Galaxies, dark matter and blood pressure

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Abstract

Galaxies, the building blocks of our Universe, are surprisingly similar to human beings in terms of statistical description. Building on this similarity, here we show that methods that are popular in Astrophysics can be successfully applied in detecting and correcting shortcomings in medical treatment of high blood pressure.

Background

Galaxies are immersed in giant halos of dark matter. It is believed that dark matter has a key role in shaping galaxies. Indeed a widely used model (Mo, Mao & White 1998) predicts that galaxy sizes are set by the motion of dark matter particles (that we call "spin") and that is indicated with \(\lambda\) and the extent of the halo:

\[ R_{\text{halo}} = R_{\text{mo}} \lambda \]

Comparing this model to the newest and most accurate catalog of observations to date can give us exciting clues about the relationship between galaxies and their dark matter halos.

How are galaxies and human beings similar?

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The distribution of galaxy sizes emerges naturally from the distribution of dark matter properties. Dark matter does have a role in shaping galaxies.

According to the model there should be \(\lambda\) times more galaxies with very large sizes with respect to data. To fit data we need a new, tighter connection between galaxies and dark matter.

### Results

Distribution of galaxy sizes

With the typical measurement error achieved in GP practices nearly half of patients is left at risk of severe complications, which may lead to hospitalization and death.

Some GPs measure the blood pressure twice before making a decision. This still leaves 20\% of patients at risk.

Improving accuracy in the measurement can reduce risk to less than 20\%. This is already achievable with current technologies, that are however more expensive.

### Simulating a Universe

#### Model ingredients:

- Distribution of \(\lambda\) (Hz of dark matter spin)
- Distribution of \(R_{\text{halo}}\)

Dark matter halo properties derived from N-body simulations.

Left: Most dark matter halos have a low spin.

Right: Dark matter halos have typical sizes of a few thousand light years.

\(\lambda\) and \(R_{\text{halo}}\) are extracted randomly from the two distributions above and are combined using equation (1) to produce galaxy sizes.

### Modeling populations: Monte Carlo simulations

Monte Carlo simulations are computational methods that allow to simulate realistic populations whose features are extracted from known distributions.

In a nutshell…

Using Monte Carlo simulations we show that:

1. The link between galaxies and dark matter as predicted by a widely used model cannot explain data;
2. Current hypertension treatment practice leaves a significant proportion of patients at risk of complications. The risk can be halved by using available devices that achieve better measurement accuracy but that are more expensive.

### Further work (still using Monte Carlo simulations)

1. Developing a better link between galaxies and dark matter;
2. Developing a “smarter” hypertension management algorithm that accounts for measurement errors;
3. Expanding our methodology to other branches of Medicine.

Monte Carlo simulations are very powerful in detecting and solving shortcomings in our understanding of both the Universe and Medicine.

### Simulating hypertension treatment history

#### Model ingredients:

- 1. Range of response to treatment (population)
- 2. Misclassification due to measurement error

Patients are controlled if their BP is between 120 and 140 mmHg. Responders have BP lower than 140 mmHg.

Left: After treatment, patients with the same initial BP have a range of BP diversity in response to treatment.

Right: Measurement process. Region where orange and blue distributions overlap indicates misclassification due to measurement error.

### Improving the hypertension management algorithm

#### Results

Fraction of controlled, undertreated and overtreated patients at the end of treatment

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Hypertension management algorithm</th>
<th>Controlled</th>
<th>Undertreated</th>
<th>Overtreated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.</td>
<td>43.2%</td>
<td>11.1%</td>
<td>45.7%</td>
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<td>2.</td>
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<tr>
<td></td>
<td>3.</td>
<td>43.2%</td>
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