Colibrí & Magnetars

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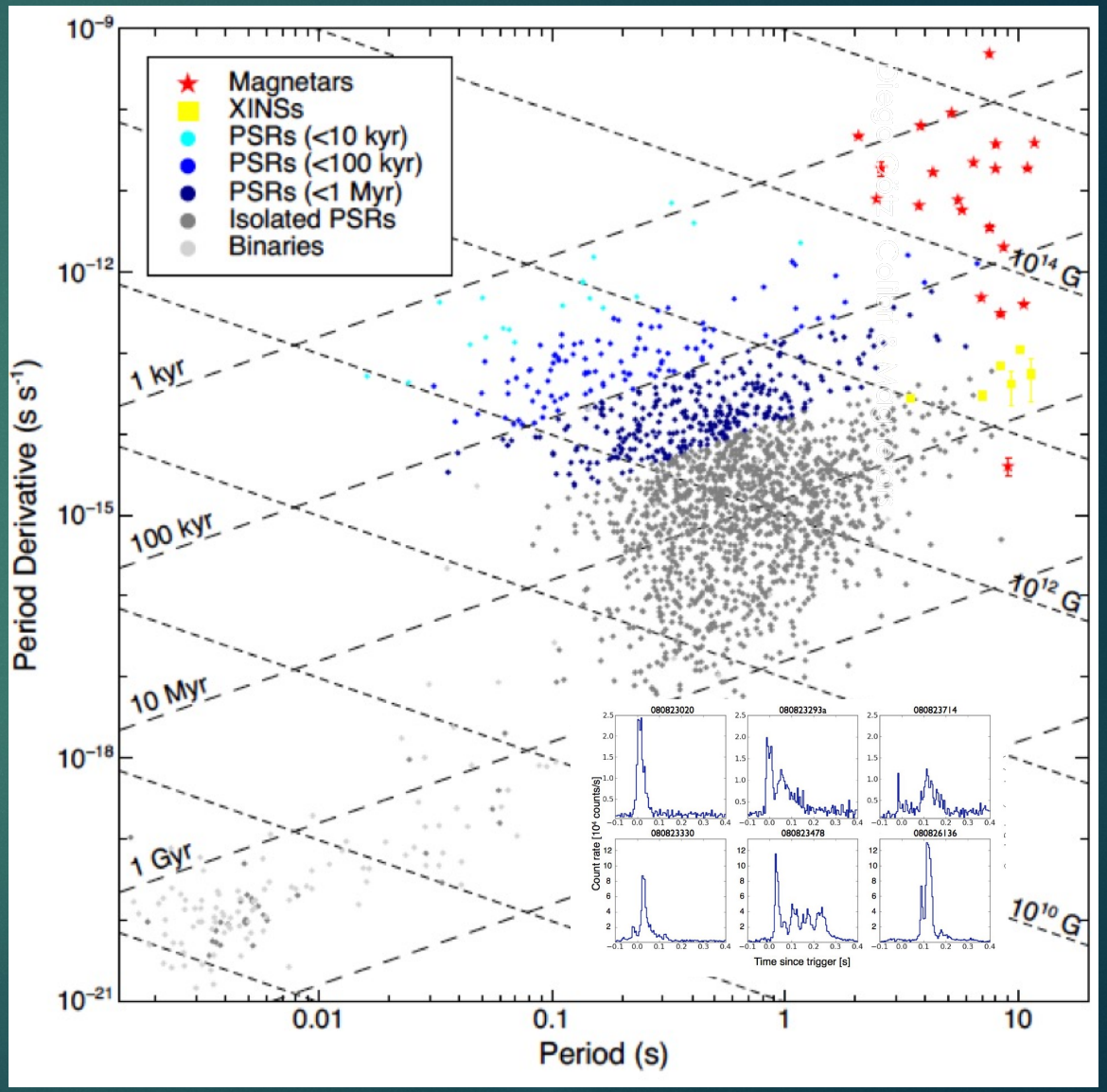
Plan of the presentation

- Magnetars
- What can we expect from Colibrí Observations
  - Magnetar Outbursts & Transient Magnetars
  - Magnetars as local short GRBs
  - Magnetars & FRBs

Magnetars

- NS that have been historically identified through two separate channels
  - Soft Gamma-Ray Repeaters (SGRs), discovered through the repeated emission of short (~0.1 s) and intense (10^{39-42} erg s-1) bursts with a quasi-thermal spectrum
  - Anomalous X-ray Pulsars (AXPs), isolated neutron stars whose X-ray emission cannot be explained the rotation energy loss
- About 30 confirmed and candidate sources, see https://www.physics.mcgill.ca/~pulsar/magnetar/main.html
- Their spin periods span 2-10 s and period derivatives 10^{-13}-10^{-11} s/s
- Derived dipole magnetic field > 10^{13}G, i.e. 100-1000 times stronger than regular radio pulsars
- They sporadically emit intermediate and giant flares (see later)
- In the magnetar model it is the decay of such a huge magnetic field that powers the observed phenomenology

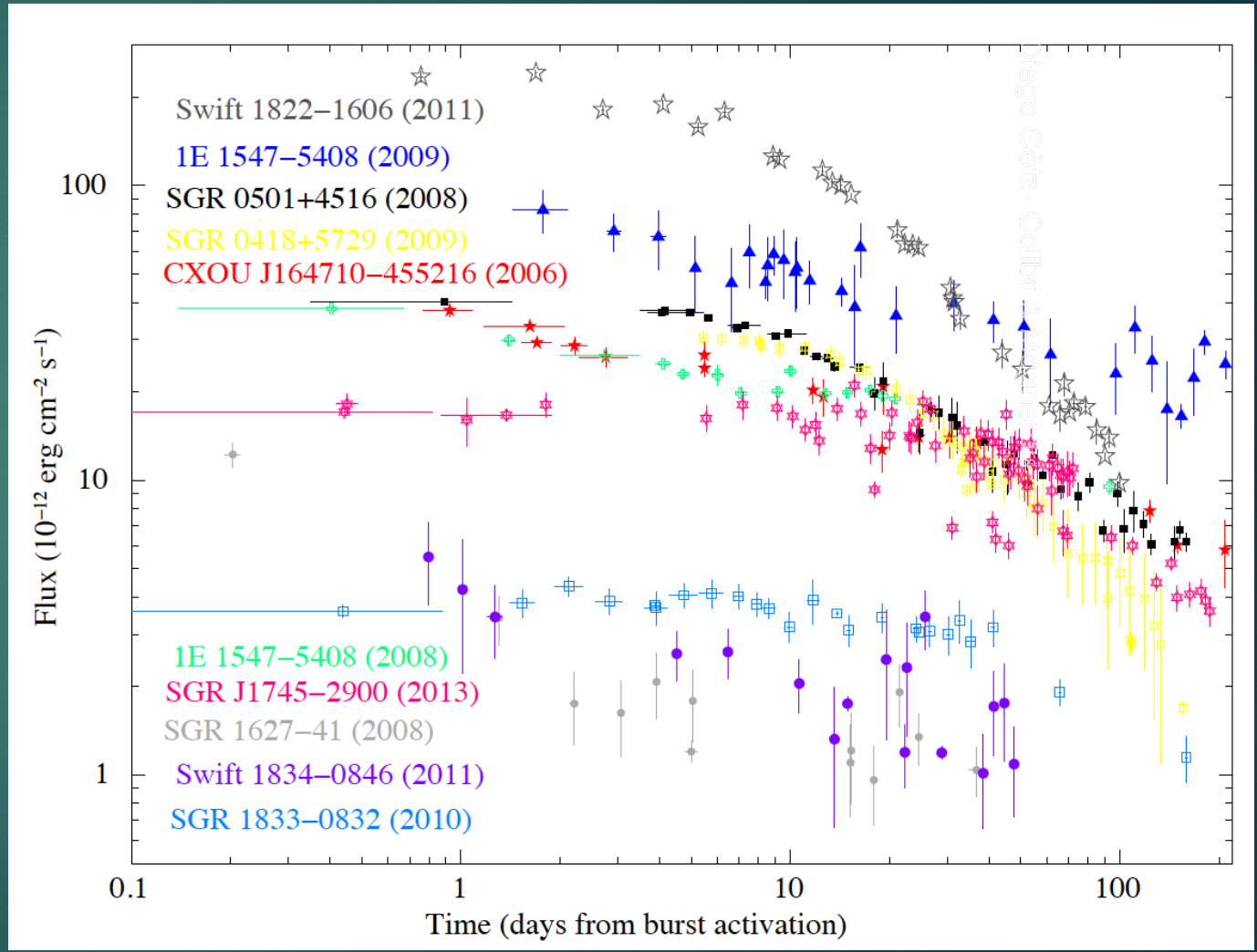


Magnetars models

- Magnetar formation: According to the original picture by Duncan and Thompson (Duncan & Thompson, 1992; Thompson & Duncan, 1993), magnetars form through magnetic field amplification by a vigorous dynamo action in the early, highly convective stages, but the initial spin period must be short, . 3 ms, to ensure efficient convective mixing. Magnetars would be, then, the endpoint of the evolution of massive stars with rapidly rotating cores -> Would imply highly energetic SN (not found), but the energy could also be carried away by GWs.
- The observed emission is powered by the ”relaxation” of a highly twisted magnetic field: the induced currents heat the NS crust and the twist decay “cracks” the NS crust inducing short bursts (through rapid magnetic field reconfiguration & reconnection)and timing glitches.

Transient Magnetars

- Recently identified as a different sub-class of Magnetars
- About half of the magnetars show spectacular months long outburst, changing its permanent flux by up to two orders of magnitude
- No clear triggering mechanism for transient emission identified yet, however it is typically preceded a short faint GRB
  - This has been interpreted as due to some form of heat deposition in a limited region of the star surface which then cools and shrinks. Until now, however, the heating mechanism has not been unambiguously identified.

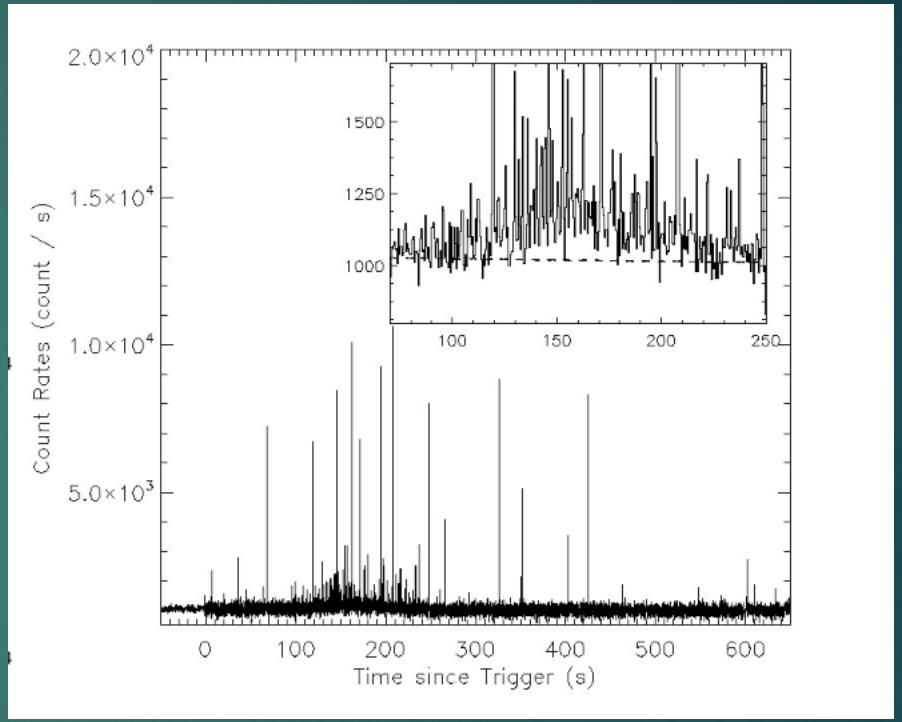


Optical and NIR emission

- Optical and NIR (variable) counterparts have been detected for a few magnetars, but they are typically too faint to be detected by Colibri (due to the high interstellar extinction which reduces the spectral coverage mostly to the NIR)
  - SGR1806-20: K_S ~19-20 (Israel et al. 2005)
  - 4U 0142+61: K~20 (Hulleman et al. 2004); H~20.6, J~22.1
  - XTE J1810-197: K_S ~20.8, H>22.5 (Israel et al. 2004)
  - 1E 2259+586: K_S ~21.7, J> 23.8, I>25.6, R> 26.4 (Hulleman et al. 2001)
  - 1E 1547.0-5408: K_S~20.3 (Mignani et al. 2009)
- The origin of this emission is still under debate, and the main dispute is whether it is due to the presence of a fossil disk (Perna et al., 2000) or if it has a magnetospheric origin (Eichler, Gedalin & Lyubarsky, 2002; Beloborodov & Thompson, 2007)

Optical and NIR emission

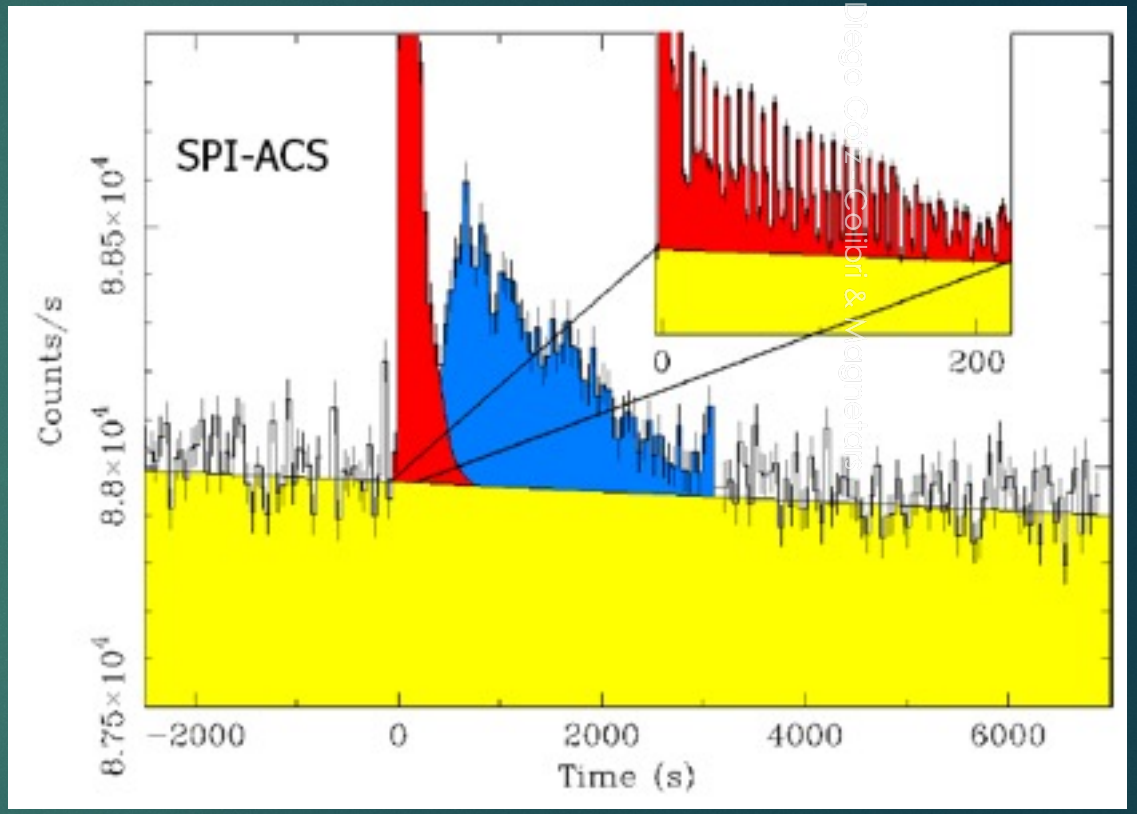
- However transient/bursting magnetars are more likely to be detected
  - SGR 0501+4516 outburst has been promptly followed-up by UKIRT, WHT, and Gemini: H~19.5-20; J~21 (within Colibri capabilities in H band!)
- Although Magnetars are faint objects for Colibrí, they are regularly discovered by Swift/Fermi through their outburst
- Colibri reaction time on a single burst is too long, but "burst forests" are sometimes observed
- An exploratory ToO programme on Colibri could help understand the nature of NIR emission on this source



Magnetar "burst forest" observed from 1E1547 by Fermi/GBM

Magnetar Giant Flares as local short GRBs

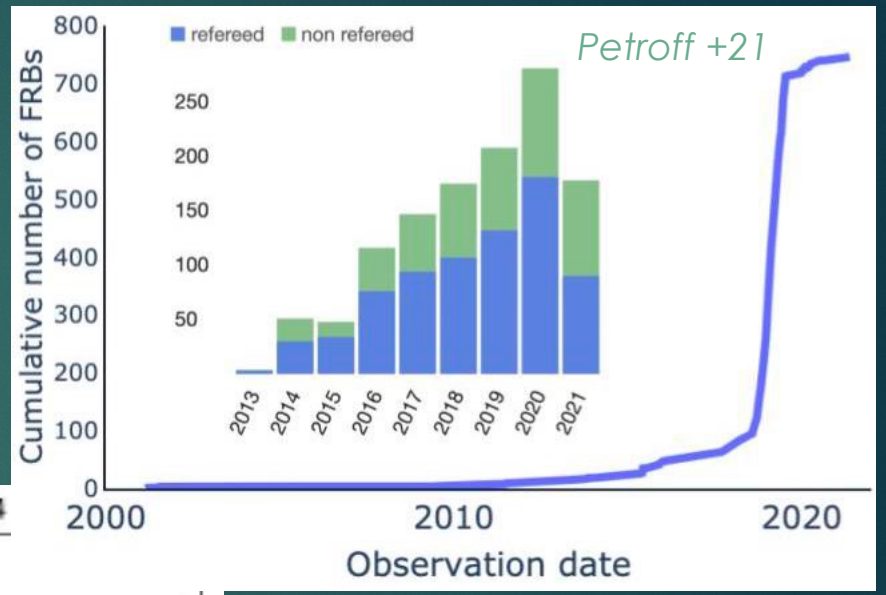
- A few Magnetars (SGR 0526-66, SGR 1900+14, SGR 1806-20 have emitted "Giant Flares", short (~0.1-0.2 s) spikes of gamma-ray radiation, followed by a ringing tail, and a high-energy afterglow
- Peak luminosities can exceed 10^{47} erg s^{-1}, which could make them appear as short GRBs in the local Universe (< 50 Mpc)
- The follow-up of short GRBs (SVOM and not), whose error box is coincident with local galaxies, is a science case related to Magnetar studies

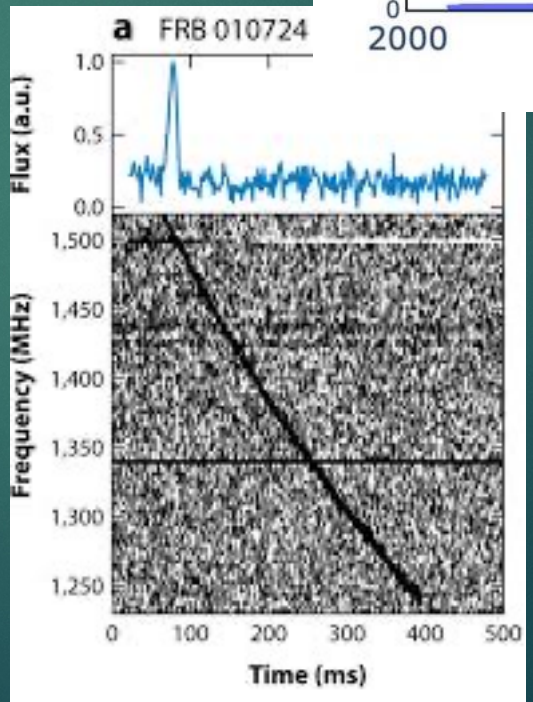


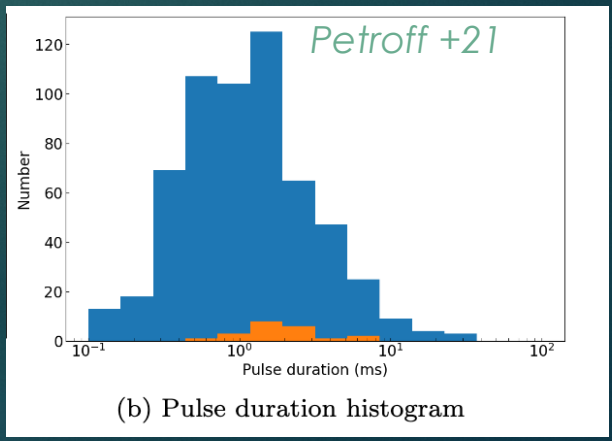
SGR 1806-20

Magnetar FRB connection

- Fast Radio Bursts (FRBs) are short (ms) and and intense (60 mJy - >100 Jy) bursts detected at radio (typically @ 1.4 GHz) bands
- Similar to Giant radio Pulses from Galactic pulsars
- The first FRB has been discovered in 2007 (Lorimer Burst) 3° off the SMC, and many more have been discovered since (including repeating ones)
- Initially the dataset was contaminated by locally produced "bursts" at Parkes (perytons)
- They appear randomly over the entire sky (10^3-10^4 per day > 1 Jy!)
- Their Dispersion Measure is compatible with being of extragalactic Origin





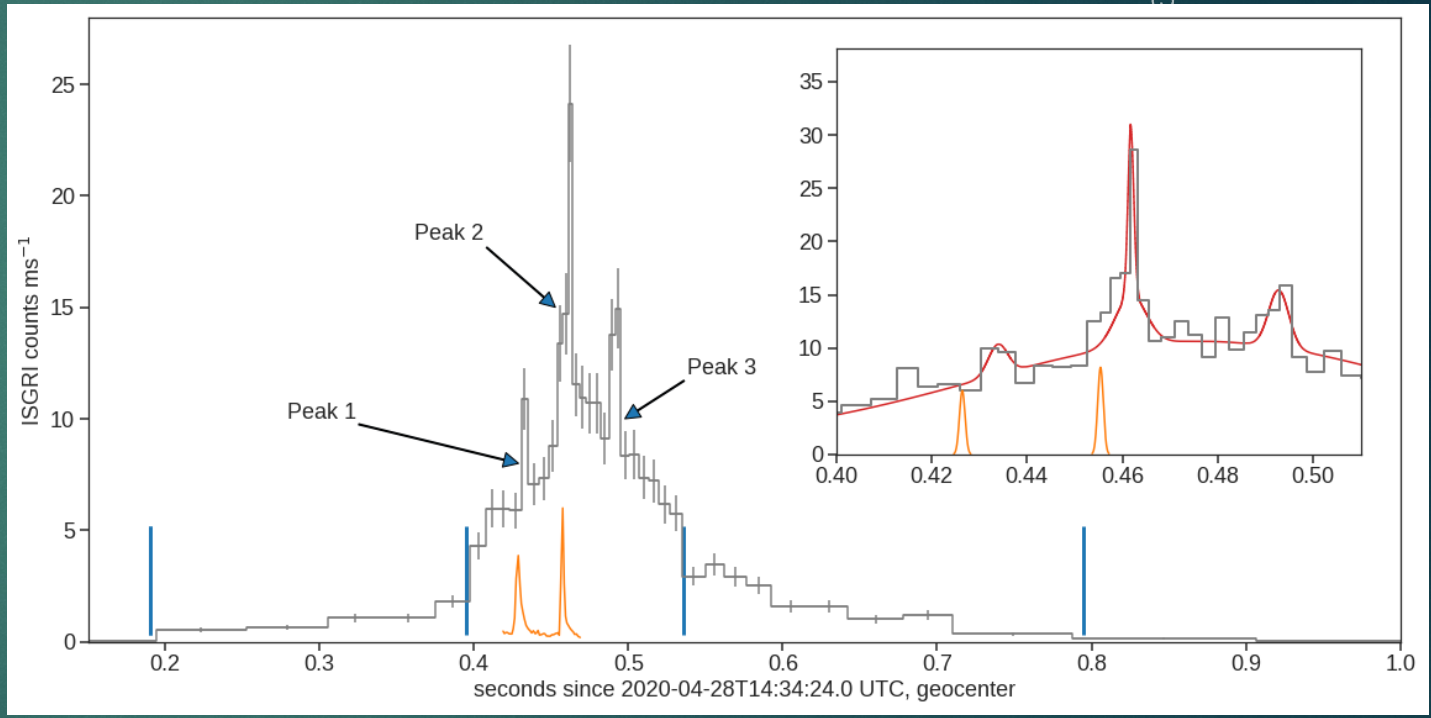


Magnetar FRB connection

- About a dozen are now localized at (sub-)arc second positions and robustly associated to a host galaxy
- Repeaters are rather associated with star forming regions, while non-repeaters have been found in hosts with low star forming activity even on their outskirts. Different Origin?
- More generally there is no consensus on the radiative processes producing FRBs. Coherent Radiation is accepted, but some models focus on magnetic reconnection, while others on curvature radiation (close to the NS surface). Other models focus on synchrotron radiation in a forward shock (like GRB afterglows)
- An even more widely discussed question is the one about the Progenitors: NS (isolated and binary), Winds in ULXs, AGNs,… In any case repeatability excludes catastrophic events.
- The strongest constraints come from the longest-lived active source seen to date, FRB 20121102A. Margalit et al. (2020) estimate a total energy budget of 10^{49}-10^{50} erg for this source, which they note *is consistent with the magnetic energy reservoir of a magnetar*

Magnetar FRB connection (SGR 1935+2154)

- On April 28 2020 at 09:51:05 and 14:34:24 UTC the Integral Burst Alert System triggered on two short bursts from SGR 1935 issuing alerts in less than 10 s, the brightest of the two bursts (14:34) was temporally coincident with the bright radio burst detected by CHIME and STARE 2
- This burst was not particularly energetic at high energies, but it differed from the typical SGR bursts because of its harder spectrum.
- The discovery of simultaneous fast bursting emission at radio and high-energy from this Galactic source supports models based on magnetars for extragalactic FRBs, although the latter involve a larger radio energy output compared to the case discussed here.



Radio emission is preceding the gamma-ray one, by ~35 ms (Mereghetti+20)

Magnetar FRB connection (SGR 1935+2154)

- If all extragalactic FRBs were characterized by ratios of radio to X-ray fluences as large as the burst from SGR1935+2154, their detection with current high-energy satellites would be difficult. However, since it is clear that a single fluence ratio is not compatible with all available measurements, future multiwavelength (and especially high-duty - cycle)observations may reveal new associations.
- Mirroring the GRB–SGR(GF)–magnetar entanglement, the observation of FRB-like radio emission and gamma-ray flares from the known galactic magnetar SGR 1935 now opens the possibility that some of the sources that have been classified as FRBs consist of galactic magnetars so far unidentified at other wavelengths, while also providing strong support for a magnetar origin of extragalactic FRBs.
- Also in the case of FRBs, fast follow-ups at optical/NIR have not been successful yet

Conclusions on Colibrí & Magnetars

- Colibrí is well adapted for fast follow-up in the NIR/Optical range
- Magnetars suffer from lack of systematic follow-up in their burst-active state
- A Colibrí follow-up program (triggered by SVOM or not) of Magnetars is highly exploratory but could provide exciting results on these enigmatic sources. We aim at a deep limit in H, about 21 mag in one hour.
  - In case of short "nearby" GRB we propose 1 hour of gri observations reaching a 24.4 mag limit, allowing to exclude the GRB nature and possible implying the extragalactic Giant Flare origin
  - In both cases we would need a revisit the next night for correct sky subtraction
- Magnetars are important astrophysical objects linking NS, GRBs, and potentially FRBs
- All of you are invited to join this project!