A CARD GAME REVEALING THE SECRETS OF STARS

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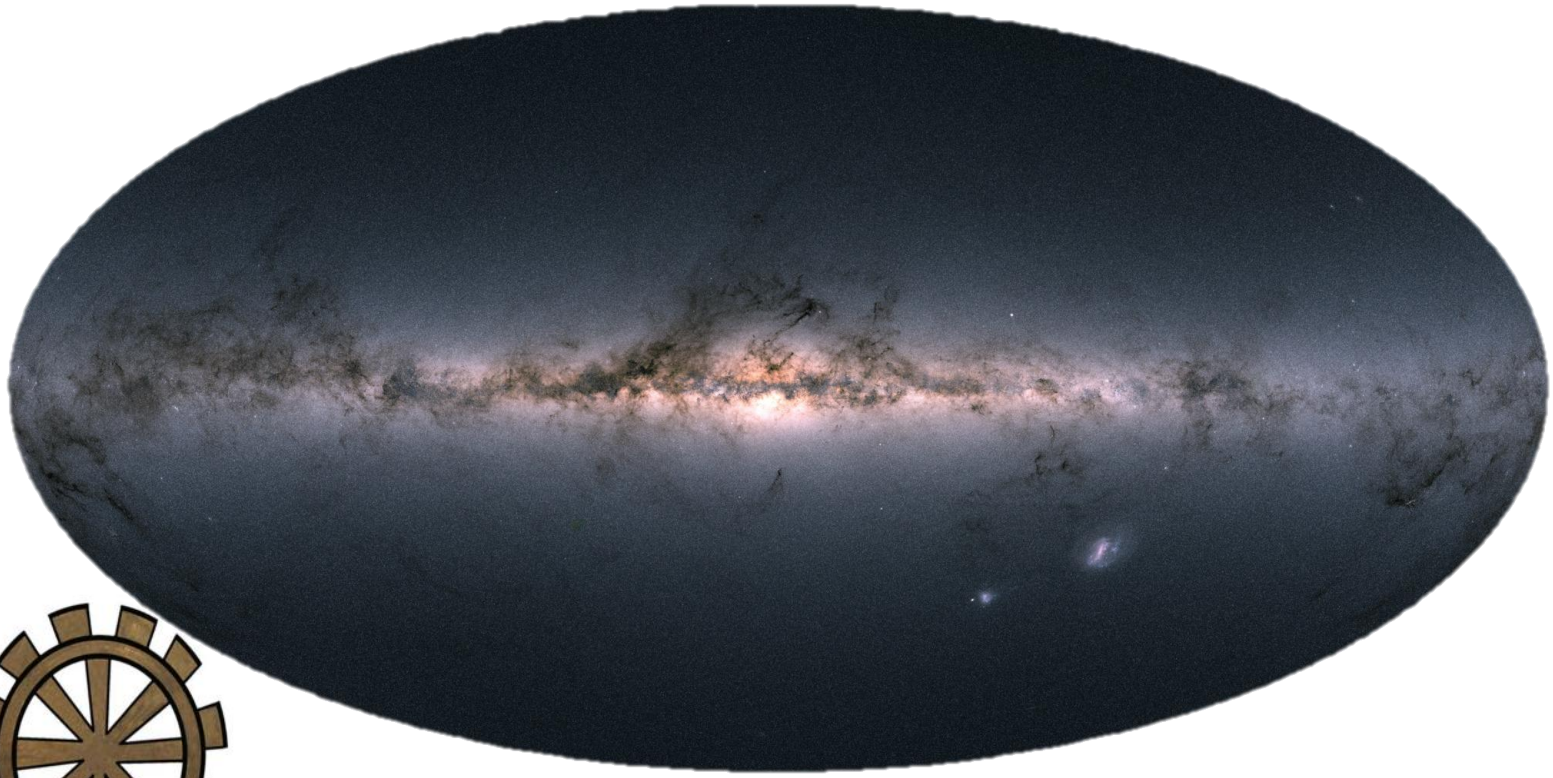
PLAY INAF

Stars shine on us at night making the night fascinating and romantic.
Our Sun is the source of life on Earth and possibly other suns are in other planets.
Stars shine for billions of years (millions at least) but how?



The stars in our Galaxy as seen by Gaia satellite –ESA-

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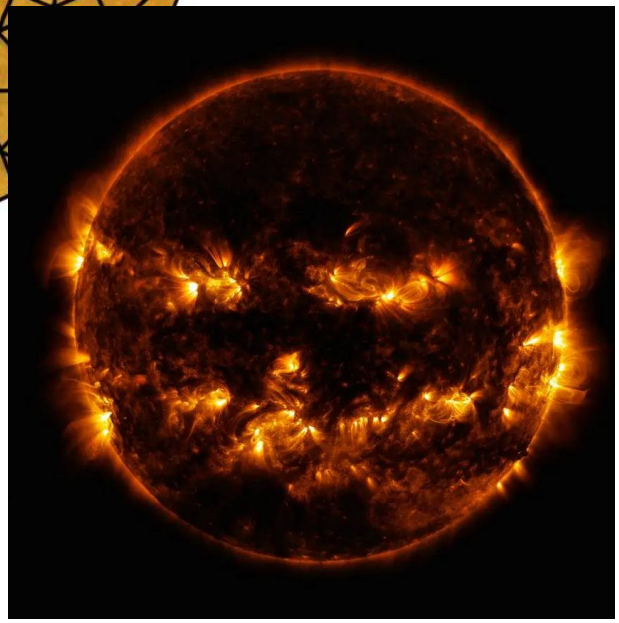
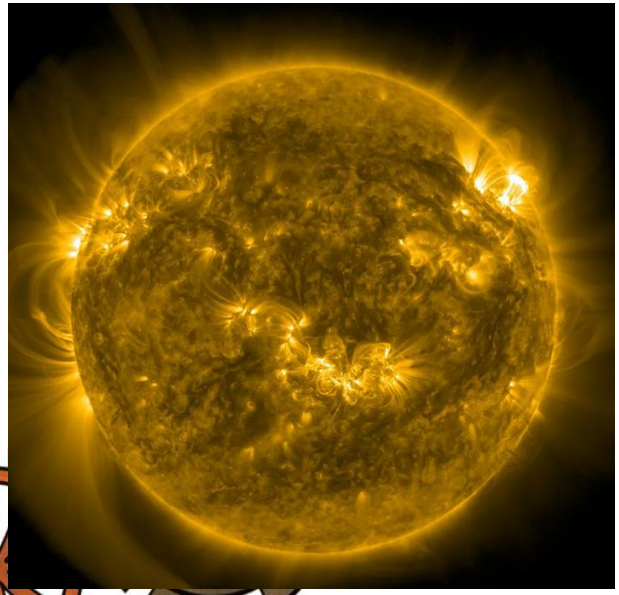


Our sun on October 8th 2014 – the Jack-o-Lantern Sun - Solar Dynamics Observatory -NASA



Our Sun on May 8th 2024 – The Northen Light all over Europe responsible - Solar Dynamics Observatory -NASA

Stars are giant spheres of hot dense gas.

The core of an Average Joe star reaches up 15 million degrees and very high densities (>100 gr/cm^3).

There, nuclear fusion reactions generate energy for billions of years.

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THE PROTON-PROTON CHAIN

The Big Bang created only Hydrogen and Helium.

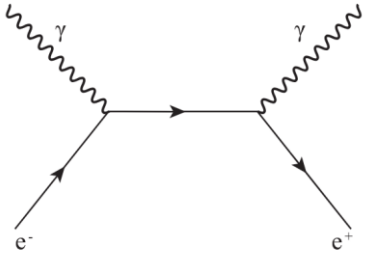
Everything else, us included, is created in the stars.

The proton-proton chain is what sustains stars from their birth for the majority of their life.

$$^{1}\mathrm{H} + {}^{1}\mathrm{H} \rightarrow {}^{2}\mathrm{H} + \mathrm{e}^{+} + \nu$$

$$^{2}\mathrm{H} + {}^{1}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \gamma$$

$$^{3}\mathrm{He} + {}^{3}\mathrm{He} \rightarrow {}^{4}\mathrm{He} + {}^{1}\mathrm{H} + {}^{1}\mathrm{H} + \gamma$$



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How do you explain complex nuclear reactions
to middle and high school students...

even to have two simple protons to come close enough
involves quantum mechanics...

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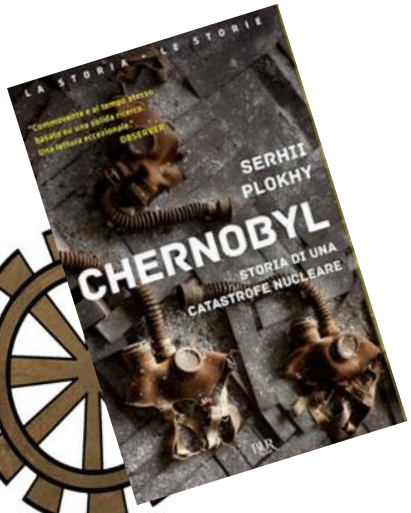
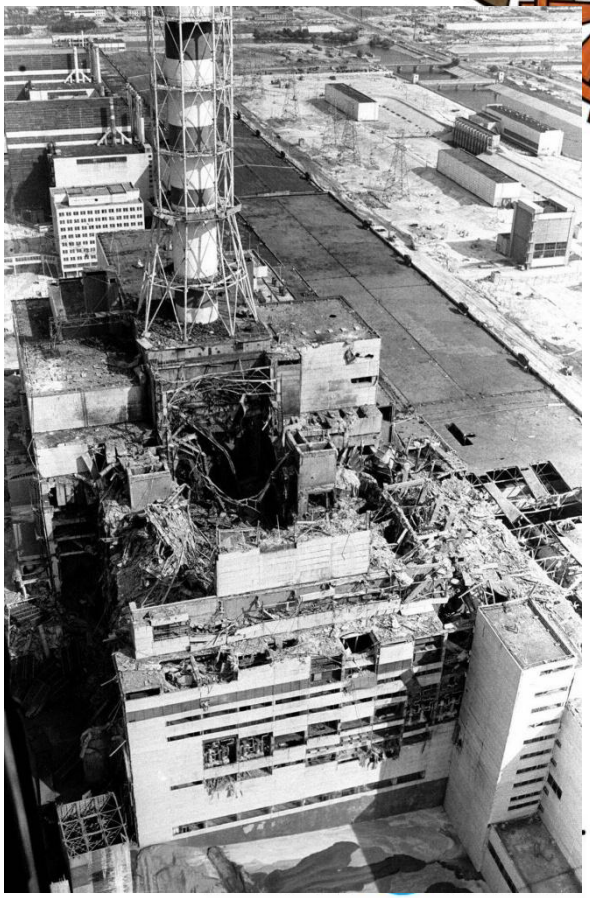
The inspiration came from far away, always nuclear reactions, but the ones at reactor number 4 at Chernobyl.

We got inspired by how the specialists involved in the emergency and following inquest managed to explain what happened that night.





~~Extre[illegible]vironment.~~

~~Nucle[illegible]hysics.~~

Universal rule of the Universe (assuming it is an isolated system): nothing disappears.

What you have before a reaction, should be there in some form after it.

In physics any fundamental particle can be described as both an entity and a wave, we introduce a third way: a colored ball with a property!

NOW DOING NUCLEAR REACTIONS BECOMES JUST A MATTER OF LOGIC AND DEDUCTION.

CAN YOU DO IT WITH CARDS?

AND THIS IS WHERE IT ALL STARTED...

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THE GAME

Board with the reactions.
Only the right hand side is known.

X+X=Deuterium+Positron+Neutrino
L1+L2=Energy
X+Y=Helium 3 + Energy
Z+Z=Helium 4 + Proton + Proton + Energy

Deck of fundamental cards: protons, electrons and neutrons,
The players have to understand who the unknowns are (hints on the cards).

Once understood, keep drawing cards until a reaction can be completed.
Collect the products.
Use products and drawn cards to do other reactions, in a chain, till Helium 4 is produced.

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THE DESIGN

All the designs are done by hand!

- Artistical open issues with AI composed images.
- The new generations were born in a CGI dominated epoch and are completely drowned in this perfect, eye-pleasing world...which does not have a thinking mind...and neither emotional soul..

We wanted something real, dirty and unperfect,
something HUMAN

+curiosity stimulated

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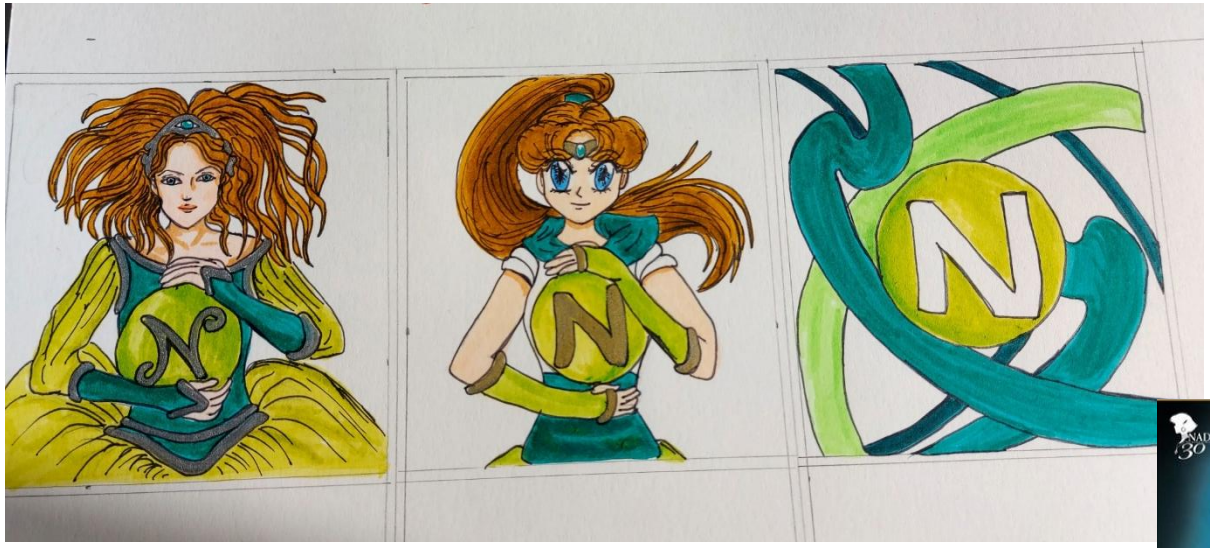
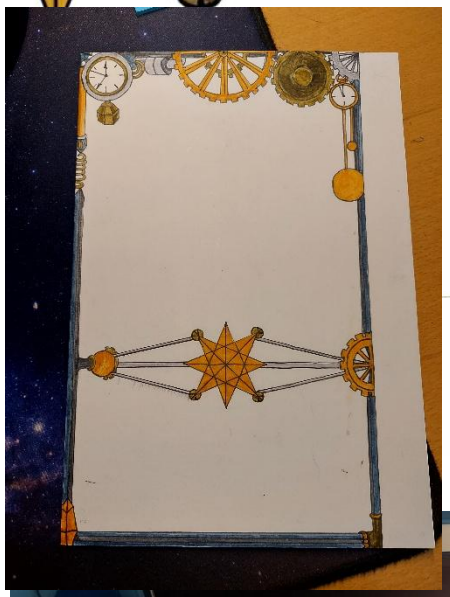
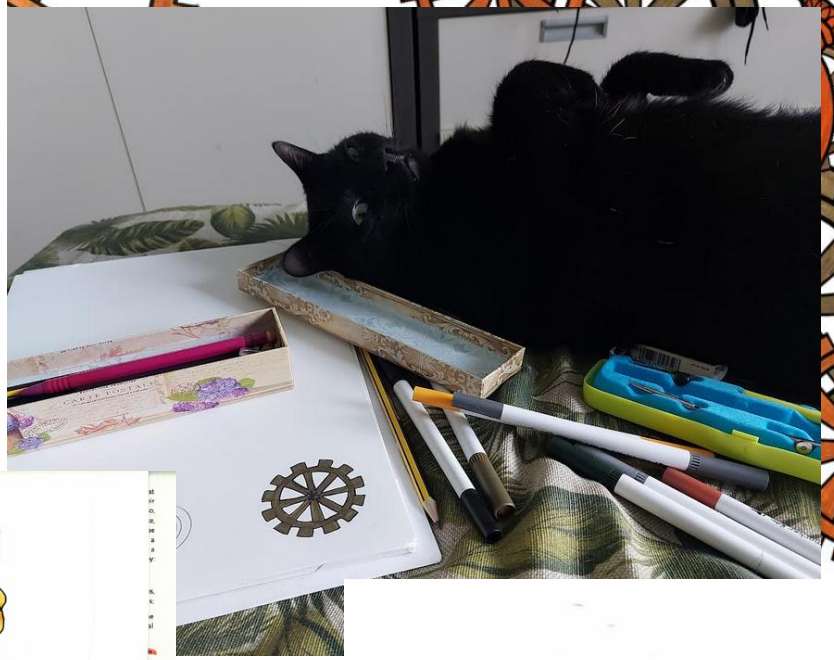
So, I put on my designer hat, ask the clients which style they prefer.

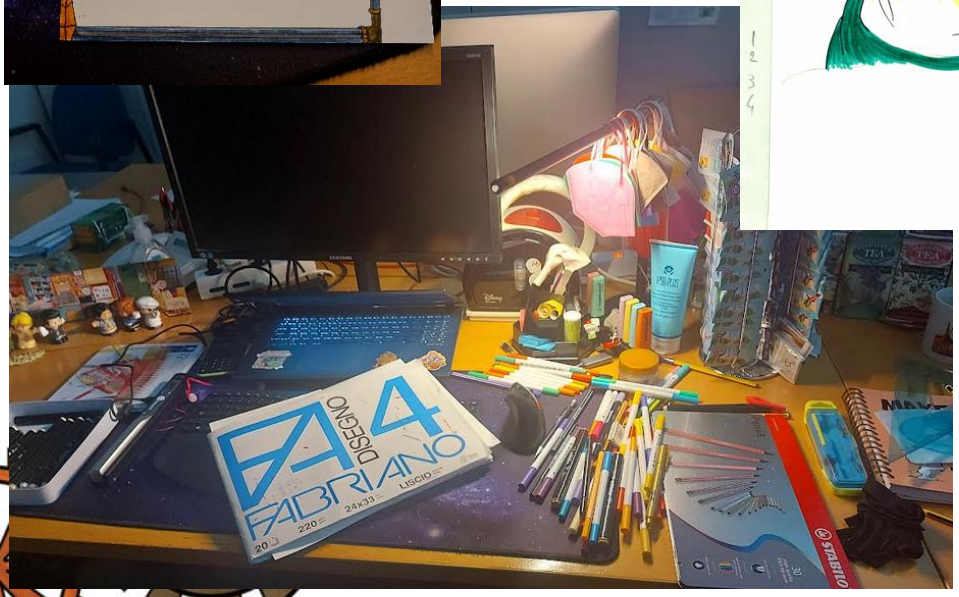


The choice fell on manga style «THE SECRET OF BLUE WATER» – Hideaki Anno, Hayao Miyazaki– was the design inspiration.

That is how an educational experience became full steam punk crazy .






A4
DISEGNO
FABRIANO

LIGHT UP YOUR STAR

Draw 5 FUNDAMENTAL cards and start making nuclear fusion reactions by identifying the unknowns in yellow on the left side!
ATTENTION: ONE FUNDAMENTAL PARTICLE LIKES TO CHANGE TO MAKE AN ATOM!
Everytime you complete one side on the left of the equations collect the PRODUCT cards on the right hand side and use them to make other reactions, drawing also from the FUNDAMENTAL card deck until you have what you need for a reaction. Accumulate the energy card on the star and drop the "INTRUDER" when you draw it. The game ends when you are left with only He4 and 2 protons in hand.

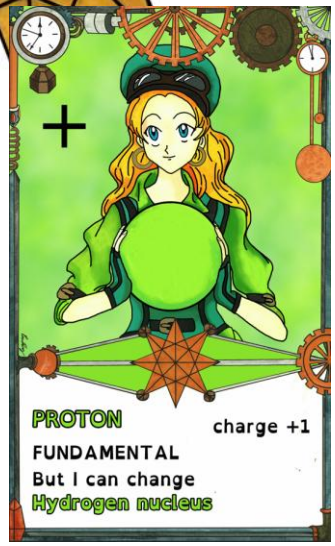
X + X = D (deuterium) + L2 (positron) + Nu (neutrino)

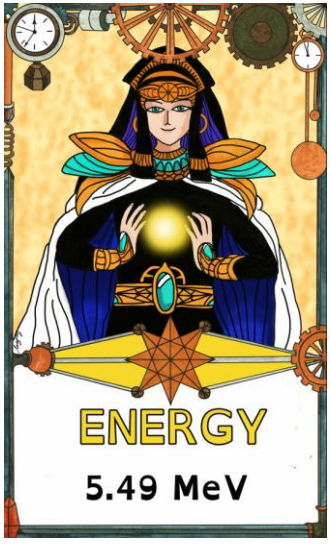
L1 + L2 = E (1.02 MeV)

X + Y = He3 (Helium 3) + E (5.49 MeV)

Z + Z = He4 (Helium) + P (proton) + P (proton) + E (12.96 MeV)

OUR CARDS





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X + X = 

+ 

+ Nu neutrino

Neutrino leaves the reaction site immediately.
The missing card stimulates curiosity

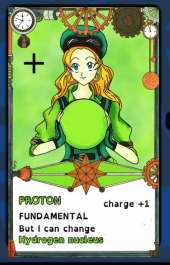
L1 + L2 = 

X + Y = 

+ 

Z + Z = 

+ 

+ 

+ 

We start by drawing 5 cards from the fundamental deck

There is a trick

Deuterium is done by 1 proton and 1 neutron...it looks easy...
But two protons create the Deuterium!

The neutron is only an intruder!
He never enters the reactions.

PLAY INAF

LIGHT UP YOUR STAR

Draw 5 FUNDAMENTAL cards and start making nuclear fusion reactions by identifying the unknowns
ATTENTION: ONE FUNDAMENTAL PARTICLE LIKES TO CHANGE TO MAKE AN A
Everytime you complete one side on the left of the equations collect the PRODUCT cards on the right hand
reactions, drawing also from the FUNDAMENTAL card deck until you have what you need for a reaction. A
star and drop the "INTRUDER" when you draw it. The game ends when you are left with only He

+

= D deuterium + L2 positron + Nu neutrino

+

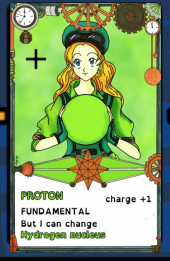
= E 1.02 MeV

+

= He3 Helium 3 + E 5.49 MeV

+

= He4 Helium +



+

+ E 12.96 Me

BECOMING A STAR

The products of the reactions are the reactants of the others, it is a chain.

As in the star's core, the reactions can take place randomly, all together or one by one. It all depends on the cards we have at hand.

Drawing the cards from the deck represents the randomness of the physical processes in the stars. You have to wait for the right particles to meet.

Sometimes you can draw 4 neutrons in a row, when all you need is a proton.

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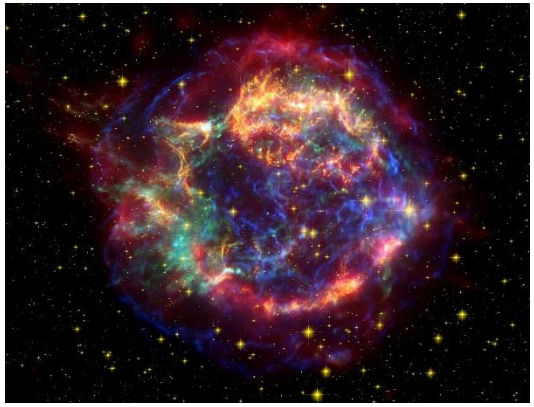
The game is made of 4 chain cycles.

The game ends when the players are left with only 4 Helium 4 and 2 product-protons.

This makes the players understand what happens in the stars, once the hydrogen is over in the center they are left with a core of helium.

This stage is the beginning of the final part of the life of a star.

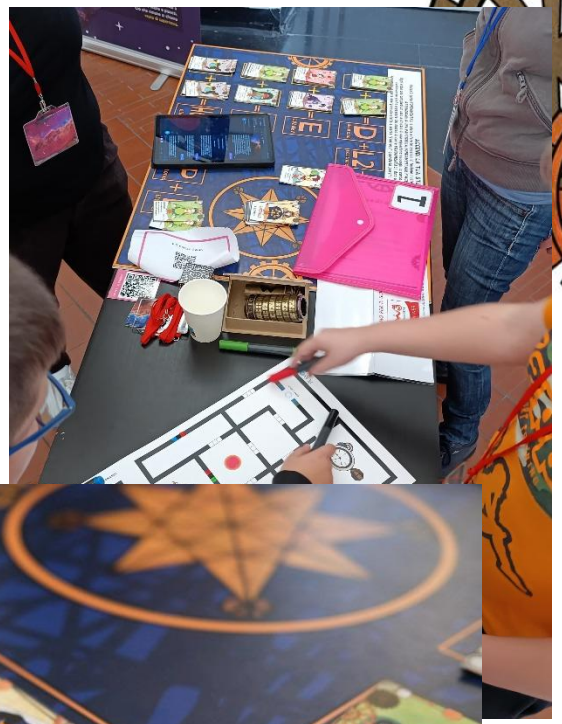
Planetary nebula –JWST-NASA



Supernova remnant - NASA/JPL-Caltech

Stellar black hole merging – SXS project

«Light up your star» has been presented at the 2024 Science Festival in Genova as one of the challenges of the Astro-Tamagotchi –see L. Leonardi talk-



Astro-Tamagotchi is now back in the «Macchine Del Tempo» Exibition in Turin.

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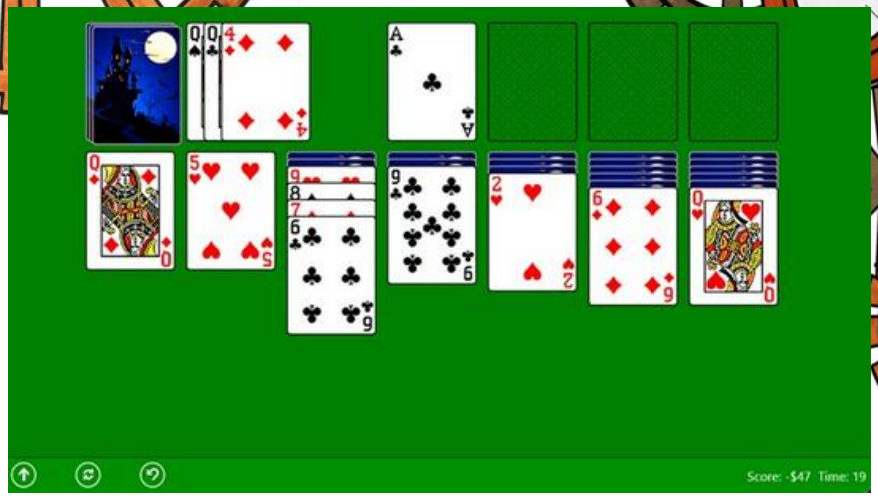
THE ASTRO-KLONDIKE!!

If you were born before the 90s you spent a significative time of your life playing this while waiting for a 11kbps connection to download a single 100kb picture



Why not learning something about the interiors of stars while doing it???

Our game is prone to be adapted to a solitaire type of game.

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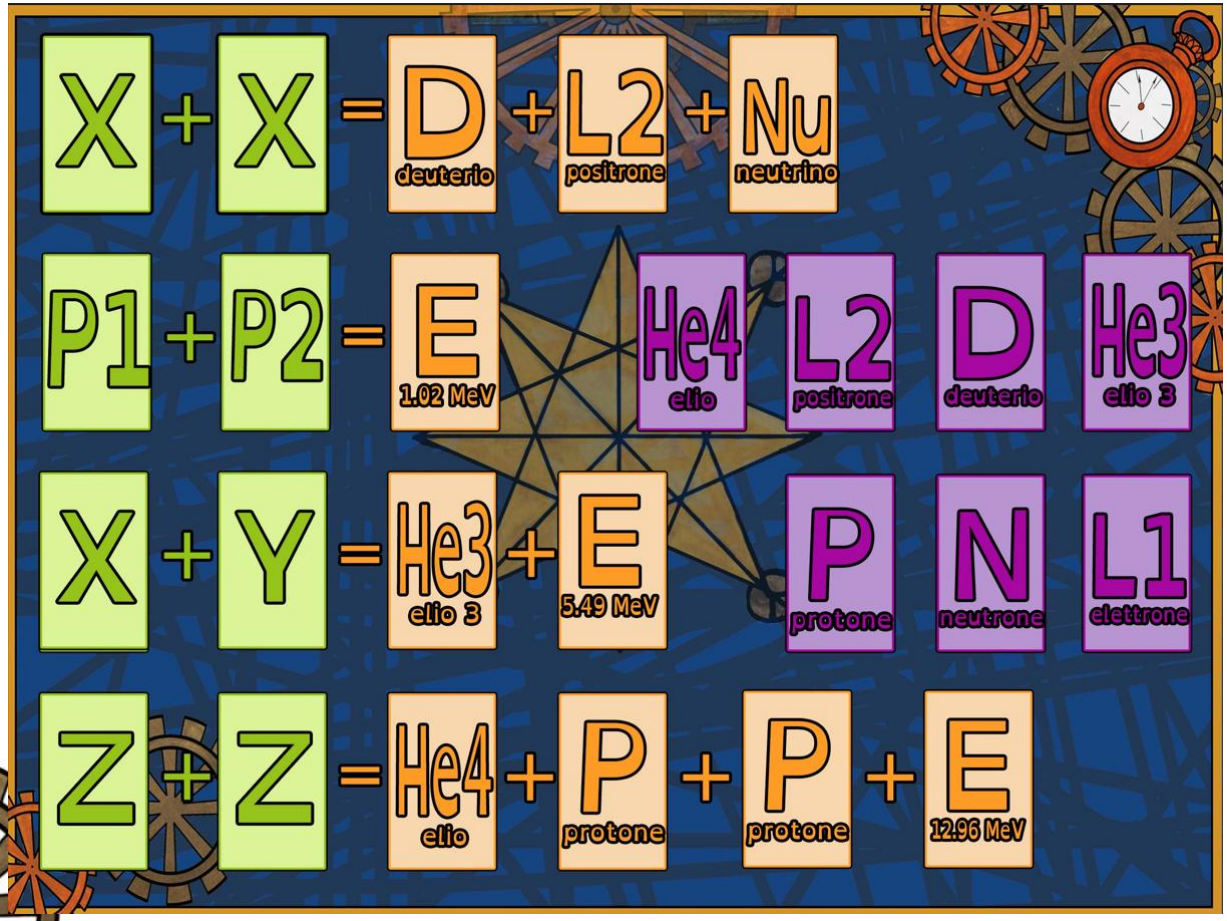
The online game is being developed in scratch, a high-level, block-based visual programming language developed by the MIT Media Lab.
Same rules, different design.



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NEUTRINO CARD!
We can simply make it fly away from the board as neutrinos do from the core of the stars.

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LEVELS!

Include other nuclear fusion reactions which also take place in the stars especially in the later stages of their life, creating the good part of the elements we know.

We are starting now from the CNO cycle

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We developed a card game that uses a pure logic and deduction environment to make nuclear fusion reactions in the core of the stars understandable.

The unique graphical design helps in memorizing the actors at play and arouse the curiosity.

Once the players understand how the reactions work, they become the interior of the star!

Waiting for the right particles to meet in their hands for pure chance, do the reaction, take the products, and wait again for a lucky draw, do a new reaction and so on, until they have fully understood how a complex physics phenomenon works, just playing with cards.

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