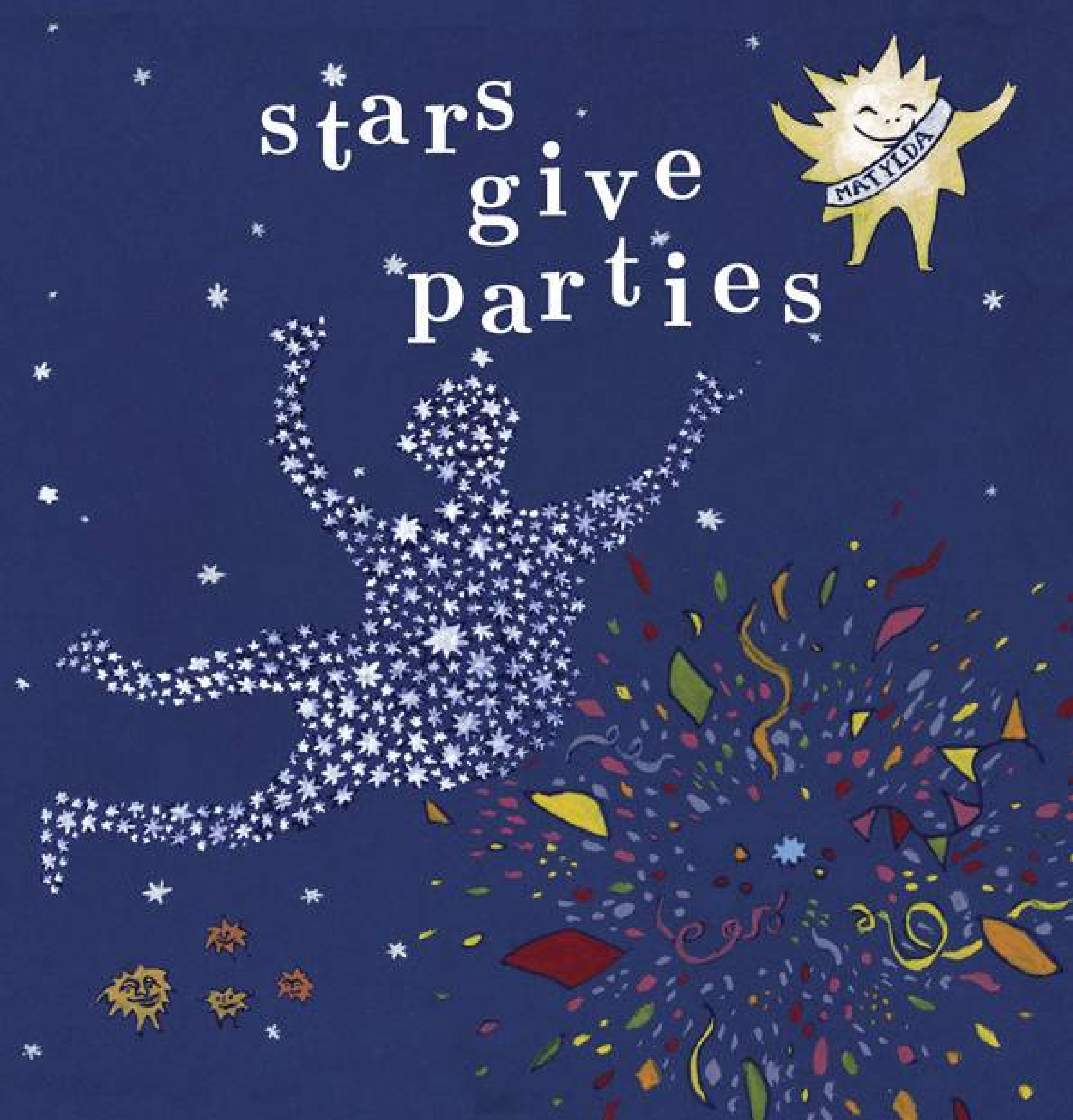
stars give parties



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Stars give parties

A story about the birth
and evolution of stars

Rosa Mª Ros Ferré

ilustrations
Maria Vidal

EUNAWE, 2011

The National Research Council (CSIC) is a Spanish institution collaborating with UNAWE and EU-UNAWE. It promotes the links between all the Hispanic countries and in this framework it supports the two Spanish-speaking programmes which are designed for children brought together by the use of one and the same language.

www.csic.es

EU-UNAWE is an educational project of the European Union, based on the UNAWE programme. Both projects use the beauty and grandeur of the Universe to encourage young children, particularly those from underprivileged communities, to take an interest in science and technology and to foster their sense of global citizenship from an early age. Although UNAWE was founded only five years ago, it is already active in 40 countries and comprises a global network of more than 500 astronomers, teachers and educators.

In three years, EU-UNAWE will have implemented universe awareness-raising activities in six countries: Germany, Italy, the Netherlands, Spain, United Kingdom and South Africa. The project includes the organization of teacher training workshops and the development of learning material for children. In the long term, EU-UNAWE intends to help produce the next generation of engineers and scientists in Europe and encourage children from underprivileged areas to realize that they are part of a much larger European global community.

www.es.unawe.org

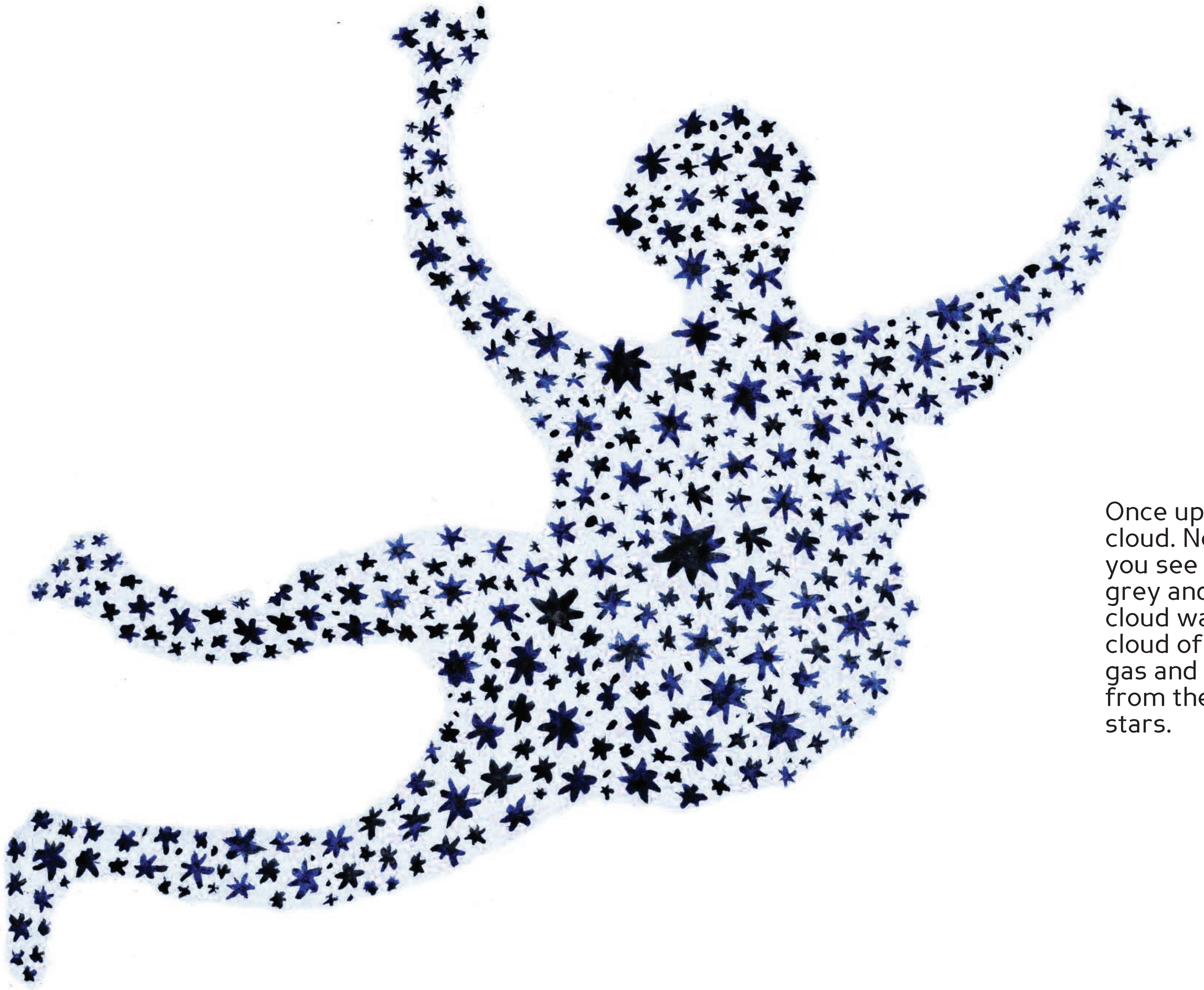
Introduction

Stars are born, evolve and die. This book explains the evolution of stars to children. The main goal is for children to be able to identify themselves with the protagonist star when she is young and then draw parallels between the changes she undergoes and the everyday life they know.

In a simple way, children are introduced to the concepts of gas clouds and interstellar dust, embryonic stars, main sequence stars, dwarf stars and the big explosions that give rise to supernovae and black holes. Who has not heard about any of those topics? And who has not wondered what they mean? Children too should know about these topics, and this book serves to make it happen.

Rosa M. Ros

A Star is born



Once upon a time there was a cloud. Not just any cloud, like those you see in the blue sky, which are grey and full of droplets. No. This cloud was bright and shiny. It was a cloud of interstellar dust, made of gas and tiny little particles coming from the matter lying between the stars.

It lay far away from us. It was a warm and cozy cloud. It was warm because the dust particles that it was made of were organizing a party and were running around playing tag. They were bumping into each other and the atmosphere was getting hotter and hotter. You may wonder what they were celebrating. To tell you the truth, they were all very happy because this cloud was going to become a mother. Inside it – in its womb, as it were - baby stars were taking shape.

Stars are like children: they develop in their mother's belly - the cloud of gas and dust - and then they come to light and grow older and older. But since the clouds of glowing gas and dust are very large, instead of giving birth to one, two or three stars, - as happens with children - hundreds of stars are born at a time. How come? The particles and spots of dust keep running for thousands of years, and after so many shocks and agitation they cling tightly to each other and get so stuck that they slowly turn into stars. So the party is over when they begin to be born. But in fact, it takes hundreds of thousands of years until they are fully formed.

Photo: V. Radeva

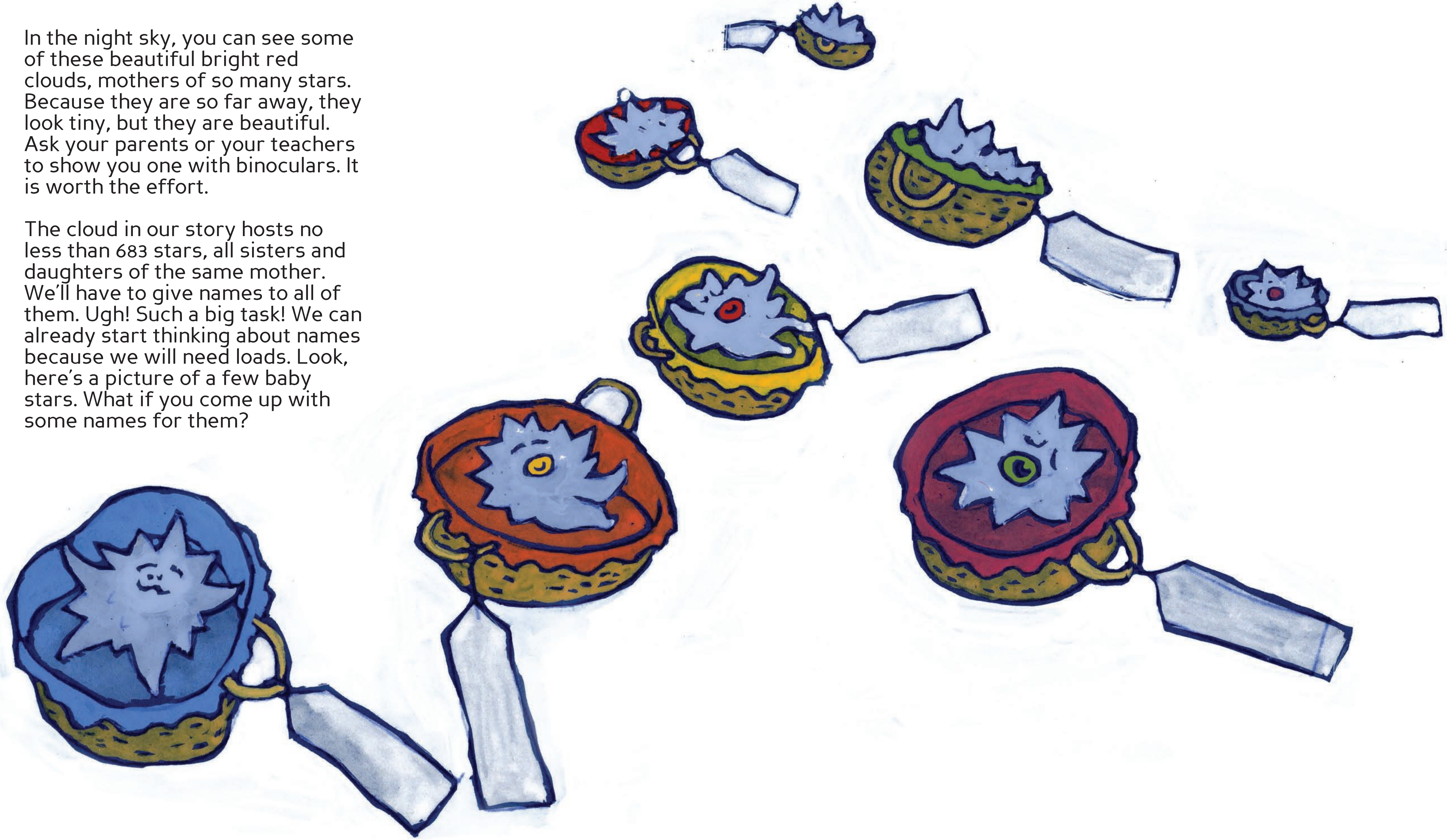
The Constellation of Orion dominates the winter sky on the southern horizon. They say that it represents a giant made of four stars: the two ones above are his shoulders, and two ones below are his knees. Also there are other three other stars in the middle (disposed like a ladder) that represent the giant's belt. Below the belt one can spot a sort of reddish cloud: this is the Great Nebula of Orion. The most beautiful one as said by the ancients!

Photo: Hubble Space Telescope

Great Orion Nebula, M42. It is 1300 light years away.
It contains enough material to create 2000 stars like our Sun.

In the night sky, you can see some of these beautiful bright red clouds, mothers of so many stars. Because they are so far away, they look tiny, but they are beautiful. Ask your parents or your teachers to show you one with binoculars. It is worth the effort.

The cloud in our story hosts no less than 683 stars, all sisters and daughters of the same mother. We'll have to give names to all of them. Ugh! Such a big task! We can already start thinking about names because we will need loads. Look, here's a picture of a few baby stars. What if you come up with some names for them?



Not all stars are equal. We will only follow one of them throughout her life. How about the one in the middle? Would you prefer another one? You can choose whichever you want.

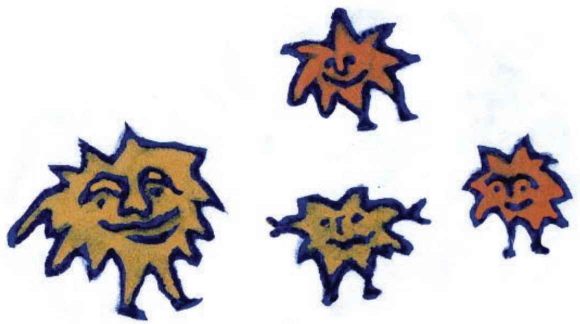
Yes. That one is fine. It is certainly the nicest and the protagonist of this tale. It's a good thing that she is fun and determined, and as such she has already decided a name for herself: her name will be Matylda. Matylda, with a Y.

Matylda? How on Earth (sorry... in the sky...) can a star be called Matylda? - the others were asking. You cannot choose this name. Stars are called Polaris, Aldebaran, Altair, Procyon, Betelgeuse. That is ... weird names, hard to pronounce. But no star would ever choose to be called Matylda. And on top of it, Matylda is not spelled with a Y! 'Well, the idea occurred to me!' she answered, 'and my name will be Matylda, Matylda with a Y!, MATYLDA is a new name, it's nice, it is my name and I like it!'

Hello kids, I am Matylda, and I'm going to tell you everything that is happening with me.

I am a white-yellowish star. Stars have different colours depending on their age and size. The hotter and larger ones are white or blue when they are born. If they are more normal, average size like me, they are somewhat cooler and yellow. During almost our whole life we are eating hydrogen and producing heavier materials inside us.

It's such a great life. That's what they call "being on the main sequence". To be honest, I have no idea what a 'sequence' is, but I like the idea of being 'main'... Yes, that's great! I like to be the main one! Be the main one for millions and millions of years... that's great! Then, after I've eaten up most of my hydrogen and got tired of being the centre of attention, I will get ready – just like the other stars - to organize my big party. Before the party, all of us get very anxious, quite neurotic. Of course, you do nothing for so long and suddenly, you have to organize it all: you'd freak out, wouldn't you? Due to the tension we puff out and become huge, and then cool down and become more reddish.



The truth is that our life depends on whether we are small or big at birth. The smaller ones live for many more years than the larger ones, who live only a short time. As they say, the big ones "live faster", but yes that's true, when they become older they "swell" into red supergiants and throw some amazing supernovae parties. Clearly, during all their life, the larger ones are more spectacular and eye-catching. They always overdo everything.

The tiny ones go unnoticed, and no-one pays too much attention to them. They always end up like the dwarfs in the fairy tales, rather small, full of wrinkles and very old. In fact, these stars are called red dwarfs, because they are small and reddish. They will gradually wither until they become cold and almost invisible in the universe. I think they're too unassuming.

I am an average star. When I grow up I will also turn orange and I will manage to be a giant, but not a particularly big one. Well, to be honest with you, I will always be average. Right now I'm still in the "nursery". I have my sisters all around me, and traces of interstellar dust between us.

I am thinking that with the remains of the material that I have so close to me, and that follows me like a ruffled skirt when I am doing my pirouettes, I can build my own planetary system. What do you think? Matylda's Planetary system? Or the "Matyldary System"? How does it sound to you?

What are you saying? That you don't like it? But it´s such a beautiful name, and you have yourselves a lovely solar system with eight planets orbiting around the sun, so why can I not have my own Matyldary system?!

Of course, I'll have to decide how many planets to have and what to call them, but well, I have plenty of time. It takes tens of millions of years before the system is ready ... so there is no rush!

Actually, do you know the names of the eight planets of the Solar System? Let's see:

1

2

3

4

5

6

7

8

Photo: Rogelio Bernal Andreo (DeepSkyColors.com)

The Pleiades open cluster, located 400 light years away. At first glance it looks as it is made of 6 or 7 stars (depending on the visual acuity of the observer). With binoculars one can spot up to 30 stars, but actually there are hundreds of stars, all born from the same gas cloud. Later, the swarm will disperse just like has happened with so many other clusters. The brightest stars are still surrounded by gaseous waste that could generate planetary systems.

Hello again, it's me, Matylda. Do you remember me? Millions of years have passed by. Now I am a yellow star. I'm colder than before. Yes, just like the sun, which is the star that you have closer and you know more about.
Well, I'm going to tell you now what has happened to me during all these thousands and thousands of years that have passed since the last time we met. I have my own planetary system. It's really cool. I love going everywhere with my planets revolving around me. It's like juggling with friends. My system has only seven, but the biggest is bigger than your Jupiter and its ring system is nicer than Saturn's one. You want to know how I called them, don't you? I knew you wanted to hear their names. Well, they are called ...Mondylda, Tuesdylda, Wednesdylda, Thursdylda, Fridylda, Saturdylda and Sundylda.
What now? What are you saying? That these are not appropriate names for planets or exoplanets? Because mine are exoplanets. Here we go again. Matylda wasn't a star name either. Well, I do like them, they are my planets and I'll choose for them the names I like the most. Besides, they are so easy to remember, aren't they? So, end of the story.
For the time being, none of them is inhabited, but a long evolution is required before life can develop. So it may be that in a few years things can change. If it happens, don't worry, I'll tell them to send you a message and you'll get in touch.

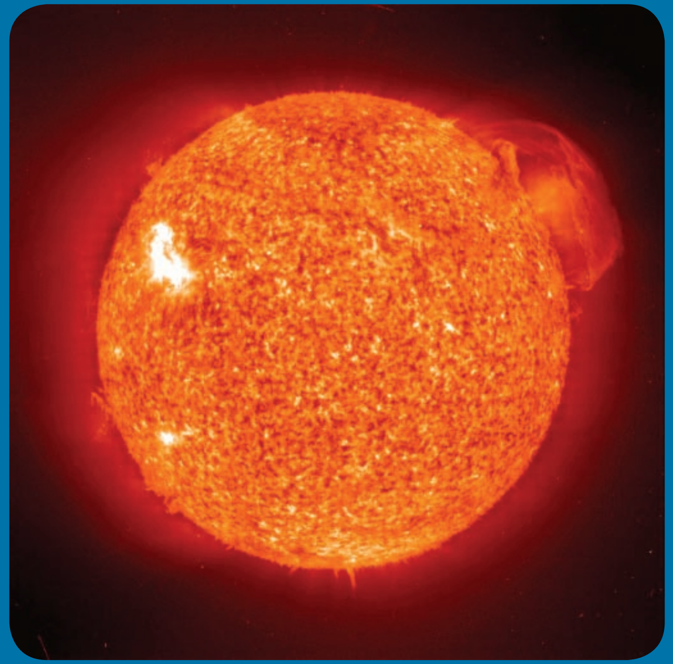


Photo: SOHO

The core of the Sun is the hottest region. It is located deep inside the Sun, below the convective zone where energy transportation occurs by convection in a turbulent non-homogeneous manner, in which some bubbles of hot and light gas go up to the photosphere (the superficial and visible area of the Sun), resulting in flares and spots.

Well, as you can see, I've grown a lot. But the truth is that stars do not grow the way children do. It is as if we grew ourselves inside. When I was born I was a ball of mostly hydrogen, which is a very simple element. In fact almost everything you see in the universe is hydrogen, plus some helium. The problem is that in order to develop different elements and eventually get a universe which is more varied and fun, they need us, the stars.

All of the elements coming from hydrogen develop inside a star. We develop oxygen, carbon, nitrogen and the biggest stars produce heavier elements like iron and magnesium. In short, we are the manufacturers of all the bricks needed to build everything you see around you. Water is made of hydrogen and oxygen. The molecules that give rise to life on Earth are composed primarily of carbon: Carbon that was born in the womb of a star. So we are very important for life, we are fundamental.

But I must admit that I'm leading a relaxed life, like the Sun, which is also an average star. So I hope to live around 10 000 million years

producing heavier and heavier elements in my belly, slowly warming up... very, very slowly, until I end up slowly cooling down...
By the way, would you like to know what I look like? Well, inside me I have lots of magnetic fields. You know the fields of the magnets.
It's great to live like this, but you can't see that from the Earth. On my surface, just like on the surface of the Sun, you can notice some turbulence as a result of my inner activity. As I generate so much energy inside me I send out hot gas bubbles, as they say, by convection. Hey, what a word! Convection! This means more or less that the heat goes out in the same way as it does when boiling a pot of milk. The lower particles climb upwards through the middle and then move slightly towards the edge, go then down to the bottom, and eventually climb up again through the middle. It's a frenetic dance and it's so much fun. The particles have to rush as fast as they can. See who gets there first. Some of them climb up like the bubbles in the milk pot, and then moving spots pop up on my surface and keep changing shape ... everything is on the go!

As time goes by, I will use up almost all my hydrogen and then I will pump up like a balloon and I will turn more red ... In fact, I will become so big that everyone will call me the “red giant”. I will then begin to burn my helium to make carbon and oxygen. But I’m planning for a big birthday party to celebrate all those years that I have been developing new elements in my belly and “boiling milk” on the surface. My ten billionth birthday has to be really special!
Anyway, as I don’t have enough material, I cannot throw a supernova party with a big bang for all to see, casting out the outer layers in a cloud of gas and dust and leaving in the centre a material that is so heavy that it lets nothing through, not even light. You know, what everyone calls a black hole. No, I’m not going to make such a tacky show. That is so unstylish. Some of them have no idea how to pass unnoticed.

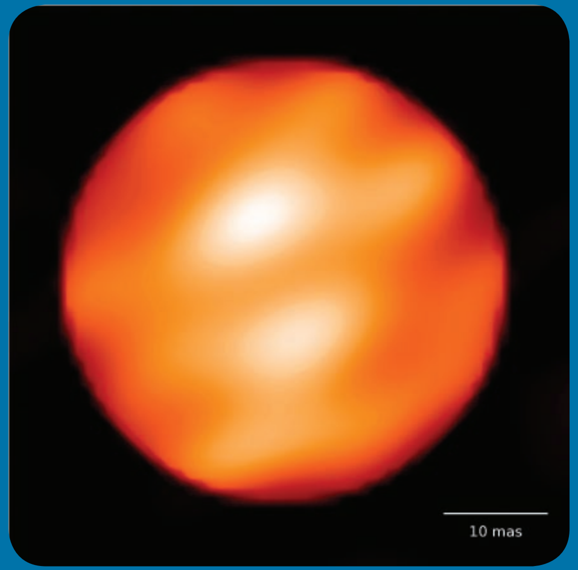


Photo: NASA/ESA

Betelgeuse is the orange star located in the left shoulder of Orion. It is 640 light years away from us. It is a supergiant star with a radius 500 to 750 times the radius of the Sun. It is a cold star in passive agony suffering from permanent tremors. It will eventually end in an explosion resulting in a supernova.

Photo: Hubble Space Telescope

M1 Crab Nebula can be observed with a small telescope. It looks like a pale spot in the shape of a crab. You can locate it in the sky near Orion to the upper right, in the constellation of Cancer. It is 6500 light years from the Earth. It is the gas remnant of the supernova explosion that Chinese astronomers observed in 1054. In the centre of the nebula there is a pulsar that rotates like a lighthouse on a regular basis every 0.33 seconds.


Photo: R. Bernal


Photo: Hubble Space Telescope


Photo: Hubble Space Telescope


Photo: Hubble Space Telescope


Photo: Hubble Space Telescope

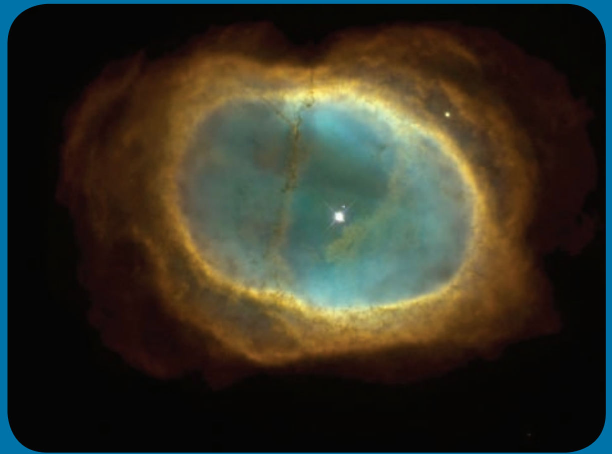


Photo: Hubble Space Telescope

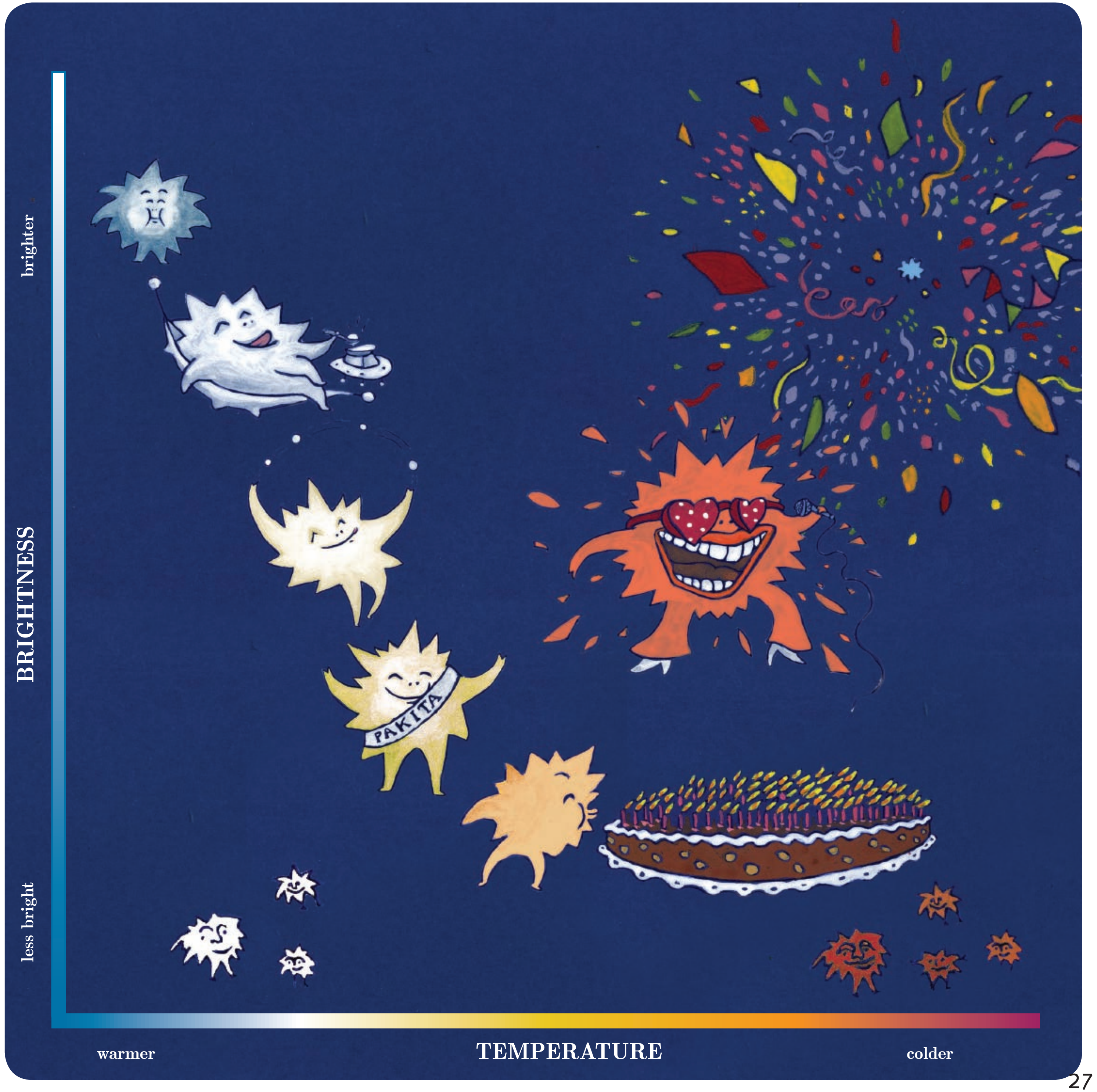
But on the other hand I do not want to say goodbye like those dwarf stars do. They wilt and cool down until they start looking like a red “withered fig”, lost in the black sky, which is impossible to see.
As I am an average star I have enough mass to throw a “cool” party. I want a nice party, neither over the top, nor ridiculous. Yeah, I’ve thought about it, my planetary system and I, we will end up as a beautiful nebula. Something similar to one of these six. Let’s see, which do you like most? They are called “planetary nebulae” and they really exist. Paint one that you think is nicer and I will take as a model.

Are you asking, what is the party going to be like? First of all we will all make a big explosion and form a beautiful nebula. The most beautiful of all. In the centre, a small memory will be left, a wonderful white dwarf, so that everyone can remember Matylda. It will be a party with all my friends and all my planets. We will launch into the universe a cloud of the material that I’ve been preparing over the years. So there will be other elements spread into the sky, besides hydrogen. Because I like to help kids like you to be born. All children are made of the elements that my friends, the stars and I, have prepared within us throughout our lives. Oh yes, I love that. Just like you do for your birthday party, when you throw streamers and confetti, we launch the dust of stars into space, which can be used to create life. To develop children in the wombs of their mothers in the same way they developed in the wombs of their grandmothers.

Tonight, when you look at the sky, remember that you are nothing but stardust.

This diagram classifies stars according to their colour and brightness. Astronomers use it to study the changes that stars undergo during their lifetime; in this way, they can learn much more about the universe.

Scientists call this figure the HR diagram, remembering the initials of the two astronomers who first devised this classification: Hertzsprung and Russell.



THE SERIOUS PART OF THE BOOK

Draw, cut and make experiments

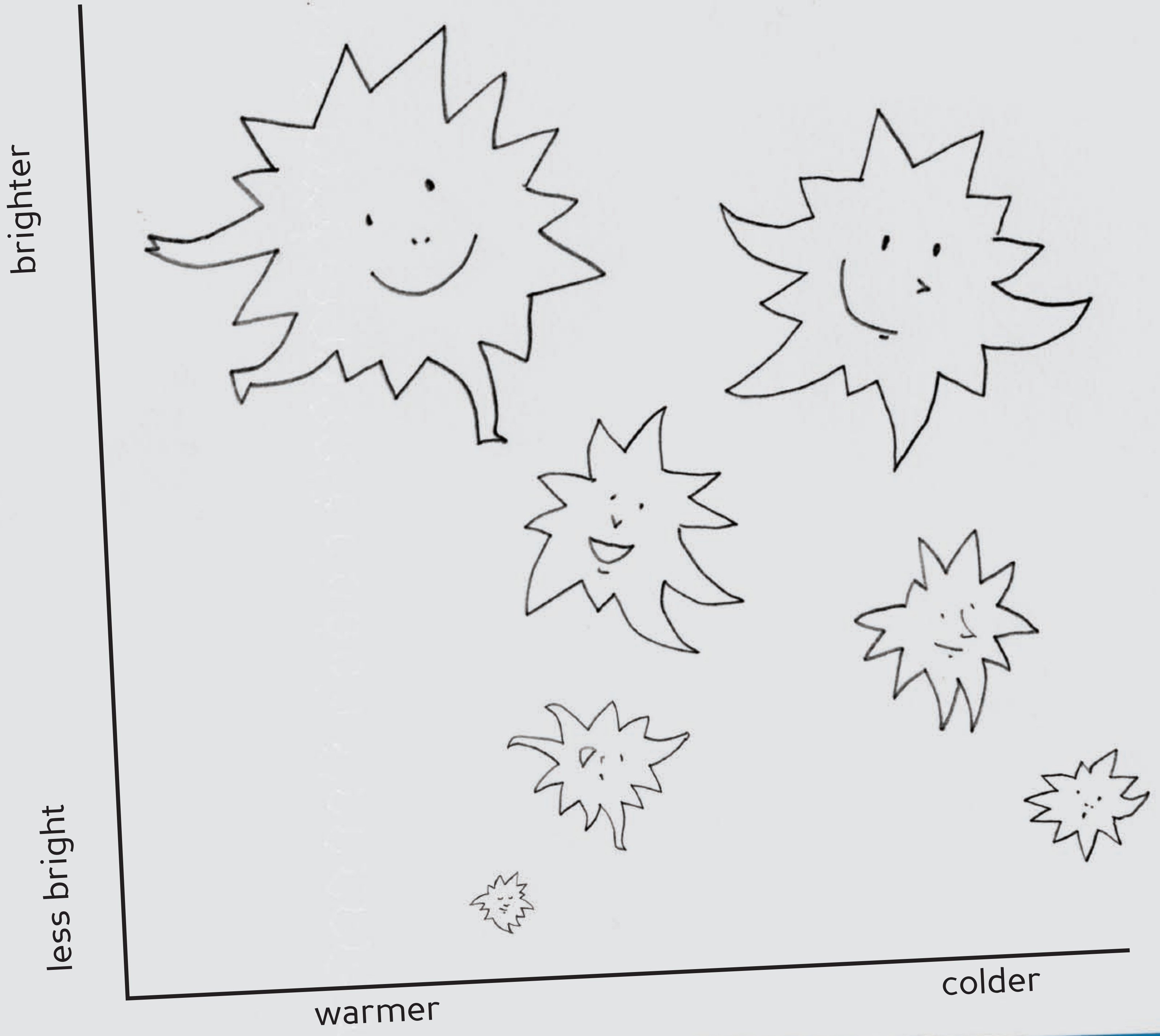
Activity 1:

Paint the coloured stars

After reading the story you know that not all stars are white as most people think. You know that they may have the following colours: blue, white, yellow, orange and red, and you also know that these colours change throughout the life of the star. The larger ones are blue and the smaller are orange or red. The colour depends on the temperature: the blue or white ones are hotter and the orange and red ones are cooler.

We ask you now to colour the stars in this figure by taking into account what you know.

by the way, remember that there are no green or purple stars!



Activity 2:

Paint and cut out a model of the Sun

Matylda is an average star, like the Sun. Inside it is made of several layers like an onion. Let's make a model of the solar interior from the inside out. We can see not only the surface of the Sun or of any other star, but we can work out how it looks inside by studying the light that reaches us. We know that the Sun is made of:

1) The core and the radiative zone, where thermonuclear fusion reactions take place. The temperatures inside the core are around 15 million degrees, while in the radiative zone temperatures are slightly lower, reaching only about 8 million degrees. Throughout the whole area closest to the core, the energy is transferred by radiation.

2) The convective zone, where energy is transported by convection, with temperatures below half a million degrees (500 000) and just below the photosphere.

3) The photosphere, that we could consider like the "surface" of the Sun, is the source of the solar spectrum, and has temperatures ranging from six thousand to four thousand degrees (from 6 400 to 4 200). It is fragmented into cells that last only a few hours. In addition, it usually has colder parts (3 000 or 3 500 degrees) that look like dark spots.

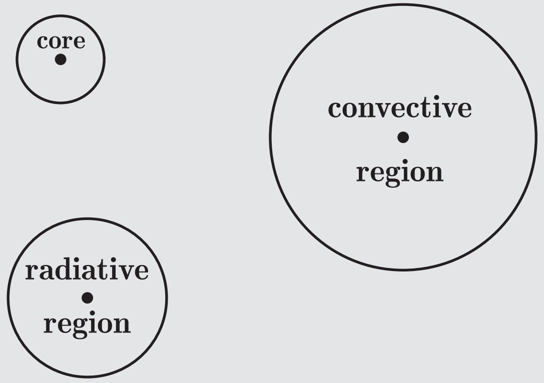
4) The chromosphere, which is outside the photosphere and has a temperature of 4 200 to 1 million degrees. It looks like vertical filaments that resemble a "burning prairie". It has protrusions (bumps) and flares.

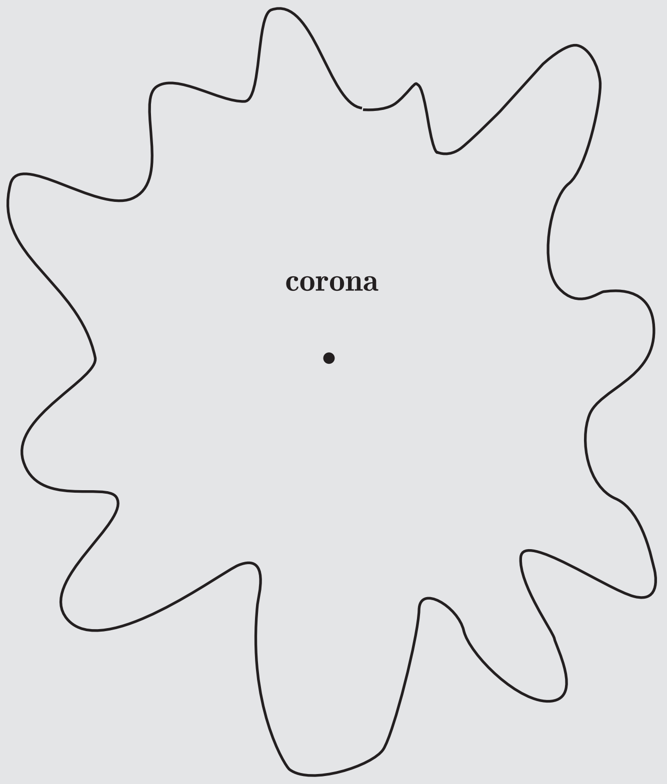
5) The corona, which is the source of the solar wind, and has temperatures ranging between one and two million degrees.

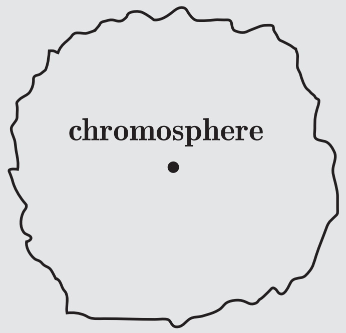
Copy all these figures onto paper (do not cut this book). Colour each area and cut them out. Place it with a pin in the centre in the order shown above. Use the following colours: white for the corona, red for the chromosphere, yellow for the photosphere, orange for the convection zone, blue for the radiative zone and light blue for the core.

The approximate radius of each region is:

- The radius of the core: 139,000 km
- The radiative region: 139,000-496,000 km above the nucleus
- The convective region: from 496,000 km to 696,000 km above the radiative zone
- Photosphere: the remaining 100 or 200 km above the convective zone. (The problem is to represent the photosphere if you want it to be to scale)
- The total radius of the Sun: 696,000 km
- The chromosphere: 150,000 km above the photosphere
- The corona: over one million km above the photosphere.







Activity 3:

A convection model

You remember that Matylda was sending hot gas bubbles from the inside outwards, more or less like milk when it boils. Particles climb up from the bottom up through the centre of the bucket, then they go to the edge and then downwards towards the bottom, and eventually back up again. We said that this movement is called convection and is typical of some stars. To see an example you can bake a cake.

Ingredients

- 3 eggs
- 1 cup yogurt
- 1 cup oil
- 3 cups sugar
- 4 cups flour
- 1 packet of yeast
- 1 cup chocolate powder
- a round pan

Method

Preheat the oven to 180 or 200 degrees. Mix all ingredients, except the chocolate, until homogeneous consistency. Grease the pan. Pour half of the mixture gently into the pan, then coat a thin layer of chocolate powder over it. Carefully pour the remaining mixture into the pan. Bake in the preheated oven for about 45 minutes. Take it out of the oven. Allow to cool and cut into pieces.

We can observe the lines of the chocolate brownie from the center toward the edges. Upon heating the cake, the convection process has started and the dough has risen through the center and moved towards the edges, making a circular motion that can be seen in the picture.

Activity 4:

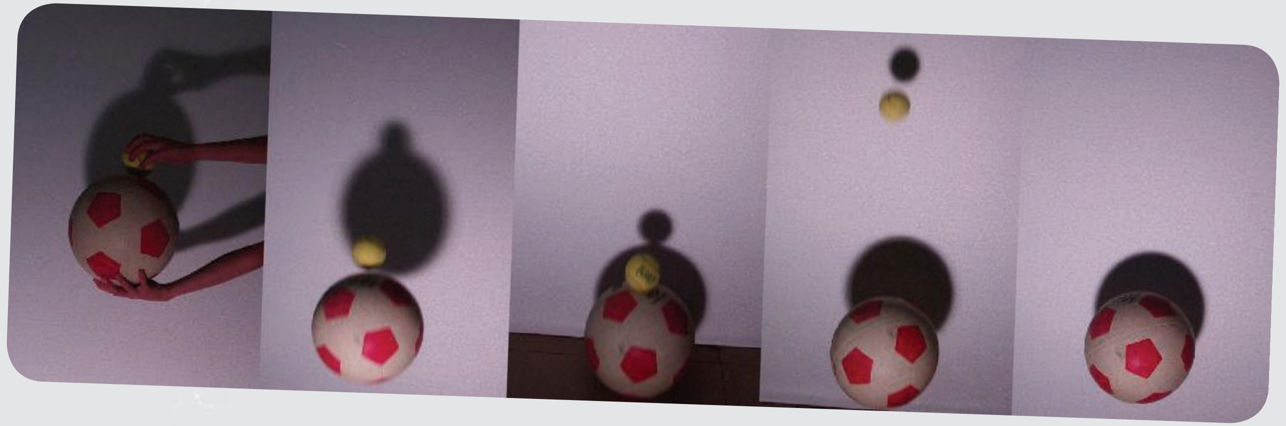
Simulating a supernova explosion

When a large star explodes as a supernova, the outer light layers fall on the dense inner areas, and bounce off the solid core. Let's make a simplified model of how the outer areas bounce against the solid core. This can be shown in an easy and rather spectacular way with a basketball and a tennis ball, by dropping them together on hard ground, as shown in the picture.

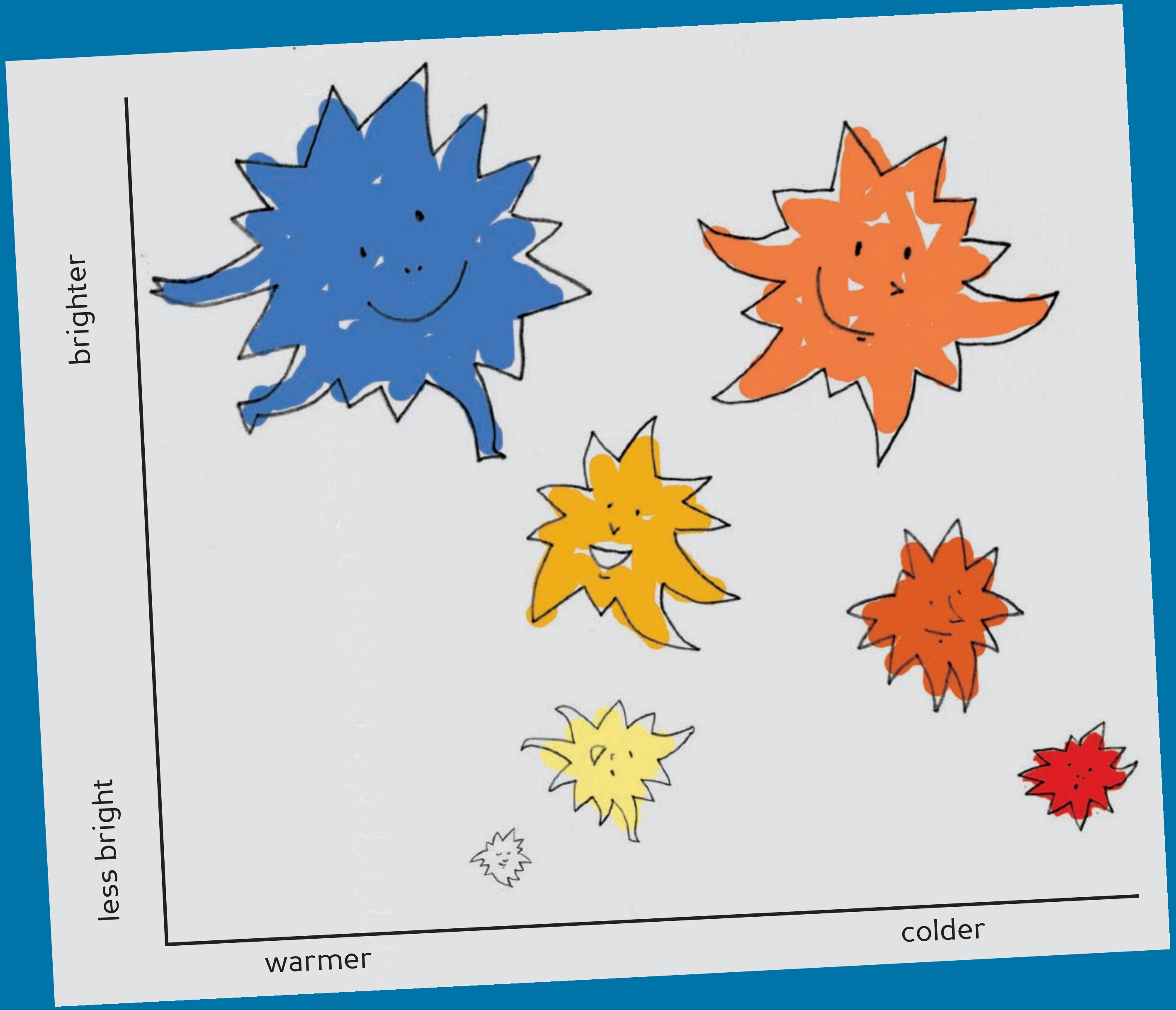
In this model, the floor represents the solid core of the star, while the basketball stands for the less dense area which bounces, and pushes in turn other even less dense areas that come behind it, represented by the tennis ball.

To build the model, bring the basketball up to our eyes and hold the tennis ball just above it, as vertical as possible. Drop them both at once. When released, they reach the ground almost simultaneously.

The large ball bounces back elastically and goes back almost with the same speed it arrived. At that point it collides with the small tennis ball, which is falling at the same speed with which the big ball goes up, so the small one is bounced upwards and reaches a much higher altitude. The idea is to show the "rebound effect" of the outer layers as they fall over the core during the explosion of a supernova.



Solution of activity 1



The aim of UNAWE is that children from all countries may have a personal, enjoyable relationship with astronomy. EU-Universe Awareness is the European branch of this global project and involves Germany, Italy, the Netherlands, Spain, United Kingdom and South Africa. Through experiences and emotions related to stargazing children begin to understand that they are also part of the universe and they have a world in front of them ready to be explored.

CSIC

EU-UNIVERSE AWARENESS

SEVENTH FRAMEWORK PROGRAMME