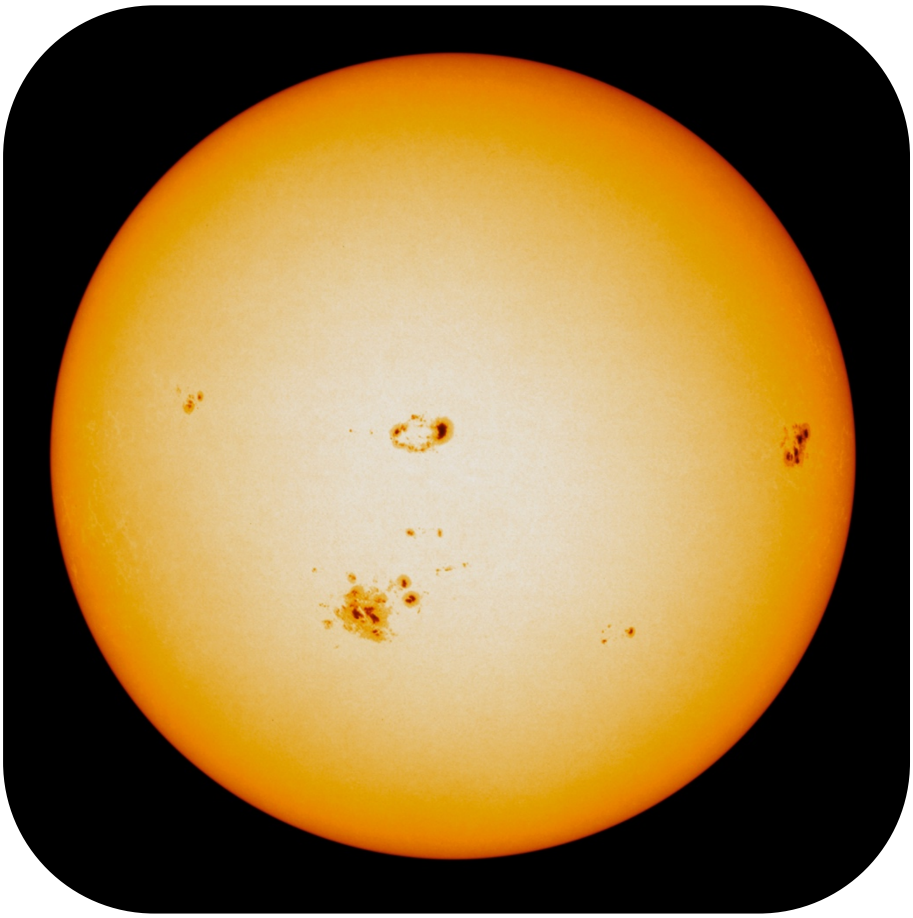
Sun’s differential rotation

Teacher’s Guide – Basic Level

CESAR’s Science Case



Introduction

This is the teacher's guide for "Sun's differential rotation" CESAR's Science Case. Note that **this guide does not contain full instructions** to successfully develop the science case, those can be found at the student's guide. This guide includes information about the learning purposes of the activity as well as about the material and background needed for it, so that the teacher may decide **weather this laboratory is suitable** for his class or not. This guide is also meant to **help the teacher trough organising the activity**, providing tips and keys for each step, as well as the **solutions** to the case's calculations and the quiz.

In this science case the students are to **calculate the Sun's differential rotation** using images from CESO (CESAR's ESAC Solar Observatory). By the end of this laboratory, students will be able to:

- Understand what differential rotation is.
- Explain how the Sun moves and how that movement is different to Earth's.
- Track targets in time-separated images.

By completing this laboratory, students will find out how astronomical pictures can be used to obtain valuable data.

Material

What will they need?

- The Sun's differential rotation Student's Guide.
- Computer with Web Browser and Internet Connection.
- Access to CESAR web tools.

Background

The Basic Level Student's Guide requires no background, everything is explained in the guide and nothing is taken for granted. However, you may want to take a look at "Sun" chapter from the CESAR Booklet to teach them about solar flares or sunspots. Also, in at this level, there's no math involved at all. If you want to consider a harder task, take a look at the intermediate level.

Even if no background nor math is needed, the concepts explained can be hard to understand, check the content before doing the Science Case, this particular one may not be suitable for kids under ten years old.

Note: Plasma is hot ionized gas. Ionized mater has its electrons removed from the atoms.

Laboratory Execution

All that students ought to do is read their guide and follow the steps. This task is suitable both for doing it alone or in small groups.

If they make no mistake, they should obtain about 14.5 degrees/day for the equator speed and a slightly smaller speed for the spot closer to the poles (never less than 9 degrees/day).

Just in case they do commit some mistake, in the following paragraphs are tips that may help you identify their error.

Sunspots rarely move in latitude, if they do, they may actually be two different sunspots.

Students will realise that there's no way to find sunspots at high latitudes, and they will have to accept that they can only have data in a narrow spectrum of latitudes close to the equator. They should try to find a sunspot as close to the poles as possible, but they probably wont find a sunspot over ±30º latitude.

Students should obtain lower velocities for higher latitudes. If they haven't, they should check if they have precisely mark the sunspots in the web tool. However, a lot of precision is needed to detect the differential rotation, even if they do get lower velocities for higher latitudes **the difference should be small** (never more than 6 degrees/day), so if after revising the process they still don't get a better result, they are good to go.

In the "Conclusions" part, they should estimate a speed value between the two speed values they obtained.

Even if the student's guide ends up here, the activity may continue with the quiz. Although this quiz can be used as a qualifiable exam, it is not only meant to be so. Even if the students have successfully calculated some velocities, if they don't fully understand the whole procedure, the quiz questions may make them doubt (some of them might be really tricky). Besides than examining them, it is a good idea to give them some time to do the test by their own, and then group them for discussing their answers. It is likely that they have different answers for some of the questions, and **by discussing them, they will achieve a much better comprehension of the whole process** they used. In the last pages of this guide, all the questions from the quiz are answered. For each question the correct answer is provided, and just in case it's not clear why, it's also indicated why the others are wrong. Finally, for each question there is one possible answer that is completely absurd, if one of this answers is given, you can be sure the student is randomly answering.

Quiz

The correct answers for the quiz are c b a d c a b d c c.

The absurd answers for each question are b c d a b c c b d a.

In case of doubt, the discussion of each question follows next:

1. Unlike the Earth, the Sun is not a rigid body. This means that

- ☐ when studding its movement, you can not consider the Earth as a compact structure.
- ☐ the Sun is about to turn into a compact structure by eating planet Earth.
- ☐ the Sun is not forced to move as a whole.
- ☐ when studding the movement of the Sun, you can consider it as a compact structure.

You do can consider the Earth as a compact structure, so answer a is not correct. You can not consider the Sun as a compact structure, so answer d is not correct. The Sun not being a rigid body means, among some other things, that it is not forced to move as a whole.

2. Unlike Earth's, the Sun's surface

- ☐ is made of water, with sea currents that are free to move anywhere.
- ☐ rotates at higher speeds in the equatorial zone.
- ☐ is made of plasma that will turn into soil after a few years.
- ☐ moves faster in the poles and slower in the equator.

Sun's surface is made of plasma that rotates faster in the equator and slower at the poles.

3. Sun's rotation speed varies with the distance to the equator, this means that if two sunspots

- ☐ appear in the centre of the Sun one right above the other, they won't remain like that.
- ☐ appear at the same distance to the equator, the distance between them will increase.
- ☐ appear at the same time, will necessarily disappear at the same time.
- ☐ appear to be friends, they will remain together forever.

The first three answers sound similar, but only the first one is correct. If two sunspots appear at the same distance to the equator, they will move at the same speed, so answer b can't be correct. Nothing proves the statement of answer c, so the only possible answer is a. If two sunspots appear in the centre of the Sun one right above the other, the one at the top would be further away from the equator, so it will move slower and it would be eventually left behind.

This means that after a while the sunspot at the bottom would have move faster and the sunspots will no longer be one right on top of the other. Look at the first image in the background section of the student's guide, all the sunspots appear right on top of the first one, but they don't end up like that.

4. We can calculate the rotation speed of the Sun by measuring the speed of sunspots because

- ☐ sunspots want to help us and they whisper the Sun's differential rotation.
- ☐ sunspots are located at the Sun's surface, that moves as a whole.
- ☐ sunspots move like sea currents as they are free to move anywhere.
- ☐ sunspots are located at the Sun's surface, whose speed we want to measure.

Sunspots are not free to move anywhere, and the Sun surface does not move as a whole; the only correct answer is d.

5. In the final pictures, a sunspot is seen in two different positions because sunspots

- ☐ are duplicated by CESAR's web tool to do the measurements.
- ☐ reproduce and duplicate like cells.
- ☐ move with the Sun's surface, and the Sun's surface constantly rotates.
- ☐ rotate faster if they are closer to the equator and slower if they are closer to the poles.

The CESAR web tool does not duplicate the sunspots, it just merges two images. The sunspots are seen in two different positions because the pictures are time-spaced and Sun's surface (where sunspots are) rotates over time. The statement in answer d is true but is not the reason.

6. You looked at two different sunspots to

- ☐ check the speed of the Sun both close to the equator and close to the poles.
- ☐ put them in the same image to measure of fast it moves.
- ☐ measure the latitude of the Sun as seen by a radiotelescope.
- ☐ obtain more than one value of the Sun's velocity and increase precision.

You looked at two different sunspots to check the speed of the Sun both close to the equator and close to the poles. For each of them, you take two pictures and put them in the same image to measure of fast it moves, but you never put two different sunspots in the same image.

7. Earth's rotation is the reason for day and night, Sun's rotation is the reason for

- ☐ Sun's day and night.
- ☐ the movement of Sun features.
- ☐ life in Earth's core.
- ☐ differential rotation.

Day and night are produced by Earth's rotation, because as the Earth is moving, the dark side and the side lighted by the Sun change over time. The Sun is always lighted because it is the light-source in the Solar System, so it does not have day and night. Sun's rotation is almost the same as differential rotation, one is not the reason for the other. The right answer is that Sun's rotation is the reason for the movement of Sun features, because the Sun features move together with Sun's surface.

8. To calculate the speed of a sunspot you

- ☐ used your knowledge about differential rotation.
- ☐ used a chronometer.
- ☐ looked at two different sunspots.
- ☐ tracked the sunspot in time-spaced images.

To calculated the speed of a sunspot we looked only at that single sunspot in different images spaced over time.

9. We say that the Sun has differential rotation because

☐ two sunspots in the equator don't necessarily have to rotate at the same speed.
☐ the plasma is differential and it does actually rotate.
☐ the plasma located at different distances from the poles may rotate at different speeds.
☐ the student's guide says so, and the students guide knows more than anyone.

Two sunspots in the equator do rotate at the same speed, the differential rotation is the different speeds of Sun's surface at different distances to the equator.

10. The Sun rotates

☐ so fast that it is flat.
☐ clockwise, like the Earth does.
☐ counter-clockwise, like the Earth does.
☐ faster in the poles.

With the North orientated upwards, the Sun rotates counter-clockwise. Check the movement of the sunspots when you choose images of the same feature with a few days of difference, the sunspot moves to the right (counter clock-wise as seen from above).