The determination of accurate distances to galaxies is a key process in astronomy. It is also a very difficult one and has been the cause of many scientific controversies. Distances are of fundamental importance to characterize the physical properties of galaxies. In addition, they provide the key information for a direct measurement of the Hubble constant $H$, which is a crucial parameter to constrain the accelerated expansion of the universe. In order to measure the equation of state parameter $w$ of the accelerated expansion of the universe with sufficient precision a very accurate value of $H$ is needed because the relative error in $w$ is twice the error of the Hubble constant, $dw/w \sim 2dH/H$. In other words, in order to determine $w$ with a precision of $\pm 2\%$ a Hubble constant accurate to $\pm 1\%$ is needed. This has led to the very ambitious goal of a $1\%$ precision measurement of the Hubble constant within the next decade. This seminar course gives an introduction into the distance determination methods, which will help to accomplish this goal.

Several IfA faculty have been and are involved in research projects which deal with the extragalactic distance scale. They have agreed to contribute to this seminar course and will give lectures about their field of activity (Fabio Bresolin, Roberto Mendez, Brent Tully).

A detailed manuscript of the course will be provided in advance of each lecture and can be downloaded from the instructor’s website.

**Content**

**Introduction and overview:**

- Why do we need a $1\%$ Hubble constant?
- The major obstacles
- Peculiar velocities and Hubble flow
- The concept of the distance ladder

**Stellar distance indicators**

- Cepheids and the period-luminosity relationship (PLR)
- Milky Way Cepheids and parallaxes, LMC/SMC Cepheids
- The Baade-Wesselink method
- Late stages of stellar evolution: the tip of the red giant Branch (TRGB), red clump stars
- Blue supergiant stars (BSGs)
- Supernovae
Galaxies as distance indicators:
- Disk galaxies and the Tully-Fisher relationship
- Elliptical galaxies and surface brightness fluctuations
- The D_N - Sigma relationship of elliptical galaxies
- The Planetary Nebulae Luminosity function
- HII-regions as distance indicators

Mega masers:
- Maser emission of ISM gas clouds
- The "maser galaxy" NGC4258 - a new anchor point
- The search for mega masers in the Hubble flow

The SHoES project:
- HST detection of Cepheids in SNIa hosts out to 30Mpc
- and HST photometry of SN in the Hubble flow

Pitfalls
- Interstellar extinction and variable reddening laws: dust is the enemy of the astronomer
- The crucial role of metallicity
- Blending and Crowding
- Lutz-Kelker bias and Malmquist bias

M31 as a new anchor point:
- The Pan-STARRS Pandromeda Survey:
- detection of 2000 Cepheids and 300 eclipsing binaries

Gravitational lensing of QSO’s and time delays:
- Monitoring surveys of strongly lensed QSO multiple images
- QSO variability and measurement of time delays

Large scale structure as distance indicator:
- Galaxy clusters and the Sunyaev-Zeldovitch effect,
- Baryonic Acoustic Oscillations