Speaker Notes for: A presentation prepared by SG for the IVOA-exec presented on 15th December (slightly updated).

Slide Number: 1

- Thank you Francesca and Bruce for the invitation, good morning, evening or night wherever you may be and thank you also for your time.

- Today I will be talking about blockchain (cryptographic) technology and its use as an interoperability driver or catalyst for the Open Development of Astronomy and Astrophysics

Blockchain for Open Development in Astronomy

(A straw-person Peer-to-Peer Electronic Cash System base-layer model for the Open Development of Astronomy: Education and Research)

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- I'll show evidence that blockchain technology is a technology worth exploring as a catalyst or interoperability driver for the Open Development of Astronomy.

- I will show that most of the developments come from academic studies and that this could be a technology improvement of The Computer and computing systems.

Outline

- Introduction: Use of blockchain technology to overcome development barriers
    - Data-Science: AI and blockchain may both be necessary.
- Cryptographic blockchain primitives and key ideas derive from academia.
- Astronomy Open Development Use-case and Metrics
- Conclusions and Recommendations for Astronomy Open Development
- Bibliography

Slide Number: 3

The First Analogue Computer

- This figure is taken from Freeth et al. 2020
- It shows a model of perhaps the first analogue computer mechanism that is the size of a shoe-box: The Antikythera Mechanism or Antikythera Computer was found from a shipwreck identified by sponge divers in 1901 that has been dated to have occurred around 2000 years earlier, developed by Ancient Greek astronomers (with know-how coming probably from Archimedes and Hipparchus.)
- After the so-called 'Decline of ancient Greece' this mechanism was 'lost' to humanity. Only in the 14 century were comparable complex machinery developed within astronomical clocks.
- This computer was made to solve mostly astronomical problems but was also used for Navigation, Agriculture and spiritual/cultural reckonings.

Intro: The Computer - Origin (and Evolution) Antikythera Mechanism (AI & blockchain)

Figure: Model of perhaps first analogue Computer Mechanism, developed by Astronomers from Freeth et al. 2021

Slide Number: 4 (Barriers to Astronomy Development)

- Some observations of barriers to Astronomy Development that could be mitigated with blockchain technology are explored.

- The figure is reproduced from the reference. It shows the half-life function for US PhD astronomy majors that is currently less than about 3 years. That is to say: on completing a PhD at US public universities, roughly 50% of PhD's in astronomy will no longer publish Astronomy papers after 3 years. It reflects the so-called 'brain-drain' hemorrhage that is inflicted upon the astronomical community, partly due to a reliance on the status-quo funding mechanism.

- In the 70's the half-life rate was roughly 30 years, and despite an increase in the proportion of secondary to main author publications, as found in the cited study, today it is about one decade lower.

- There is also the issue of other crisis points related to the centralized nature of funding decisions in Astronomy Development, like budget freezes, government shutdowns, etc.

Introduction (Barriers to Open Development)

Crisis points

- Half-life function drop or Human brain drain in Astronomy Development
- Centralized funding and operating decisions
- Ministry of Science was downgraded to Secretary - Macri government 2018
- Government Shutdowns eg: Obama and Trump Science Shutdowns

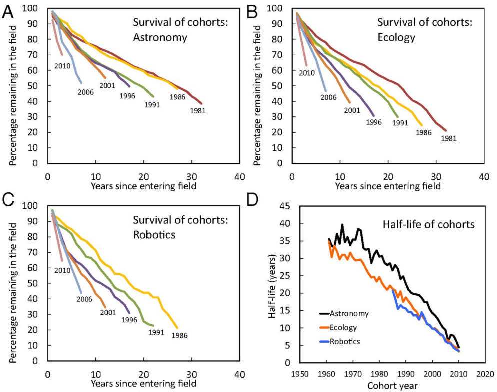


Figure: Half-life function
Milojević, Radicchi, and Walsh, 2019

Slide Number: 5 (Intro. Cont., Barrier to Astro. Dev.)
Self Explanatory, see "testimonies" hyper-link

Introduction Cont. (Barriers)

US government shutdown: testimonies depicting barrier to Astronomy Development. Bryan Wang's testimony follows:

My name is Bryan Wang, and I am a high school junior who was inducted into Sigma Xi in 2018 after winning the Student Poster Competition. This is my story concerning the government shutdown.

Science is central to my life: both my parents pursued it, it's always been my favorite subject, and I know I want to pursue a career related to science. Last summer I interned at the University of California Santa Cruz Astrophysics Department under professor Joel Primack and graduate student Clayton Strawn. Not only was the project that I worked on reliant on the use of the Department of Energy's National Energy Research Scientific Computer Center supercomputers, but the summer research program for high schoolers which I was doing was partly funded by the National Science Foundation. When I presented my work at the 233rd American Astronomical Society meeting in Seattle in January 2019, I was extremely disheartened to find that multiple meetings I had looked forward to, including those hosted by NASA, were canceled.

Slide Number: 6 (Intro: barriers to OD, taken from Report by Fernando D. Stefani)

- This data shows the R & D investment expressed as a % GDP (vert. axis) vs Time [yr] (horizontal axis) for different nation states.

Intro: barriers to OD by Fernando D. Stefani, Aug 2018

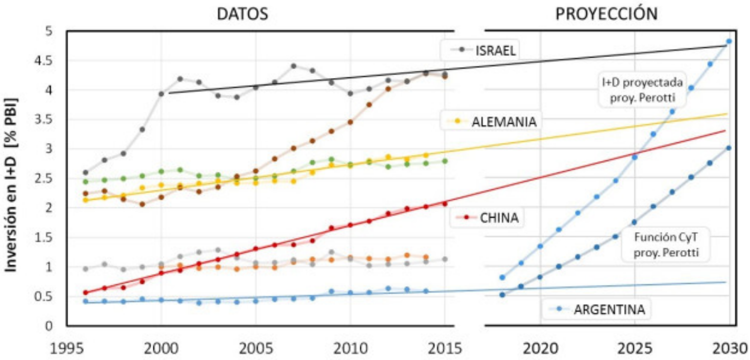


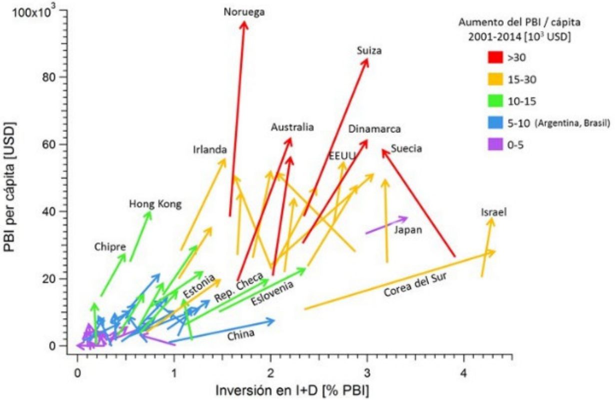
Figura 12. Evolución de la inversión en I+D expresada en porcentaje del PBI para 8 países de referencia. Fuente: UNESCO http://data.uis.unesco.org/. Proyecciones lineales a 2030 para Israel, Alemania, China y Argentina. Para Argentina se muestra además la propuesta de inversión en la función "Ciencia y Técnica" según el proyecto de ley del Senador Perotti, y la proyección correspondiente de inversión total en I+D.

Page **36** of **50**

Slide Number: 7 (Intro: barriers to OD from Fernando D. Stefani's report)

- This data show the R & D investment expressed as a % GDP (Hor. axis) vs GDP/capita [USD] (Vert. axis) for different nation states. Countries are color coded for: increase in GDP per capita. It can be seen that countries that invest more in R& D as a percentage of GDP also have higher USD yield per capita

Introduction (Barriers to OD, Report by Fernando D. Stefani- August 2018)



Evolución entre 2001 y 2014 del PBI per cápita y la inversión en I+D de los mismos 61 países analizados

Figure: Report Prof Stefani

Slide Number: 8 (Intro: barriers to OD from Fernando D. Stefani's report)

- These data show the number of active research scientist per million for some selected Nation States (Vertical axis) vs time [yr] (Horizontal axis).

- What is evident considering the three figures of the last three slides is that some countries experience more severe systemic issues in R&D funding than do others, and some of these also have fewer active research scientists per million and lower GDP per capita growth rates

Fernando D. Stefani- August 2018

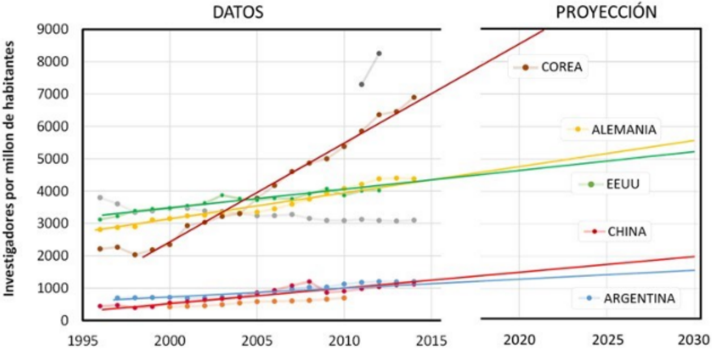


Figure: Number of active research scientist per million ▸ Report Prof Stefani

- This figure from Wikipedia commons is derived from data in Reinhart and Rogoff (2009) has been reproduced (not by me) with the Ecdat R-package from https://en.wikipedia.org/wiki/File:BankingCrises.svg and shows the instances of financial crisis that have afflicted 70 different nation-states.
- It is evident that during the Bretton Woods accords when the global reserve was gold, crisis instances were near a global minimum
- During the periods of major crisis, funding priorities that include basic necessities will compete, since government funds are more limited

Gold Standard via Bretton Woods: Banking Crisis

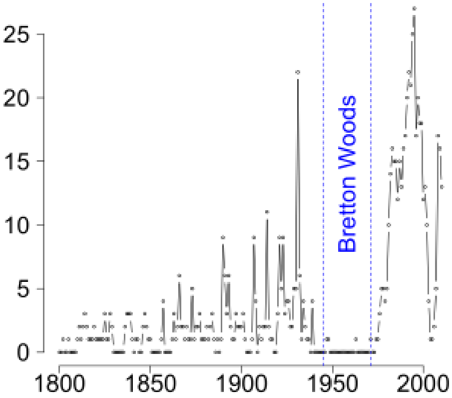


Figure: Banking Crisis reproduced in ▸ R from 70 countries from 1800:2010 from Reinhart and Rogoff (2009)

Slide Number: 10

Bitcoin's Academic Pedigree from Narayanan and Clark (2017)

- This figure is adapted from Narayanan and Clark (2017). I've included DEFI, automatic market making technology and the notion of governance tokens.
- It depicts cryptographic blockchain primitives that lead-up to the so-called Nakamoto consensus, plus key ideas, that include DEFI protocols
- It debunks the false notion that open blockchain protocols were devised by amateur computer hackers
- An analogy is made to the 'lost' Antikythera mechanism, however perhaps the ΔT or time between invention & technological adoption given existing (internet) protocols is much reduced.
- A mention is also made that for adoption it will be up to existing institutions to incorporate blockchain technology instead of new institutions, as mentioned by Nararyanan.

Bitcoin's Academic Pedigree (Narayanan and Clark 2018)

Blockchain technology based on 'forgotton' academic advances in computer science (not by random hackers).

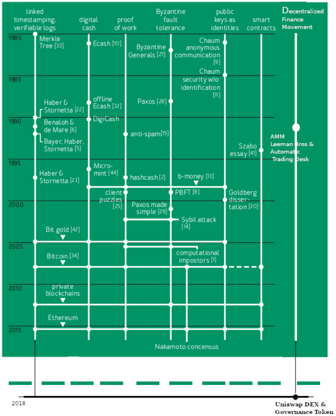


Figure: Blockchain key ideas lead to Nakamoto consensus and DEFI (adapted from Narayanan & Clark 2018): ▸ Narayanan & Clark 2017

Slide Number: 11 Bitcoin (as a world reserve) standard.

- Mention is made to a book by Saifedean Ammous and an academic book review of it included in the reference list by Hansen.

The Bitcoin Standard

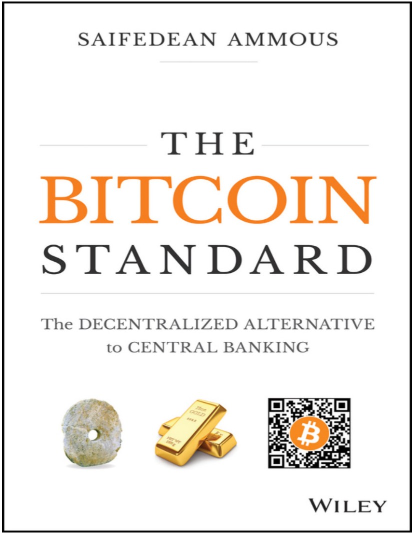


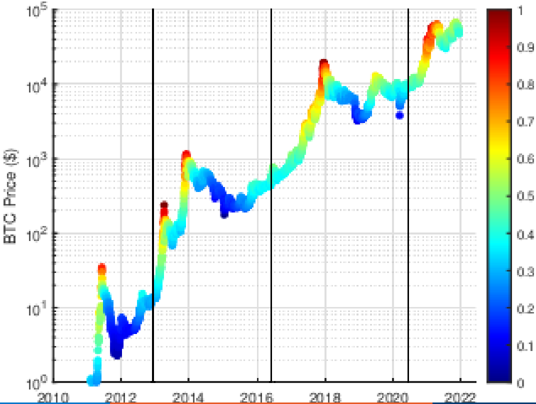
Figure: The Bitcoin Standard, book

BTC vs USD, as global reserve currency standard

- Here is an adapted figure by Cowen 2021 showing the weekly average of BTC vs USD with a colour coded risk metric as modeled by him.
- Emphasis is made on the volatility that has even reached 50% daily draw downs, yet the 'fair' value curve as modeled by Ben Cowen (over longer time-scales) appears to strictly follow a monotonically increasing function.
- For this figure I have added the block reward halving as solid vertical lines that occur after every 210K blocks.

BTC VS USD

Figure: Adapted figure from Cowen (2021) showing the price function (in USD) of BTC in time (Yrs). A potential reserve currency for Astronomy OD? The color-bar is a risk metric modelled by Cowen (2021) for the 3 previous market-cycles that have been added by SG (vertical lines) marking bitcoin mining reward halvings after each 210k blocks.



Slide Number: 13 (Metrics and Use-Case)

- IVOA community established AOD metrics to account for 'challanges'. These metrics may include things like: h-index; citations; outreach; GitHub pull requests; Tflop capacity for HPC; other data-feeds, eg ADS Astropy code acknowledgements; You-tube course-ware, etc.

- Establish programable AOD blockchain oracle services (see "The Graph (subgraphs)", "UNISWAP", "Chainlink", etc .

- Appeal to DEFI grant funding to fund AOD projects via existing governance protocols

- Re-value historical astronomical patrimony; Example of NFT for collated material of the first validation attempt of GTR via angular diffraction of a background star image with line-of-sight towards The Sun's disk, as attempted in 1912 by the former staff of the OAC and other groups. The idea would be for the creation of an NFT with Santiago Paolantonio, that could include his paper (translation), Santiago's signature, plus those of the Director of the OAC and the director of the Museum of the Astronomical Observatory of Cordoba, David Merlo, etc.

- I mention that other blockchains and Layer 2 solutions could be used if Tx fee's are an issue. Such an NFT or NFT series could be made with a smart-contract to split 'royalties' every time the NFT is transferred to another owner.

Use-Case: Establish Metrics for Oracle(s) & Governance funding via DEFI grants

- Metrics for Oracle services:
  Out-reach, lectures/talks by Astronomers, telescope open-nights, h-index, citations, code pull requests, HPC Tflop capability, you-tube views, PhD graduate numbers, etc., all could be considered to constrain and engineer tokenomics to form the basis of protocol standards, including on-chain analysis.
- Liquidity Pools to fund AOD
- NFT to restore value to historical patrimony, outreach, fund meetings, student talk and poster prizes, etc

Figure: NFT collectable, world first experiment event to constrain Einstein's GTR via diffraction, foto by the Córdoba Observatory team taken during the 1912 eclipse expedition. The Perrine settlement is located in the right, attached to the big white building. Courtesy of the Museo Astronómico del Observatorio Astronómico de Córdoba, Córdoba, Argentina. (source: Paolantonio 2019.)

Slide Number: 14 (JACA)

- Self explanatory

Use Case & Metrics (talk SG prepared, basis of this talk): Jornadas de Astronomia Computacional IATE, Cordoba Argentina - November 2021

Over 80 researchers attended/day over 2 days.

- Argentine astronomers face increasingly difficult situation in updating hardware (including PC), and operating costs. Telescope infrastructure, capital and operational costs becoming difficult to stay competitive and independent (eg: Gemini cut-back, TOROS Dev).
- HPC resources are exceptionally hard to fund (eg: a new HPC machine becomes obsolete at end of 5th year).
- Pooling resources, and using community developed software like Astropy appears to help, yet other funding barriers are implicit and competitive 'handicap' must be recognized and addressed.
- USD stable coin liquidity pools could help amortize devaluation of grant monies that often take 2-3 years to arrive: with undesirable consequences, often project infrastructure must be scaled-down from original scope.

Slide Number: 15 Conclusions and Recommendations

- Self explanatory

Conclusions and Recommendations

- AI techniques necessary but blockchain is hardly explored.
- DEFI grants to date exceed 10's billion USD and on sideline waiting to fund AOD. Community development is urgently required.
- IVOA DAO could be established and metrics discussed with all 19 National Members + 3 international members to create Oracle service(s) via Data-Feeds for incentive grant AOD schemes
- Complimentary Development of AOD metrics and convergence between: Astropy, IVOA and IAU communities would be ideal.
- L2 channels, eg: Lightning, and on Ethereum etc., could be created for Observatories, and other National Institutions, IVOA national members, Public Universities etc.. Must also take advantage of TAPROOT DEFI grants on Bitcoin that with Schnorr signature schemes allows multisig smart contracts with low Tx costs through Lightning, to fund AOD efforts (BIP 340, 341, and 342).

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