The Goal

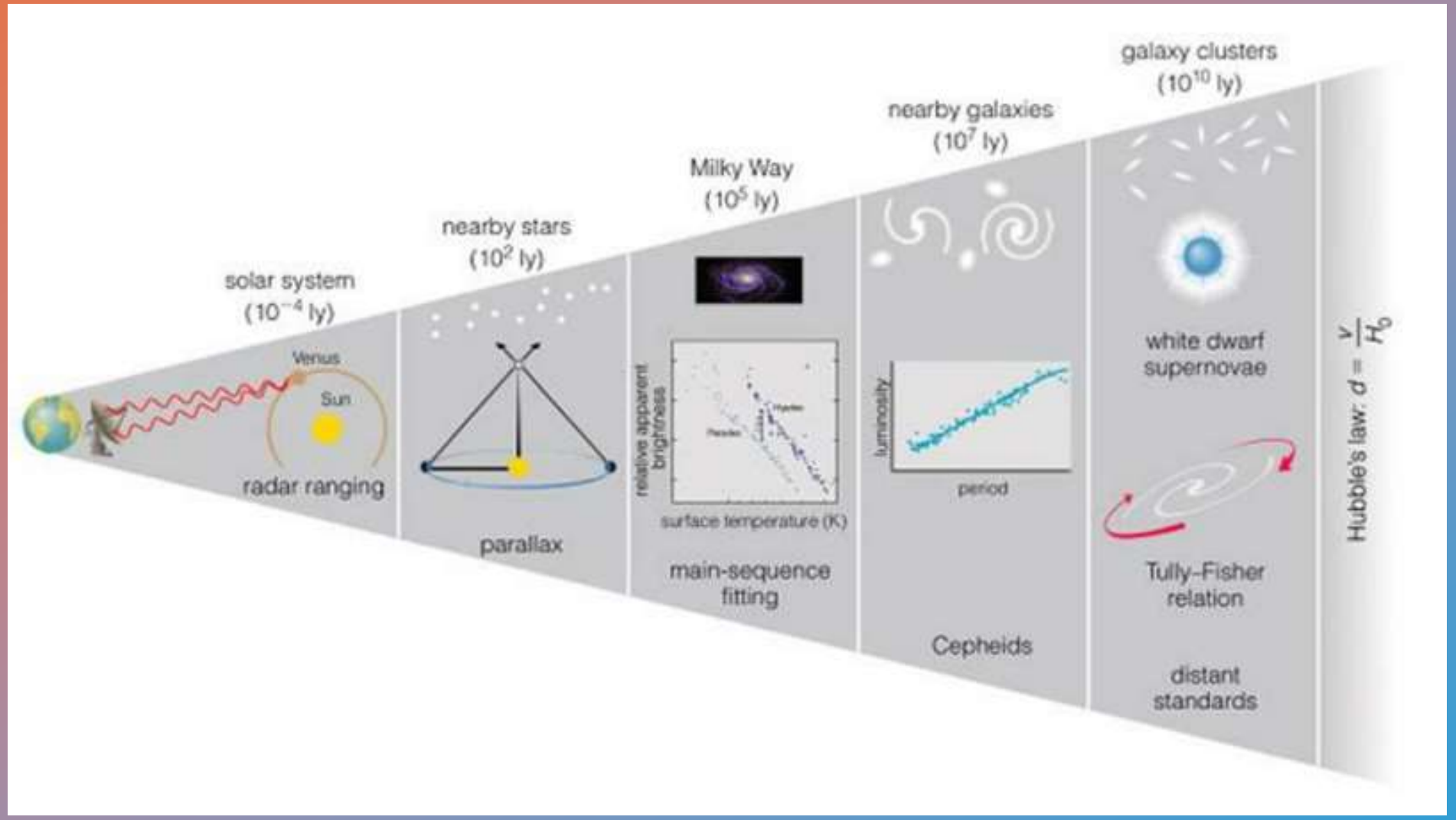
We want the distance to a cluster. This is an exercise in Main-Sequence fitting, using photometry, and involves colors and magnitudes.

Data

DataSet	RA-deg	DEC-deg	Plx-mas	G-mag	BP-mag	RP-mag
MS	0.244412131	-79.85552413	10.94562589	15.504415	16.970705	14.3157787
MS	0.565735258	52.29704469	6.775092411	17.375195	19.062326	16.1252914
MS	2.3459818	67.55771592	7.54530636	13.744278	14.588653	12.8429569
MS	10.02153122	-54.59457808	10.1552097	15.319839	16.725668	14.1595917
MS	13.24577506	-24.09377043	8.854822225	17.168344	19.02643	15.888274
MS	13.97521146	66.57498556	8.026735859	15.530185	16.819702	14.400629
MS	16.59069833	-36.75789058	18.96771216	9.778462	10.312944	9.0925422

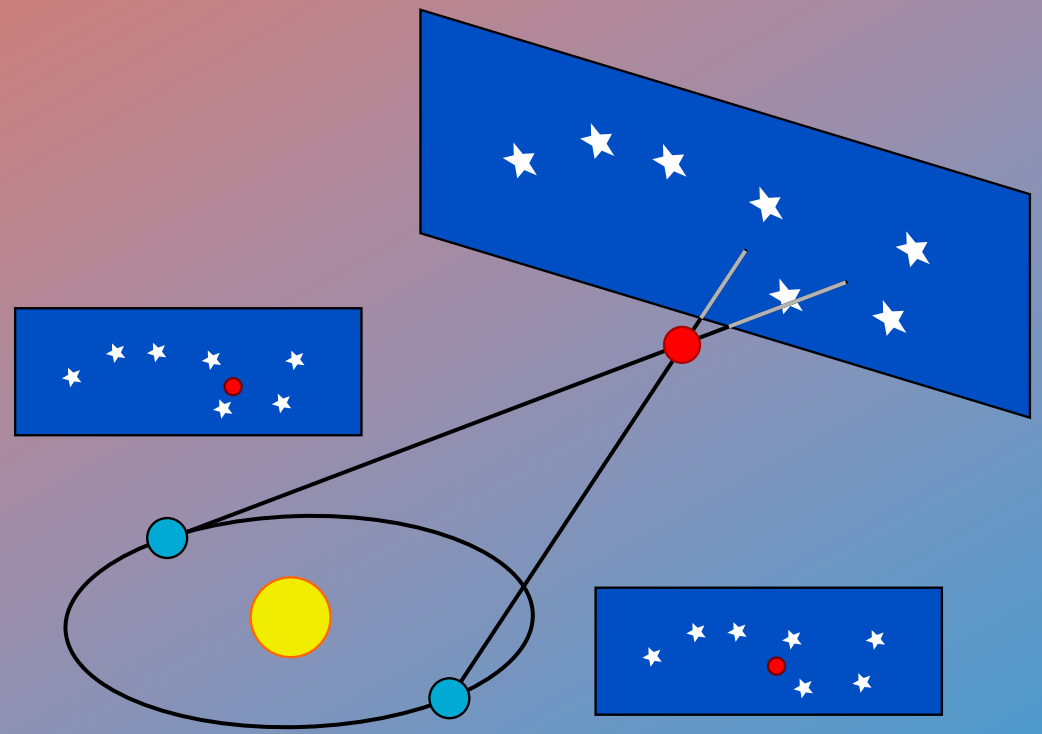
Cluster	55.7356588	24.22937922	--	17.094841	18.978615	15.800222
Cluster	55.91547586	23.69242221	--	17.853973	19.832811	16.521322
Cluster	56.09808816	24.13263089	--	8.972041	9.213455	8.561195
Cluster	56.11667946	24.17155988	--	12.943953	13.674229	12.004852
Cluster	56.21356304	23.5724431	--	18.868423	21.073959	17.47245
Cluster	56.22433096	23.92128736	--	10.590246	11.024535	9.982679
Cluster	56.24565011	23.38893761	--	13.374578	14.203643	12.481163
Cluster	56.28498314	23.41697506	--	17.780386	19.695827	16.452774
Cluster	56.28648351	24.84215027	--	15.99179	17.340973	14.727977
Cluster	56.30058825	23.36477034	--	16.11487	17.743353	14.877634
Cluster	56.34788036	24.85080233	--	14.467274	15.619524	13.387757

The Cosmic Distance Ladder



The Problem

Direct parallax measurements become difficult once stars are hundreds or thousands of parsecs away.



Using the Distance Modulus

The main-sequence stars in any population of stars follow closely the same relation between color and absolute magnitude:

$Mg = a(BP - RP) + b$

The cluster stars lie along a parallel line, but
offset by the cluster's distance modulus.

$(m - M) = mg - Mg$

TABLE 9-1
Distance Moduli

$m_v - M_v$	d(pc)
0	10
1	16
2	25
3	40
4	63
5	100
6	160
7	250
8	400
9	630
10	1000
⋮	⋮
15	10,000
⋮	⋮
20	100,000
⋮	⋮

The Procedure

From the main sequence data, compute absolute magnitude for for each star where d = 1000/Plx-mas:

$$Mg = mg - 5\log(d - 5)$$

Fit the linear relationship between Mg and BP- RP:

$$Mg = a(BP - RP) + b$$

Use the offset between the cluster stars and the main sequence stars to find the cluster's distance:

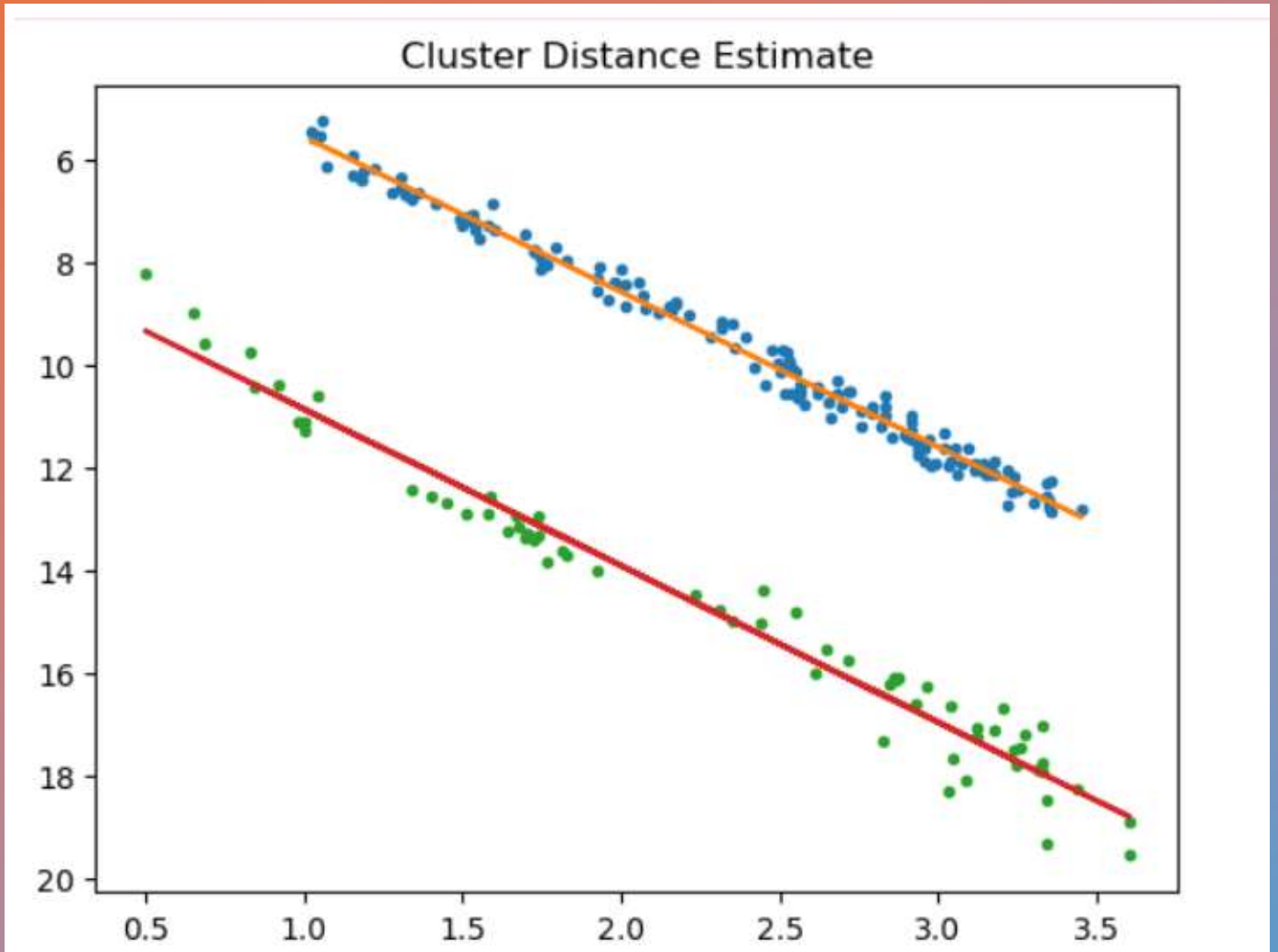
$$m - M = mg - Mg$$

The vertical offset between the two lines is:

$$b(\text{cluster}) - b(\text{main sequence}) = m - M$$

Convert back to parsecs gives:

$$d(\text{cluster}) = 10^{[(m-M + 5]/5}$$



MS Stars Best Fit: G = 3.025 (BP-RP) + 2.512

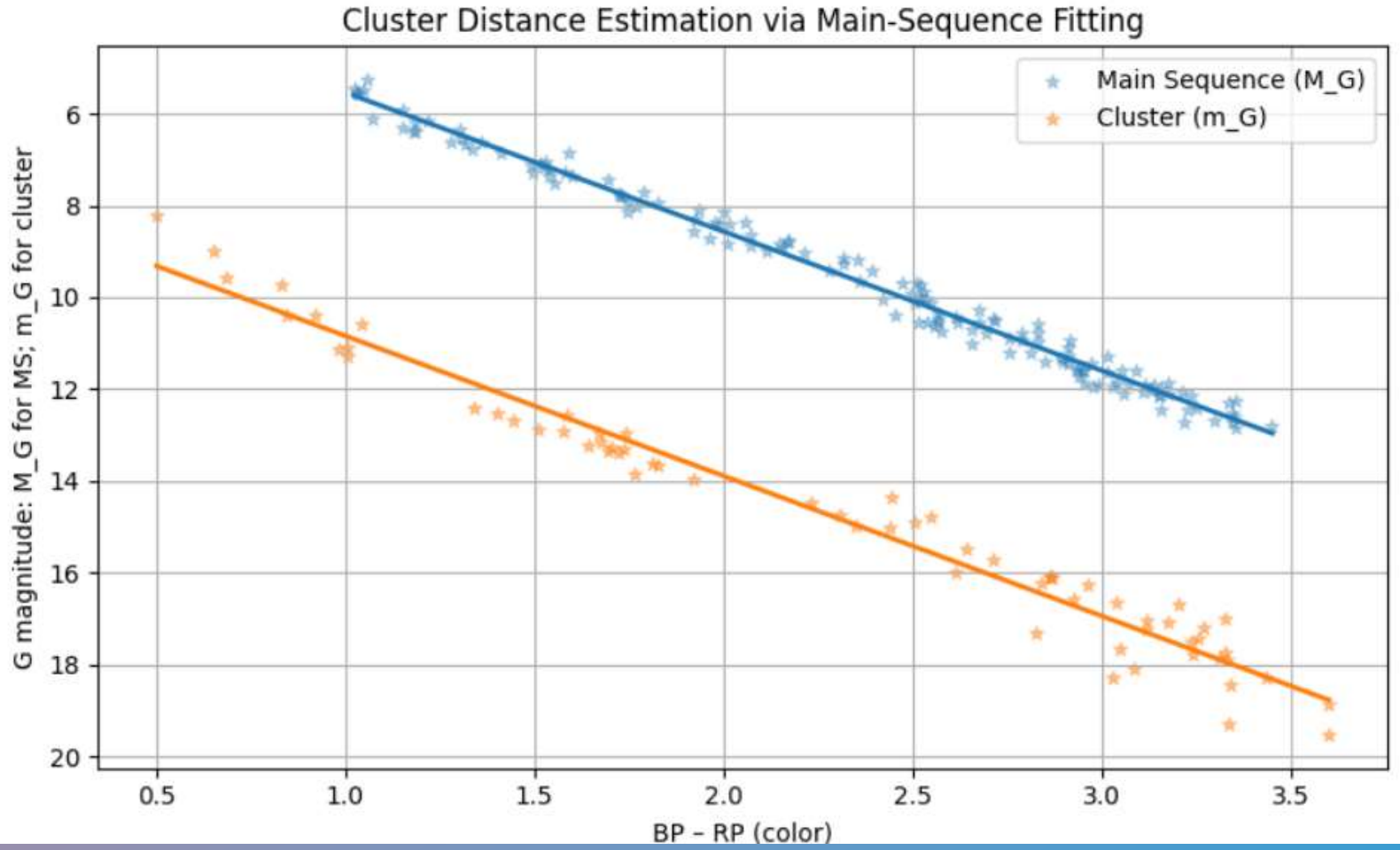
Cluster Stars Best Fit: G = 3.053 (BP-RP) + 7.791

Cluster Distance 117.0 pc

Code Snippet

```
# distance in parsec
dist_pc = 1000.0 / ms['Plx-mas']

# distance modulus = 5*log10(d) - 5
# absolute mag M = m - (5*log10(d) - 5)
ms['M_G'] = ms['G-mag'] - (5*np.log10(dist_pc) - 5)

# Cluster stars apparent magnitude, color
cl = df[df['DataSet'] == 'Cluster'].copy()
cl = cl.dropna(subset=['BP-mag', 'RP-mag', 'G-mag'])
cl['color'] = cl['BP-mag'] - cl['RP-mag']

# Fit straight lines by least-squares
def fit_line(x, y):
    xmean, ymean = x.mean(), y.mean()
    slope = ((x - xmean)*(y - ymean)).sum() / ((x - xmean)**2).sum()
    intercept = ymean - slope*xmean
    return slope, intercept

# Main-sequence fit in color againist absolute mag
slope_ms, int_ms = fit_line(ms['BP-mag'] - ms['RP-mag'], ms['M_G'])

# Cluster fit in color againist apparent mag
slope_cl, int_cl = fit_line(cl['color'], cl['G-mag'])

# Compute distance modulus and cluster distance
dm = int_cl - int_ms                    # m - M
distance_pc = 10**((dm + 5) / 5)        # per distance modulus formula
```

```
MS fit:   G = 3.0296(BP-RP) + 2.5043
Cl fit:   G = 3.0512(BP-RP) + 7.7874
Distance modulus (m-M): 5.2831
Distance to the cluster: 113.9 pc
------------------------------
Multi-Point Average Method:
Points used (Color): [1.05 1.62 2.19 2.77 3.34]
Offsets at points:   [5.31 5.32 5.33 5.34 5.35]
Avg Distance Modulus: 5.3303
Avg Distance:         116.4 pc
------------------------------
```



Messier 45, The Pleiades

Distance via Parallax is 135 to 136 Parsecs

Adventures we didn't sign up for:

Corey

1.

2.

3.

Tim

1. Trying to read my own code after choosing poor variable names.

2. Pondering the mental state of a language programmer who called a python math function 'coerce'.

3. Reflecting on why I'm proud of myself for figuring out how to use a star for graphing a data point instead of a dot.


The End