RUNG 2: MOVING CLUSTER METHOD

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INTRODUCTION

• Used to determine distances within the Milky Way!
  • A few hundred pcs

• Most important motion based method

• Clusters are gravitationally bound
  • Stars move through space collectively
  • Record change in positions of stars in the cluster with time
    • Cos of the bulk motion of the cluster
    • Direction of motion can be determined ($\vec{v}$)
• Remove Sun’s peculiar motion
• Trace the directional vectors of each star to get a Convergent Point
  • Highest density in great Circle intersections
DIRECTIONAL VECTORS

- \( v_r = v \cos \phi \)
- \( v_t = v \sin \phi \)
- \( v_t = v_r \tan \phi \)

- \( v_t \rightarrow \text{tangential velocity} \)
- \( v_r \rightarrow \text{radial velocity} \)
- \( v \rightarrow \text{space velocity} \)
Observables:

- Proper motion
  - Direction
  - Convergent Point
- Radial Velocity
  - Spectra
DISTANCE TO THE CLUSTER

• Transverse velocity $v_t \equiv \text{proper motion } \mu$

• $\mu = \frac{v_t}{d}$

• $d$ can then be determined
  • Average radial velocity $v_r$
  • Average $\mu$

• $d = \frac{\langle v_r \rangle \tan \varnothing}{\langle \mu \rangle}$  \text{SI units}$

• $d = \frac{\langle v_r \rangle \tan \varnothing}{4.74 \langle \mu^\prime \rangle}$  \text{pc, km/s \& arcsec/yr}$
ASSUMPTIONS & UNCERTAINTIES

• All stars gravitationally bound
  • Belong to the cluster
• Similar age, distance, kinematics, metallicity
• Space velocity vectors are parallel
  • Random motions, rotation can contribute to errors
• Defining a convergent point accurately
  • Works best with clusters with large angular size
• Cluster must be close enough
  • Proper motions can be measured accurately
• Foreground and Background stars must be identified
  • Error in direction, radial velocity
• Increasing distance – less change in proper motion
Open clusters
- Hyades (200) – 47 pc
- Ursa Major (60) – 24 pc
- Pleiades (600) – 115 pc
- Scorpio-Centaurus (100) – 170 pc
- Works for a few hundred parsecs
• Historically important
• Trigonometric parallax didn't work
  • For some stars
  • Distances
  • Absolute magnitude
• Set the scale to galactic and extra-galactic distances
  • Main sequence fitting
• Not anymore
  • Parallax measurements have improved

HYADES WAS STANDARD

Carrol & Ostlie 2nd Ed.
RECENT WORK

- Galli, P. A. B. et al. 2017
  - Distance to Pleiades
  - DOI: 10.1051/0004-6361/201629239
  - Mean parallax – $7.44 \pm 0.08$ mas
  - Distance – $134.4 \pm 2.8$ pc

- Non-HIPPARCOS weighted mean – $135.0 \pm 0.6$ pc
  - VLBI – $136.2 \pm 1.2$ pc
  - $133 \pm 5$ pc – Gaia using brightest cluster members

- HIPPARCOS
  - 115-120 pc