Relativistic cosmology from F to Sz (F = Friedmann, Sz = Szekeres)

(Lectures at the 2021 Białowieża school on Geometry and Physics)

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1: A quick (and superficial) introduction to general relativity

It will give the participants the idea of the field equations of general relativity (the Einstein equations). They are the basis from which all cosmological models were derived.

2: The Friedmann – Lemaître (FL) models and their basic implications

This lecture will introduce the evolution equations of the FL models, their relation to observational cosmology, the definition and properties of redshift, the description of horizons, the "history of the Universe" based on these models, and redshift drift as a possible test of the hypothesis of accelerated expansion of the Universe.

3: The Lemaître – Tolman (LT) models and their relation to some of the cosmological observations

These models are the simplest existing generalisation of the FL models. In spite of being spherically symmetric, they allow for several interesting insights, within the exact theory, into the consequences of existence of matter condensations and rarefactions (voids) observed in the Universe. This lecture will show how the description of formation of such structures follows from the evolution equations of the LT models. It will also show how inhomogeneities in matter distribution can mimic the accelerated expansion of the Universe by perturbing the propagation of light rays. Finally, it will be shown that nonradial rays propagating through a mass inhomogeneity undergo a direction drift, which may become a measure of inhomogeneity in large-scale matter distribution when the observations become sufficiently precise. The light rays reaching the present observer that were emitted radially soon after the initial singularity (the Big Bang) get *blue*shifted rather than redshifted, i. e. their observed frequency is *higher* than at the emission point.

4: The Szekeres (Sz) models and their observational implications

These models are fully nonsymmetric generalisations of the LT models. They arise by making the spheres, invariantly defined in the LT geometry, non-concentric. This allows for describing a still larger collection of phenomena observed in the actual Universe. One of them is mimicking the observed gamma-ray bursts by blueshifting the photons of the relic radiation (unlike in LT models, the blueshift in the Sz models occurs only along two opposite preferred directions).

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There will be 4 lectures, each lasting 50 minutes. The division of the subject into the four topics listed above will not coincide with the division of time into the four lectures.