Comparative adverbial phrases

Another interesting fact concerning the observations developed thus far is that even in English-type languages, when the crucial morpheme designating comparison is directly attached to the standard just as in the Japanese-type, the conceptual expansion is carried out without difficulty. This is achieved by employing adverbial phrases designating comparison. The present observation holds with regard to all the English-type natural languages cited in this study.

(5) a. Compared with (In comparison to) Japan, the population of Korea is small(er). [English]

b. *Im Vergleich zu Japan ist die Bevölkerung von Korea klein(er).* [German]

General cases of conceptual expansion

Turning our eyes to general cases of conceptual expansion, we find that arguments lexically selected by the predicate of a clause are to be ready targets of expansion, in contrast to adjunctional phrases in the periphery of the clause. (6a) is an instance of metonymy, where "*the kettle*" refers to the water in the kettle. However, the parallel expansion does not obtain in (6b). As an adjunct, the water contained in the kettle is not likely to be designated by the container. The intended meaning is realized in (6c), where a specific reference is made to the content of the kettle.

(6) a. The kettle is boiling.
(the kettle = the water in the kettle)

b. I put out the fire with the kettle.
(*the kettle = the water in the kettle)

c. I put out the fire with the water in the kettle.

"*The soup*" in (7a) refers to the fire heating the soup. Even if we know that the soup is put on the cooking stove, on hearing the utterance (7b), we will not take it to mean that the speaker got burnt by the fire heating the soup. Rather, the speaker got burnt by the soup itself. Thus, in the position of an adjunct, literal interpretations are readily selected.

(7) a. Turn off the soup. (the soup = the fire heating the soup)

b. I got burnt by the soup.
(*the soup = the fire heating the soup)

From the cases shown above, we can summarize the observations thus far presented in the following general formula:

(8) Entities profiled through either lexical selection or constructional importance will be readily selected as a target of conceptual expansion.

Conventional cases

The comparative structure in English has been claimed to reject an expanded reference of the standard expression. Nevertheless, conventional examples are attested in the position of the standard even though they are not semantically parallel with the subjects at face value.

(9) a. On that matter, the American administrators seem to have more flexibility than *the Kremlin*. (*the Kremlin* = administrators in the Russian government)

b. These stories are written better than *Shakespeare*.
(*Shakespeare* = Shakespeare's works)

The important thing in dealing with conventional cases is that it is hard to find examples where the expansion is admitted to participants only when they function as peripheral elements in the described event. "*The Kremlin*" will refer to the Russian administrators irrespective of the argument status of the phrase in question. In other words, this expansion has nothing to do with the peripheral character of comparative standards in English. Regarding the exceptional behavior of a conventional type of conceptual expansion, we can add a second principle to the one cited in (8) as follows:

(10) A conceptual expansion licensed only to entities in unprofiled positions is not likely to be observed.

This means when a conceptual expansion is observed in unprofiled positions, the same conceptual expansion will be readily observed in profiled positions, but not vice versa. In line with (10), (9) can be regarded as a subregularity subjected to a conventional type of expansion.

Summary

The discussion in the former part of the paper leads to the following generalizations which apply to the conceptual expansion in a restricted context of comparative constructions.

(11) a. The conceptual expansion of the standard of comparison readily occurs if the mandatory morpheme of comparison is attached to the standard.

b. If the relevant morpheme is attached to the comparative predicate, the expansion of the standard is not likely to occur.

Through the observation of expansion in more general contexts, these statements are interpreted as a realization of the principle stated in (8). And the unexpected expansions found in (9) can be treated with the principle (10) dealing mainly with the irregularity of conventional cases.

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X-ray Astronomy in the Laboratory with a Miniature Compact Object Produced by Laser-Driven Implosion

Paper in journals : this is the first page of a paper published in ***Nature Physics.***
[***Nature Physics***] 5, 821 – 825 (2009)

nature physics

LETTERS

PUBLISHED ONLINE: 18 OCTOBER 2009 | DOI: 10.1038/NPHYS1402

X-ray astronomy in the laboratory with a miniature compact object produced by laser-driven implosion

Shinsuke Fujioka[1]*, Hideaki Takabe[1], Norimasa Yamamoto[1], David Salzmann[1], Feilu Wang[2], Hiroaki Nishimura[1], Yutong Li[3], Quanli Dong[3], Shoujun Wang[3], Yi Zhang[3], Yong-Joo Rhee[4], Yong-Woo Lee[4], Jae-Min Han[4], Minoru Tanabe[1], Takashi Fujiwara[1], Yuto Nakabayashi[1], Gang Zhao[2], Jie Zhang[3,5] and Kunioki Mima[1]

X-ray spectroscopy is an important tool for understanding the extreme photoionization processes that drive the behaviour of non-thermal equilibrium plasmas in compact astrophysical objects such as black holes[1–4]. Even so, the distance of these objects from the Earth and the inability to control or accurately ascertain the conditions that govern their behaviour makes it difficult to interpret the origin of the features in astronomical X-ray measurements. Here, we describe an experiment that uses the implosion[5] driven by a 3 TW, 4 kJ laser system[6] to produce a 0.5 keV blackbody radiator that mimics the conditions that exist in the neighbourhood of a black hole. The X-ray spectra emitted from photoionized silicon plasmas resemble those observed from the binary stars Cygnus X-3 (refs 7, 8) and Vela X-1 (refs 9–11) with the Chandra X-ray satellite. As well as demonstrating the ability to create extreme radiation fields in a laboratory plasma, our theoretical interpretation of these laboratory spectra contrasts starkly with the generally accepted explanation for the origin of similar features in astronomical observations. Our experimental approach offers a powerful means to test and validate the computer codes used in X-ray astronomy.

X-ray spectroscopy with an X-ray satellite is the main observational method to give information about compact objects, especially black holes. Black holes are indirectly studied by observing the X-ray continuum from a heated accretion disc and the X-ray fluorescence from the ambient gas of the stellar wind and the surface of a companion star in their binary systems. To derive physical properties from the observations, X-ray astronomers rely on non-local-thermodynamical-equilibrium (LTE) atomic physics in a cold ambient gas subject to an extreme radiation field, for which the mean radiation temperature is of the order of 1 keV. Theoretical models have been developed on the basis of the observed spectra[1–4] and complex computer codes were developed to analyse the observed X-ray spectra[12–16]. The underlying assumption of these models is that the spectrum originates from a photoionized plasma. In other words, the intense radiation from the compact object photoionizes the gas, and generates a relatively low-electron-temperature highly ionized non-LTE plasma. However, laboratory experiments on non-LTE photoionized plasmas have not been possible, mainly owing to the lack of an intense source of X-ray continuum radiation. Only recently has pulsed power apparatus, laser and Z-pinch, reproduced the extreme conditions in the Universe[17–20].

Here, we present a terrestrial generation and spectroscopy of non-LTE photoionized plasma. The novelty of the present experiment is the notion that a laser-driven implosion can create a flash of brilliant Planckian X-rays that can be used to simulate X-rays from a astronomical compact object. X-ray spectra with two characteristic spectral peaks were observed for a photoionized silicon plasma generated in the laboratory. This spectral shape closely resembles those observed from Cygnus X-3 and Vela X-1, as shown in Fig. 1a–c. In Fig. 1a,c, even the small bump between the two peaks is reproduced. The spectral resolution in the experiment was $\Delta h\nu = 7$ eV owing to the size of the photoionized plasma ($500 \times 500\,\mu m^2$). This resolution is similar to that of the astronomical observations in Fig. 1b,c. The error bars in the laboratory experiment originate dominantly from signal fluctuation in the three different laser shots and those in astronomy originate from photon statics. Uncertainties of the energy scale are 2 eV in the laboratory experiment and in the range between 1 and 2 eV (refs 7, 9) in the astronomical observation.

Cygnus X-3 is a well-known X-ray object identified in the early stages of X-ray astronomy[21]. It is a binary system consisting of a black-hole candidate and a companion star. A schematic of such a binary system is shown in Fig. 2a, in which the gravitational energy of the accreting material is converted into thermal energy, which is the origin of the strong radiation emitted from the accretion disc[22]. Figure 1b shows an X-ray spectrum from Cygnus X-3 observed with a spectrometer onboard the Chandra X-ray satellite. The spectrum is thought to be strongly redshifted by 800 km s^{-1} (ref. 7). Line X-rays from highly ionized silicon ions are emitted from the surface of the companion star, the area of which is much larger than that of the accretion disc and the black hole. The electron temperature of the surface is determined to lie in the range of 5–50 eV by fitting the spectral shape of several radiative recombination continua[7,8]. This temperature is too low to ionize silicon atoms to hydrogen- and helium-like ions. This fact is direct evidence that the lines in the kiloelectronvolt range are

[1]Institute of Laser Engineering, Osaka University, 2-6 Yamada-oka, Suita, Osaka, 565-0871, Japan, [2]National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China, [3]Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 1000190, China, [4]Laboratory for Quantum Optics, Korea Atomic Energy Research Institute, 1045 Daedeok Street Yuseong-gu, Daejon 305-353, Korea, [5]Department of Physics, Shanghai Jiao Tong University, Shanghai 200240, China. *e-mail: sfujioka@ile.osaka-u.ac.jp.

The following is a comment on the published paper shown on the preceding page.

Miniature of X-ray Star in Osaka University

FUJIOKA Shinsuke, TAKABE Hideaki
(Institute of Laser Engineering)

Introduction

Development of inertial confinement fusion energy is a strong driving force behind operation and construction of big laser facilities, such as GEKKO-XII (Osaka University, Japan), OMEGA (University of Rochester, USA) and Z-pinch machines in the world. Extreme laser facilities, i.e. National Ignition Facility in United State and Laser MegaJoule in France, are now ready for the first realization of the controlled thermonuclear fusion ignition in the history of humankind. These pulse power apparatuses also enable us to create materials having high-energy-density, which do not exist naturally on the earth.

High-energy-density laboratory astrophysics [1] is a new discipline for investigating astronomical phenomena experimentally, including fundamental properties of material for x rays (opacity) and high pressure (equation of state), energy transport, hydrodynamics, and particle acceleration. In addition to traditional observations and computer simulations, such laboratory experiments confirm and deepen our understanding of astrophysical phenomena, thereby enabling quantitative comparison between experimental results, astronomical observations, and model predictions under well-defined conditions. Here, we report a novel laboratory experiment of astronomical photoionized plasma generated with a high-power laser [2, 3].

Background

One example of the astronomical photoionized plasma is accreting clouds around an astronomical compacts object, i.e white dwarf, neutron star, and black hole. In a high-mass binary x-ray star (Fig. 1(a)), a compact object sweeps up material as it orbits through the stellar wind of a massive companion star. When the material is accreted onto the compact object, a fraction of its gravitational potential energy is converted into thermal energy of the material, and a part of the thermal energy is released as Planckian x-ray radiation (~ 10,000,000 Kelvin in radiation temperature), which in turn ionizes the surrounding stellar wind. Photoionized stellar wind emits line x-rays, which carry a wealth of information about the geometry and physical parameters that characterize its nature.

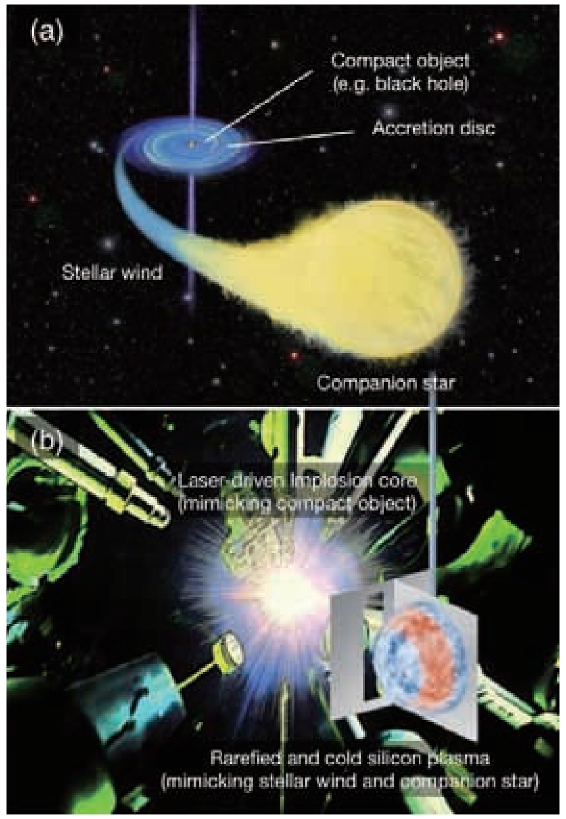

Figure 1
(a) Illustration of x-ray star, a binary system of a compact star and a companion star.
(b) Schematic view of the x-ray star generation with high-power laser.

Theoretical models have been developed on the basis of observed spectra and complex computer codes are written to analyze them. Verification and validation of photoionized plasma models and codes are difficult, because laboratory experiments of photoionized plasma are rare, mainly owing to the lack of high flux x-ray sources.

Experiment

In the previous experiment, it was attempted that an x-ray star miniature was produced by using a laser heated hohlraum, however, reproducing high temperature x-ray stars close to 10,000,000 Kelvin was not achievable mainly owing to low energy coupling between laser and x ray temperature in the hohlraum. The novelty of the present experiment is to use a laser-driven implosion that creates a flash of brilliant, continuum x-rays, which simulate those produced by an astronomical compact object. As demonstrated below, an imploded core plasma emits a nearly Planckian continuum x-ray pulse of 5,000,000 Kelvin radiation temperature. It irradiates a low-density silicon plasma. Silicon is highly abundant in the universe. In fact, characteristic line emissions from silicon ions are observed in CYGNUS X-3 and VELA X-1.

Figure 1 (b) shows the experimental scheme. A hollow spherical polystyrene shell of 500 μm diameter and 6.0 μm thickness, which is the source of the Planckian radiation, is positioned at the target chamber center. The spherical shell is imploded by twelve beams from the GEKKO-XII laser facility, carrying 4.0 kJ of total energy in the form of 1.2 ns green laser pulses. The 0.5 x 0.5 mm^2 silicon target was positioned 1.2 mm away from the radiator. The silicon target was heated by a weak Nd:YAG laser pulse whose intensity, duration, and incident angle were respectively 5x10^{10} W/cm^2, 10 ns, and 10 degrees relative to the target normal. Consequently a slowly expanding, cold (< 300,000 Kelvin), low density (<10^{20} cm^{-3}) silicon plasma mimicking astronomical ambient plasma was produced. Part of the silicon plasma was irradiated through the slit by 5,000,000 Kelvin Planckian radiation whose intensity was 6.5x10^{-4} times the blackbody value.

Result & Analysis

Figures 2 are x-ray spectra from the laboratory plasma, VELA X-1 and CYGNUS X-3, respectively. In x-ray astronomy, the emission peaks near 1.867, 1.855, and 1.840 keV in Fig. 2 (b) and (c) are identified as stemming from resonance (w; $1s^2\ {}^1S_0$ - $1s2p\ {}^1P_1$), intercombination (x, y; $1s^2\ {}^1S_0$ - $1s2p\ {}^3P_1$), and forbidden transitions (z; $1s^2\ 1S_0$ - ${}^1s2s\ {}^3S_1$) of helium-like silicon ions, respectively.

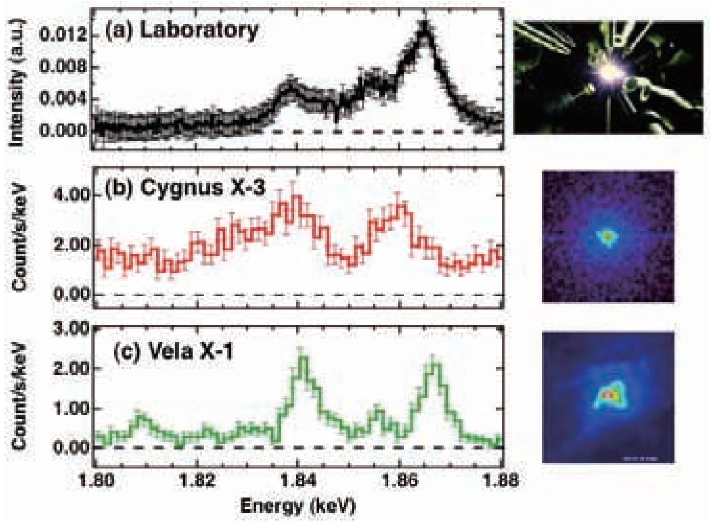

Figure 2
Comparison of x-ray spectra observed in the laboratory and astronomy. X-ray spectra obtained from mimic x-ray star in laboratory (a), CYGNUS X-3; black hole candidate (b), and VELA X-1; neutron star (c), respectivity.

Our developed model [5] includes a simulation of the incident radiation field and its effects on the energy and ionization balance in the photoionized silicon plasma. The computational spectrum exhibits two spectral peaks: (i) the $1s^2\ {}^1S_0$ - $1s2p\ {}^1P_1$ resonance transition in helium-like silicon ions at 1.863 keV, and (ii) a combination of satellite lines (j, k, d, s, t; $1s^2\ nl$ - $1s2p\ nl$) from Li-like ions around 1.840 keV. The computations indicate that the resonance line stems from photoionization of a K-shell electron in Li-like ions followed by radiative decay of an L-electron into the K-shell vacancy. The satellite lines originate from a similar mechanism in Be-like ions.

The atomic code indicates that the forbidden line of helium-like silicon ions should occur at 1.84 keV. This photon energy is coincidentally almost equal to that of the satellite lines, but the transition probability of the forbidden line is 10^{-8} times smaller than that of the resonant line. Consequently the population of the $1s2s\ {}^3S_1$ state must be 10^8 times larger than that of the $1s2p\ {}^1P_1$ state, if the peaks near 1.84 keV do in fact stem from the forbidden transition. We have estimated the time-scales of several possible mechanisms that could generate an overpopulation of the $1s2s\ {}^3S_1$ metastable state. All these time-scales turned out to be much longer than the lifetime of the laboratory photoionized plasma. It therefore seems difficult to believe that electrons accumulated in the $1s2s\ {}^3S_1$ state in the present experiment. It is worthwhile to note that the Li-like satellite lines, which are generated from Be-like species by photoionization, should be incorporated also in the analysis of astronomical spectra.

Summary

Laboratory spectroscopy of non-thermodynamical equilibrium plasmas photoionized by intense radiation is key to understanding x-ray stars, such as black holes, in astronomical observations. Photoionized silicon plasmas can be generated using a 5,000,000 Kelvin Planckian x-ray source created by a laser-driven implosion. The measured x-ray spectrum demonstrates that an extreme radiation field can be produced in the laboratory. This model experiment offers a novel test bed for validation and verification of computational codes used in x-ray astronomy. The scheme also offers new opportunities to predict the existence of astrophysical phenomena or objects prior to astronomical observation.

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