**2020 年湖北省科技奖（自然科学奖）提名**

**公示内容**

1. **项目名称：中子星在极端恒星爆发现象中的关键作用**
2. **提名者及提名意见**

**提名者：华中师范大学**

**提名意见：**

极端恒星爆发过程是检验恒星演化理论的重要途径，是探索极端条件下基本物理规律的天然实验室。该项目紧紧围绕爆发过程中所产生中子星的能量输出效应，在伽马射线暴、超亮超新星、快速射电暴等天文学前沿方向获得了如下重要科学发现：（1）基于引力波辐射对新生中子星演化的重要影响，揭示了中子星星风对伽马射线暴余辉辐射的重要贡献，为余辉光变曲线的多样性提供了理论解释。（2）揭示了超亮超新星和伽马射线暴中子星能源的统计关联，为理论上统一这两类不同天文现象的物理起源奠定了重要基础。（3）限制了能够产生快速射电暴现象的中子星的物理属性（年龄、磁场等），从而为将此类奇特现象与前两类爆发现象的联系提供了重要支持。五篇代表作共获SCI引用95次，其中他引66次，获得了国际天文界的广泛认可。项目主要完成人俞云伟曾于2011年获全国优秀博士学位论文作者奖、于2013年入选教育部新世纪优秀人才计划、于2018年获国家自然科学基金委优秀青年基金项目资助。

**提名该项目为湖北省自然科学奖 一 等奖**

1. **项目简介**

恒星的剧烈爆发现象是大质量恒星演化末期可能经历的一个重要环节，是中子星等致密天体的主要产地，是宇宙中物质循环的重要通道。揭示伽马射线暴和超亮超新星等极端恒星爆发现象的能量来源和爆发机制是当前天文学研究的一个重要目标。为此，基于公开的天文观测资料，该项目从多个理论角度论证了一颗新诞生的快速旋转高度磁化中子星（毫秒磁星）在这些爆发过程所起到的关键作用，获得了如下几个方面的重要成果：

**一、揭示了中子星星风对伽马射线暴余辉辐射的重要贡献。**一直以来，伽马射线暴的余辉辐射都被认为主要来源于抛射物的外激波作用过程。该项目从新生中子星的早期演化（特别是考虑的引力波辐射的影响）入手，提出中子星的星风可直接产生X射线余辉辐射，从而为理解余辉光变曲线的多样提供了合理的解释。同时也为研究新生中子星性质打开了一个通道。

**相关引用和评价举例如下：**

1. **Oganesyan et al. 2020, ApJ, 893, 88:** The plateau phase, observed up to several ×10^4 s requires long-lasting activity of the central engine, which can be provided either by the long-term evolution of the accretion disk around a black hole (Kumar & McMahon 2008; Cannizzo & Gehrels 2009; Lindner et al. 2010) or by the spin-down power released by a newly born millisecond spinning and highly magnetized neutron star (Dai & Lu1998a, 1998b; Zhang and Mészáros 2001; Dai 2004; **Yu et al. 2010;** Dall’Osso et al. 2011; Metzger et al. 2011).
2. **Beniamini & Mochkovitch 2017, A&A, 605A, 60:** Several studies have suggested a spinning down highly magnetized pulsar (“magnetar") as the origin for the plateau of GRB 070110 (Troja et al. 2007; Lyons et al. 2010; **Yu et al. 2010;** Du et al. 2016).
3. **Kumar & Zhang 2015, Physics Reports, 561, 1:** One possibility is that the entire observed X-ray afterglow of these GRBs is powered by a long-lasting central engine model. It can be from a millisecond magnetar without collapsing into a black hole (e.g. Yu et al., 2010). The canonical X-ray lightcurve can be matched with the accretion history in the collapsar GRB model ( … ) or with the spindown power of a magnetar central engine (**Yu et al., 2010;** Metzger etal., 2011)”。
4. **Lü & Zhang 2014, ApJ, 785, 74:** Since the observed X-ray emission may not come from the external forward shock emission (e.g. can be from external reverse shock, Dai 2004; Yu & Dai 2007, or from internal dissipation of the magnetar wind, **Yu et al.2010**), these GRBs could be still powered by magnetars.
5. **Rowlinson, et al. 2010, MNRAS, 409, 531:** Magnetar models have also been proposed to explain late central engine activity in SGRBs, for example late time plateaus in the X-ray afterglows (Fan & Xu 2006; **Yu, Cheng, & Cao 2010;** Dall’Osso et al. 2010) and X-ray flares (Fan, Zhang, & Proga 2005; Gao & Fan 2006).

二、**揭示了超亮超新星和伽马射线暴中子星能源的统计关联并为它们的统一理论解释构建了框架。**不同于由放射性元素衰变所供能的普通超新星，超亮超新星的能量被认为主要来自于中心中子星，从而使它们与伽马射线暴现象存在相似性。该项目通过大样本的统计揭示了两类现象的差异主要来自于中心中子星磁场强度的不同，从而使这两类现象有可能被纳入到一个统一的理论框架中。该项目还将此思想推广到更为普通的超新星现象中，为宋史中对SN 1054超新星的历史记录做出了新的解释。

相关引用和评价举例如下：

1. **Blanchard et al. arrXiv: 2020.09508:** In addition to the complex shape of the pre-SN mass distribution itself, we ﬁnd a trend between the pre-SN masses and the magnetar initial spin periods; SLSNe with lower ejecta masses exhibit systematically slower initial spins. This conﬁrms initial indications of such a trend from the modeling of a smaller sample of bolometric light curves by **Yu et al. (2017).**
2. **Blanchard et al. 2018, ApJ, 865, 9:** Nicholl et al. (2017c) show that the engine parameter distributions of fast and slow SLSNe-I overlap with no clear offset; the slow events simply prefer somewhat lower magnetic ﬁelds and higher ejecta masses (see also **Yu et al. 2017**).
3. **Moriya et al. 2018, SSRv, 214, 59:** **Yu et al (2017)** also modeled 31 SLSNe similarly and found parameter ranges of initial period 1.4−12 ms, B = (0.5−4.8)×1014 G, and Mej = 0.5 − 17.9 M⊙

**三、限制了能够产生快速射电暴现象的中子星的物理属性。**快速射电暴现象是近年发现的一类十分奇特的天文现象，年轻中子星是这些现象非常可能的起源之一。因此，该项目对这些年轻中子星的属性做出了重要的限制，并预示它们很可能诞生于伽马射线暴和超亮超新星这两类爆发现象，为解决快速射电暴的起源问题做出了重要贡献。

**相关引用和评价举例如下：**

1. **Gourdji et al. 2020, arXiv: 2003.02706:** A related interpretation is that the persistent radio source is a nebula powered by a magnetar, supplying a highly magnetized plasma (e.g. Murase et al. 2016; Beloborodov 2017; **Cao et al. 2017;** Metzger et al. 2017; Nicholl et al. 2017).
2. **Straal et al. 2020, A&A, 634, A105:** Although the electron column density in the wind is Lorentz invariant (n0dl0 = ndl, **Yu 2014)**, the plasma frequency is not. In the observer’s frame the plasma frequency is Doppler-boosted (**Yu 2014; Cao et al. 2017**) and this needs to be taken into consideration when the determining the DM contributed by the wind.
3. **Kisaka et al. 2017, PASJ, 69, L9:** The propagation effects on the radio emission and the possible association of a persistent radio source could give signiﬁcant constraints on the model for FRB121102 (**Cao et al. 2017;** Dai et al. 2017; Kashiyama & Murase 2017; Lyutikov 2017; Metzger et al. 2017)…. This NS nebula model gives the constraints on the NS properties as the dipole ﬁeld ∼10^13–10^14 G, the initial rotation period ∼ a few ms, and the age ~10^2 yr (**Cao et al. 2017;** Dai et al. 2017; Kashiyama & Murase 2017; Lyutikov 2017; Metzger et al. 2017).
4. **Kokubo et al. 2017, ApJ, 844, 95:** The absence of the signiﬁcant DM contribution from the supernova remnant is consistent with the time-constancy of the observed DM of FRB121102 (Section 1), which requires that the supernova remnant, if present, should be older than ∼100 years and thus have little DM contribution of =100 pc cm^−3 (Murase et al. 2016; Piro 2016; **Cao et al. 2017;** Metzger et al. 2017; Tendulkar et al. 2017).

该项目自2009年实施以来，在国际天文学主流期刊ApJL，ApJ，MNRAS，A&A和国内天文学代表性期刊RAA上发表SCI论文19篇，获总引用313次（据NASA ADS统计）。在该项目执行期间，项目主要完成人俞云伟曾于2011年获全国优秀博士学位论文作者奖、于2013年入选教育部新世纪优秀人才计划、于2018年获国家自然科学基金委优秀青年基金项目资助。

1. **代表性论文专著目录（不超过5篇，其中国内科技期论文原则上不少于1/3）**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 序号 | 论文（专著）名称/刊名/作者 | 年、卷、页码 | 发表时间（年月 日） | 通讯作者（含共同） | 第一作者（含共同） | 国内作者 | 他引总次数 | 检索数据库 | 论文署名单位是否包含国外单位 |
| 1 | Constraining the Age of a Magnetar Possibly Associated with FRB 121102/ The Astrophysical Journal Letters/操小凤、俞云伟、戴子高 | 2017，839，L20 | 2017.4.20 | 俞云伟 | 操小凤 | 操小凤、俞云伟、戴子高 | 17 | SCI | 否 |
| 2 | A Statistical Study of Superluminous Supernovae Using the Magnetar Engine Model and Implications for Their Connection with Gamma-Ray Bursts and Hypernovae /[The Astrophysical Journal/俞云伟、朱锦平、李少泽、吕侯军、邹远川](https://publons.com/journal/936/)   | 2017，840，12 | 2017.5.1 | 俞云伟 | 俞云伟 | 俞云伟、朱锦平、李少泽、吕侯军、邹远川 | 20 | SCI | 否 |
| 3 | SN 1054: A pulsar-powered supernova? / Research in Astronomy and Astrophysics/李少泽、俞云伟、黄艳 | 2015,15,1823 | 2015.11 | 俞云伟 | 李少泽 | 李少泽、俞云伟、黄艳 | 0 | SCI | 否 |
| 4 | THE ROLE OF NEWLY BORN MAGNETARS IN GAMMA-RAY BURST X-RAY AFTERGLOW EMISSION: ENERGY INJECTION AND INTERNAL EMISSION/The Astrophysical Journal/俞云伟、郑广生、操小凤 | 2010，715，477 | 2010.5.20 | 俞云伟、郑广生 | 俞云伟 | 俞云伟、郑广生、操小凤 | 26 | SCI | 否 |
| 5 | Long-term evolution and gravitational wave radiation of neutron stars with differential rotation induced by r-modes/Research in Astronomy and Astrophysics/俞云伟、操小凤、郑小平 | 2009,9,1024 | 2009.9 | 俞云伟 | 俞云伟 | 俞云伟、操小凤、郑小平 | 3 | SCI | 否 |

1. **主要完成人（完成单位）（不超过5人）**

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| **序号** | **姓名** | **完成单位** |
| 1 | 俞云伟 | 华中师范大学 |
| 2 | 操小凤 | 湖北第二师范学院 |