WELCOME !

Thank you!

- All of you, especially the long travellers (Japan, US)

- Funding and organisation partners (Knut and Alice Wallenberg Foundation, European Research Council, Stockholm University, Wenngren Foundation).

- AT2017gfo

- Albert Einstein

- Internet

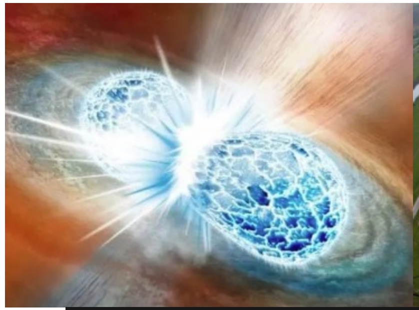
- …

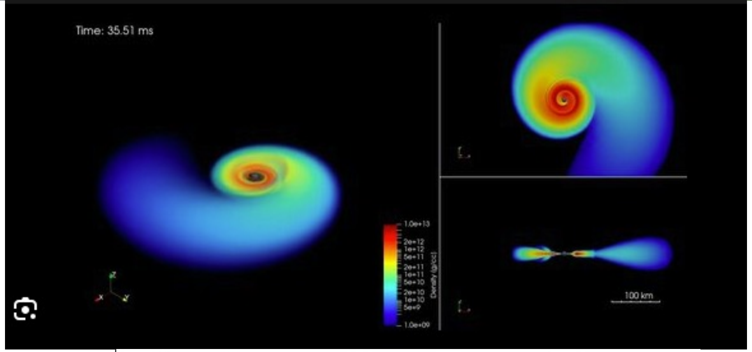
The kilonova era – a unique moment in time for astrophysical research

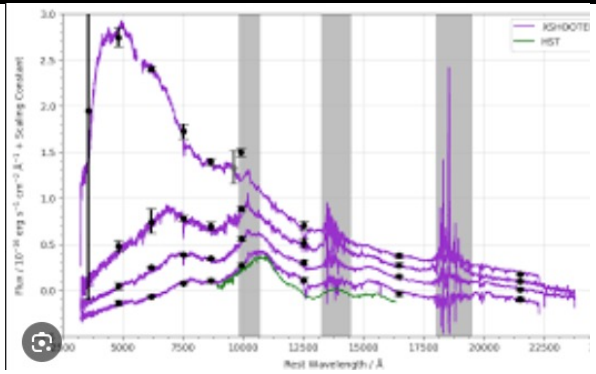
- An **incredible success for fundamental physical theory** (relativity --> GWs, quantum mechanics, nuclear physics) : the phenomenon was, quite accurately, predicted before discovery (**Li & Paczynksi 1998**, **Metzger+2010**).

- An **incredible success for large-scale collaborative efforts**.
    - LIGO
    - Transient surveys
    - Atomic physicists, nuclear physicists, hydrodynamics and radiative transfer modellers coming together for the theory.

- A **unique opportunity for us** to be part of writing a truly astonishing chapter in the book of astronomical science.







A prediction for the ages!

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

Mon. Not. R. Astron. Soc. **406,** 2650–2662 (2010) doi:10.1111/j.1365-2966.2010.168

Electromagnetic counterparts of compact object mergers powered by the radioactive decay of *r*-process nuclei

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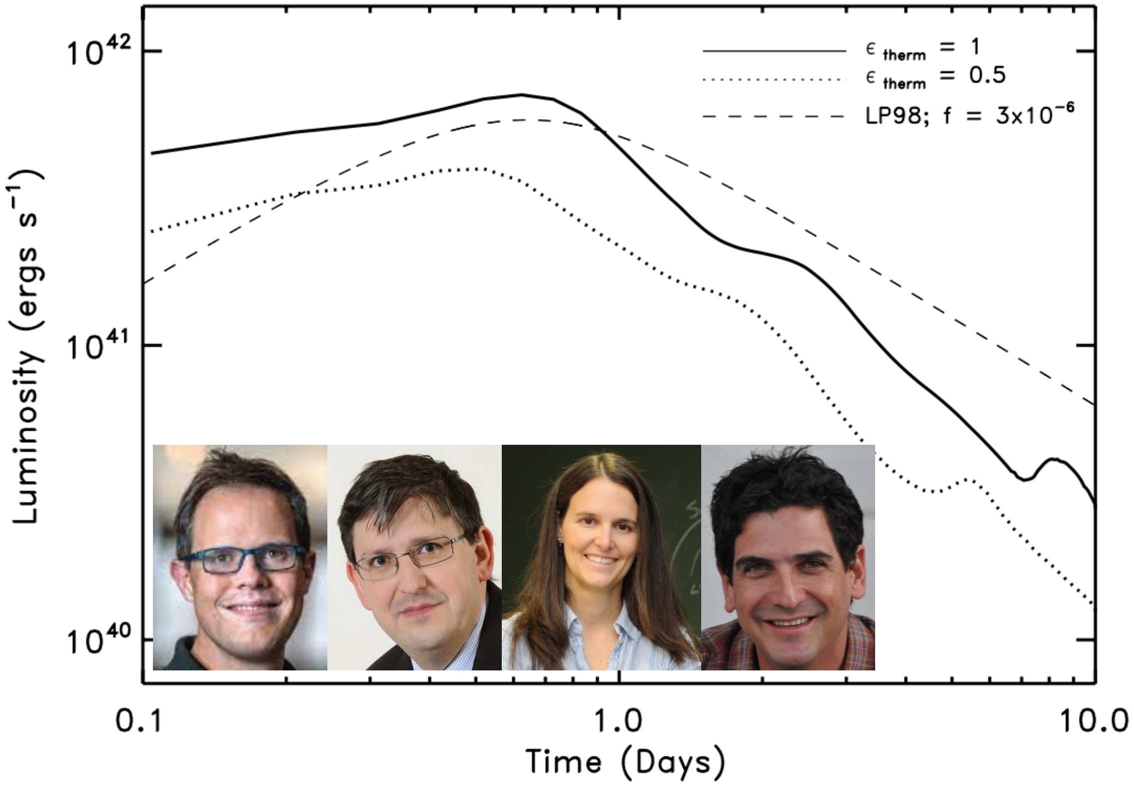


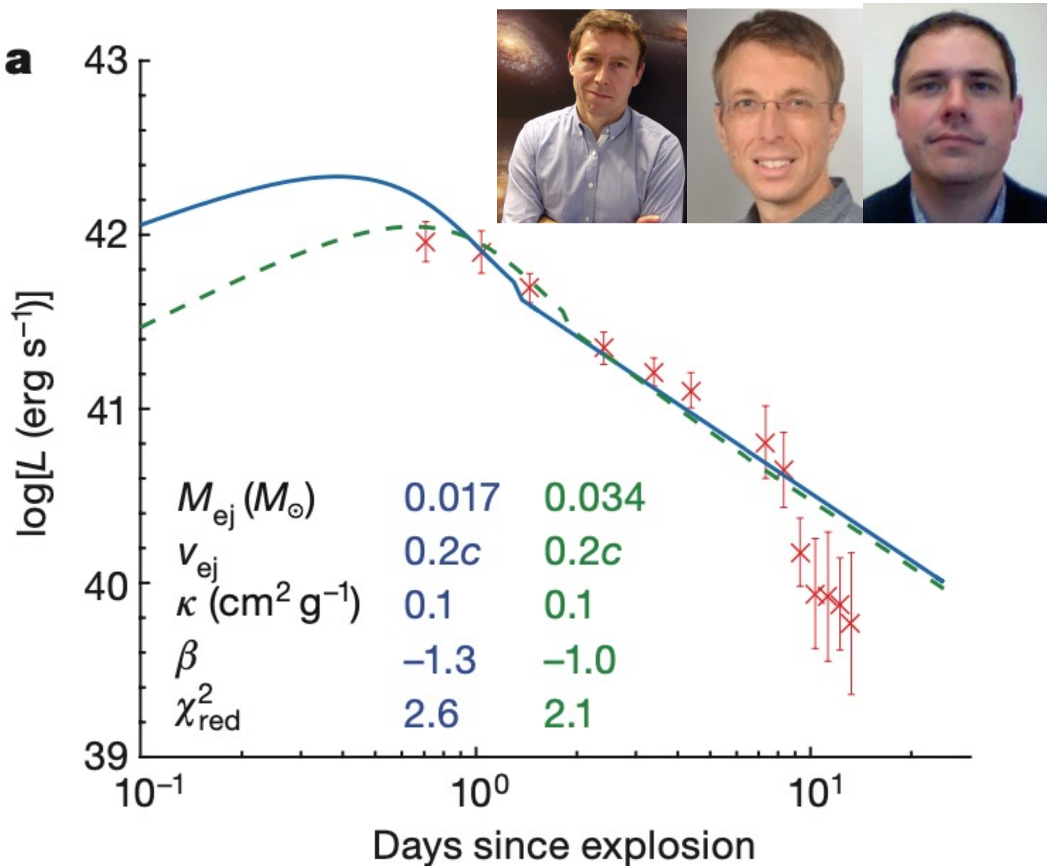
LETTER

doi:10.1038/nature24303

A kilonova as the electromagnetic counterpart to a gravitational-wave source

A list of authors and their affiliations appears at the end of the paper.

Smartt et al 2017



The origin of the idea?

* The establishment of cosmological distances to GRBs (1997) → neutron star mergers firmly onto the agenda.
* As with the discovery of the neutron (Chadwick 1932) to the explanation of SN as formation of neutron stars (Baade & Zwicky 1934) it took only about 1 year for someone to link the major leap to a new phenomenon.

TRANSIENT EVENTS FROM NEUTRON STAR MERGERS

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Bodan Paczynksi

David Spergel

It is a great pleasure to thank D. N. Spergel for asking us the question "what might be the observable consequences of neutron star mergers?" and for his useful comments. One of us (B. P.) acknowledges hospitality he experienced while on sabbatical at the Institut d'Astrophysique, CNRS, in Paris.

From Li & Paczynksi 1998

Astron. Astrophys. 341, 499–526 (1999)

Mass ejection in neutron star mergers

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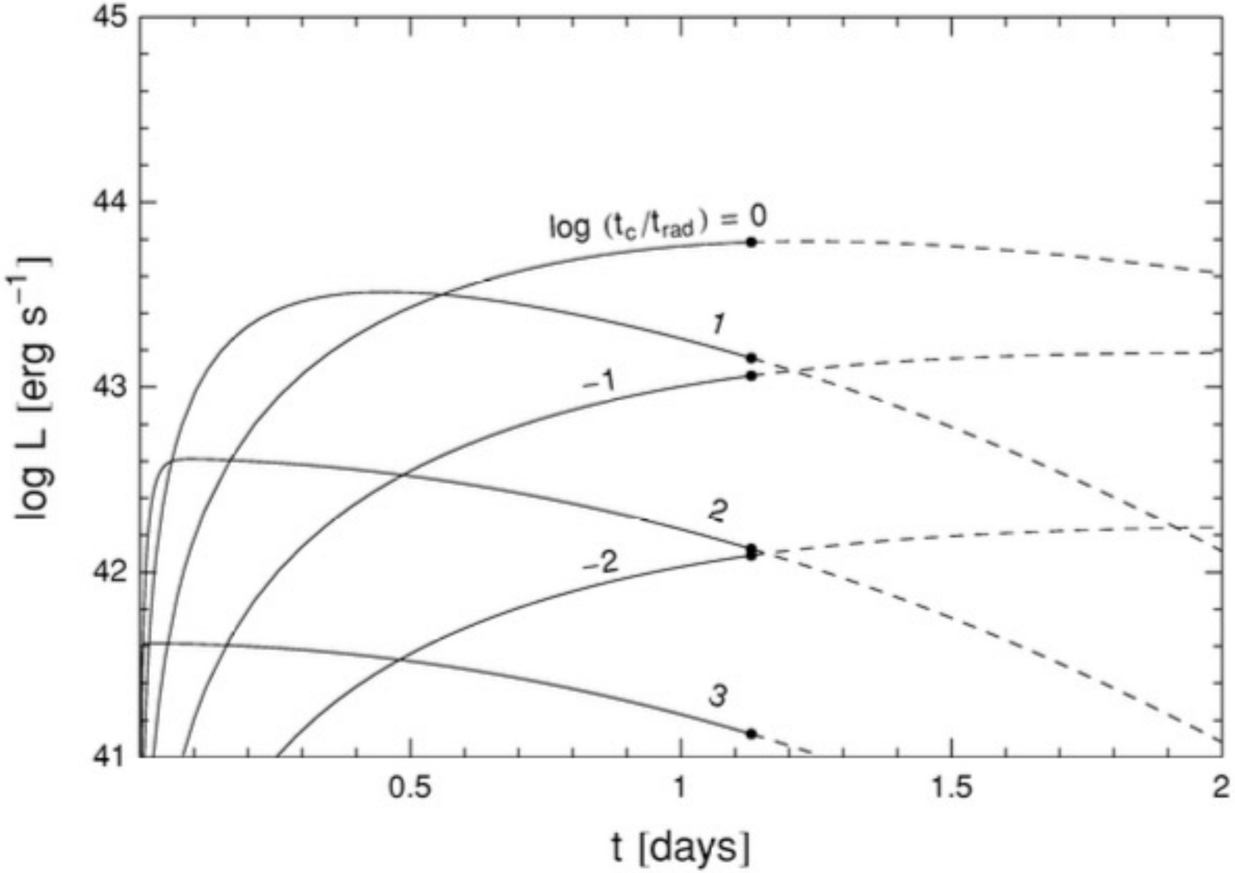


FIG. 1.—Time variation of the bolometric luminosity of the expanding sphere generated by a neutron star merger, shown for a number of models with various values of the logarithm of the ratio of two timescales t_c, when the sphere becomes optically thin, and the radioactive decay time t_{rad}. The models were calculated for the fraction of rest-mass energy released in radioactive decay $f = 10^{-3}$, the mass $M = 10^{-2}\ M_\odot$, and the surface expansion velocity $V = 10^{10}$ cm s^{-1}. For the adopted opacity $\kappa = 0.2$ cm^2 g^{-1}, we have $t_c = 0.975 \times 10^5$ s = 1.13 days, as indicated by the filled circles, separating the solid lines (corresponding to the optically thick case) and the dashed lines (corresponding to the optically thin case).

Radioactive heating.—Assume that the radioactive decay of an element isotope proceeds on a timescale t_{rad}, and releases a total amount of energy equivalent to a fraction f of the rest mass, so that the heat generation rate per gram per second is

$$\epsilon = \frac{fc^2}{t_{rad}} \exp\left(\frac{-t}{t_{rad}}\right) . \qquad (4)$$

If there are several decaying element isotopes, the total heat generation rate is the sum of the rates of the individual element isotopes. If there are many decaying element isotopes with different decaying timescales, the summation can be replaced by an integration. Nuclear lifetimes are distributed roughly uniformly in logarithmic intervals in time; thus, the total heat generation rate may be approximated as[1]

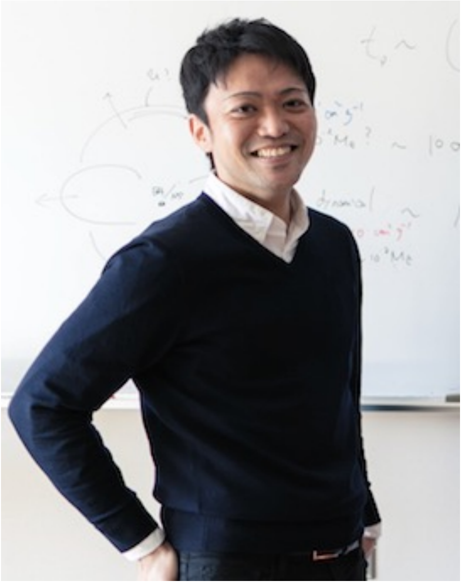
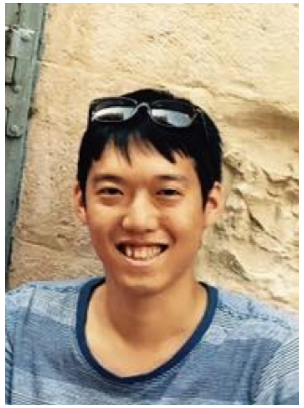
$$\epsilon = \frac{fc^2}{t} \quad \text{for } t_{min} \le t \le t_{max},\ t_{min} \ll t_{max}. \qquad (5)$$

While our model requires many improvements, the single most important is a quantitative estimate of the abundances and the lifetimes of the radioactive nuclides that form in the rapid decompression of nuclear-density matter. It is possible that

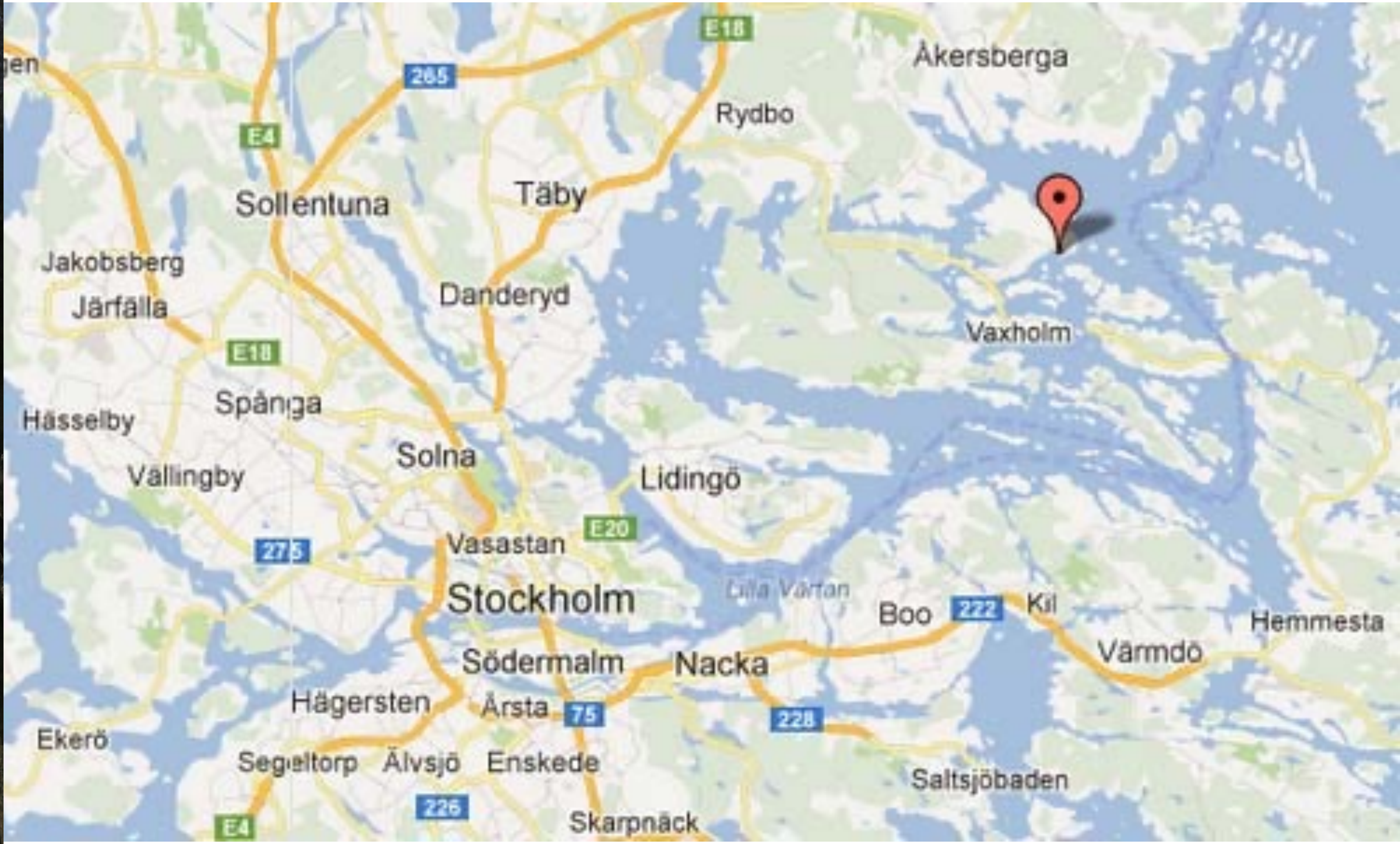
Yungelson 1998). It is very intriguing that the high-redshift supernova search (Schmidt at al. 1998) revealed mysterious optical transients that typically have no host galaxy, as would be expected of neutron star mergers.

Next steps

- **What is the actual nuclear decay power?** (**Metzger+2010**).
- **What is the actual opacity?** (**Barnes & Kasen 2013**)
- **What are the actual ejecta masses, composition, and velocities? Hotokezaka+2013, Wanajo+2014,** See Stephan's and Gabriel's talks.
- **What are the light curves and spectra with state-of-the-art radiative transfer modelling? (Tanaka & Hotokezaka 2013, Kasen, Badnell & Barnes 2013, Kawaguchi+2016)**
- **How do we localize and find the things? (Tanvir, Levan et al. 2013, +…)**


The **Ytterby Mine** : discovery site of 8 of the elements in the periodic table!



Tantalus (Ancient Greek: Τάνταλος *Tántalos*) was a Greek mythological figure, most famous for his punishment in Tartarus: he was made to stand in a pool of water beneath a fruit tree with low branches, with the fruit ever eluding his grasp, and the water always receding before he could take a drink. He was also called **Atys**.

Scandium (Scandinavia)

Yttrium

Tantalum (Tantalus)

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	* 71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	89 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	** 103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	100 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
**	89 Ac	90 Th	91 Pa	[illegible]	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Gadolinium (Johan Gadolin)

Terbium

Dysprosium

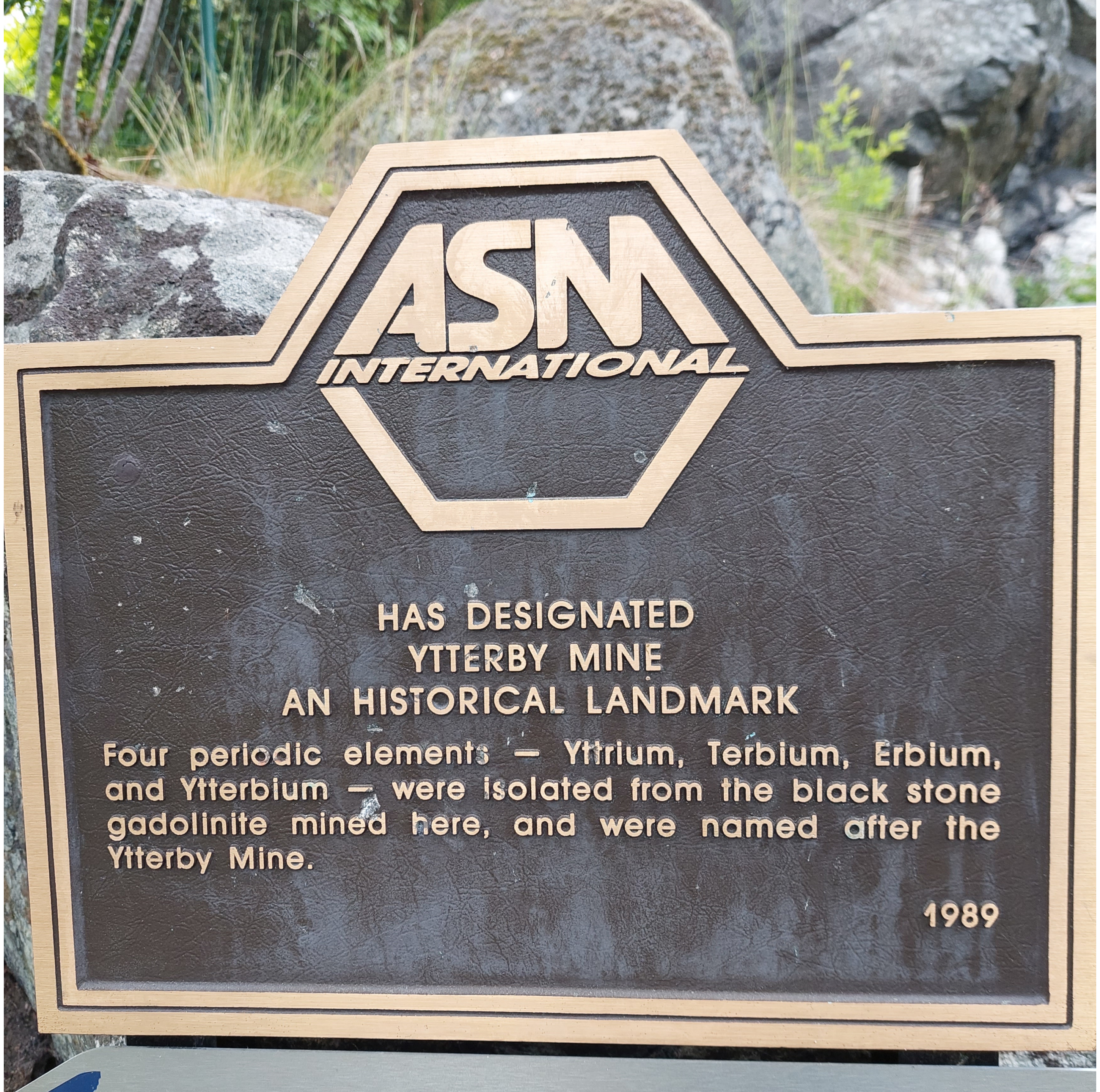
Holmium (Stockholm)

Erbium

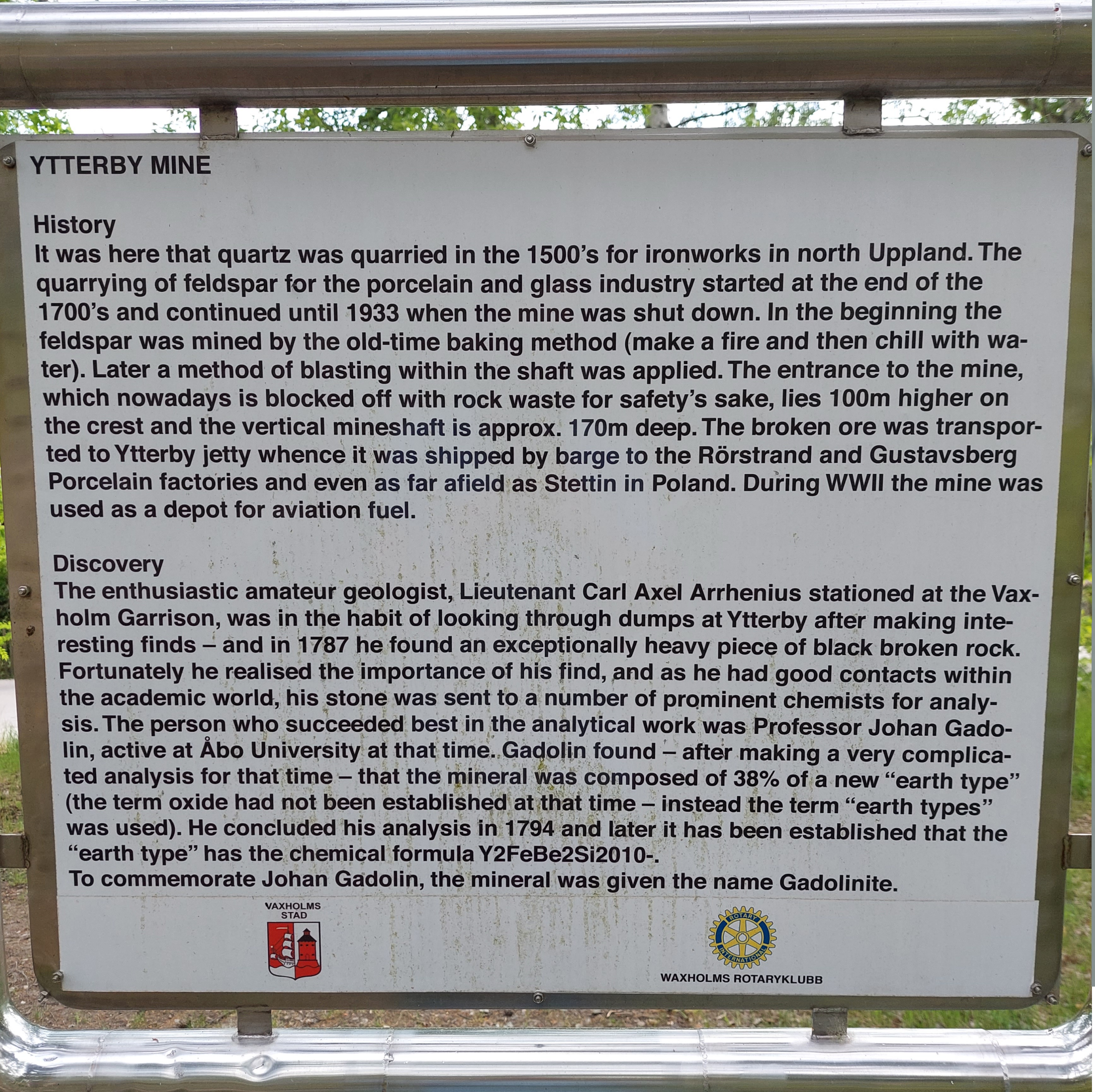
Thulium (Thule)

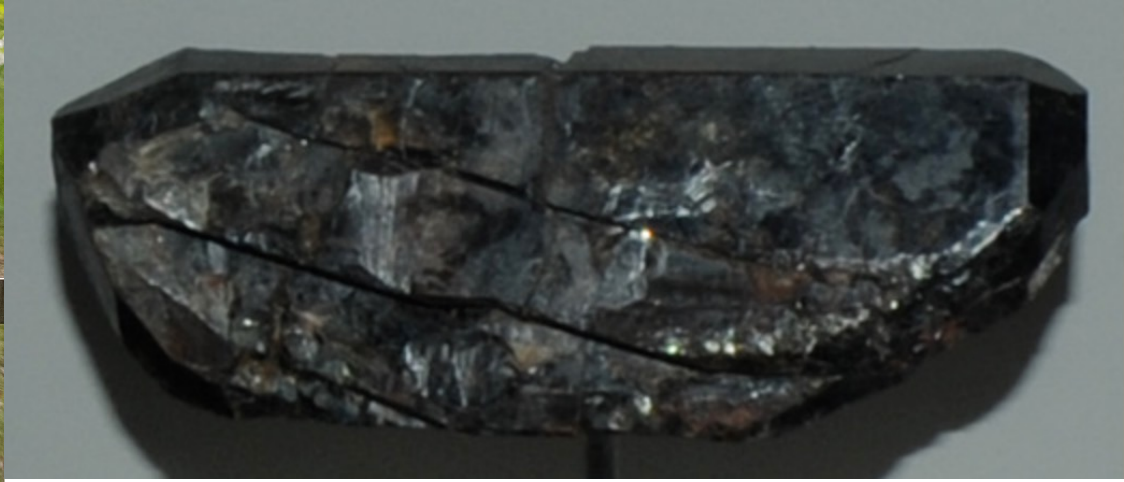
Ytterbium


Yttriumvägen
Wallsjöhus
BYGGPLATS



I note that the Swedish chemists were not so much inte greek mythology as in how many ways "Ytterby" can be twisted around!


YTTERBY MINE
History
It was here that quartz was quarried in the 1500's for ironworks in north Uppland. The quarrying of feldspar for the porcelain and glass industry started at the end of the 1700's and continued until 1933 when the mine was shut down. In the beginning the feldspar was mined by the old-time baking method (make a fire and then chill with water). Later a method of blasting within the shaft was applied. The entrance to the mine, which nowadays is blocked off with rock waste for safety's sake, lies 100m higher on the crest and the vertical mineshaft is approx. 170m deep. The broken ore was transported to Ytterby jetty whence it was shipped by barge to the Rörstrand and Gustavsberg Porcelain factories and even as far afield as Stettin in Poland. During WWII the mine was used as a depot for aviation fuel.
Discovery
The enthusiastic amateur geologist, Lieutenant Carl Axel Arrhenius stationed at the Vaxholm Garrison, was in the habit of looking through dumps at Ytterby after making interesting finds – and in 1787 he found an exceptionally heavy piece of black broken rock. Fortunately he realised the importance of his find, and as he had good contacts within the academic world, his stone was sent to a number of prominent chemists for analysis. The person who succeeded best in the analytical work was Professor Johan Gadolin, active at Åbo University at that time. Gadolin found – after making a very complicated analysis for that time – that the mineral was composed of 38% of a new "earth type" (the term oxide had not been established at that time – instead the term "earth types" was used). He concluded his analysis in 1794 and later it has been established that the "earth type" has the chemical formula Y2FeBe2Si2010-.
To commemorate Johan Gadolin, the mineral was given the name Gadolinite.
VAXHOLMS STAD
WAXHOLMS ROTARYKLUBB



Lunch discussion topic: *How did they realize they had found a new element back in those days (late 1700s/early 1800s)?*

Note that spectroscopy was not coming into use until 1859.

Wikipedia doesn't help that much…

Mosander discovered lanthanum in 1838. This came from the Cerite-(Ce) from Bastnaes, Sweden, which at the time was the only abundant source for "Cerium", which had been discovered therein by Berzelius and Hisinger, and independently by Klaproth, in 1803. At that time, one of the two known components of the mineral ytterbite (later named gadolinite) was a white oxide called ceria. Mosander partially decomposed ceria by heating it and treating the resulting salt with dilute nitric acid.[5][6][7] He was hesitant to report his results, both for fear of embarrassing his mentor Berzelius, by showing that his discovery cerium was not an element; and because he was uncertain that he himself had reduced cerium to all of its components. Berzelius eventually suggested the name "lanthan", for "hidden" for this new discovery.[8]

From "Episodes from the history of the rare earth elements"

Episodes from the History of the Rare Earth Elements

Screenshot

Table 1 Discovery and etymology of the rare earths

Rare Earth	Year of Discovery	Discoverer	Origin of Name	Reference
Yttrium (Y)	1794	Gadolin	Ytterby, a village near Stockholm	Chapter 1
Cerium (Ce)	1803	(i) Berzelius & Hisinger (ii) Klaproth	Ceres, an asteroid discovered in 1801	Chapter 2
Lanthanum (La)	1839	Mosander	To lie hidden (Greek)	Chapter 3
Erbium (Er)	1843	Mosander	Ytterby	Chapters 3 & 4
Terbium (Tb)	1843	Mosander	Ytterby	Chapters 3 & 4
Ytterbium (Yb)	1878	Marignac	Ytterby	Chapters 4 & 5
Holmium (Ho)	1879	Cleve	Stockholm (Latin)	Chapter 4
Thulium (Tm)	1879	Cleve	Northernmost region of the inhabitable world (Latin)	Chapter 4
Scandium (Sc)	1879	Nilson	Scandanavia (Latin)	Chapter 4
Samarium (Sm)	1879	Lecoq DeBoisbaudran	Samarskite, an ore named after the Russian army officer Samarsky	Chapter 4
Gadolinium (Gd)	1880	Marignac	Johan Gadolin	Chapter 4
Praseodymium (Pr)	1885	Auer	Green twin (Greek)	Chapters 4 & 7
Neodymium (Nd)	1885	Auer	New twin (Greek)	Chapters 4 & 7
Dysprosium (Dy)	1886	Lecoq DeBoisbaudran	Hard to get at (Greek)	Chapter 4
Europium (Eu)	1901	Demarçay	Europe	Chapter 4
Lutetium (Lu)	1907	(i) Auer (ii) Urbain	Paris (Latin)	Chapters 5 & 7

Topics to be addressed at the workshop, and questions to think about during the week

- What ***efforts are underway in theoretical and experimental atomic physics*** relevant for the problem?
- What ***efforts are underway in the radiative transfer modelling*** relevant for the problem?
- ***How are models used to link into analysis frameworks and observation planning?***

- From the current literature analyzing AT2017gfo, ***what do we feel is convincingly established***, what is still more speculative?
- What are the current ***most severe obstacles for progress – and how can atomic phycisists, RT modellers, and workers on other KN aspects solve them together***?
- ***What have we learned fro****m* ***50 years of supernova research***, how do we apply these lessons to kilonovae?

PLEASE ENJOY YOURSELVES!
THANK YOU