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EXCELENCIA MARÍA DE MAEZTU

MAGNESIA

The first outburst of the young magnetar Swift J1818.0-1607

Abubakr Ibrahim

N. Rea , A. Borghese, F. Coti Zelati, E. Parent, et al.

THE X-RAY UNIVERSE 2023

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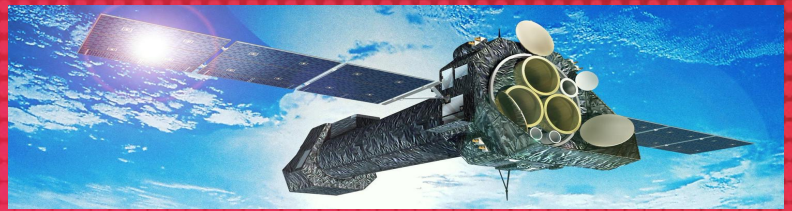
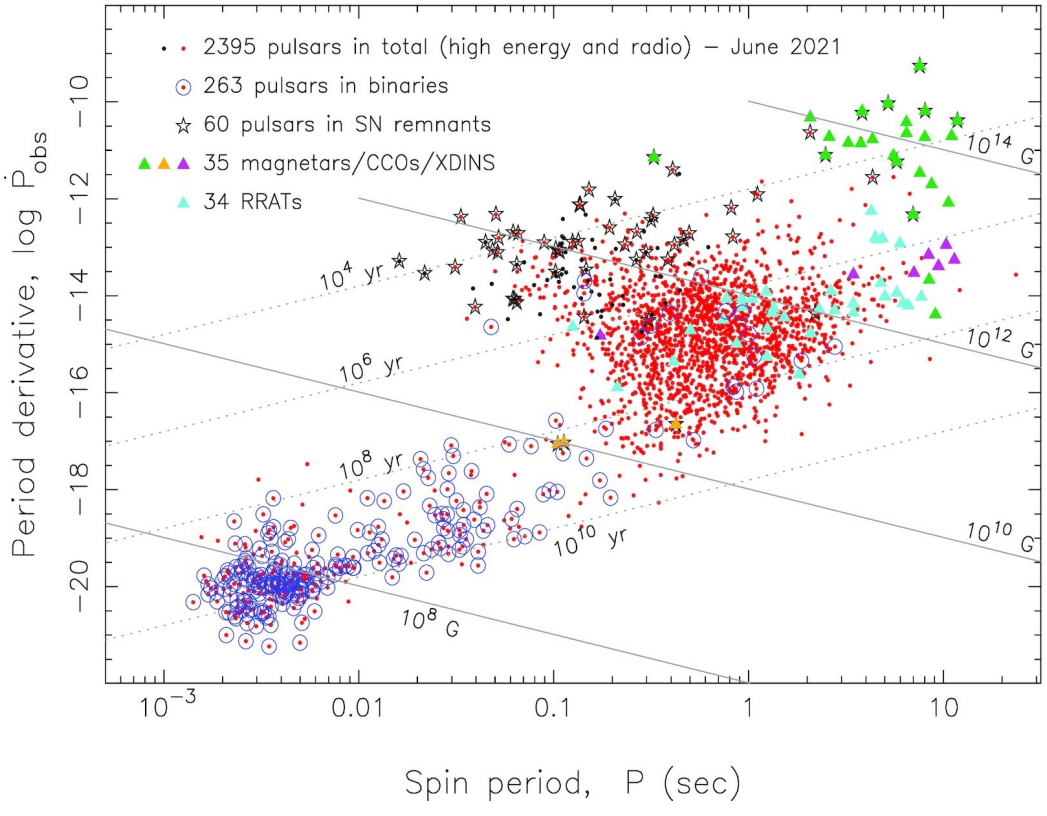


Introduction

Magnetars

- A sub-group of isolated neutron stars with ultra-high magnetic fields of 10^{14} --10^{15} G.
- The decay of their B powers their electromagnetic radiation
- P ~ 0.3 – 12 s
- Pdot ~ 10^{-13} – 10^{-11} s s^{-1}
- Soft X-ray emission with luminosities in the range of L_X ~ 10^{31} – 10^{36} erg s^{-1}



Duncan & Thompson (1992); (Kaspi & Beloborodov 2017; Esposito et al. 2021), Fig: Jawor & Tauris (2022)

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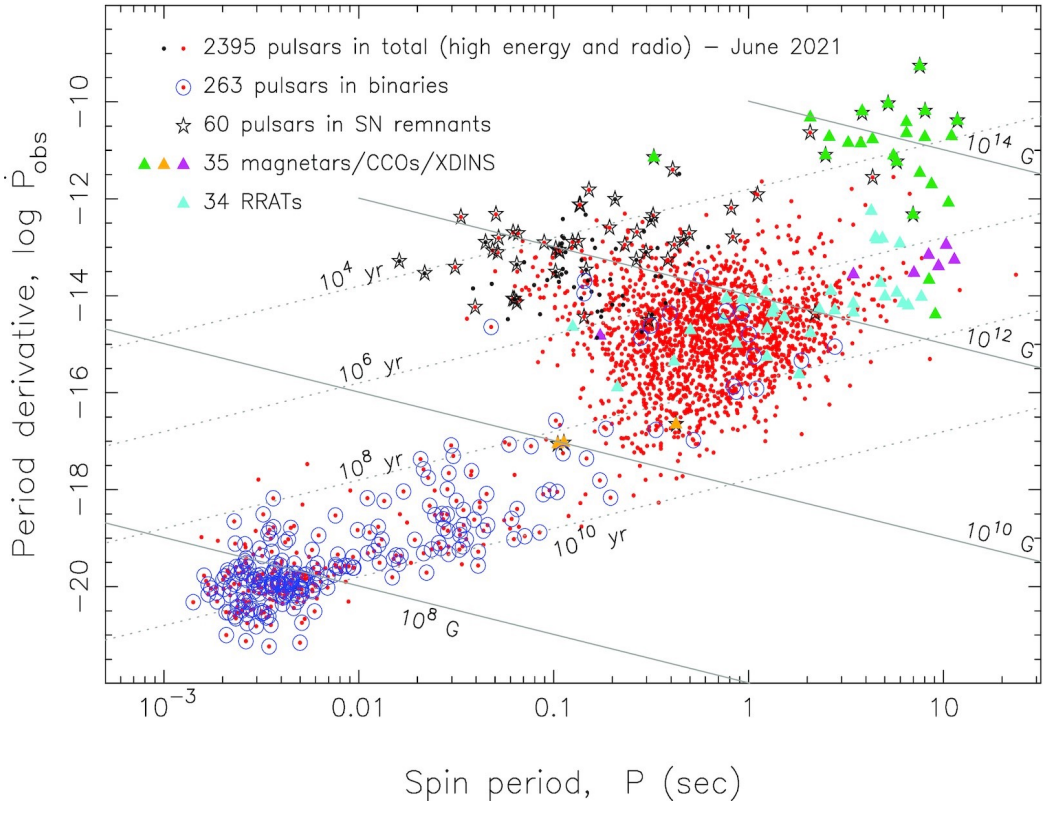
Transient Activities:

- Bursts (milliseconds to seconds)
- Giant flares (seconds to tens of minutes)
- Outburst: A sudden increase in their persistent X-ray fluxes (10–1000)



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The discovery of Swift J1818

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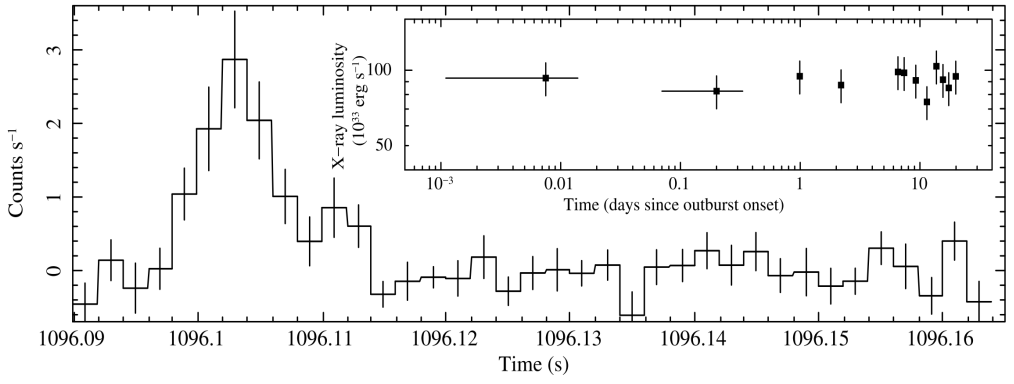
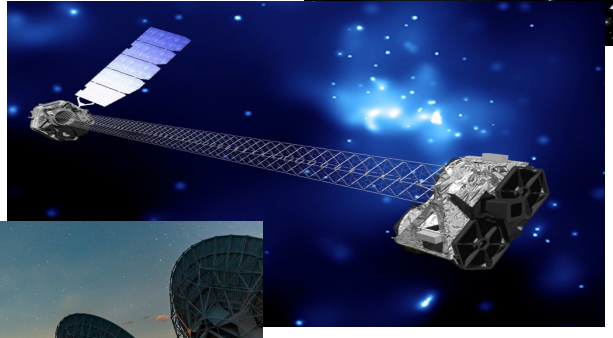
- Discovered in 2020 March through an outburst
- P ~ 1.36 s
- Radio observations confirmed Swift J1818 is a new radio-loud magnetar
- Pdot ~ 8.2×10^{-11} ss^{-1}
- B ~ 3.4×10^{14} G (leads to tau ~ 265 yrs)



Ref: Esposito et al. 2020; Evans et al. 2020; Karuppusamy et al. 2020; Champion et al. 2020

Observations

- Shortly after its outburst from March 2020--October 2021 (19 Months)
- X-ray monitoring campaign with XMM-Newton (~137 ks) and NuSTAR (~180 ks)
- Radio continuum observations with the Very Large Array (VLA)



Credits: ESA-C. Carreau, NASA/JPL-Caltech, Bettymaya Foott, NRAO/AUI/NSF

Spectral Analysis

Diffuse X-ray emission

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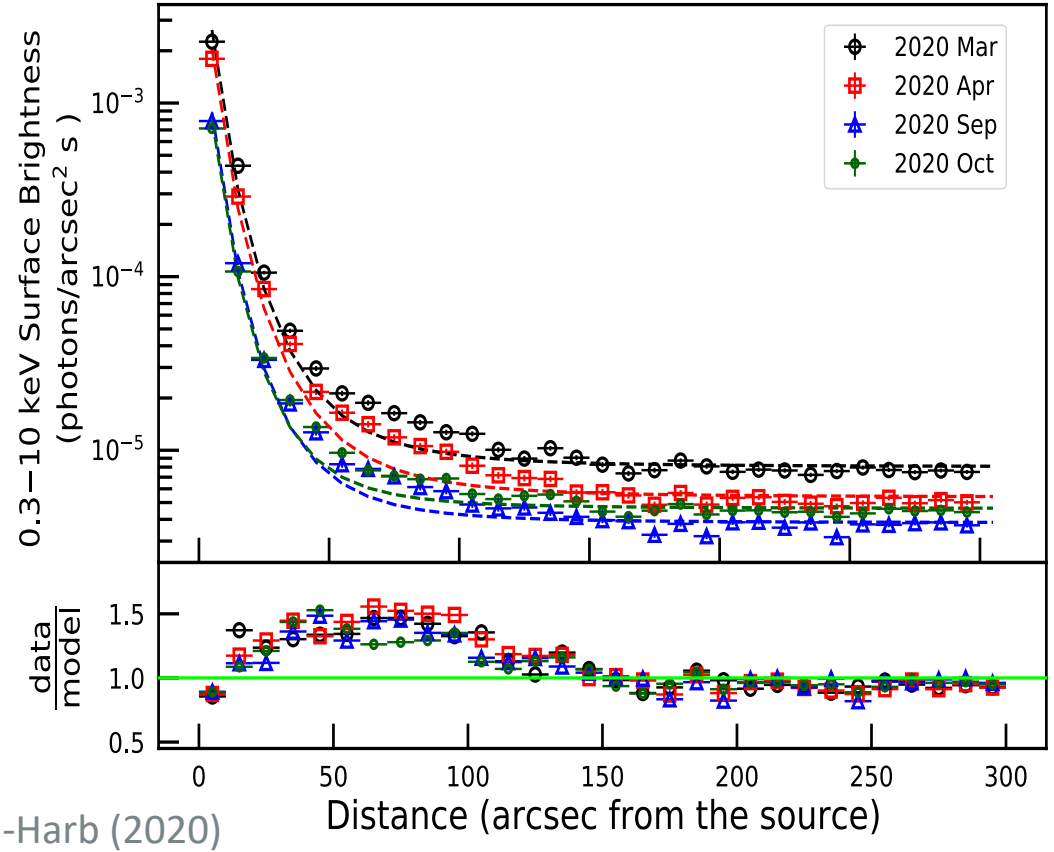
- Previous work reported a detection of a diffuse emission
- Use EPIC-pn data to infer about the spatial extent of the diffuse emission
- Extract a radial profile of the observed surface brightness (up to 300") and fit with the king function (PSF)



Ref: Esposito et al. (2020) , Blumer & Safi-Harb (2020)

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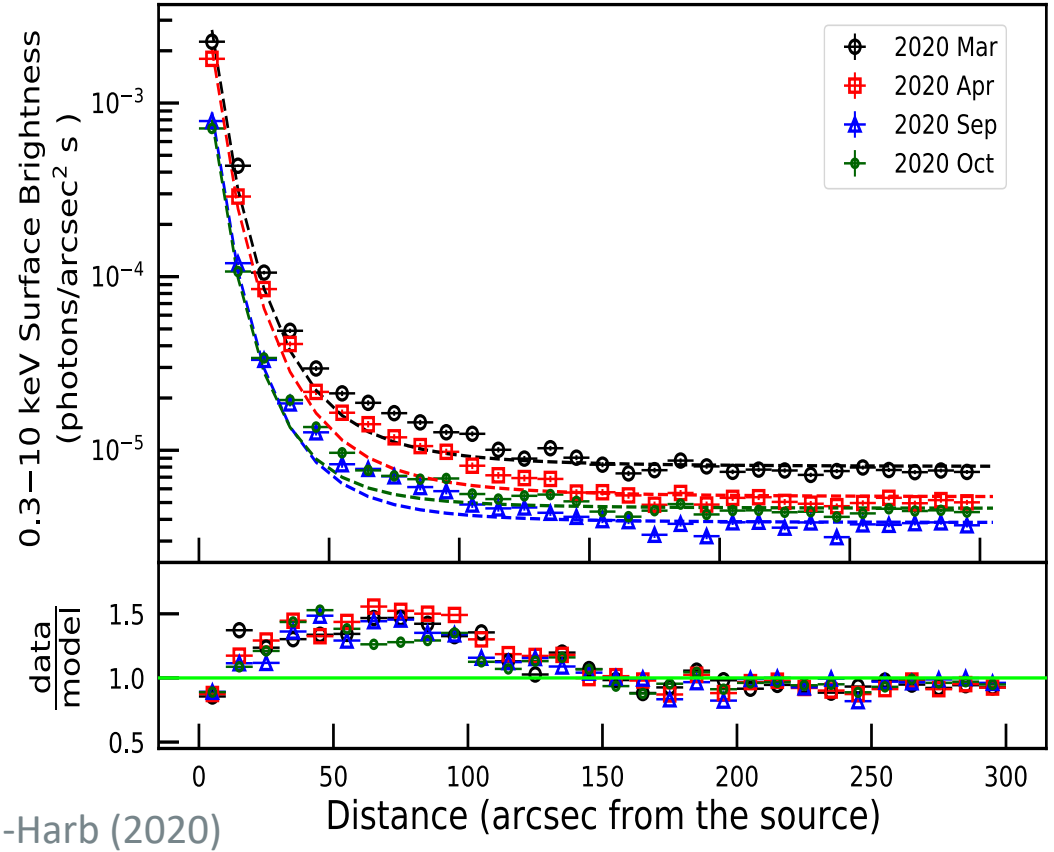
diffuse emission within ~ 50" – 110"



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Spectral Analysis

Diffuse X-ray emission

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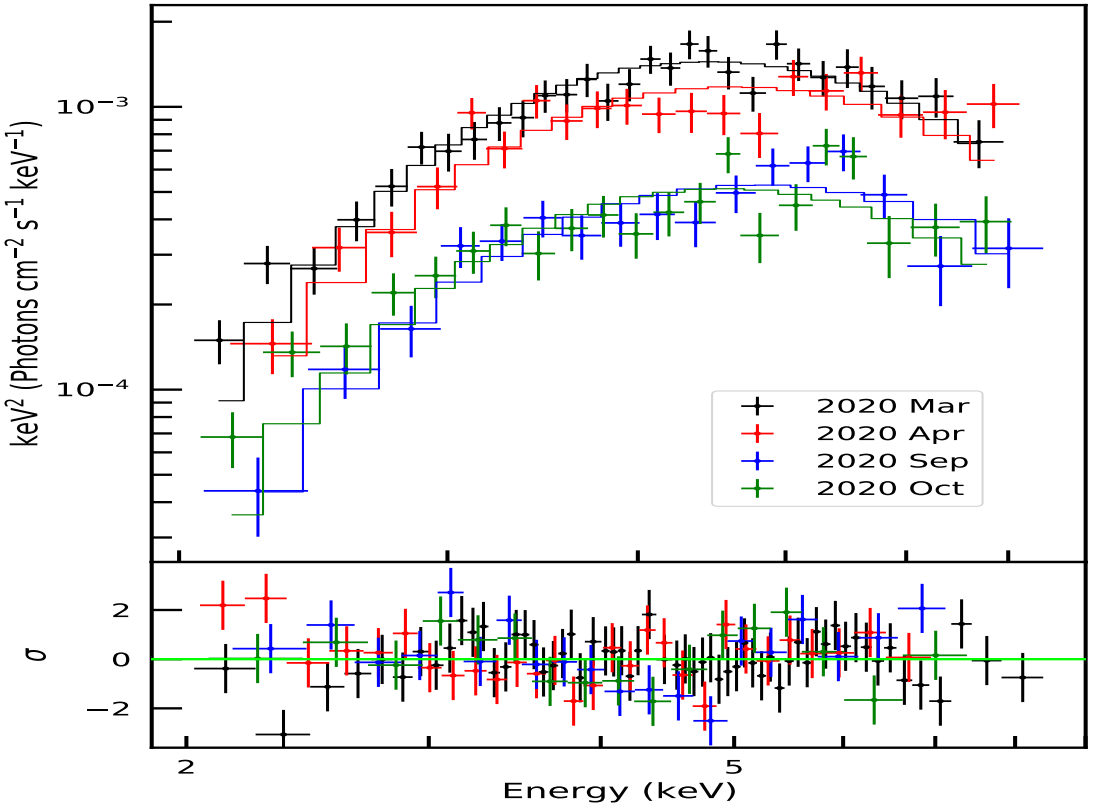
- Extract 2 -- 8 keV spectra by selecting photons with an annulus (50"--110") centered on the source.
- The best fit (χ_r^2~1.2) with a single BB model



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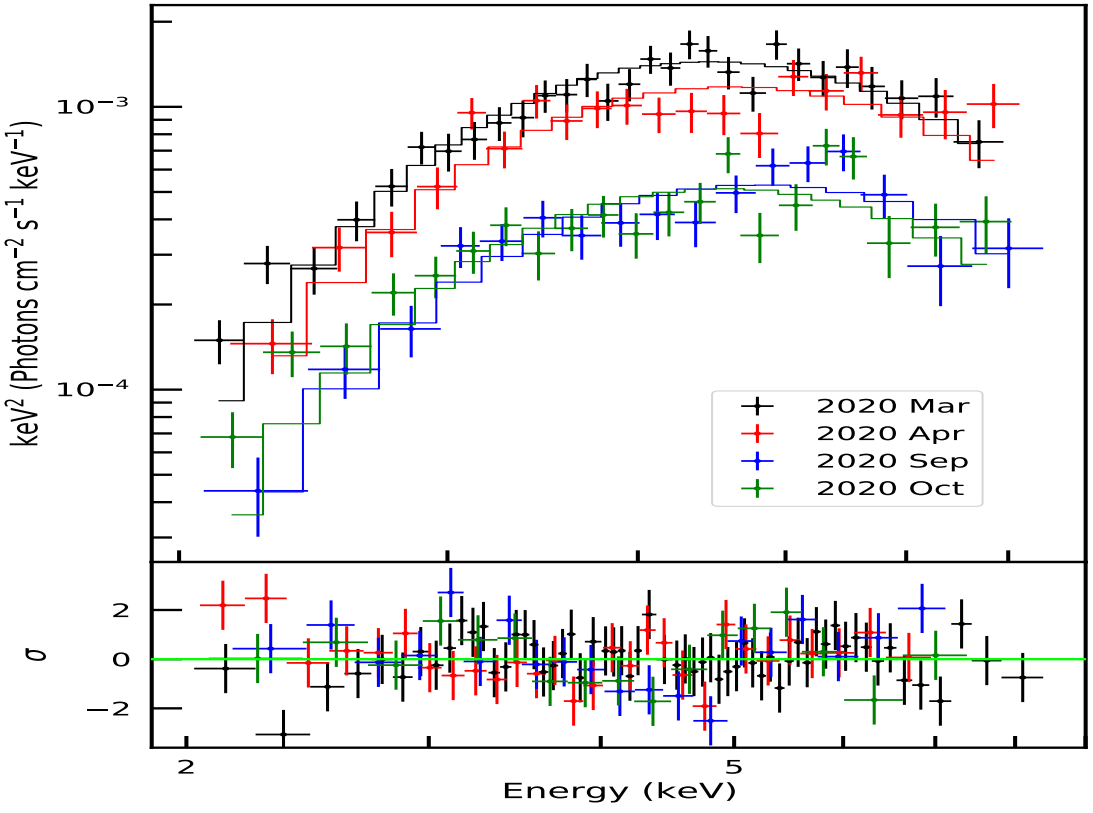
35% flux reduction of the diffuse X-ray emission ➔ the dust scattering-halo is the main source of the diffuse X-ray emission



Spectral Analysis

X-ray emission of Swift J1818

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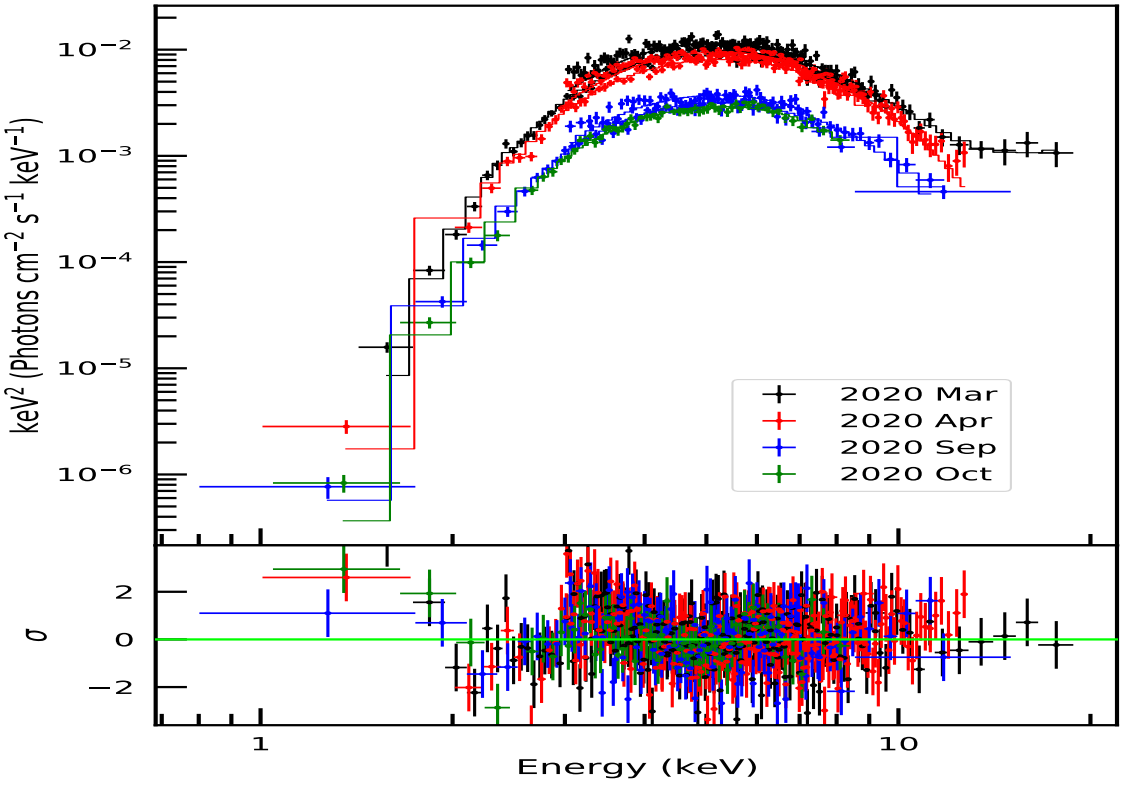
EXCELENCIA MARÍA DE MAEZTU

- Performed following the standard procedure with XSpec package
- 1--10 keV XMM-Newton/EPIC-pn and 3 --13 keV NuSTAR/FPMA(3) spectra
- Best model: BB+PL with a reduced ch^2 = 1.4



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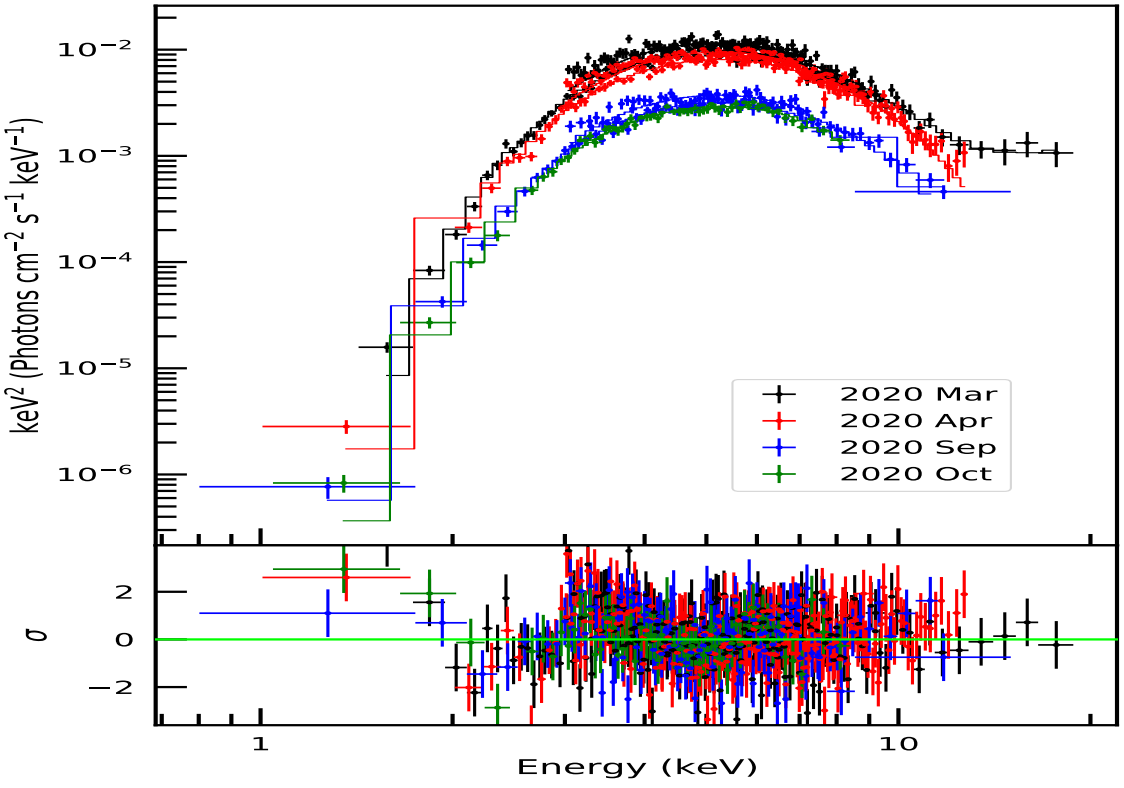
$N_H \sim 1.24\ (0.02) \times 10^{23}\ cm^{-2}$

$kT_{BB} \sim 1.1$ keV

$\Gamma \sim 1.0\ (+/-0.6)$



Spectral Analysis

Long-term spectral evolution

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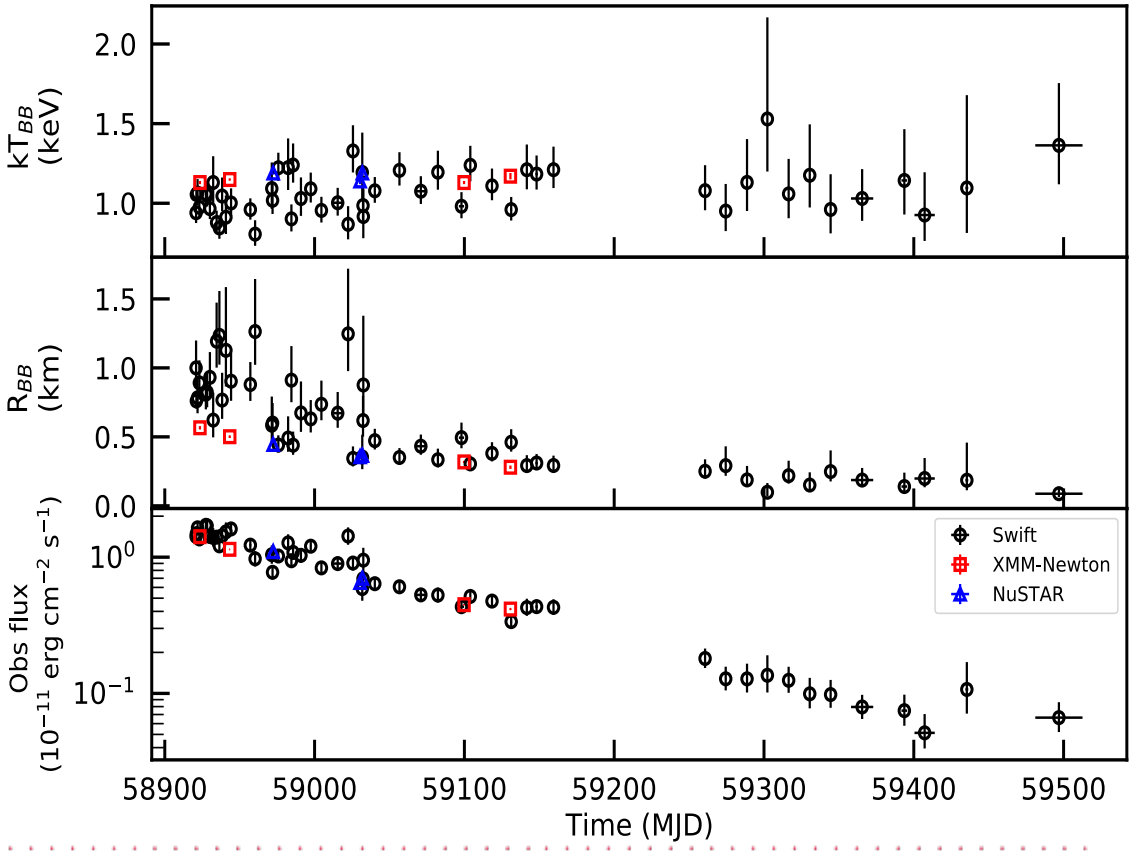
- Swift/XRT monitoring campaign
- Modelled with an absorbed BB model (fixed N_H)



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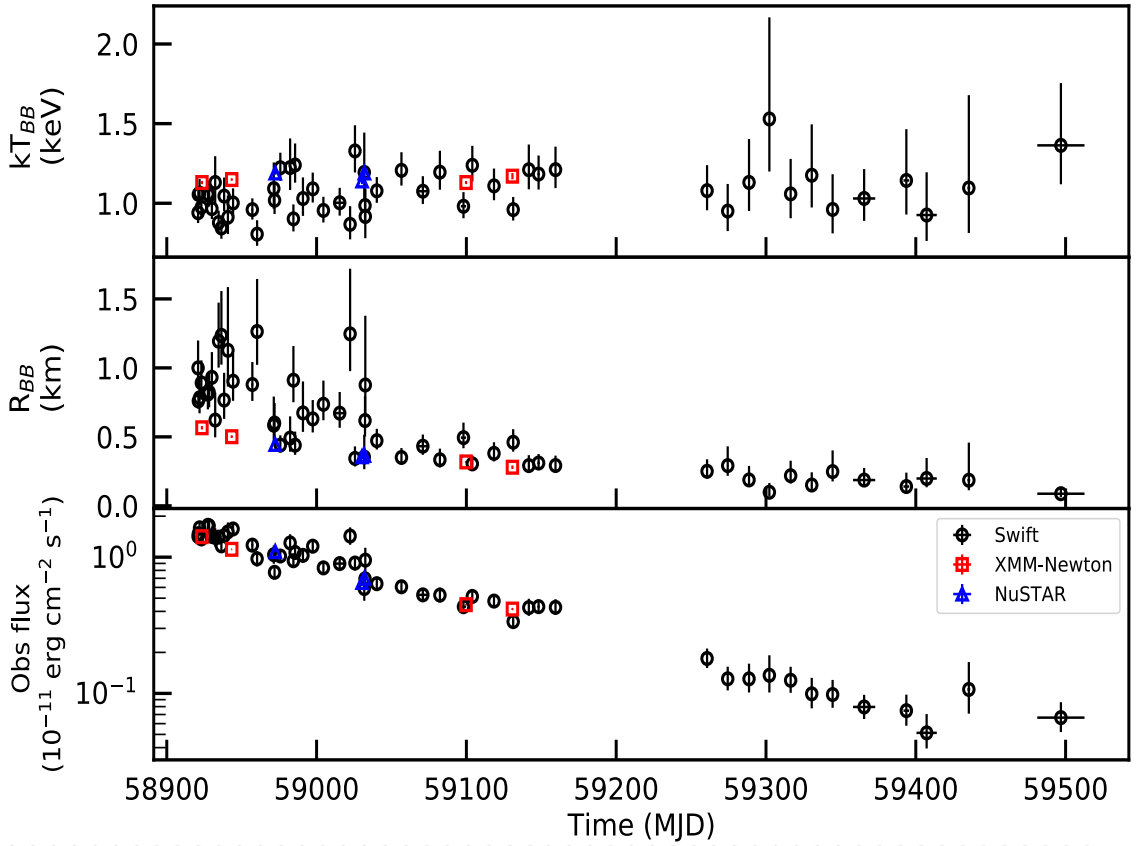

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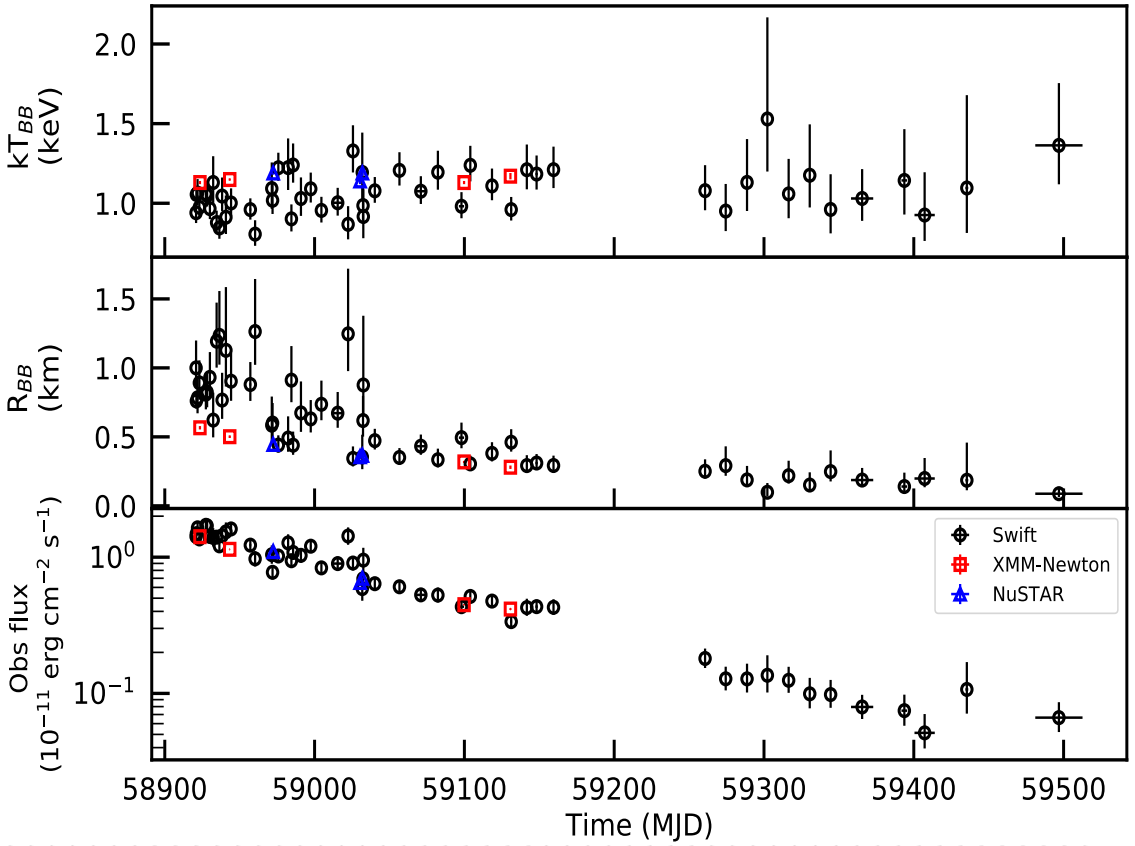
- Decreasing on the BB radius during the first seven months, from 0.6 to 0.3 km, then settled at an average of 0.2 km



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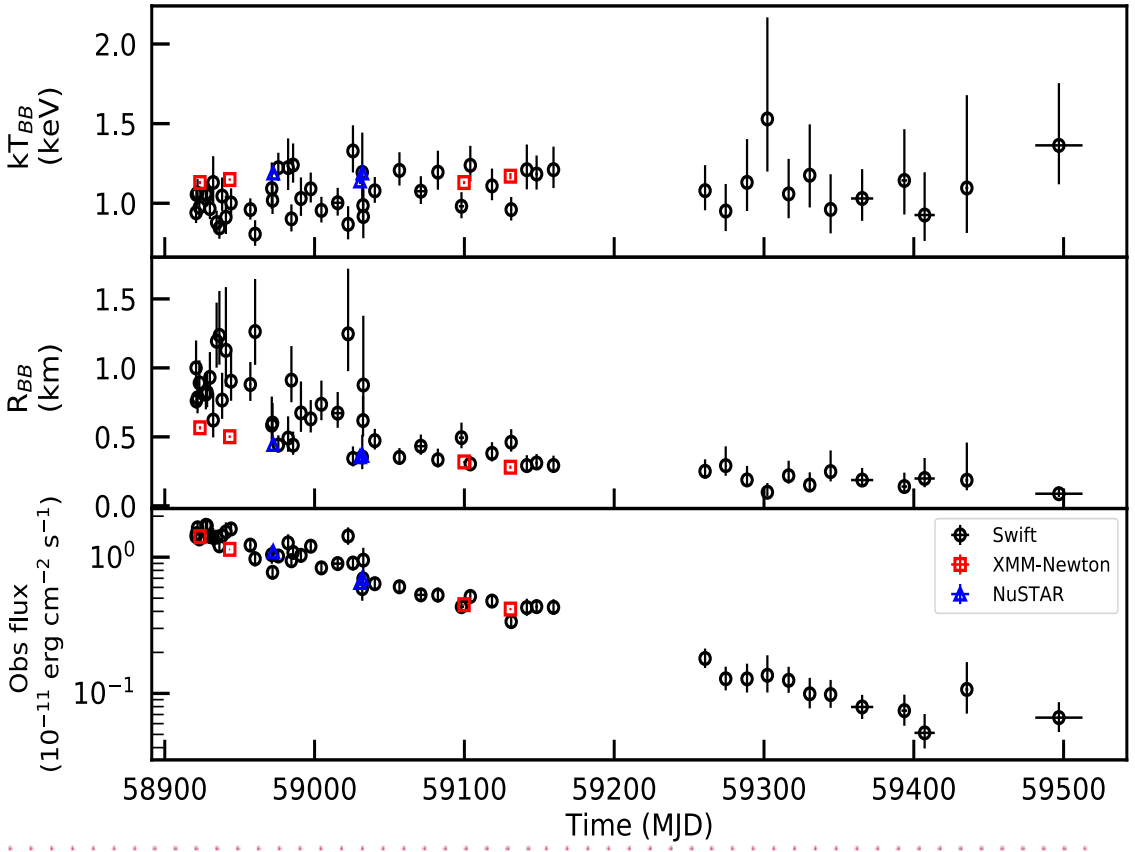
- Decreasing on the BB radius during the first seven months, from 0.6 to 0.3 km, then settled at an average of 0.2 km
- Almost a constant blackbody temperature of 1.1 keV



Radio observations

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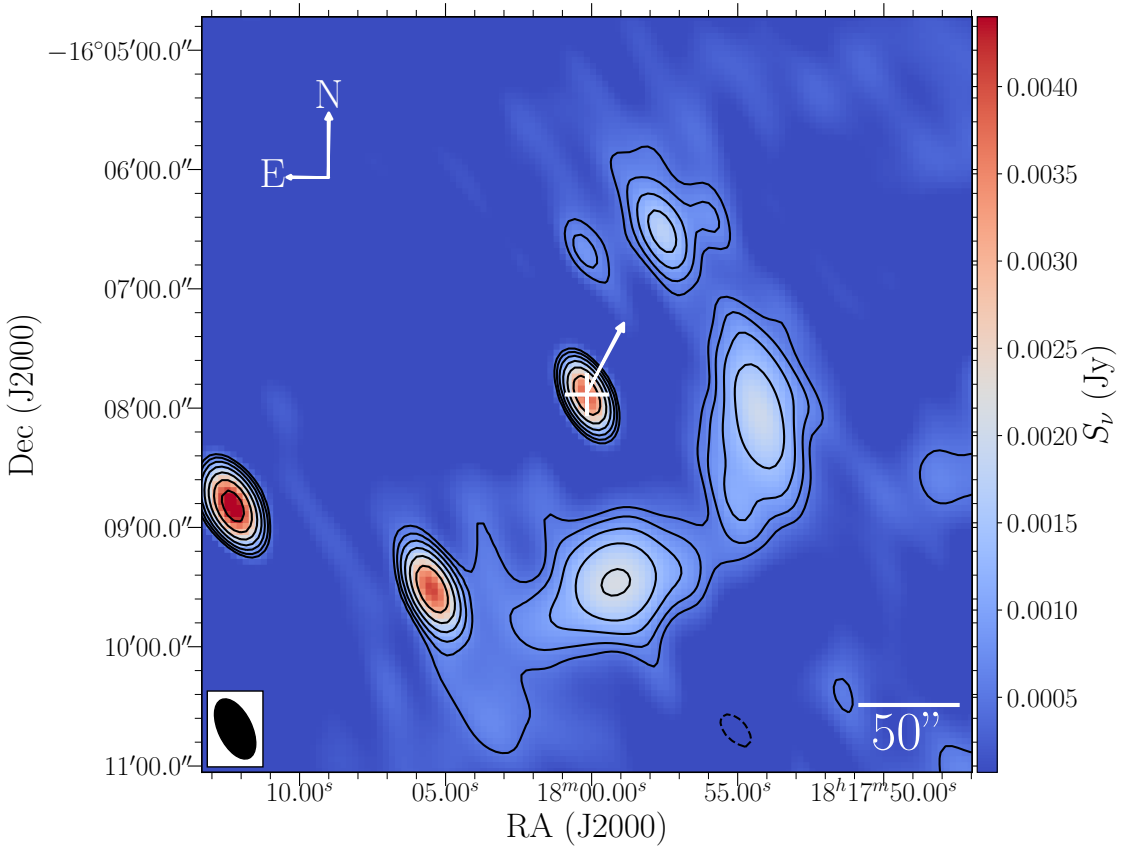
- Performed with VLA in 2021 March 22, within S-band
- Detection of a radio counterpart of the J1818 (as a point source) with peak flux density of 4.38 (0.05) mJy
- Detection of a bright half-ring of the diffuse structure at 90" to the west of the source



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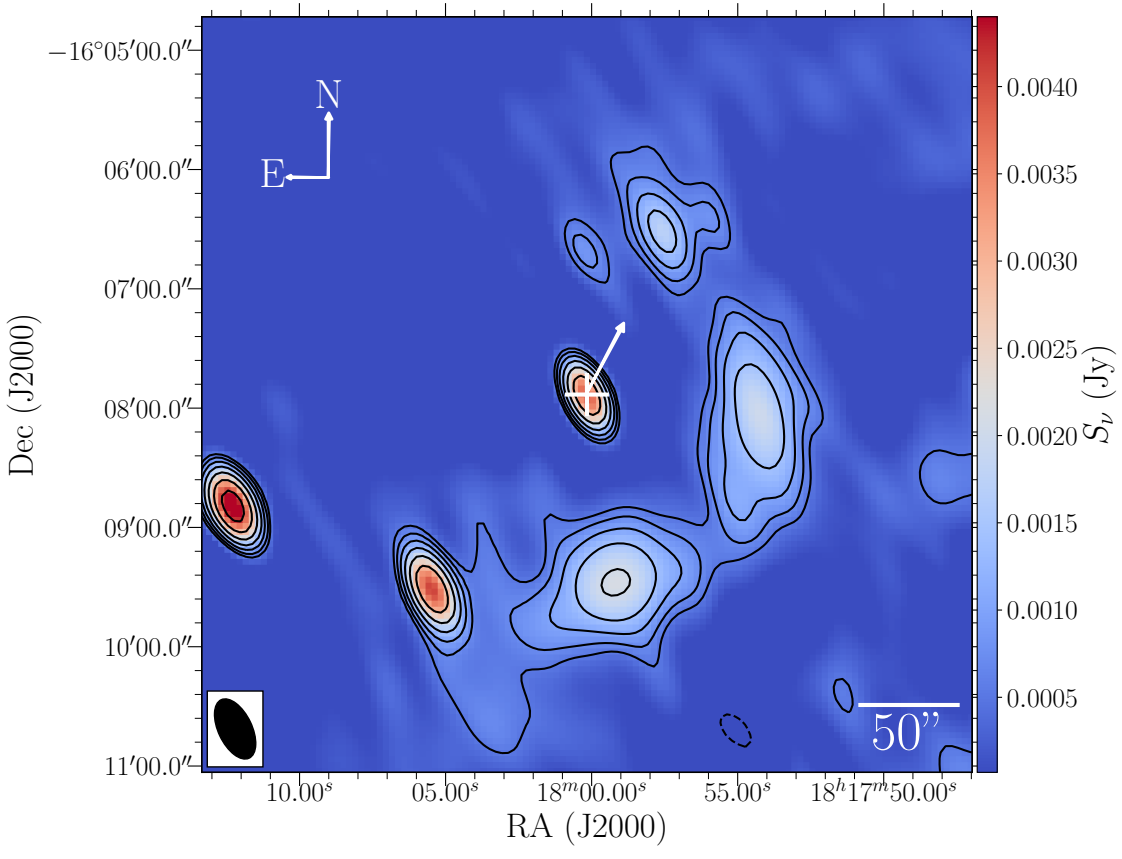

This could be associated with the supernova remnant of this young magnetar

Timing Analysis

- Phase-coherent timing solution was not feasible due to the *phase ambiguity* during the phase connection procedure
- The spin frequencies for each epoch were calculated using ToAs

Instrument/Obs.ID	Ref. Epoch (MJD)	ν (Hz)
$XMM/0823591801$	58923.40	0.7334073(7)
$NuSTAR/80402308002$	58923.40	0.7334068(2)
$XMM/0823593901$	58943.30	0.733356(6)
$NuSTAR/80402308004$	58944.00	0.7333558(6)
$NuSTAR/80402308006$	58972.40	0.73329(3)
$NuSTAR/80402308008$	59030.40	0.7331763(4)
$NuSTAR/80402308010$	59031.90	0.733173(1)
$NuSTAR/80402308012$	59099.50	0.7330509(3)
$XMM/0823594001$	59099.80	0.7330506(5)
$XMM/0823594201$	59130.60	0.7330035(5)

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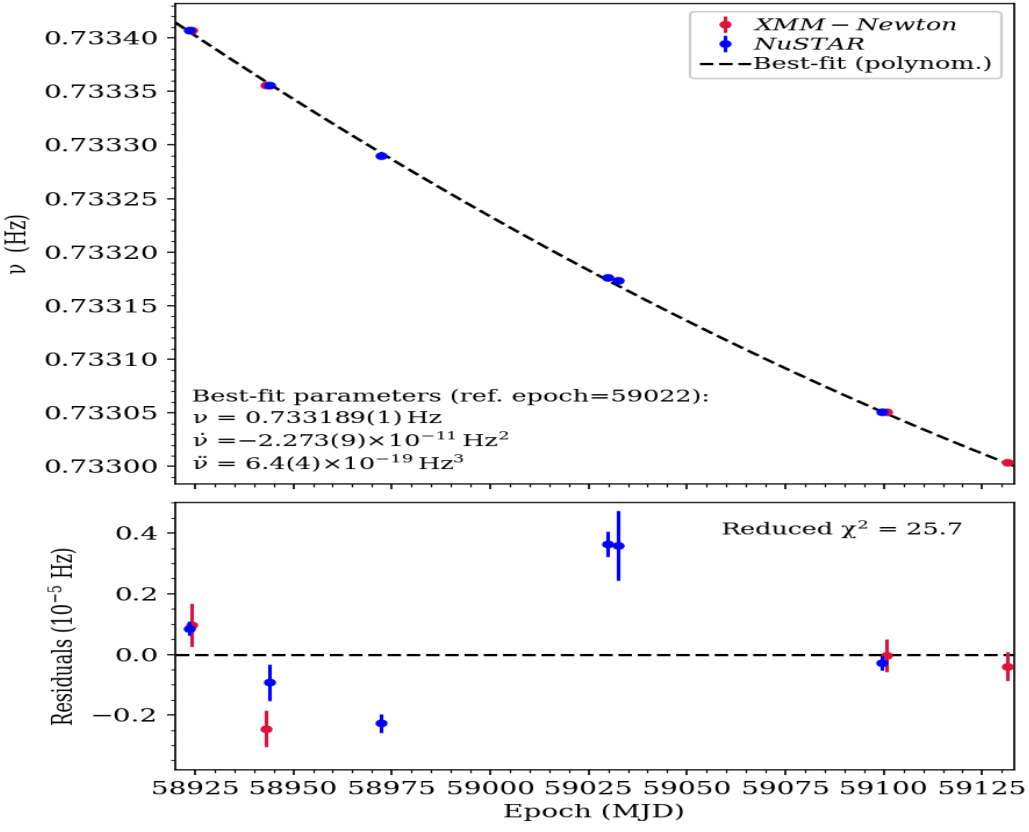
- Phase-coherent timing solution was not feasible due to the *phase ambiguity* during the phase connection procedure
- The spin frequencies for each epoch were calculated using ToAs
- The long-term average spin evolution v(t) was fit with a second order polynomial function
- The best-fit spin-down rate of $-2.273(9)\times10^{-11}$ Hz^2 at MJD 59022
- The large ch^2 is due to the large time gaps between the observations



Timing Analysis

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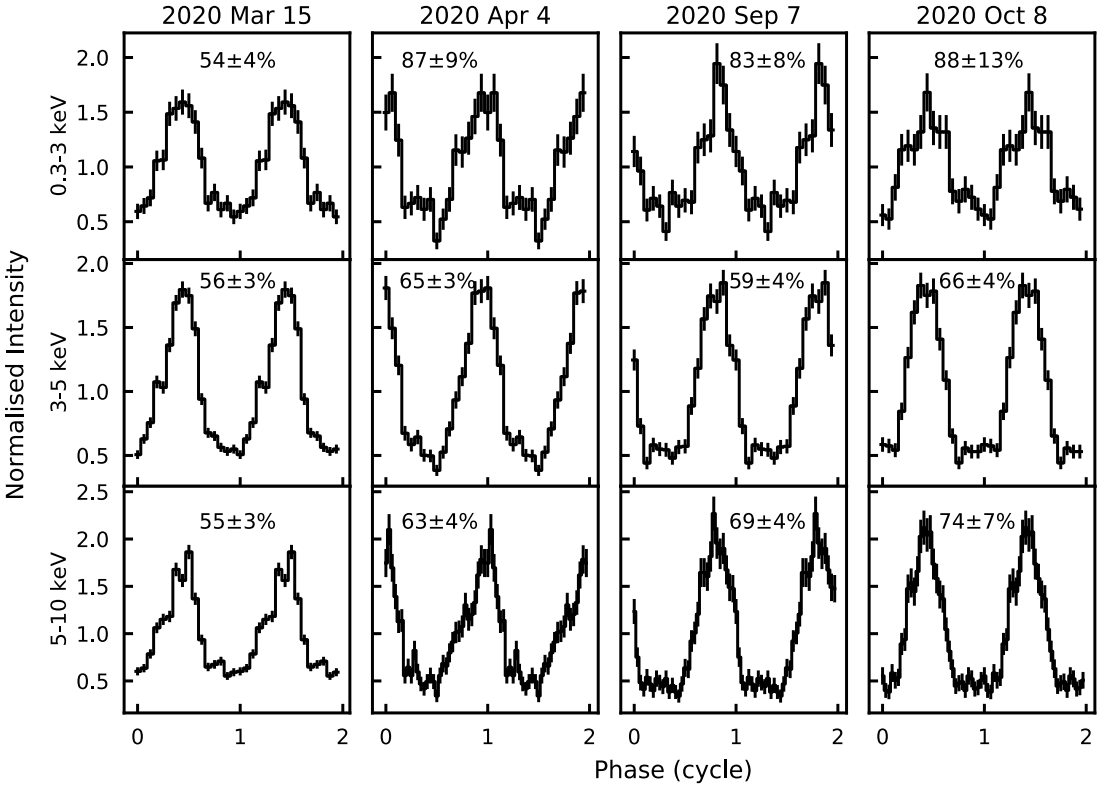
X-ray pulse profile

- To investigate possible changes in the shape and amplitude of the X-ray with the photon energy:
- Energy-resolved pulse profiles extracted from the EPIC-pn data sets in three energy bands
- Increasing pulsed fraction (PF) for a given energy band
- For the 0.3--10 keV energy interval: increase with time, from (53±2)% to (64±3)% between March and October 2020



Summary

- Swift J1818.0–1607 is a very young and radio-loud magnetar with a spin period of 1.36 s
- The long-term spectral evolution shows a rabid decay in the 1-10 keV flux
- The timing analysis reveals a large torque variability, with an average spin-down rate of -2.3×10^{-11} Hz^2
- Confirm the bright diffuse X-ray and radio emission
- The diffuse X-ray emission might be due to a dust scattering halo and that the radio structure may be associated with the supernova remnant of this young pulsar, based on its morphology

Thank You!

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Observations

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Table A1
Observation Log of Swift J1818, Including the Observations Analyzed by Esposito et al. (2020) above the Double-horizontal Solid Lines

Instrument[a]	Obs.ID	Start YYYY-MM-DD hh:mm:ss (TT)	Stop	Exposure (ks)	Count rate[b] (counts s^{-1})
Swift/XRT (PC)	00960986000	2020-03-12 21:18:22	2020-03-12 21:36:48	1.1	0.15 ± 0.01
Swift/XRT (PC)	00960986001	2020-03-12 22:57:45	2020-03-13 05:13:02	4.9	0.14 ± 0.01
Swift/XRT (WT)	00960986002	2020-03-13 20:47:55	2020-03-13 21:21:15	2.0	0.16 ± 0.01
Swift/XRT (PC)	00960986003	2020-03-15 00:10:37	2020-03-15 03:36:52	1.5	0.14 ± 0.01
NuSTAR/FPMA	80402308002	2020-03-15 03:58:21	2020-03-15 15:58:03	22.2	0.443 ± 0.005
XMM/EPIC-pn (LW)	0823591801	2020-03-15 07:57:47	2020-03-15 14:41:12	22.1	1.45 ± 0.01
Swift/XRT (WT)	00960986004	2020-03-19 09:33:11	2020-03-19 11:16:56	1.7	0.19 ± 0.02
Swift/XRT (WT)	00960986005	2020-03-20 04:34:19	2020-03-20 04:49:56	1.8	0.20 ± 0.01
Swift/XRT (WT)	00960986006	2020-03-22 02:35:21	2020-03-22 03:01:56	1.6	0.16 ± 0.01
Swift/XRT (WT)	00960986007	2020-03-24 05:51:38	2020-03-24 09:02:56	1.2	0.13 ± 0.01
Swift/XRT (WT)	00960986008	2020-03-26 05:40:29	2020-03-26 23:20:56	1.1	0.19 ± 0.01
Swift/XRT (WT)	00960986009	2020-03-28 03:40:53	2020-03-28 18:07:56	1.2	0.18 ± 0.02
Swift/XRT (WT)	00960986010	2020-03-29 16:25:13	2020-03-30 21:03:56	1.3	0.16 ± 0.01
Swift/XRT (WT)	00960986011	2020-04-01 19:17:34	2020-04-01 19:25:56	0.5	0.17 ± 0.02
NuSTAR/FPMA	80402308004	2020-04-04 02:01:09	2020-04-05 13:36:09	59.1	0.339 ± 0.002
XMM/EPIC-pn (FF)	0823593901	2020-04-04 03:44:15	2020-04-04 13:32:52	33.4	1.08 ± 0.01
Swift/XRT (WT)	00089033001	2020-04-05 05:51:22	2020-04-05 06:18:56	1.6	0.13 ± 0.01
Swift/XRT (WT)	00960986012	2020-04-17 11:22:40	2020-04-18 17:58:56	2.1	0.22 ± 0.01
Swift/XRT (WT)	00960986013	2020-04-21 01:15:46	2020-04-21 12:42:55	1.3	0.17 ± 0.01
Swift/XRT (WT)	00960986014	2020-05-02 07:58:09	2020-05-02 12:50:56	1.3	0.13 ± 0.02
NuSTAR/FPMA	80402308006	2020-05-02 20:56:09	2020-05-03 20:26:09	42.2	0.277 ± 0.003
Swift/XRT (PC)	00089033002	2020-05-02 22:22:26	2020-05-02 22:49:53	1.6	0.08 ± 0.01
Swift/XRT (PC)	00969823991[c1]	2020-05-06 17:38:19	2020-05-06 17:48:46	0.6	0.08 ± 0.01
Swift/XRT (PC)	00969823001[c1]	2020-05-06 18:43:12	2020-05-06 20:42:42	1.9	0.09 ± 0.01
Swift/XRT (WT)	00969823002	2020-05-13 05:39:09	2020-05-13 10:16:56	1.3	0.13 ± 0.01
Swift/XRT (WT)	00969823003	2020-05-15 05:19:42	2020-05-15 20:02:56	1.6	0.13 ± 0.01
Swift/XRT (PC)	00972614991	2020-05-16 15:04:54	2020-05-16 16:27:25	1.7	0.08 ± 0.01
Swift/XRT (WT)	00969823004	2020-05-21 20:38:46	2020-05-21 22:24:56	1.9	0.10 ± 0.01
Swift/XRT (WT)	00969823005	2020-05-28 00:46:46	2020-05-28 20:09:56	2.5	0.14 ± 0.01
Swift/XRT (WT)	00969823006	2020-06-04 08:14:35	2020-06-04 18:08:56	2.7	0.12 ± 0.01
Swift/XRT (WT)	00969823007[c2]	2020-06-12 01:11:04	2020-06-13 07:21:56	1.5	0.13 ± 0.01
Swift/XRT (WT)	00969823008[c2]	2020-06-15 08:53:23	2020-06-15 12:12:55	0.4	0.12 ± 0.02
Swift/XRT (WT)	00969823009[c2]	2020-06-18 19:16:44	2020-06-18 19:21:56	0.3	0.10 ± 0.02
Swift/XRT (WT)	00969823010	2020-06-21 20:47:49	2020-06-22 21:07:56	3.1	0.05 ± 0.01
Swift/XRT (WT)	00969823011	2020-06-25 05:54:07	2020-06-25 23:46:56	3.1	0.07 ± 0.01
NuSTAR/FPMA	80402308008	2020-06-30 02:46:09	2020-06-30 15:16:09	23.5	0.129 ± 0.002
NuSTAR/FPMA	80402308010	2020-07-01 19:01:09	2020-07-02 01:01:09	12.3	0.161 ± 0.003
Swift/XRT (PC)	00089033003	2020-07-01 19:49:42	2020-07-01 20:12:54	1.4	0.041 ± 0.006
Swift/XRT (PC)	00980513991	2020-07-02 07:11:35	2020-07-02T08:34:14	1.7	0.061 ± 0.006
Swift/XRT (WT)	00969823012	2020-07-02 08:49:43	2020-07-02 16:22:56	1.7	0.059 ± 0.006
Swift/XRT (PC)	00089033004	2020-07-10 01:31:26	2020-07-10 08:10:54	3.6	0.059 ± 0.004
Swift/XRT (PC)	00089033005	2020-07-26 12:23:40	2020-07-26 18:58:52	3.8	0.050 ± 0.003
Swift/XRT (PC)	00089033006[c3]	2020-08-07 03:12:00	2020-08-07 08:10:52	2.8	0.057 ± 0.005
Swift/XRT (PC)	00089033007[c3]	2020-08-12 17:14:14	2020-08-12 17:33:52	1.2	0.031 ± 0.005
Swift/XRT (PC)	00089033008	2020-08-21 00:20:13	2020-08-21 14:47:27	3.0	0.044 ± 0.004
Swift/XRT (PC)	00089033009[c4]	2020-09-04 07:12:43	2020-09-04 10:36:53	1.4	0.041 ± 0.006
NuSTAR/FPMA	80402308012[d]	2020-09-07 00:41:09	2020-09-08 00:11:09	39.3	0.097 ± 0.001
XMM/EPIC-pn (FF)	0823594001	2020-09-07 15:12:48	2020-09-07 22:38:50	26.7	0.429 ± 0.005
Swift/XRT (PC)	00089033010[c4]	2020-09-07 17:58:15	2020-09-07 19:30:52	2.0	0.043 ± 0.005
Swift/XRT (PC)	00089033011	2020-09-11 17:17:33	2020-09-12 04:34:52	4.8	0.044 ± 0.003
Swift/XRT (PC)	00089033012	2020-09-26 00:03:15	2020-09-26 20:39:53	4.5	0.040 ± 0.003
XMM/EPIC-pn (FF)	0823594201	2020-10-08 10:24:17	2020-10-09 00:49:31	49.4	0.288 ± 0.004
Swift/XRT (PC)	00089033013	2020-10-08 14:47:04	2020-10-09 20:58:54	4.8	0.036 ± 0.003
Swift/XRT (PC)	03110882001	2020-10-19 08:54:19	2020-10-19 23:37:52	4.7	0.037 ± 0.003
Swift/XRT (PC)	00089033014	2020-10-25 09:43:50	2020-10-26 23:59:52	4.2	0.038 ± 0.003
Swift/XRT (PC)	00089033015	2020-11-06 06:55:28	2020-11-06 16:48:54	4.2	0.035 ± 0.003
Swift/XRT (PC)	00013996001	2021-02-15 09:24:24	2021-02-15 22:35:52	4.5	0.018 ± 0.002
Swift/XRT (PC)	00013996002	2021-03-01 00:16:23	2021-03-01 21:05:53	3.8	0.013 ± 0.002
Swift/XRT (PC)	00013996003	2021-03-15 14:26:25	2021-03-15 17:58:53	4.6	0.009 ± 0.002
Swift/XRT (PC)	00013996004	2021-03-29 01:52:19	2021-03-29 10:10:54	4.5	0.009 ± 0.001