SIX FAVORITE RECIPES TO COOK UP THE UNIVERSE

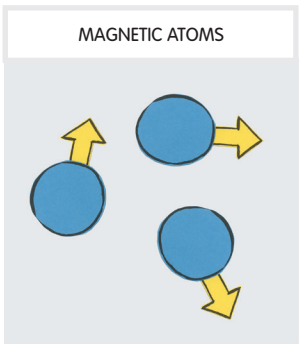
http://hebergement.u-psud.fr/supraconductivite/recits/index_en.html

This work has been done during the diploma of Margaux Khalil and Claire Thibon of DSAA de Design d'Illustration Scientifique of école Estienne in collaboration with Julien Bobroff (LPS, Universite Paris-Sud) and Roland Lehoucq (CEA-Saclay). Translation : Mélanie Mora Y Collazo.

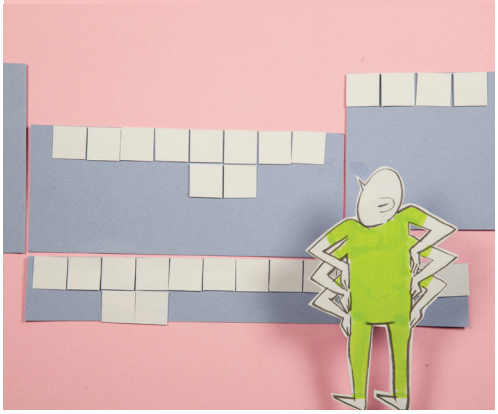
A great thank to the teaching team of Ecole Estienne, to Michèle Garrec and Blandine Berthe for their help. We want to thank for their financial support the Institute for Complex Adaptive Matter (ICAM), the Societe Française de Physique and the Chaire «La Physique Autrement» of Fondation Paris-Sud supported by Air Liquide

MAGNET

TO MAKE A MAGNET, WE NEED :

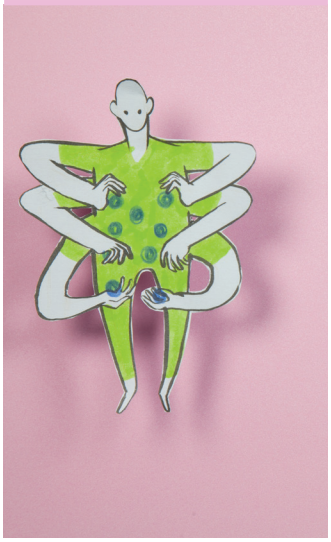


IN ORDER TO PRODUCE A MAGNET, WE FIRST HAVE TO CHOOSE THE GOOD KINDS OF ATOMS.

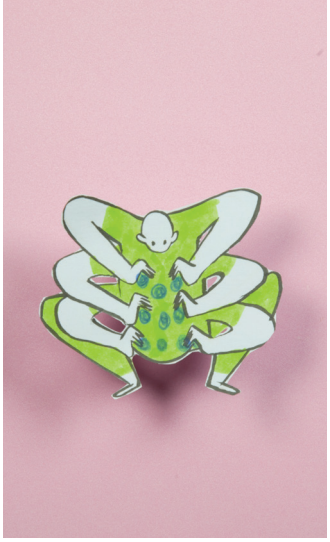


IRON ATOMS, FOR INSTANCE, WHICH ARE MAGNETIC AND HAVE SPIN.

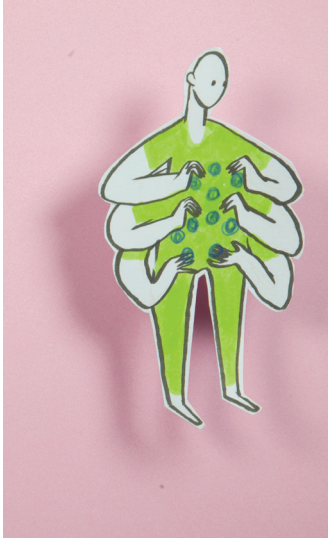
METALLIC BONDING WILL HOLD THEM TOGETHER…



AND SHAPE THEM…

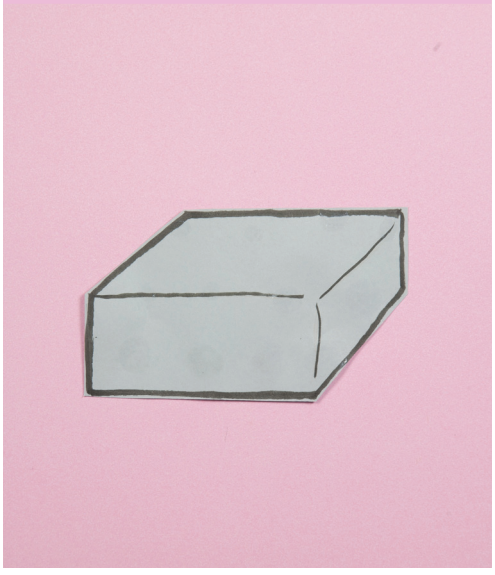


INTO A SOLID.

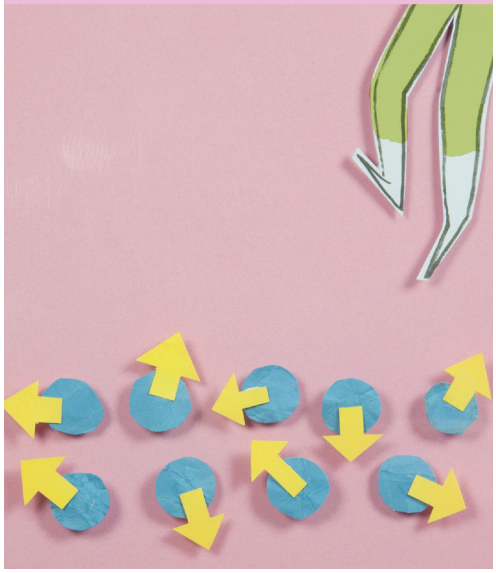


ONCE THEY ARE GATHERED, THESE ATOMS WILL FORM THE SOLID STRUCTURE…

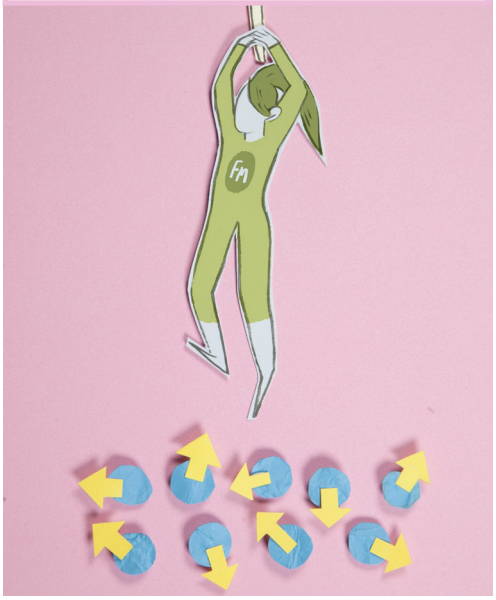
BUT IT WILL NOT ALWAYS BE A MAGNET!



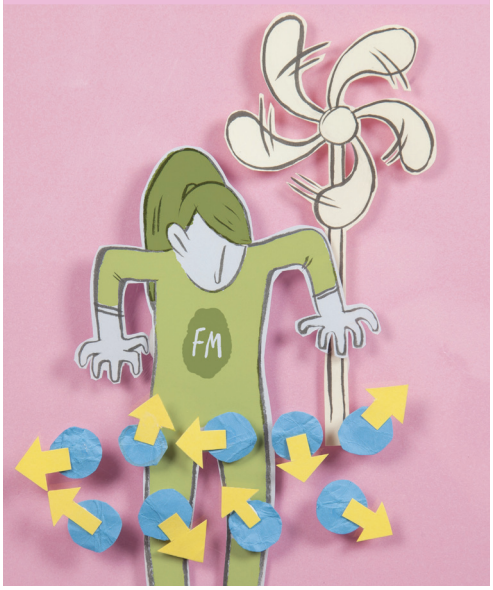
IN ORDER TO MAGNETIZE A SOLID, WE STILL NEED A LITTLE HELP…



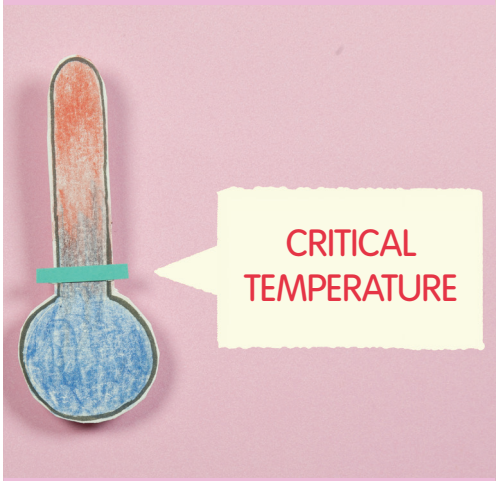
FROM THE FERROMAGNETIC INTERACTION.



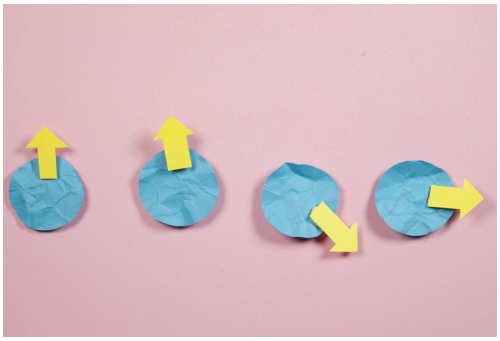
IT WILL USE ITS POWERS TO MAKE SPINS ALIGN…

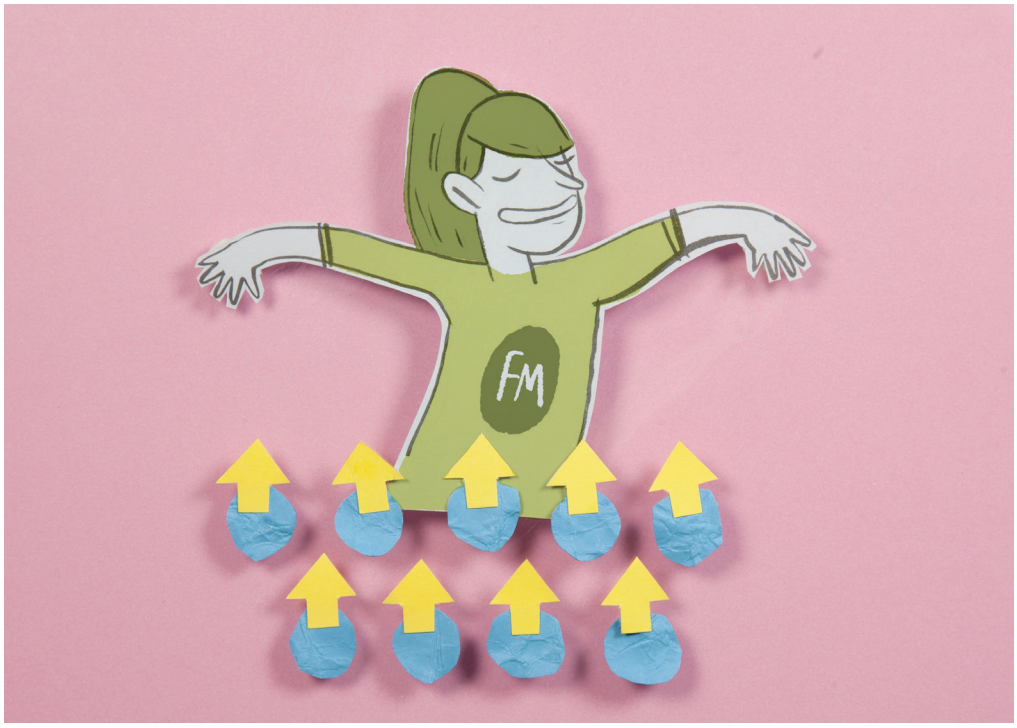


TO DO SO, THE INTERACTION WILL LOWER THE TEMPERATURE TO A CRITICAL TEMPERATURE…

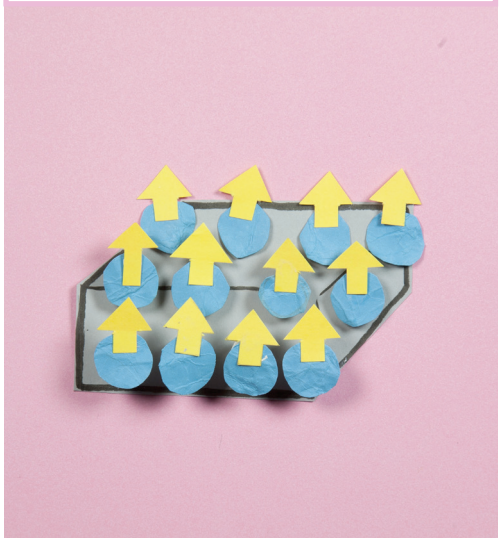


WHEN THE TEMPERATURE IS LOW ENOUGH, THE SPINS WILL PAIR OFF AND ALIGN.

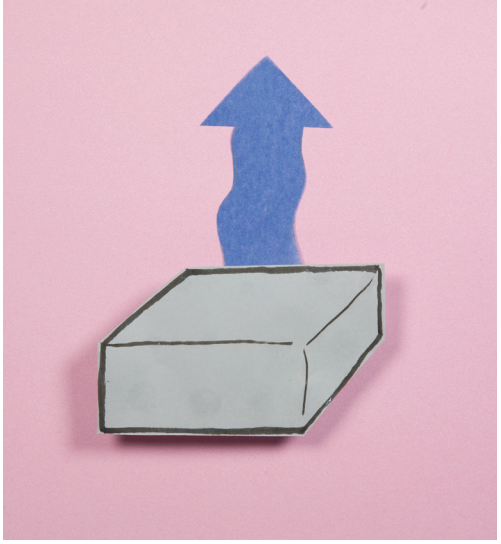




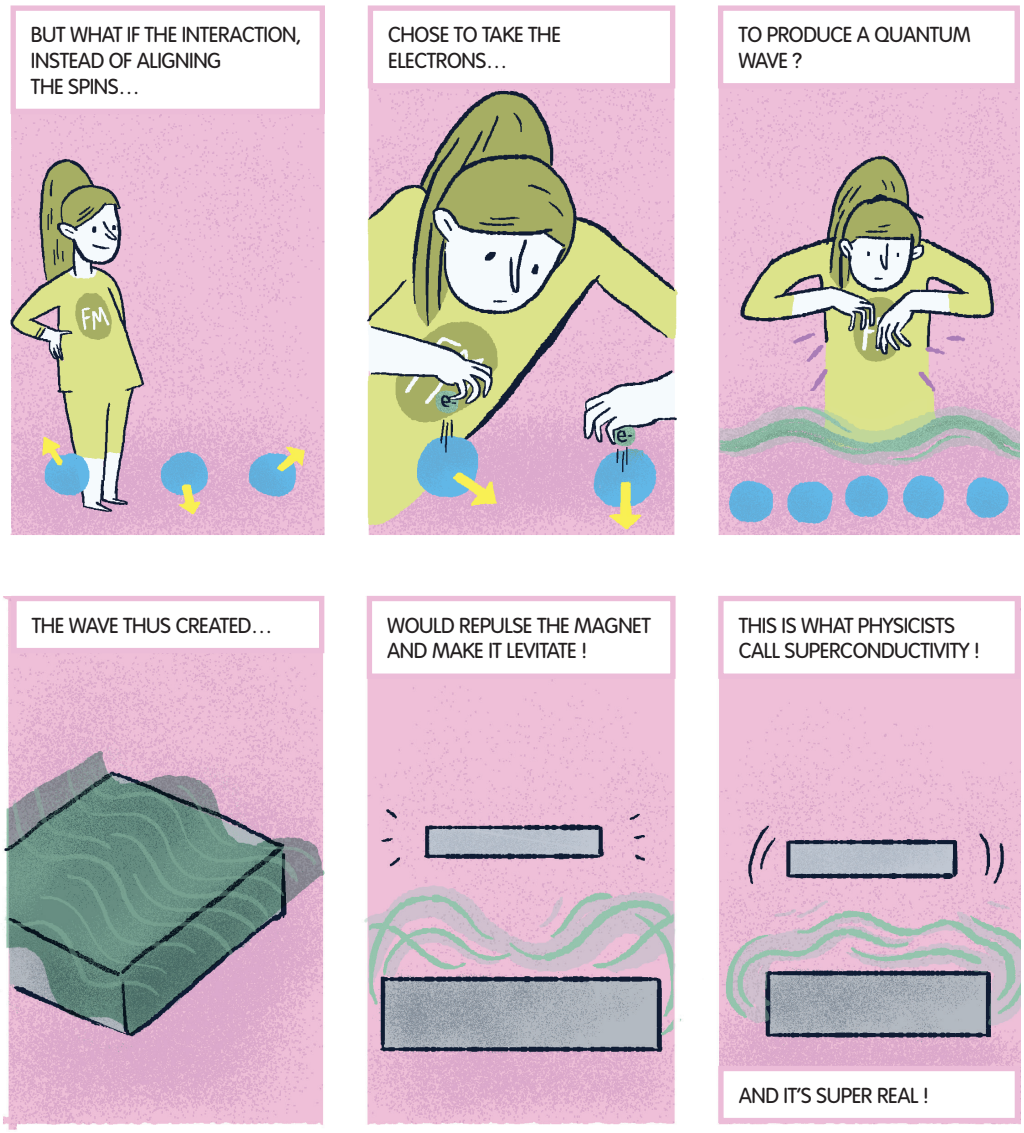
THE EFFECTS OF THE ALIGNED SPINS WILL ADD UP, GIVING THE SOLID A NORTH POLE AND A SOUTH POLE.



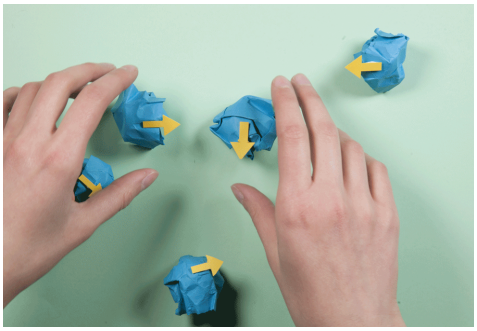
AND THERE'S YOUR MAGNET !

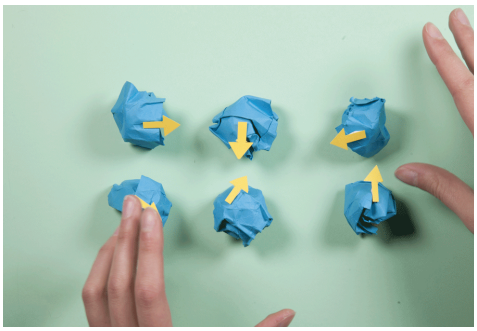


BUT WHAT IF THE LAWS OF PHYSICS WORKED DIFFERENTLY?



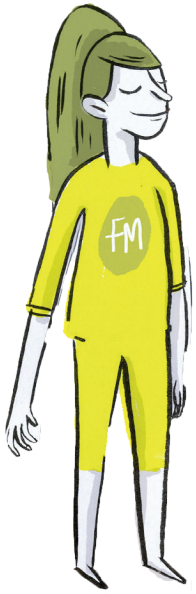
METALLIC BOND

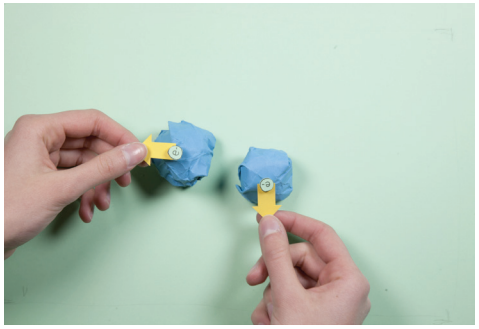


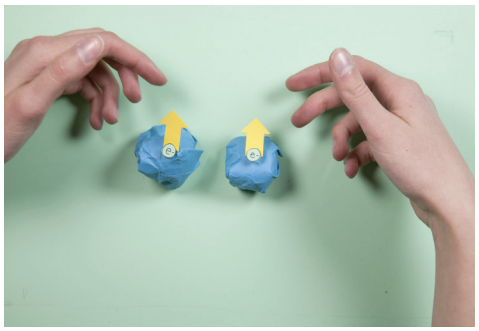


This interaction allows atoms to stick to one another to form a metal. To do so, the metal atoms all share their electrons, which will then be able to move around freely and form a kind of electric liquid. These electrons give metals their solidity. It is called metallic bonding.

FERROMAGNETIC INTERACTION



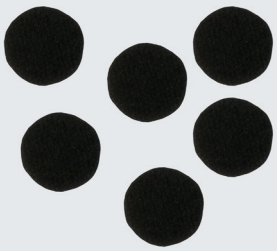




This interaction makes two spins – small magnets carried by the electrons to two neighbouring atoms – to align. Were the spins not parallel, the electrons would be able to coexist in one same atom, but this would be at great cost because two electrons repulse each other electrically. To avoid this additional cost, the electrons choose to have parallel spins, so that they can profit from the exclusion principle.

DIAMOND

TO MAKE A DIAMOND, WE NEED :

CARBON ATOMS	TIME
	

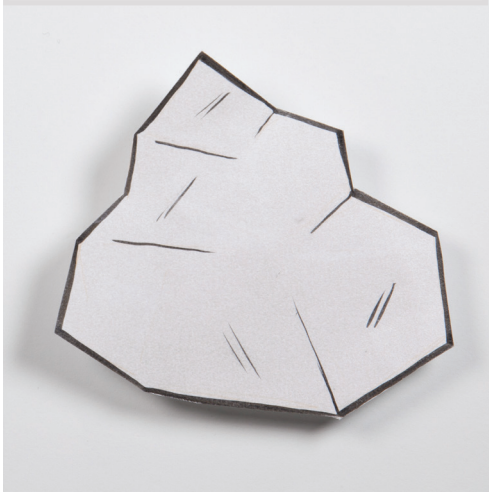
TO MAKE OUR DIAMOND, WE NEED SOME CARBON ATOMS.

SOME MORE…

A LOT OF CARBON ATOMS !

BUT HOW CAN A STACK OF ATOMS BECOME…

A DIAMOND ?



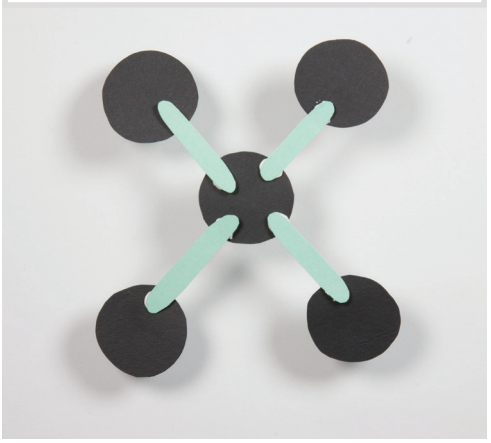
TO MAKE THAT HAPPEN, WE NEED A COVALENT BOND.

THE COVALENT BOND WILL TAKE ONE CARBON ATOM...

AND SNATCH ONE OF ITS ELECTRONS...

TO ATTACH IT TO ONE ELECTRON FROM ANOTHER ATOM. THIS IS WHAT PHYSICISTS CALL THE COVALENT BOND.

EACH ATOM SHARES ITS FOUR ELECTRONS WITH ITS NEIGHBOURS, THUS FORMING A VERY TIGHT BOND.

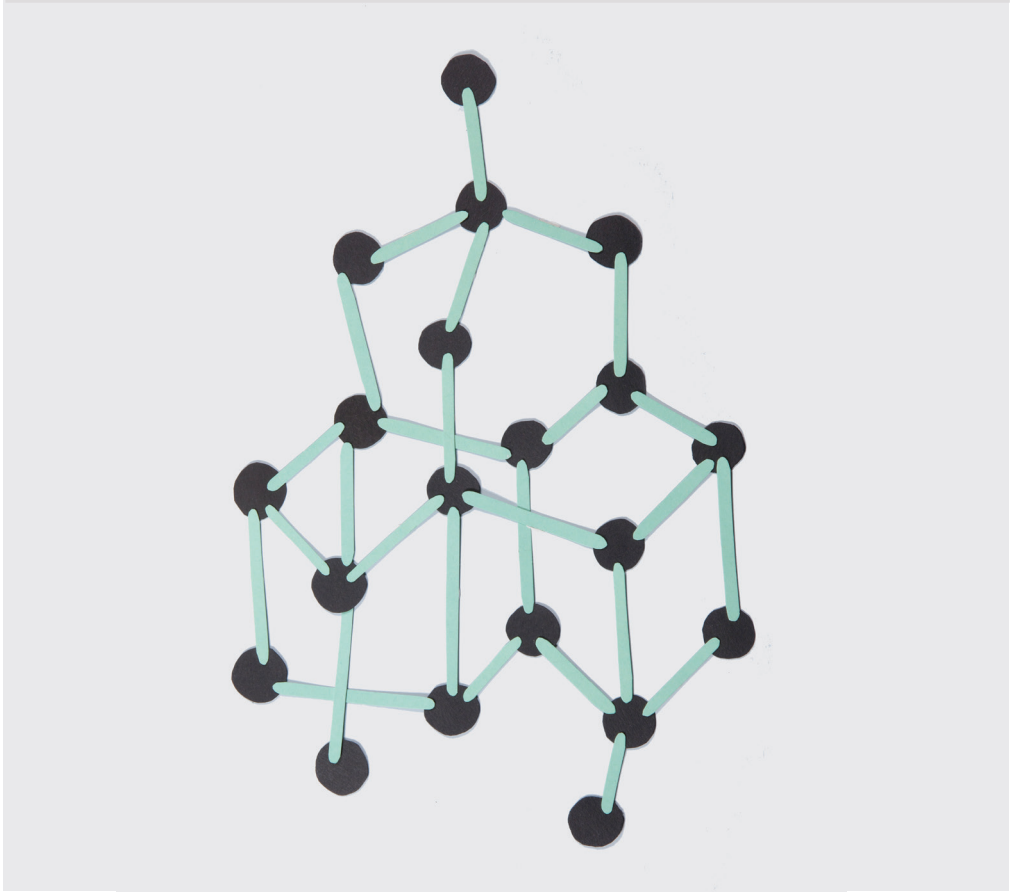


THE INTERACTION PERFORMS ITS MAGIC ON ALL THE CARBON ATOMS.

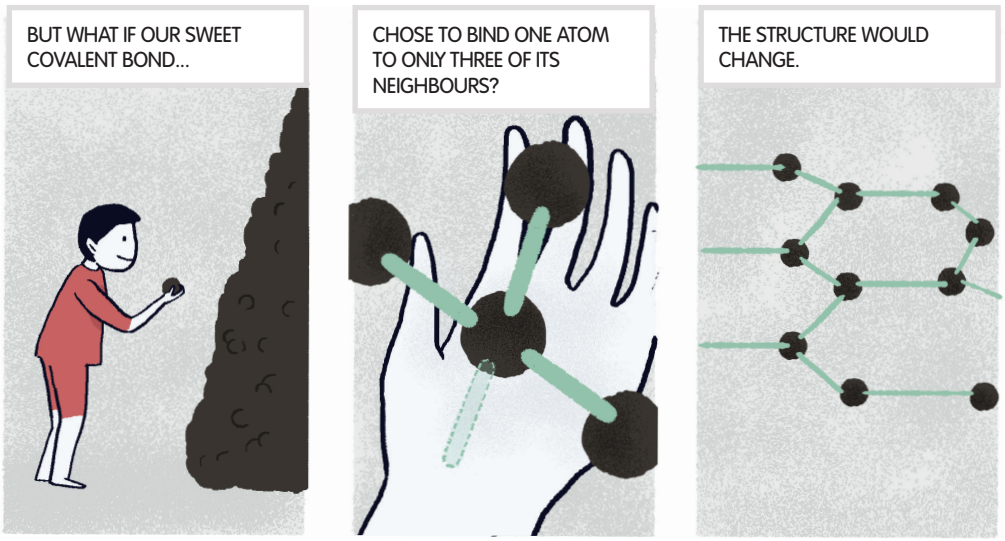
IT TAKES A LONG TIME.

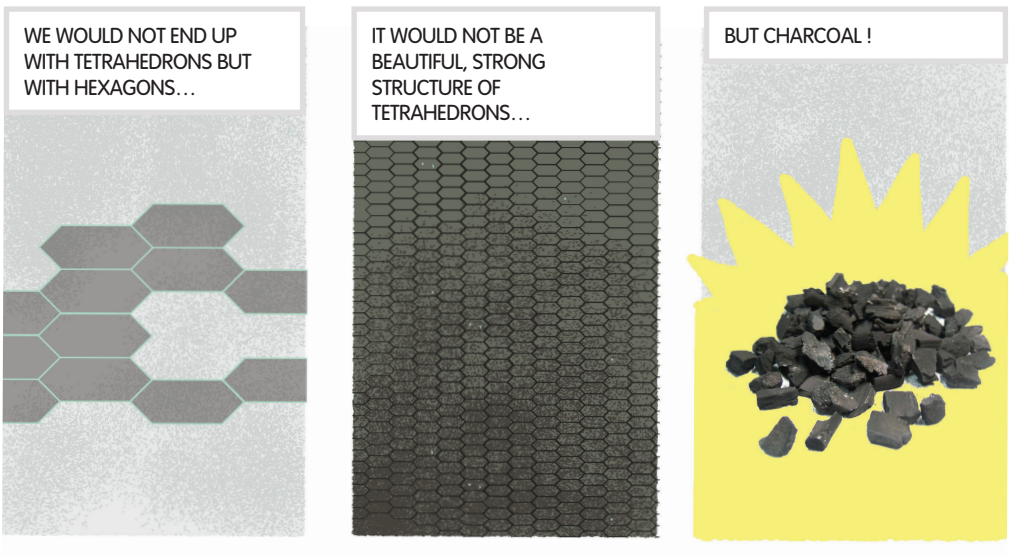
A VERY, VERY LONG TIME.

THE PROCESS HAS TO BE REPEATED ON BILLIONS OF BILLON ATOMS. IT USUALLY TAKES A FEW MILLION YEARS… WHEN IT'S DONE, THE BONDED CARBON ATOMS FORM A STRUCTURE OF INTERLOCKING TETRAHEDRONS… AND THERE'S YOUR DIAMOND.

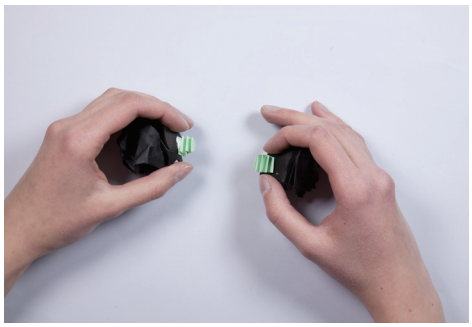


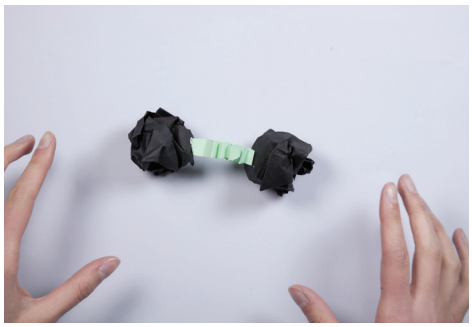
BUT WHAT IF THE LAWS OF PHYSICS WORKED DIFFERENTLY?





COVALENT BOND

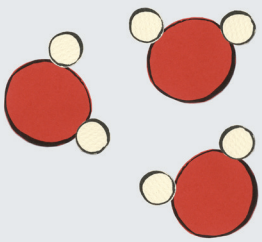




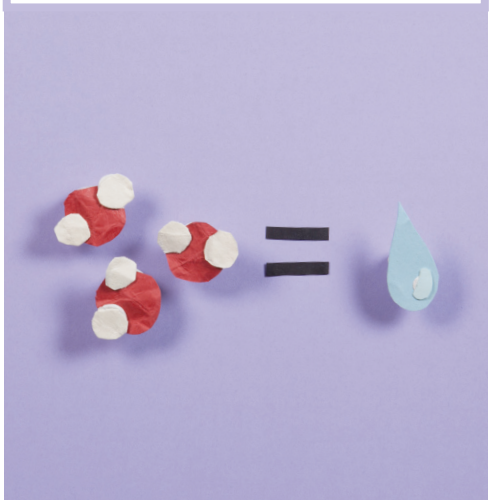
This is one of the bonds which connects two atoms in matter, such as two carbons in a diamond. It's when two atoms put each one an electron in a common bond. This covalent bond is very strong because it allows the atoms to reach a stable quantum favorable situation.

BUBBLE

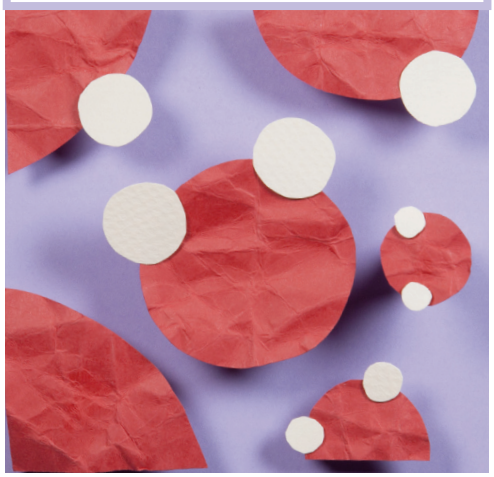
TO MAKE A SOAP BUBBLE, WE NEED :

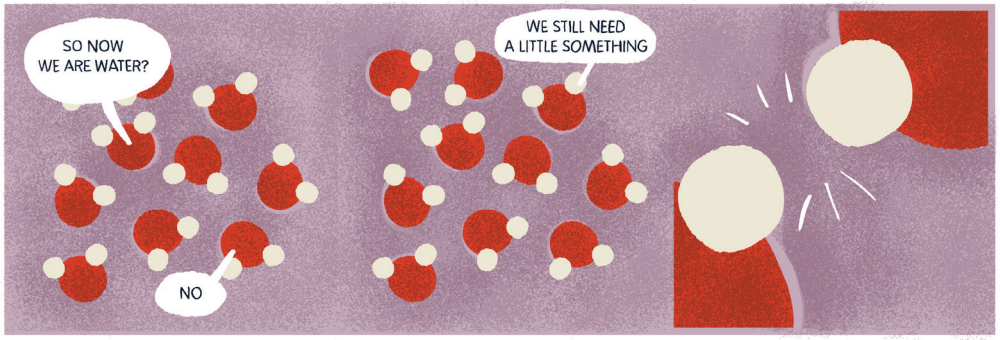
H_2O MOLECULES	SOME SURFACTANT	AIR
		

TO MAKE WATER, WE NEED H_2O MOLECULES.

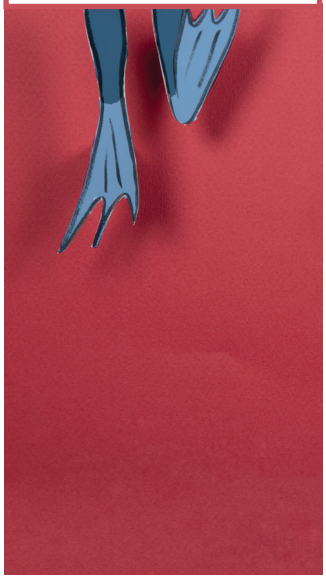


WE WANT TO GATHER THESE MOLECULES AND WARM THEM UP TO ABOUT 20 DEGREES.





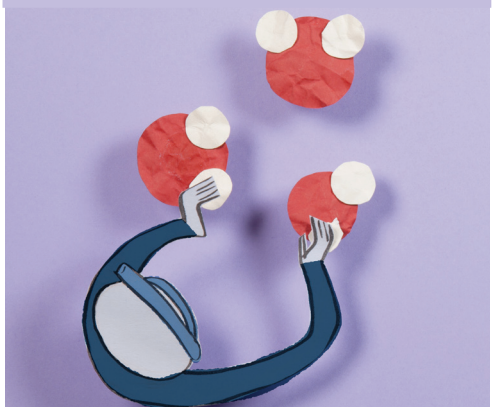
IN ORDER TO PRODUCE WATER ...



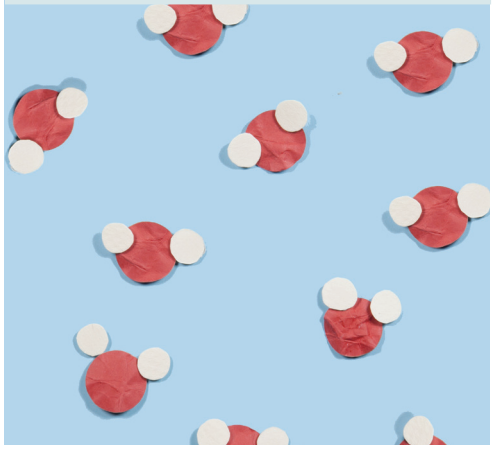
WE NEED ...

SOME HYDROGEN BONDING!

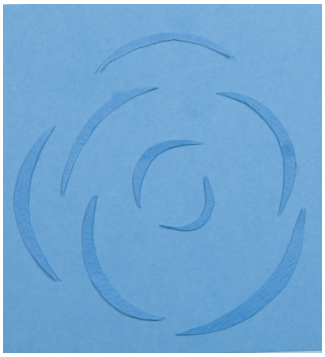
HYDROGEN BONDING WILL JOIN THE MOLECULES TOGETHER, LINKING AN OXYGEN ATOM WITH A HYDROGEN ATOM.



THE MOLECULES ARE THEN ATTACHED TO ONE ANOTHER ...

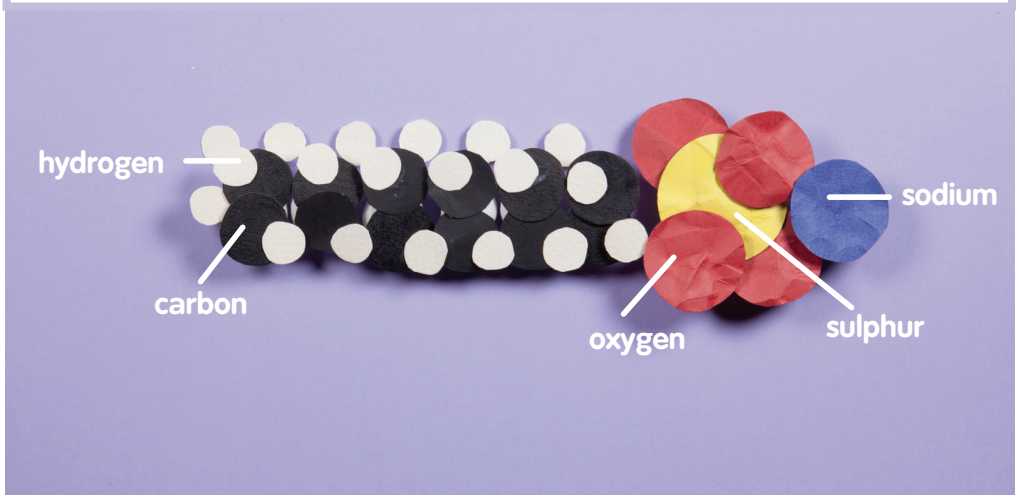


TO FORM WATER !

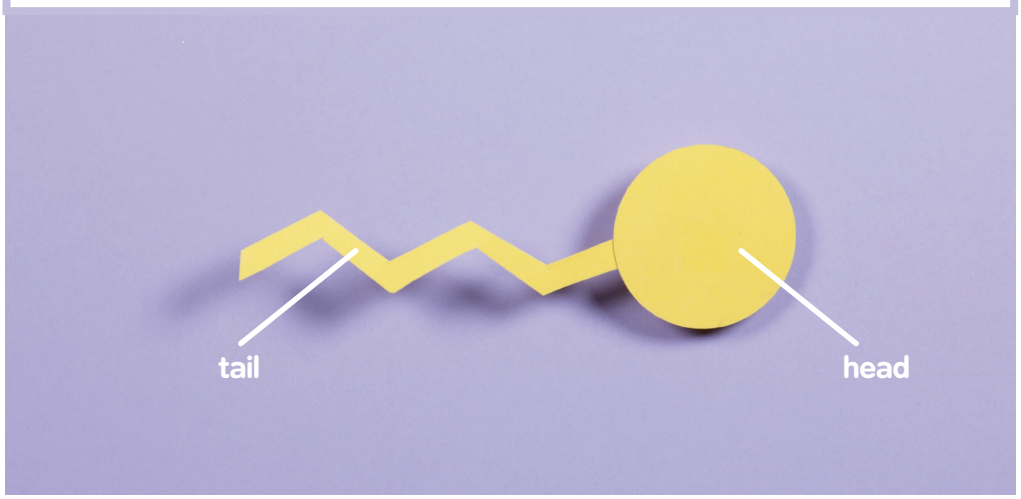


NOW, TO MAKE A BUBBLE, WE NEED SOME SOAP.

SOAP IS COMPOSED OF SURFACTANT MOLECULES, SUCH AS SODIUM DODECYL SULFATE ($C_{12}H_{25}NAO_4S$).



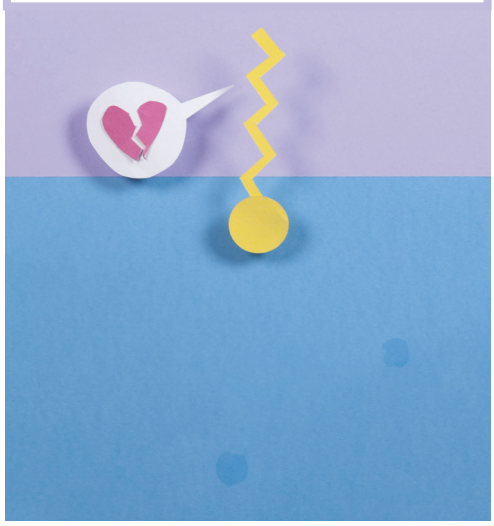
BASICALLY, WE HAVE :



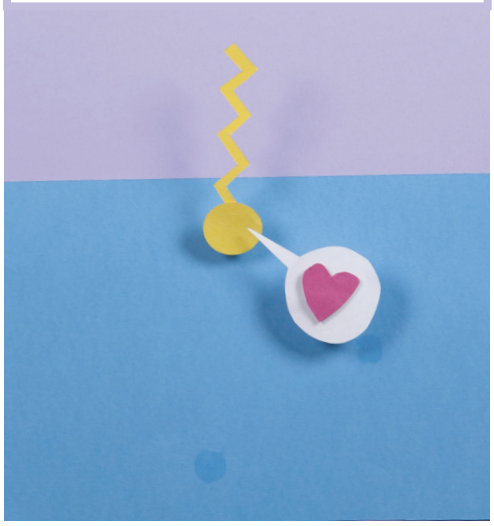
THE HEAD, WHICH IS ELECTRICALLY CHARGED BECAUSE OF SODIUM, CAN EASILY STICK TO THE MOLECULES OF WATER, IN ACCRODANCE WITH THE LAWS OF ELECTRICITY. HOWEVER, THE TAIL WITH THE ATOMS OF CARBON AND HYDROGEN DOESN'T LIKE WATER, BECAUSE WATER IS FORCED TO CHANGE ITS STRUCTURE WHEN IN CONTACT.

THIS ELECTROSTATIC INTERACTION WAS USED TO ATTRACT THE HEADS TO THE WATER.

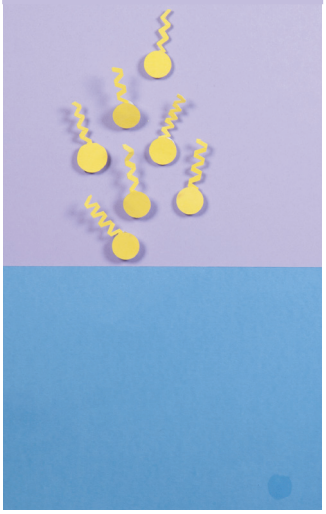
THE TAIL IS THEREFORE HYDROPHOBIC…



AND THE HEAD IS HYDROPHILIC !

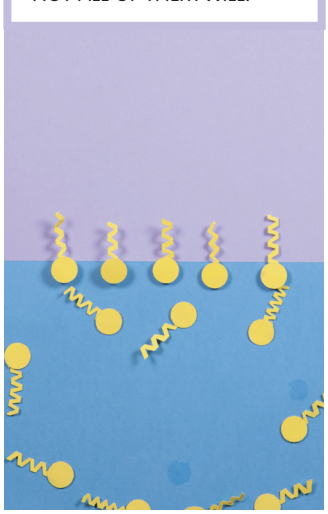


SO WHEN WE POUR SOAP INTO WATER…

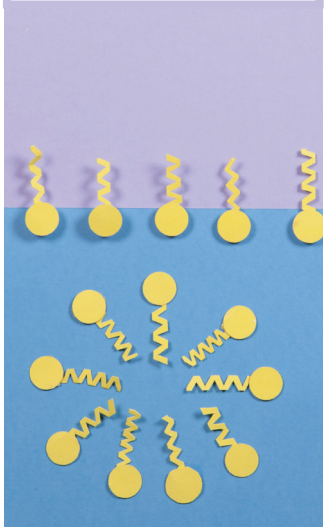


THE TAILS OF THE MOLECULES WILL STRIVE TO AVOID WATER.

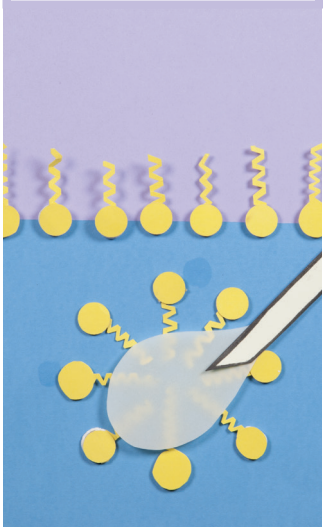
SOME WILL MANAGE TO GET OUT OF THE WATER, BUT NOT ALL OF THEM WILL.



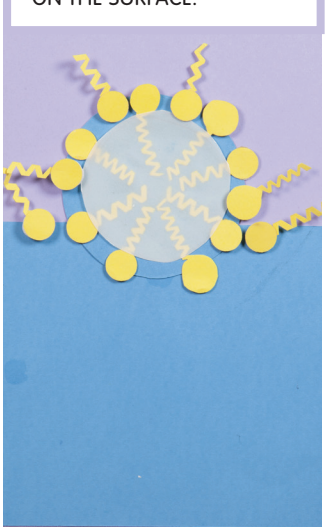
THE TAILS WILL THEN FORM SMALL SPHERES TO SHIELD THEMSELVES FROM WATER.



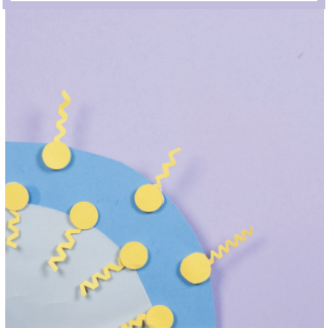
IF YOU BLOW ON THEM, THE AIR WILL PENETRATE THE SPHERES…



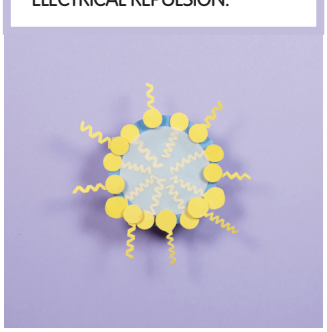
AND WILL PUSH THE MOLECULES BACK UP, WHICH WILL GRAB THOSE ON THE SURFACE.



BUBBLES ARE MADE BY THE AIR IN THE MIDDLE AND BY A LAYER OF WATER STUCK BETWEEN TWO LAYERS OF SURFACTANT.

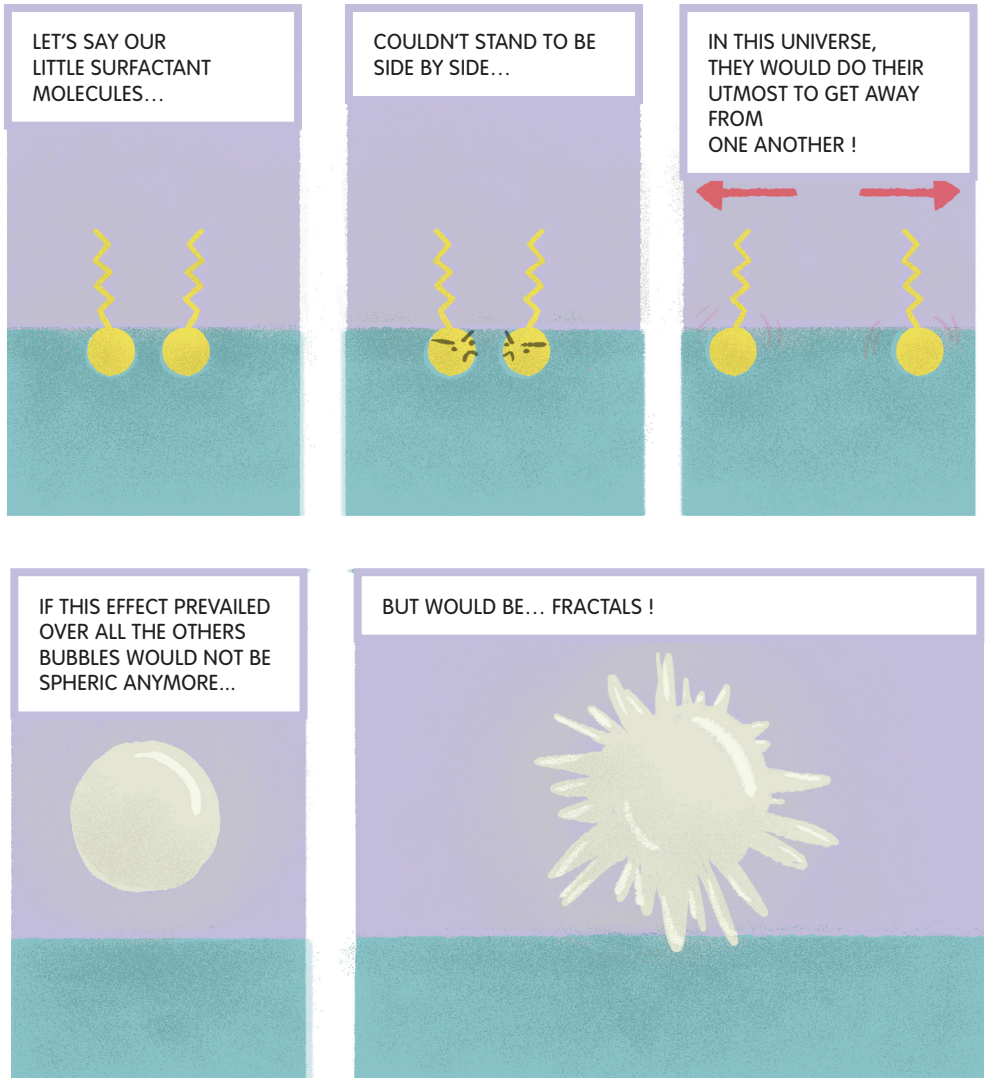


BUBBLES CAN RESIST BECAUSE THE SURFACTANT MOLECULES SEPARATED BY WATER REJECT ONE ANOTHER: THAT'S ELECTRICAL REPULSION.



THE FILM OF WATER ON A SMALL BUBBLE IS EXTREMELY THIN, A MERE FEW HUNDRED NANOMETRES.

BUT WHAT IF THE LAWS OF PHYSICS WORKED DIFFERENTLY?

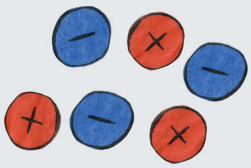


HYDROGEN BOND

This interaction causes hydrogen atoms to bond with other molecules. For instance: when you put two molecules of water close together, one of the positively charged hydrogen atoms of one molecule will bond with the negatively charged oxygen atom of the other molecule.

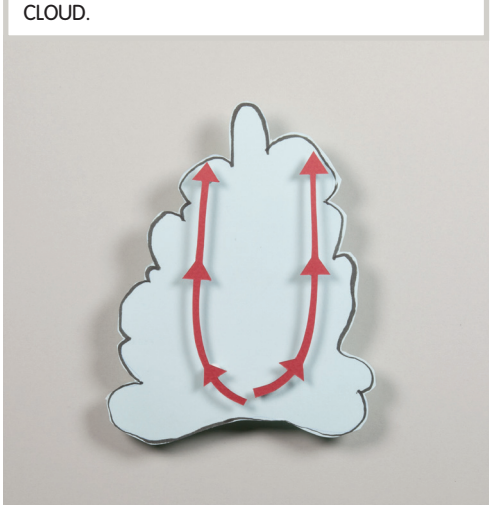
THUNDER

TO MAKE LIGHTNING HAPPEN, WE NEED :

A CUMULONIMBUS	ICE AND DUST PARTICLES	ELECTRIC CHARGES
		

CUMULONIMBUSES ARE MADE OF ICE AND DUST PARTICLES.

BECAUSE OF DIFFERENCES IN TEMPERATURE, THE AIR CURRENTS TRAVEL UPWARDS THROUGH THE CLOUD.



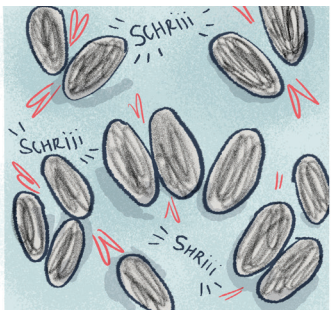
THESE CURRENTS CAUSE THE PARTICLES TO RUB AGAINST ONE ANOTHER.

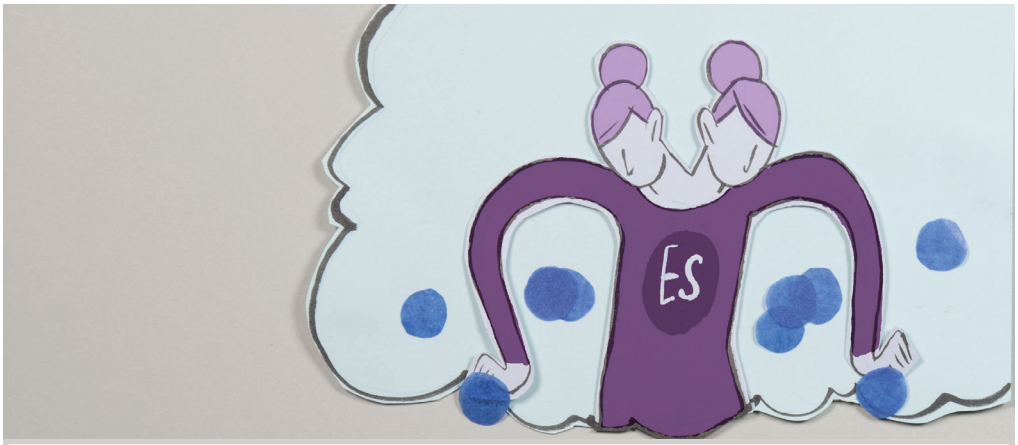
THIS FRICTION WILL ENABLE A TRANSFER OF ELECTRONS BETWEEN THOSE PARTICLES.

BECAUSE OF THAT, THE PARTICLES WILL BECOME CHARGED, EITHER POSITIVELY OR NEGATIVELY.

ELECTRIC CHARGES WILL BEGIN TO ACCUMULATE IN ONE PART OF THE CLOUD...

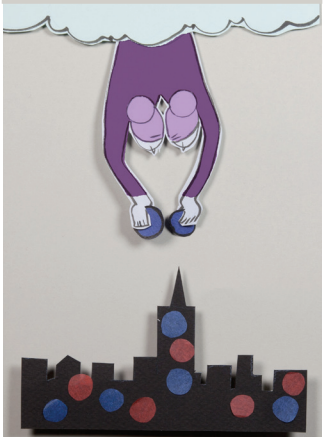
CAUSING DISCHARGES TO FORM INSIDE.

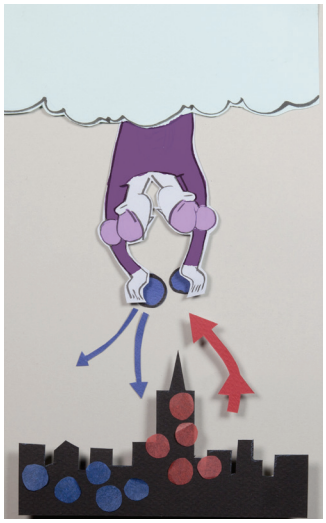




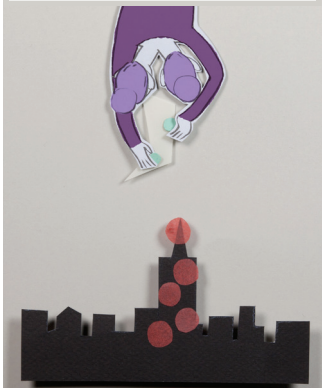
ELECTROSTATIC INTERACTION, NOW PRENSENT IN THE CLOUD, WILL AFFECT THE NEGATIVE CHARGES.

MAKING THEM ATTRACT THE POSITIVE CHARGES.

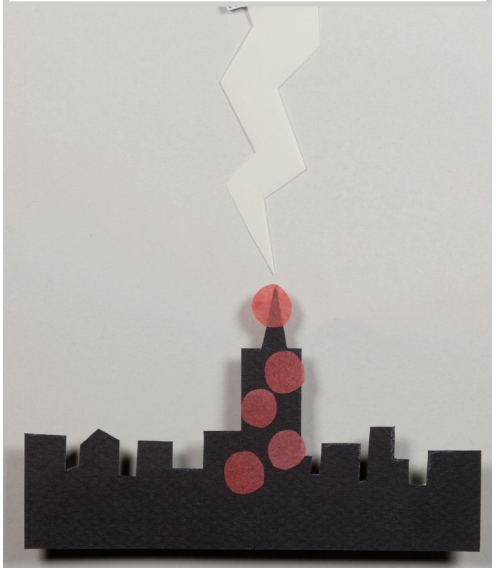


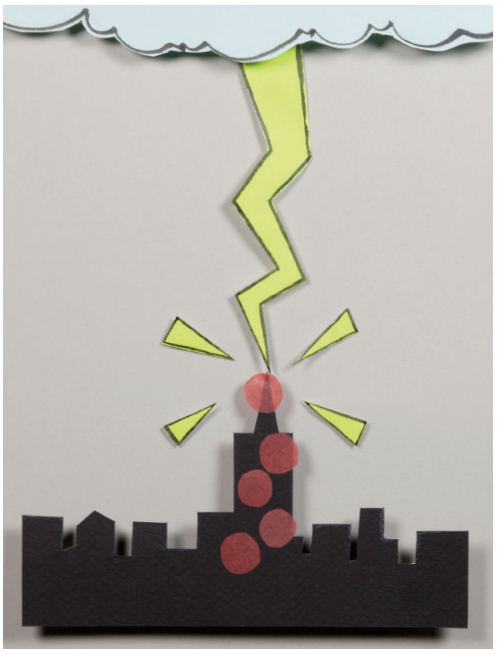


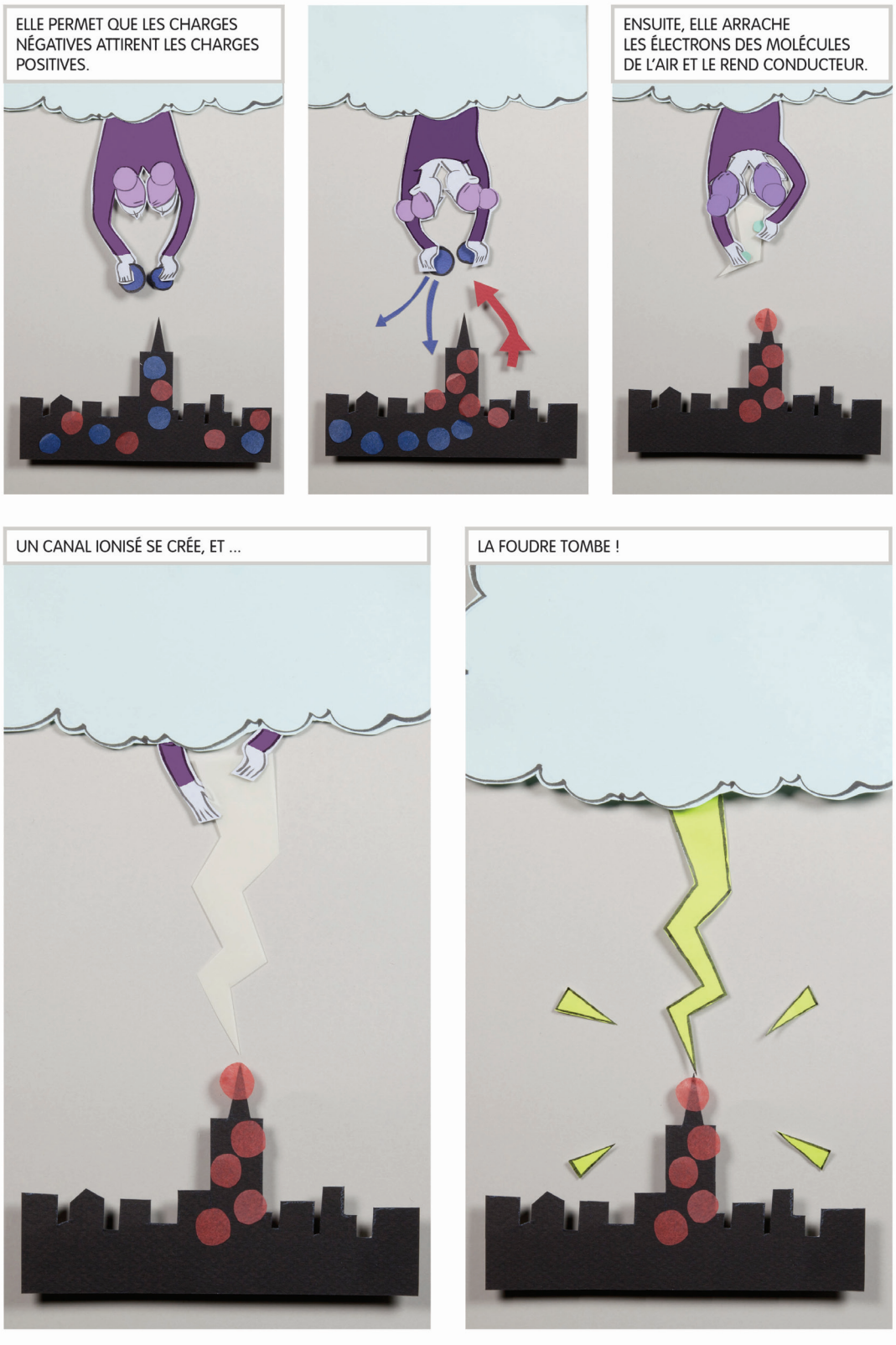
THEN, IT WILL REMOVE ALL THE ELECTRONS FROM THE MOLECULES OF AIR TO MAKE IT CONDUCTIVE.



A CHANNEL OF IONIZED AIR HAS NOW FORMED AND…

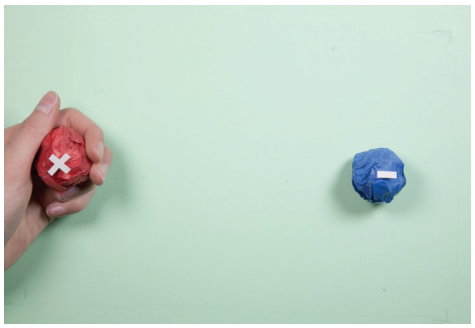





ELLE PERMET QUE LES CHARGES NÉGATIVES ATTIRENT LES CHARGES POSITIVES.
ENSUITE, ELLE ARRACHE LES ÉLECTRONS DES MOLÉCULES DE L'AIR ET LE REND CONDUCTEUR.
UN CANAL IONISÉ SE CRÉE, ET ...
LA FOUDRE TOMBE !


SI ÇA VOUS INTÉRESSE, JE PEUX VOUS EXPLIQUER LA FOUDRE.
C'EST SUPER INTÉRESSANT !

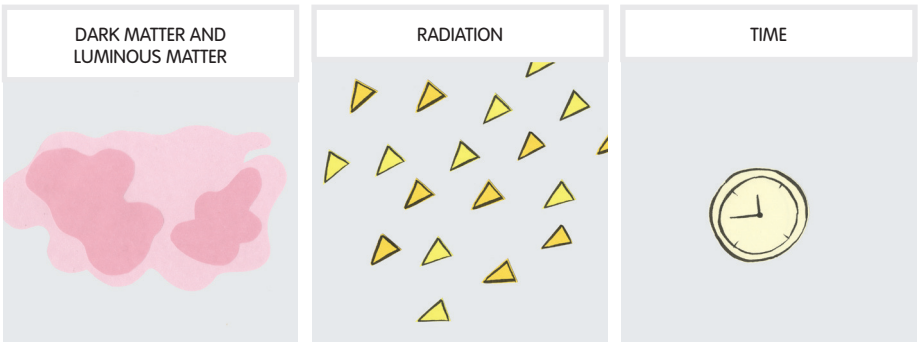
ELECTROSTATIC INTERACTION



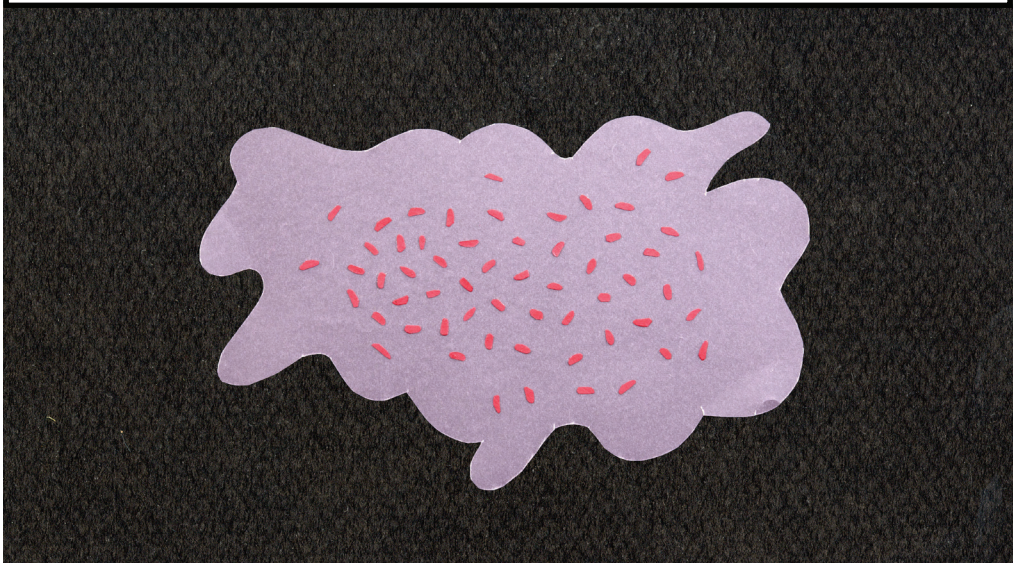
This interaction is due to the fact that an electric charge is surrounded by an invisible electric field. This field attracts all other charges with an opposite sign, but pushes back same-sign charges. We get:
+ attracts -
+ pushes back +
- pushes back -
The closer the charges are, the stronger the interaction.

GALAXY

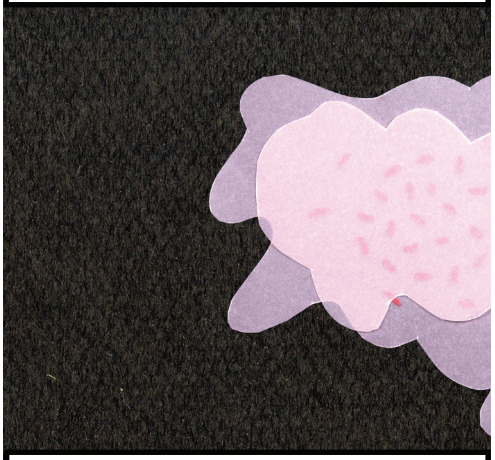
TO MAKE A SPIRAL GALAXY, WE NEED :



IT ALL BEGAN A FEW 13.8 BILLION YEARS AGO, IN THE PRIMORDIAL GAS OF THE UNIVERSE.
THIS GAS CONTAINED LUMPS, THEREFORE IT WAS NOT HOMOGENEOUS.



GAS IS THE STATE MATTER TAKES ON.



IT IS MADE UP OF ORDINARY **LUMINOUS MATTER**, AKIN TO THAT OF WHICH WE ARE MADE.

AND OF UNOBSERVABLE **DARK MATTER**, HYPOTHESIZED BY SCIENTISTS.

GAS GRAVITY IS THE DOMINANT INTERACTION HERE.

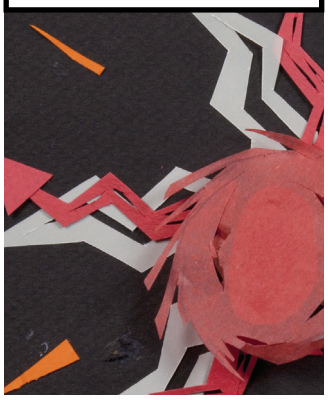
GRAVITY IS A BIT STRONGER IN THE LUMPS BECAUSE THEY ARE DENSER.

BECAUSE THEIR GRAVITY IS STRONGER

THE LUMPS WILL ATTRACT NEIGHBOURING MATTER

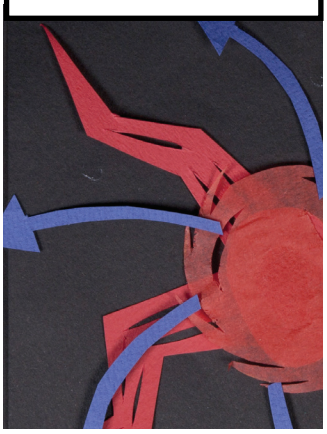
THEREFORE GAINING MORE AND MORE DENSITY.

ACCELERATING THE PROCESS OF COLLAPSE

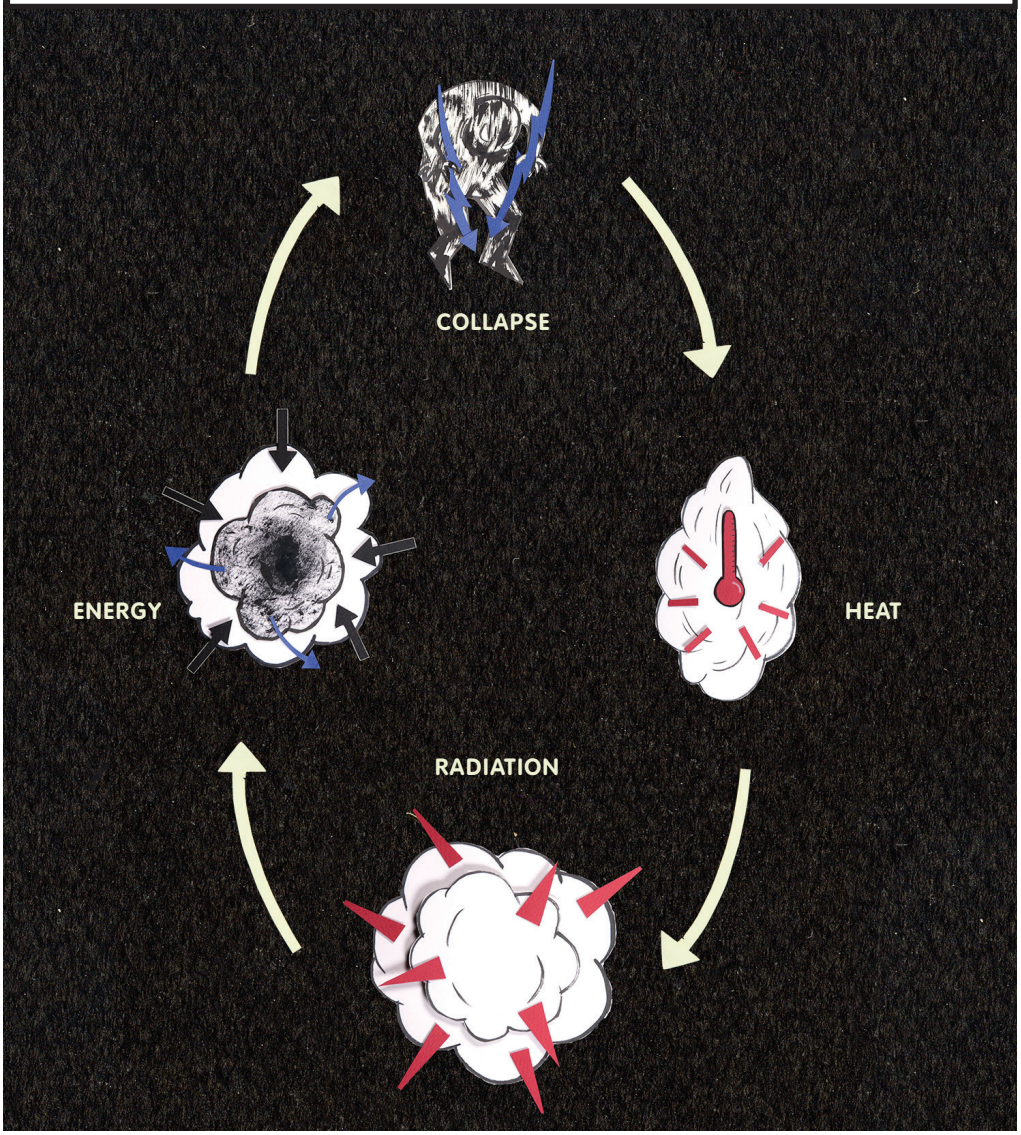


WHICH IN TURN HEATS UP THE GAS

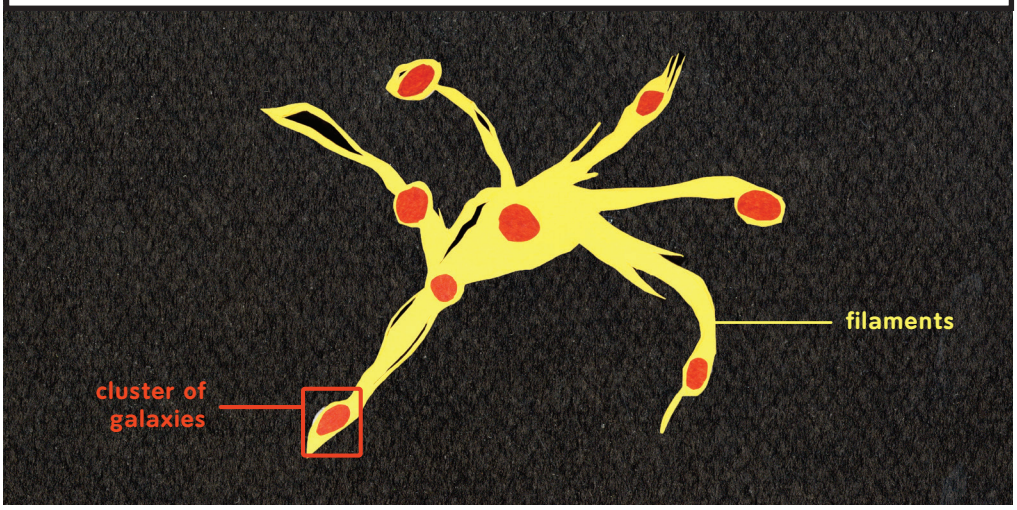
WHICH WILL RADIATE ENERGY.



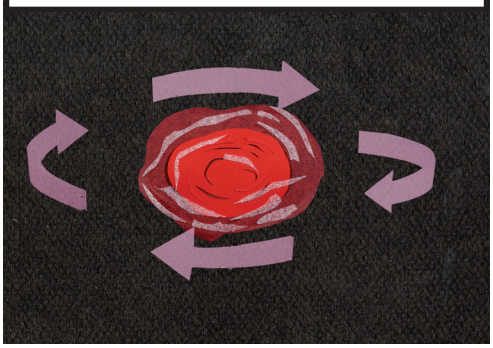
WHEN A GAS COLLAPSES, IT GETS HOTTER. WHEN IT GETS HOTTER, IT RADIATES. WHEN IT RADIATES, IT LOSES ENERGY. WHEN IT LOSES ENERGY, IT COLLAPSES…



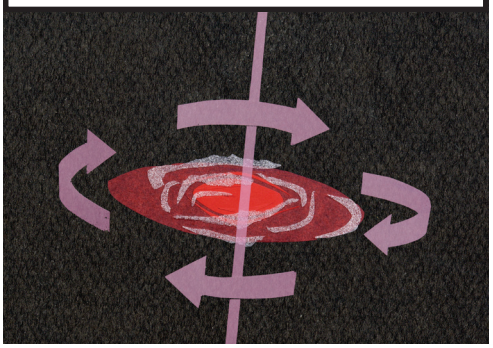
THE IMPRINT LEFT BY THE COLLAPSE CREATES FILAMENTS, AND SO EACH LUMP IS AT THE ORIGIN OF WHAT IS NOW A CLUSTER OF GALAXIES.



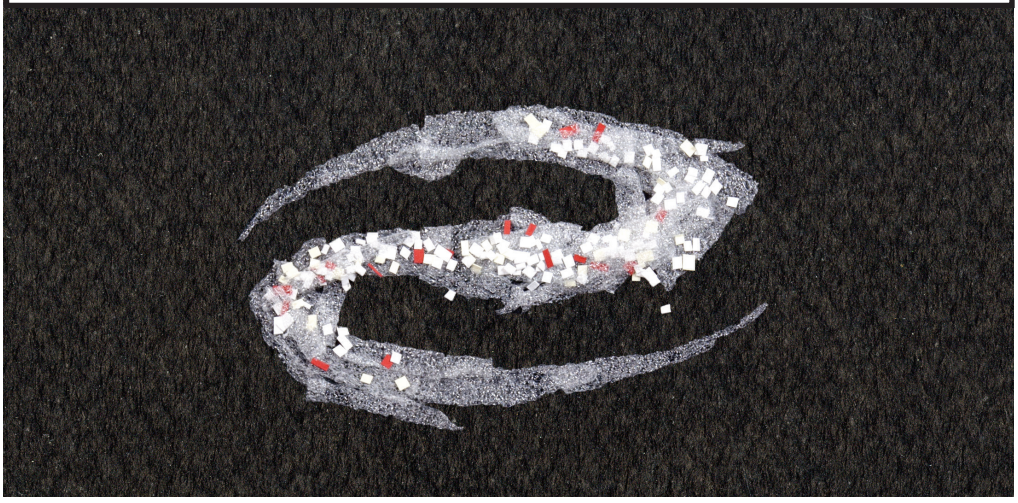
ROTATING GALAXIES ARE SUBJECTED TO THE CENTRIFUGAL FORCE

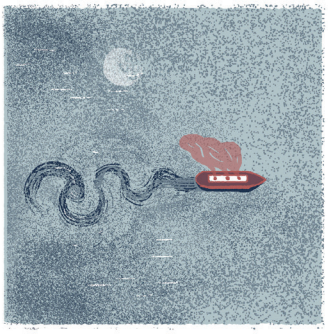


WHICH WILL FLATTEN THEM DOWN TO A THIN DISK.



THIS IS HOW, STEP BY STEP, SPIRAL GALAXIES ARE FORMED !





GRAVITY

Gravity is one of the four fundamental forces. It causes massive objects to attract each other under the effect of their mass. The more massive the object is, the stronger the force. It was first described by Newton, then by Einstein within the general relativity theory, but Newton's theory is more than enough if the objects' speed is not too high, which is often the case.

STAR

TO MAKE A STAR, WE NEED :

AN INTERSTELLAR CLOUD	TIME
	

A FEW MILLIONS YEARS AGO, IN A GIANT INTERSTELLAR CLOUD…

THE CLOUD MAINLY CONTAINS DIHYDROGEN AND MORE THAN 140 OTHER MOLECULES.

IT IS COLD AND NOT VERY DENSE.

IT IS OPAQUE IN VISIBLE LIGHT…

… BUT TRANSPARENT IN INFRARED LIGHT.

IN THIS CLOUD, TWO INTERACTIONS FIGHT : GRAVITY ATTRACTS THE PARTICLES BUT GAS PRESSURE COUNTERACTS GRAVITY AND PUSHES THEM BACK.

THE FORCES ARE BALANCED OUT : GRAVITY COMPRESSES THE CLOUD AND PRESSURE DILATES IT.

STARS GIVE OFF RADIATION,
HEATING UP THE SURFACE OF THE CLOUD.

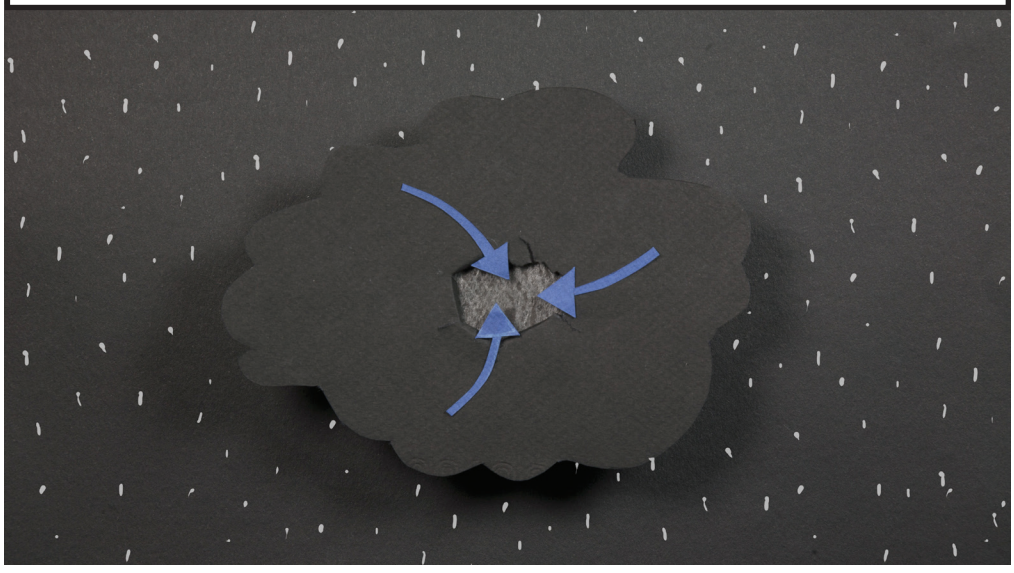
AND SO IT GETS COLDER AS YOU GET TO THE
HEART OF THE CLOUD.

IN THE COLDER AREAS…

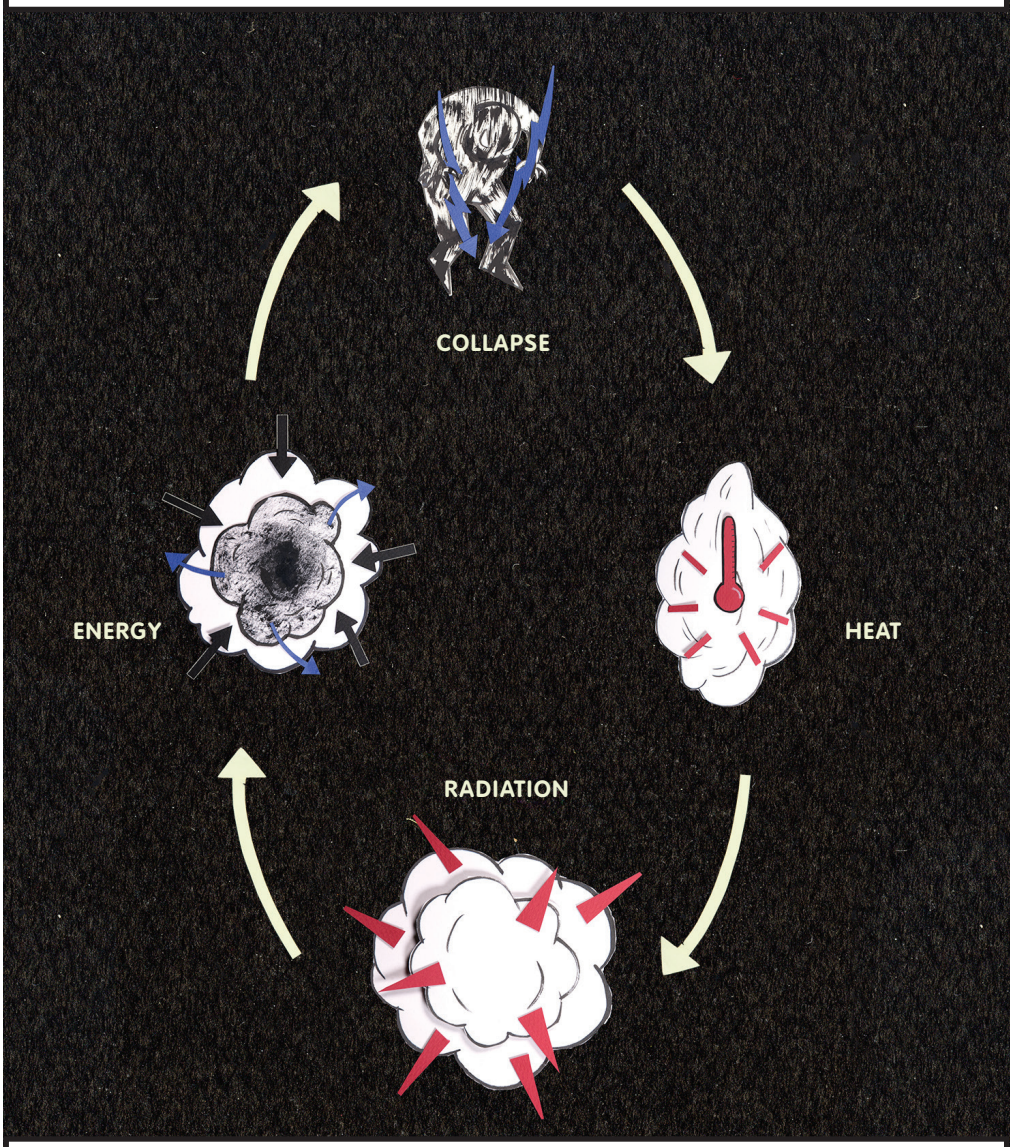
PRESSURE DECREASES…

SO THAT GRAVITY HAS THE
UPPER HAND.

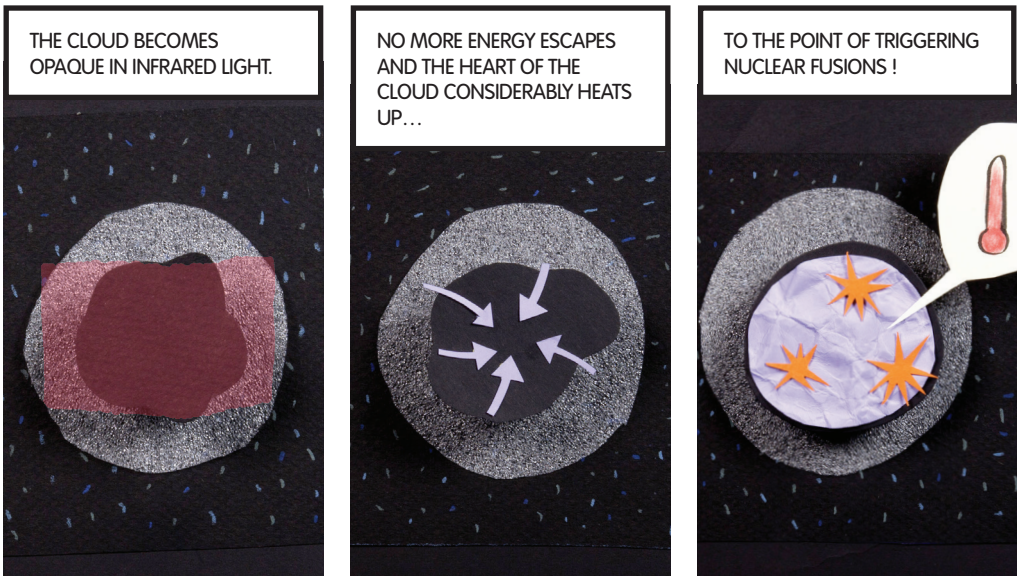
THE CENTRAL PARTS OF THE CLOUD COLLAPSE UNDER THEIR OWN GRAVITY.

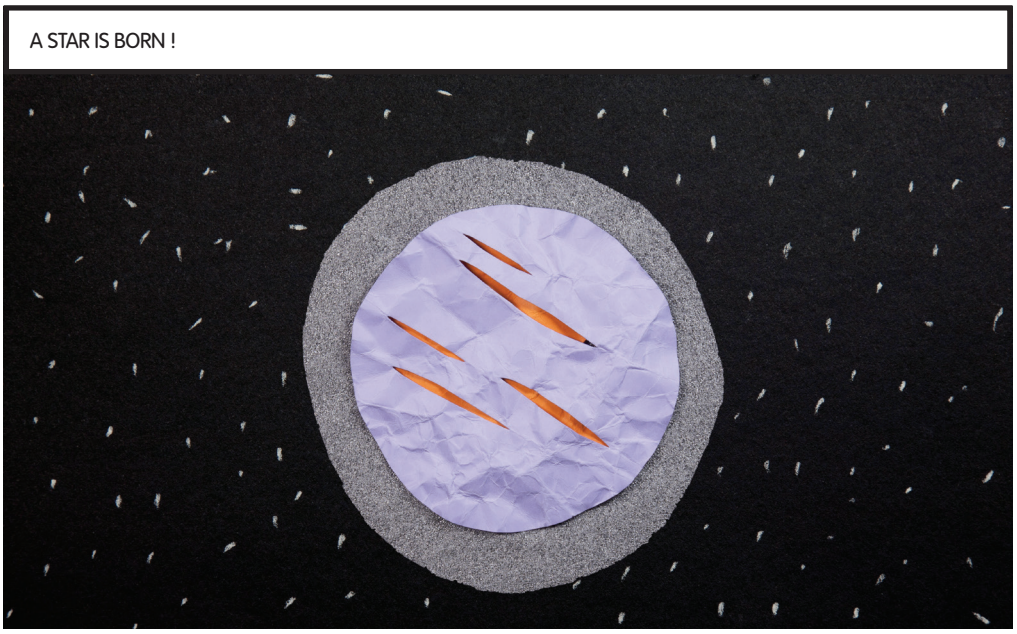


WHEN A GAS COLLAPSES, IT GETS HOTTER. WHEN IT GETS HOTTER, IT RADIATES. WHEN IT RADIATES, IT LOSES ENERGY. WHEN IT LOSES ENERGY, IT COLLAPSES…



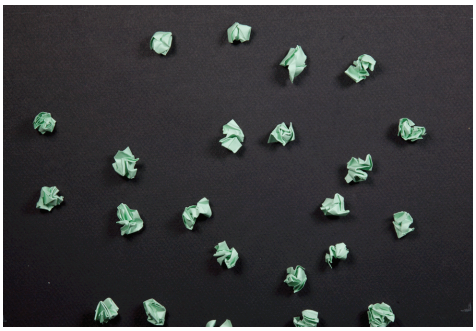
BUT! ONCE THIS CYCLE STOPS…


THE CLOUD BECOMES OPAQUE IN INFRARED LIGHT.
NO MORE ENERGY ESCAPES AND THE HEART OF THE CLOUD CONSIDERABLY HEATS UP…
TO THE POINT OF TRIGGERING NUCLEAR FUSIONS !


A STAR IS BORN !


YOU KNOW, YOU'RE SO BEAUTIFUL I COULD MAKE YOU A STAR !
OH STOP IT, WON'T YOU!

GAS PRESSURE



Pressure is a force exerted by a fluid or a solid on a given surface. Pressure in a gas is achieved by the never-ending collisions of the gas particles on the insides of a container. Atmospheric pressure is the consequence of the weight of the atmosphere, which is ten tons by square metre. .

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