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GRB 080319b and SN1054

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Abstract. A typical SN Type IIp model can fit the SN1054 explosion light curve when data coming from European sources are also considered. Though a detailed study of these texts reveals a number of problems in their precise datation, it is likely that they actually describe the observation of an unusual celestial event which occurred in a day near to the one of Pope Leo IX's death (19 April, 1054). In particular, they seem to show that a very bright transient celestial phenomenon, lasting about 30 min, was observed. We already suggested that this Medieval testimonies were due to a very short and bright light flash in the first phase of the SN precursor collapse. The discovery of a similar flash in GRB 080319b brought us to consider this hypothesis more deeply. We thus scaled the intensity of the GRB 080319b to a distance of 1.83 kpc, in order to evaluate the intensity of a similar flash in the SN1054. We then took this value as input of the atmospheric optical effects simulation code *HaloSim3*, using the point-like source option for the dates and sites reported in European texts connected with the SN1054 event, and in various atmospheric conditions. The results are remarkably similar to the effects reported in Medieval chronicles.

1. Introduction

The supernova explosion of AD 1054, which originated the Crab Nebula and Pulsar, is an astronomical event which has been deeply studied by means of historical sources. Apart from the well-known testimonies of the Chinese Song Empire, which give us just two photometric points (on 4 July 1054, and 17 April 1056, respectively), a lot of additional information could be collected from western sources to derive an approximate lightcurve, dating the SN "flash" event back to 11 April, 1054.

In fact, the final lightcurve best resembles that of a IIp SN showing the typical decay due to the production of 0.07 $M_{\odot}$ of ^{56}Ni. We noticed Polcaro & Martocchia (2005) that a single point may be out from the fit: that is the very first one, obtained from the *Tractatus de Ecclesia S. Petri Aldenburgensi*, the chronicle of the Church of St. Peter in Oudembourg (in present day Belgium) written by an anonymous monk or clerk some 20 years after the reported events. In the original text the event brilliance is described as comparable to the Sun brilliance:

Qui beatissimus pontifex Leo post initium constructionis praefati templi sancti Petri sequenti anno 18 Kal. Maii, feria 2, circa meridiem feliciter migravit a seculo. Et in ipsa hora transitus sui a corpore non solum Romae, ubi corpus eius iacuit, verum etiam in toto orbe terrarum ***circulus eximiae claritatis hominibus apparuit in coelo per spatium fere mediae horae****, Domino fortasse demonstrante, quod ipse* ***coronam*** *inter diligentes se percipere dignus esset in caelo.*[1]

[1] *And the most blessed Pope Leo, after the beginning of the construction of the aforementioned*

Middle Age sources clearly entail several problems regarding both the precise datation of the events and their interpretation, because getting rid of symbolic motives is not easy. Nevertheless this source is very likely to be the testimony of a truly unusual celestial phenomenon which occurred in a date very near to the day Pope Leo IX passed by (19 April, 1054).[2]

Taking the source "literally" one should believe, as we suggested, that the flemish monk has been the only human being to observe a true SN "flash" right in the initial minutes of the explosion - within *half a hour*, apparently, as said in the latin original (and stressed in boldface above). It is interesting to see what physical implications would this observation have, first of all from the point of view of the event energetics.

On 19 March, 2008, a GRB exploded and could be promptly observed in all spectral bands, including optical, with the newest-generation instruments: GRB 080319b Cwiok et al. (2008); Bloom et al. (2009). The optical flash was so luminous that it overlapped the naked-eye visibility threshold ($m_V \simeq 5.7$). The flash was in fact the intrinsically most luminous optical transient ever observed; on the other hand the decay was rather rapid (see Fig.7 in Bloom et al. (2009)). The newest luminosity distance estimate, based on a "standard" cosmological model with $H_0 = 71$ km s^{-1} Mpc^{-1} and the observed spectral redshift $z = 0.937$, is 6.01×10^6 kpc i.e. a comoving distance of about 3.1 Gpc[3]. Therefore this explosion was about 10^6 times more energetical than that of an "average" SN (see Fig.5 in Bloom et al. (2009)).

This unexpected astronomical event gave us the opportunity for a simple *Gedankenexperiment*. Let us scale the GRB 080319b optical lightcurve to the distance of SN1054, that is the nowadays' Crab Nebula ($\simeq$ 1.98 kpc): we find that, for some minutes, such a SN would have a brilliance comparable to the Sun brilliance ($m_{V\odot} \simeq -26.7$) in our sky, and would remain more luminous than about magnitude -15 *per spatium fere mediae horae*.

Moreover, it would remain visible with naked-eye in the daylight for more than two months (in the conservative hypothesis of a naked-eye daylight visibility threshold of about -3.5 magnitudes[4]). Let us remember that, considering the lightcurve derived from all our historical sources, the SN1054 was observed until the end of July, that is for more than three months after its appearance on April 11^{th}. An "ordinary" SN at the Crab distance would not stay visible in the daylight for more than a few minutes.

Going on with the *Gedankenexperiment*, we asked ourselves what the appearance would be of such an extremely luminous source in the day sky - a source comparable to the Sun for luminosity, but pointlike for geometry. We used the online simulator *HaloSim3*[5], which allows to compute disc- or pointlike celestial objects refraction figures created in the sky by atmospheric ice cristals. Of course, the effects depend on several variables including: the source intensity (i.e. number of rays used for the ray-tracing procedure), its height over the horizon, atmospheric conditions (pencentage and shape of the ice cristals). With the most triv-

church of St. Peter, in the following year, on the 18th day before the rst of May, a Monday, around midday, happily departed this world. And at the same hour as his leaving of the esh, not only in Rome, where his body lies, but also all over the world there appeared to men a circle in the sky of extraordinary brightness which lasted for about half an hour. Perhaps the Lord wished to say that he [the Pope] *was worthy to receive a crown in Heaven between those who love Him.* (Guidoboni, Marmo & Polcaro 1994)

[2] Some problems arise if we try to date the event precisely: the actual date of the Pope's death was Tuesday, April 19, while April 14th was a Thursday. However, from a deeper analysis of the Flemish text and from its comparison with the Arabic text discovered by Brecher et al., 1978, it was suggested that the exact day of the event was April 12, 1054 (Guidoboni, Marmo & Polcaro, 1993 and 1994).

[3] Mihran Vardanyan's *iCosmos* web calculator: `http://icosmos.co.uk/`; for more reference on cosmological distances see e.g. Hogg (2000).

[4] For reference on precise calculations see e.g. `http://cdsads.u-strasbg.fr/abs/1983QJRAS..24..246H`

[5] *HaloSim3* online calculator: `http://www.atoptics.co.uk/halo/halfeat.htm`

Table 1. The historical records of SN1054 (revised version of Table 2 in Polcaro & Martocchia, 2005).

Date	CD	Ref.	location	appearance as...	likely m_V / notes
04/11/1054	6132	a.	Fustat	*star*	
04/11/1054	6132	b.	Flanders	*bright disk at noon*	~ -7
04/24/1054	6145	c.	Ireland	*fiery pillar*	
late April 1054		d.	Rome	*bright light*	< -3.5
05/10/1054	6161	e.	Liao Kingdom	*star*	during Sun eclipse
05/14/1054	6165	f.	Armenia	*star*	
late May 1054(?)		g.	Italy	*very bright star*	
late May 1054		h.	Japan	*new star... as Jupiter*	~ -4.5
June 1054		h.	Japan	*star*	
$\sim$ 06/20/1054				Crab in conjunction with Sun	not visible
07/04/1054 ? (*)	6216 ?	i.	Song Empire	*star... like Venus*	~ -3.9
08/27/1054 ? (*)	6270 ?	i.	Song Empire	*star... like Venus*	~ -3.9
1055		a.	Constantinople	*star*	
04/17/1056	6869	i.	Song Empire	*no more visible*	$> +6$

JD=CD+2100000
References: a. *Diary of Ibn Butlan* b. *Tractatus de ecclesia ...* c. *Irish Annals* d. *De Obitu Sancti Leonis* e. *Sung-shih hsin-pien* f. *Etum Patmich* g. *Rampona Chronicles* h. *Mei Getsuki* i. *Sung hui-yao*.

(*) *For 23 days* - but the datation may have been falsified (or may just refer to the communication to the Emperor), thus to be possibly shifted before.

ial assumptions about a superluminous, pointlike object at the Crab coordinates, appearing in the Oudembourg (51^o) sky at noon in an atmosphere dense of randomly-oriented exagonal cristals we get the sort of image which is reproduced in Fig.1. This indeed looks like a *circulus eximiae claritatis* or even a *corona* in the sky.

Similarly spectacular forms - or even more spectacular, when exotic ice cristals distributions are considered - are produced by the simulator when setting the latitude to Rome (41.5^o). It is worth remembering what Libuin, a Roman chronicler, wrote about "the death of Saint Leo" ("De Obitu Sancti Leonis"):

Qua scilicet hora quidam, Albertus nomine, ceteri quinque de Tudertina urbe protestati sunt, vidisse se ***quasi stratam pallis fulgentibus adornatam et innumeris coruscantem lampadibus****, qua anima eius ab angelis ducebatur ad coelum...* ("A man named Albert and five other people from Todi say that, at the same time, they saw something that looked like a road, decorated with wonderful adornments and shining with innumerable lamps, along which his soul was led to the heaven by angels").

Interestingly, we have indipendent confirmation that solar halos observations were recorded with high precision by European observers in that epoch: for instance, a chronicler of the Quedlinburg Abbey wrote in AD 1020 Ghignoli & Polcaro (2007):

Deinde in XV Calend. August., feria II, luna XXIII, incipiente hora diei III usque post VI, apparuit circulus magnus circa solem colorem iris habens, quem alii quatuor lucidiores circuli binis loris in modum crucis complexi sunt; attamen tribus rarescentibus duo, id est medius et aquilonaris, diutissime perstiterunt. ("Then, on July 18th, a Monday, 23rd moon, at the beginning of the 3rd hour of the day, till after the 6th, a large circle surrounding the Sun appeared, with the color of the rainbow, which embraced other four brighter circles with two strings from both sides, forming a cross; while three were vanishing, two, i.e. the central and the southern one, lasted for a very long time").

The difference between Sun halos and the halos produced by a pointlike source with a

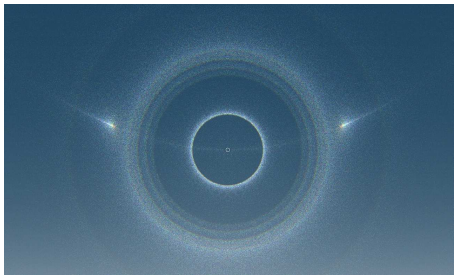

Fig. 1. A "SN halo" calculated with *HaloSim3* for the parameters described in the text.

magnitude similar to the solar magnitude is that the latter may show an even more precise shape, with well-defined forms, like in a drawing, since the central source is not diffuse - and there is no sun shining in the middle, of course.

Our *Gedankenexperiment* thus leads to three conclusions: (1) the occurrence of SN events of such a huge luminosity in our sky is possible, as a matter of principle, if GRB 080319b is confirmed to be a SN at cosmological distance; (2) a hyperluminous source in our sky may produce amazing halos, with even better-defined geometrical shapes than in the case of solar halos; (3) SN1054 lightcurve, as we derived it from several historical records, is pretty similar to the optical lightcurve of GRB 080319b apart from distance (flux) scaling. Although serious Middle-Age phylological criteria prevent us from claiming for sure that the Oudembourg text has to be taken literally, i.e. as a precise observation report, nevertheless we want to stress here that the physical elements given in that text are all plausible.

More well-funded criticism about the hypothesis that the anonymous monk of Oudembourg was really looking in the direction of a SN precursor in the very first 30 minutes following the collapse may come from other reasons. First of all, such an extremely energetic SN explosion in the Earth "vicinity" is an unlikely event, from a strictly statistic point of view. Moreover, it is an event whose possible consequences on the Earth atmosphere and life itself should be investigated, since ionizing radiation would streak as powerfully as the optical radiation does.

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