Compute the distance between stars

It is easy to compute the distances between stars with a little high-school math. Just to make it easier, there are some handy spreadsheets that do the math for you (`RR_Star_Distance.xls` and `RR_Star_Distance.ods`). It is the same spreadsheet, stored in two formats.

The spreadsheets were done by an astrophysicist who is too humble to attach his name. He did not use the high-school math method below, he used the more elegant law of cosines to compute distance. Just type the stars data into the green squares. These are his abbreviations:

RA: Right Ascension (corresponds to longitude)
Dec: Declination (corresponds to latitude)
Dist: Distance in light-years.

Doing it by hand

The locations of stars are given in ascension, declination, and distance. Compute the distance between them in 3 easy steps:

1. Convert the ascension & declination into decimal degrees (they are often given in other formats).
2. Convert from spherical coordinates to rectangular coordinates.
3. Compute the distance.

Converting into decimal degrees

There are many ways to write degrees:

- 17h 34m 56.06945s - hours/minutes/seconds
- +12° 33′ 36.1346″ - degrees/minutes/seconds
- -12° 33.45′ - negative degrees / decimal minutes
- 1.23456° - decimal degrees

You will need decimal degrees

hours/minutes/seconds to decimal degrees

Convert seconds to minutes and add to minutes: minutes += (seconds / 60)
Convert minutes to hours and add to hours: hours += (minutes / 60)
Convert hours to degrees: decimal degrees = hours * 15

degrees/minutes/seconds to decimal degrees

Convert arc seconds to minutes and add to minutes: minutes += (seconds / 60)
Convert minutes of arc to degrees and add to degrees: degrees += (minutes / 60)
If degrees are negative, treat them like they are positive, then subtract them from 360.

Converting parsecs to light-years

Multiply parsecs by 3.26156 to get light-years. Do all math in light-years.

Converting spherical coordinates to rectangular coordinates

You need a calculator with trigonometric functions.

Spherical coordinates:

A = Ascension (longitude, right ascension) in decimal degrees
D = Declination (latitude) in decimal degrees
R = Radius (distance) in light-years

Compute rectangular Coordinates

X = R * cos(A) * cos(D)
Y = R * sin(A) * cos(D)
Z = R * sin(D)

Compute the distance in rectangular coordinates

Q = distance between star 1 and star 2 in light-years
Q = squareroot[square(X1-X2) + square(Y1-Y2) + square(Z1-Z2)]

Example

Compute the distance from Arcturus to Alpha Centauri. Since Alpha Centauri is close to Earth, we will know we did it right if the answer is similar to the distance between Arcturus & Earth.

Arcturus (Star 1)

Right ascension: $14^h\ 15^m\ 39.7^s$
Declination: +19° 10' 56"
Distance: 36.7 ly

Convert right ascension from HMS to decimal degrees:
$39.7^s / 60 = 0.662^m$
$15^m + 0.662^m = 15.662^m$
$15.662^m / 60 = 0.261^h$
$14^h + 0.261^h = 14.261^h$
A1 = 14.261h * 15 = **213.915 decimal degrees**

Convert declination from DMS to decimal degrees:
56" / 60 = 0.933'
10' + 0.933' = 10.933'
10.933' / 60 = 0.182°
+19° + 0.182° = 19.182°
D1 = 19.182 decimal degrees

R1 = 36.7 light years

Alpha Centauri (Star 2)

Right ascension: $14^h\ 39^m\ 36.49400^s$
Declination: –60° 50’ 02.3737”
Distance: 4.37 ly

Convert right ascension from HMS to decimal degrees:
$36.49400^s / 60 = 0.608^m$
$39^m + 0.608^m = 39.608^m$
$39.608^m / 60 = 0.660^h$
$14^h + 0.660^h = 14.660^h$
A2 = 14.660h * 15 = **219.9 decimal degrees**

Convert declination from DMS to decimal degrees:
02.3737” / 60 = 0.040’
50’ + 0.040’ = 50.040’
50.040’ / 60 = 0.834°
Do everything in positive numbers:
60° + 0.834° = 60.834°
This is negative declination, so subtract from 360°:
360° – 60.834° = 299.166°
D2 = **299.166 decimal degrees**

R2 = 4.37 light years

Convert to rectangular coordinates

X1 = R1 * cos(A1) * cos(D1) = 36.7 * (-0.830) * 0.944 = **-27.8**
Y1 = R1 * sin(A1) * cos(D1) = 36.7 * (-0.558) * 0.944 = **-19.3**
Z1 = R1 * sin(D1) = 36.7 * 0.329 = **12.1**

X2 = R2 * cos(A2) * cos(D2) = 4.37 * (-0.767) * 0.487 = **-1.63**
Y2 = R2 * sin(A2) * cos(D2) = 4.37 * (-0.641) * 0.487 = **-1.36**
Z2 = R2 * sin(D2) = 4.37 * (-0.873) = **-3.82**

Compute the distance

Q = squareroot(square(X1-X2) + square(Y1-Y2) + square(Z1-Z2))
Q = squareroot(square(-26.2) + square(-17.9) + square(15.9))
Q = squareroot(686 + 320 + 253)
Q = squareroot(1259)
Q = 35.5 light years from Arcturus to Alpha Centauri
Arcturus is 1.2 light-years closer to Alpha Centauri than it is to Earth.

Roaring Rockets

Distance is used to compute travel times in the Roaring Rockets game.

Fast ship: 1 day of travel time per two light-years
Normal ship: 1 day of travel time per light-year
Slow ship: 2 days of travel time per light-year