# On the Content of Cold Electrons and Positrons in Relativistic Jets

**Vladimir V. Zheleznyakov, Sergey A. Koryagin**

*Institute of Applied Physics, Russian Academy of Sciences*

*e-mail: koryagin@appl.sci-nnov.ru*

## Abstract

**We analyze the possibility to determine the plasma composition of relativistic jets in blazars and microquasars from the data on polarization and intensity of their synchrotron radiation in the radio frequency band. We propose a universal plot that allows to determine the abundance of nonrelativistic electrons and the presence of positrons in the specific objects from their intensity frequency spectra and polarization at several frequencies. As a result, we find that electron plasma component in the jets of the blazars 3C 279 and BL Lacertae is relativistic. In the jets of the microquasar GRS 1915+105, the cold plasma density can be comparable or significantly exceeds the relativistic particle density. The observed parameters of the jet of 3C 279 does not require the necessary presence of positrons in it.**

**The details of the proposed approach are presented in the paper [12].**

## Problem

**One of the unsolved problems in the physics of blazars is the plasma composition of their jets: electrons + protons or electrons + positrons.**

## Approach

**Plasma composition determines the polarization and refractive indices of electromagnetic normal waves propagating in a jet magnetized plasma. These characteristics of the normal waves influences the polarization of the observed radio emission from a jet.**

- **The Faraday effect in the normal plasma (without positrons) makes the planes of polarization be different at different frequencies.**

- **The Faraday effect vanishes in a plasma composed of electron-positron pairs, and the observed radiation becomes polarized in one plane at all frequencies.**

**Thus, plasma composition in jets may be identified from the polarization of their synchrotron radiation [8, 9, 11, 12]**

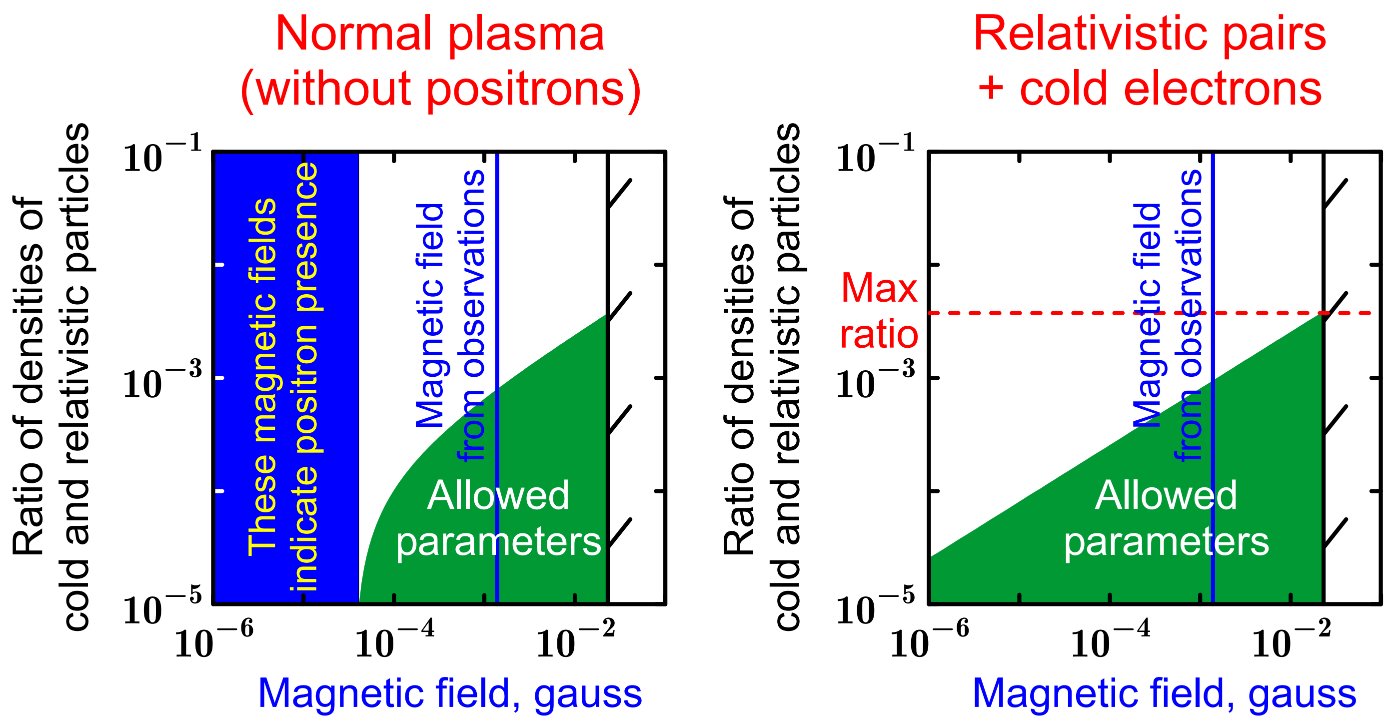
## The key observational parameters of a jet [1–3, 5–7, 10]

- **Brightness temperature is proportional to the sum of densities of relativistic electrons and positrons and does not depend on the cold (nonrelativistic) plasma density.**
- **The Faraday rotation is proportional to the difference of densities of relativistic electrons and positrons and is very sensitive to the cold plasma density.**

## Convenient diagram for analysis of composition

**We consider the plane of parameters magnetic field—relative abundance of cold electrons. The ratio of observed brightness temperature to the rotation measure confines the green area of jet parameters which conform to observations. We plot diagrams for the two limiting plasma compositions: 1) normal composition (no positrons); 2) relativistic electron-positron pairs + cold electrons.**

## Diagrams for the jet of archetypal blazar 3C 279




## Relativistic plasma

**The peaks of green areas of allowed parameters in diagrams describe the maximum relative abundance of cold electrons. The peaks go down with increase of brightness temperature and go up with increase of the Faraday rotation. Thus, relativistic plasma composition should be expected for bright jets with small Faraday rotation.**

- **We find that the relative abundance of cold electrons is less than 1 % in the jets of the blazars 3C 279 and BL Lacertae. Thus, plasma in the blazar jets is relativistic.**
- **The jets of the microquasar GRS 1915+105 contain more cold than relativistic electrons.**

## Positrons

The green area of allowed parameters for the normal plasma (without positrons) excludes too low magnetic field strengths (see the left diagram on the previous page). At low magnetic field only relativistic electrons produce the Faraday rotation larger than the observed value (if the brightness temperature is fixed). The addition of cold electrons increases the Faraday rotation and discrepancy with observations. The Faraday rotation can be decreased to the observed value if some of relativistic electrons are substituted by positrons.

Thus, if observations point out that magnetic field strength in the jet lays outside the allowed interval for the normal plasma composition, then this jet necessarily contains positrons.

The magnetic field strength can be determined from the frequency of the maximum synchrotron radiation intensity [4].

- For the jet of 3C 279, the magnetic field strength is not low enough and conforms to normal as well as electron-positron pair plasmas.

## Perspectives

The polarization spectrum near the peak frequency of the jet synchrotron radiation can distinguish the plasma composition [11]:

- Cold plasma strongly depolarizes radiation at this frequency.
- Normal relativistic plasma (without positrons) produces considerable circular polarization.
- Electron-positron pair plasma maintains strong linear polarization (if magnetic filed is homogeneous enough).

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