**Central Supermassive Black Holes**

The masses of supermassive black holes (SMBH) at the centers of galaxies can be determined from the range of velocities of stars with orbits very near the center of the galaxy. Since many stars are orbiting near the centers of galaxies, some are moving toward us and some are moving away from us. The velocities of the stars depend on the mass of the SMBH, the more massive the black hole, the faster the stars orbit. We observe the combined light of these stars to measure the dispersion (range) of velocities of the stars. In the table below are the measured velocity dispersions in 10 nearby galaxies (including the Milky Way).

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| --- | --- | --- | --- | --- |
|  | **Galaxy Type** | **Central Velocity Dispersion (km s-1)** | **Black Hole Mass (solar masses)** | **Galaxy Magnitude** |
| **Milky Way** |  | 75 |  | -19.0 |
| **Andromeda** |  | 160 |  | -20.0 |
| **NGC 221** |  | 55 |  | -16.3 |
| **NGC 584** |  | 150 |  | -21.3 |
| **NGC 1052** |  | 100 |  | -18.5 |
| **NGC 3115** |  | 200 |  | -20.0 |
| **NGC 3379** |  | 133 |  | -19.8 |
| **NGC 4258** |  | 167 |  | -22.8 |
| **NGC 4374** |  | 296 |  | -21.2 |
| **NGC 4486** |  | 333 |  | -21.5 |

On the computer, look up the type of galaxy each is (elliptical, S0, spiral, barred spiral, irregular). Wikipedia is a good source for this.

The relation between black hole mass and velocity dispersion is given below, and is also shown graphically in the top chart on the next page.

$$Mass\_{SMBH}=1.8\*10^{8}(\frac{σ}{200 km s^{-1}})^{5.1}solar masses$$

Using either the equation or the chart, estimate the mass of the central black hole for each galaxy in the table above. Only a rough estimate is needed.

The absolute magnitude of each galaxy is also given in the table above. Recall that absolute magnitude is the magnitude that an object would have if it were located at a distance of 10 parsecs. Galaxies are very bright because they contain many stars, so their absolute magnitudes are large negative numbers. In the bottom chart on the next page, plot a graph of the SMBH masses vs. absolute magnitude. **What is the relationship between SMBH mass and the luminosity of a galaxy?**