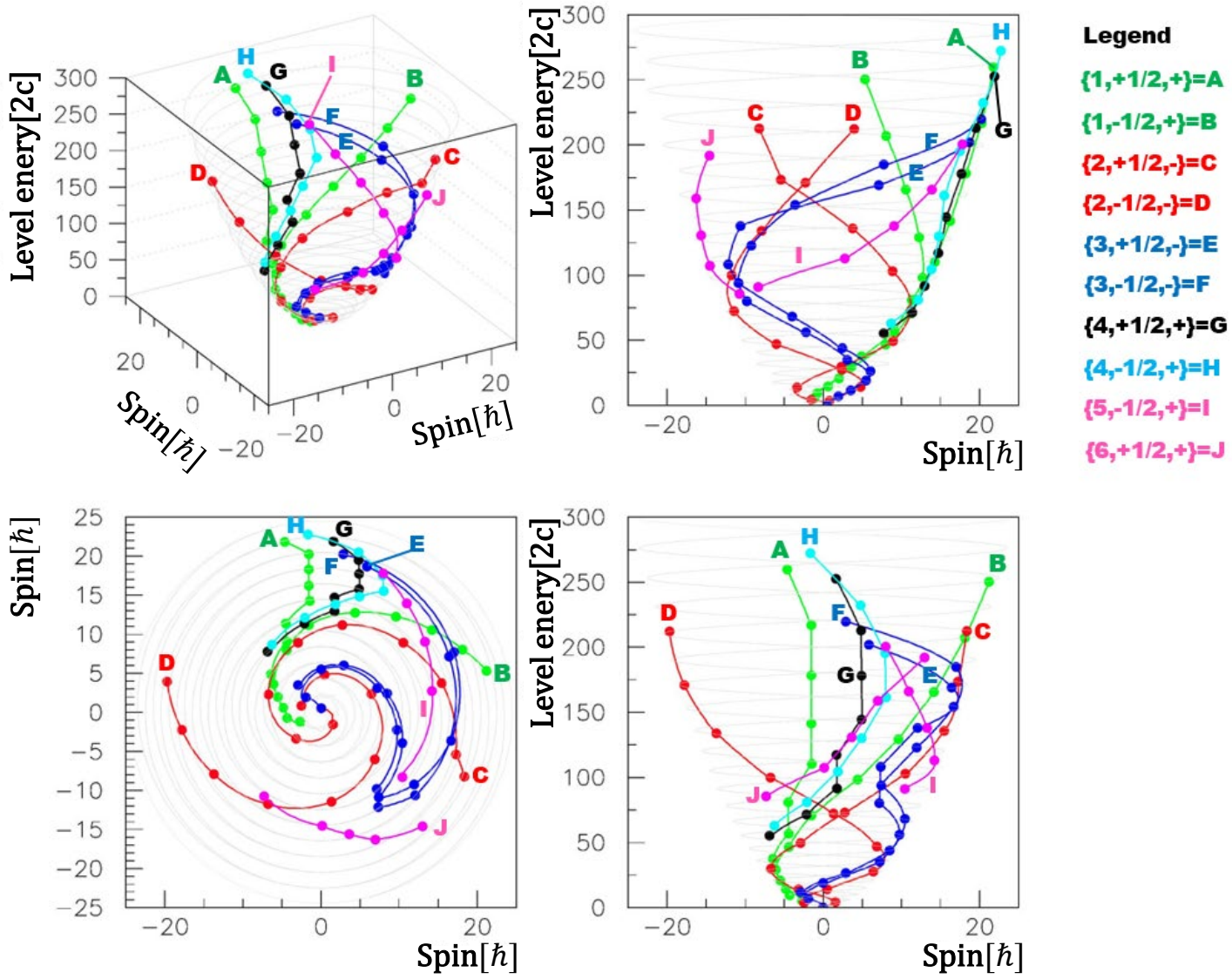


**Fig. Double Helix of $^{171}$Yb nucleus**

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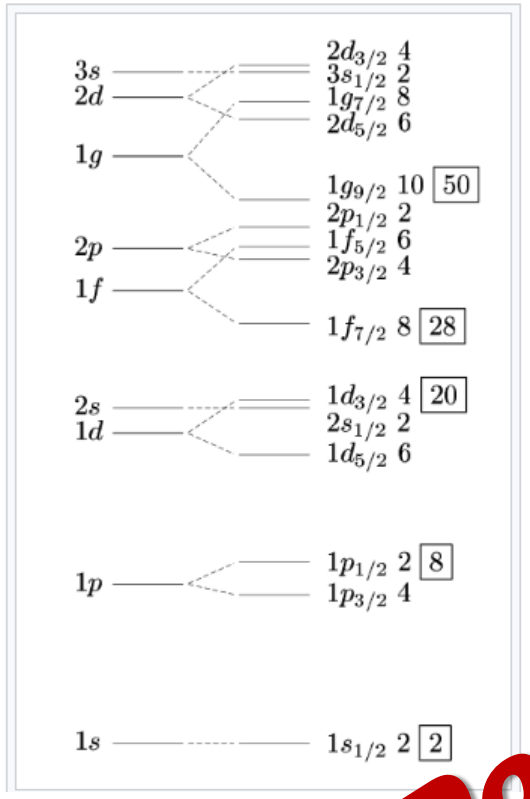
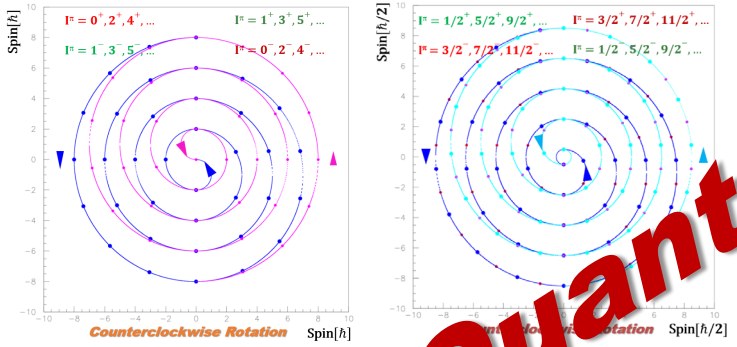
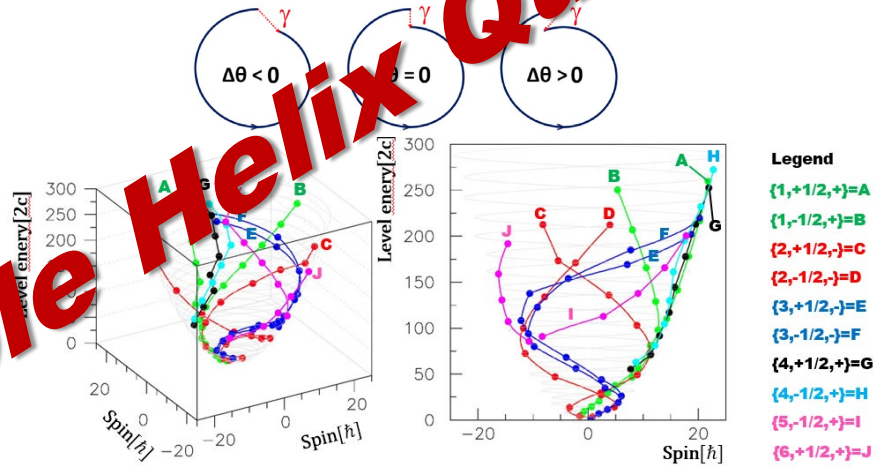
# Microscopic (Shell Model)

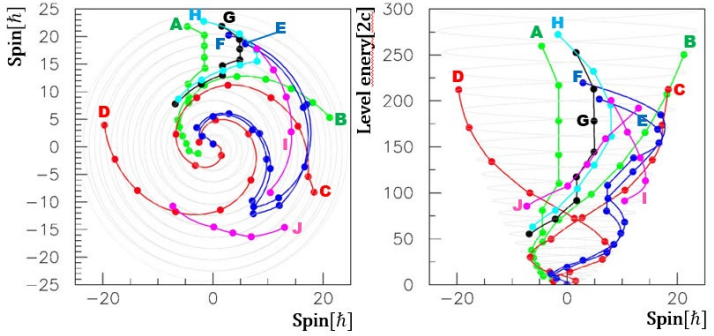



https://en.wikipedia.org/wiki/Nuclear_shell_model

# Mesoscopic (Double Helix)




# Macroscopic (prolate/oblate)

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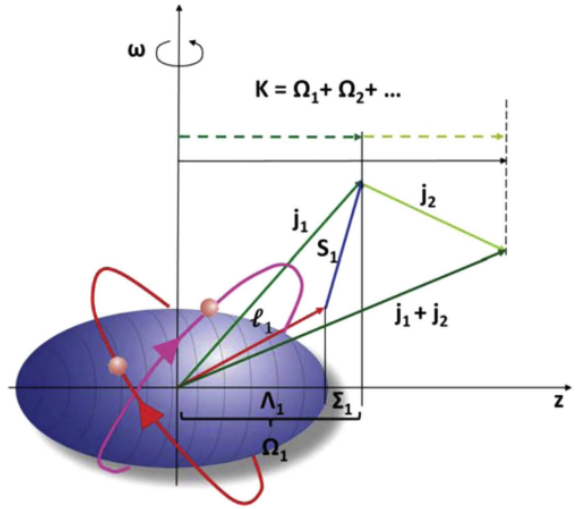


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# Double Helix Quantum Vortex

# Irrotationality vs. Vorticity

*Aage N. Bohr, Rotational Motion in Nuclei, Nobel Lecture, December 11, 1975*

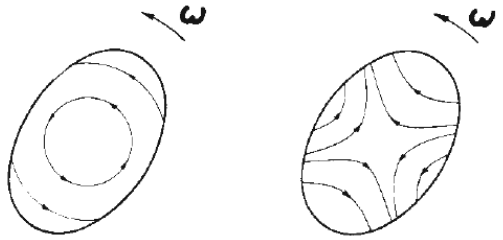
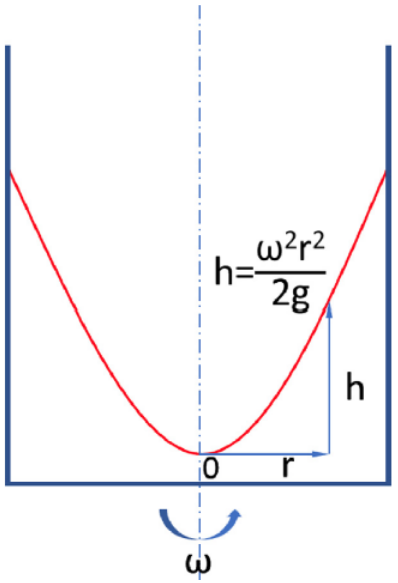



Fig. 2. Velocity fields for rotational motion.

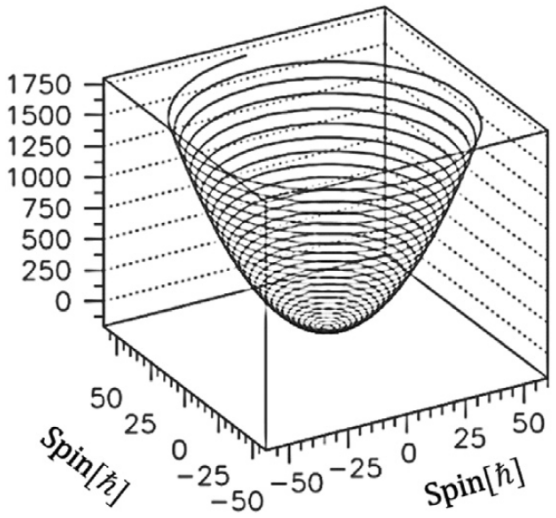
*P. Gulshani, Nucl. Phys. A 832 (2010) 18*

$$\vec{\zeta}_{av} = 2\vec{\omega}(1 - \frac{1}{N}) \approx 2\vec{\omega}$$

*Rigid flow*




*Fluid mechanics: forced vortex (rigid flow)*




*Quantum helix vortex*