Laser Induced Fluorescence Detection of Organic Matters in Comets, Asteroids, and Icy Moons

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The origin and evolution of life study

Complex organic molecules have been speculated in space. Amino acids and several hydrocarbon compounds (cometary molecules e.g., acetaldehyde, CH3CHO) were found in comets (Crovisier et al. 2004) by radio spectroscopy. A common protein (alanine) and amino acid (isovaline) are found to be abundant in carbonaceous meteorites (Pizzarello and Weber 2004, Cronin & Pizzarello 1997). These prebiotic molecules may have played an important role in the origin and evolution of life (Chyba et al. 1990) Researchers believe that comets and asteroids may contain, sustain, and nurture these building blocks of life, and could tell us about the origin and evolution of life.

Why not illuminate the objects with laser!

Laser induced fluorescence can provide important and detailed information about organic matters present in comets and asteroids or in a path in space. Laser-induced fluorescence spectrum can be analyzed for ranges of organic molecules for identification, diagnose, and track the evolution. Long-term remote observation is possible by comets/asteroid orbiting satellites. Fluorescence illumination and observation is rapidly expanding microscopy technique in the medical and biological sciences. On the surface of the Earth, LIDAR has been observing and providing important information for plant identification, monitoring of plant growth and development, mineral deficiency and presence of other stresses. Developing a method and technique using laser induced illumination and fluorescence spectrum will give us a range of continuous data containing information about evolution of organic molecules. The technique can be expanded to space for observation and detection of organic molecules.

Developing the flight instrument and analytical software

Space-Time high resolution fluorescence telescope with laser producing component needs to be developed. Lidar instrument has been used to measure the distance to an interplanetary object. It sends a pulse of light to the target body and measures the round trip time required for the light signal to travel to and from the bounce point on the target body. By measuring this so-called "light travel time," the distance between the spacecraft and target body can be accurately determined. This allows high space-time resolution analysis. Terrestrial based LIDAR and FLIDAR system can be utilized for developing the flight instrument that composed of various range laser production, emission, and detection component. Acquired spectral data is sent to us and analytical software is used for identification. CCD camera can be equipped for imaging.

Basic Concept

Fluorescence specific Space Lidar systems transmit and detect the reflected and scattered light in the ranges (Fig. 1). The laser beam interact with the target materials, and re-emit light. The reflected and scattered lights are detected and analyzed in relation to the originally transmitted laser signal. This allows for determination of some of the properties of the target materials.

Fig. 1

Laser Type	Wavelength (nm)
Argon fluoride (UV)	193
Krypton fluoride (UV)	248
Xenon chloride (UV)	308
Nitrogen (UV)	337
Argon (blue)	488
Argon (green)	514
Helium neon (green)	543
Helium neon (red)	633
Rhodamine 6G dye (tunable)	570 650
Ruby ($CrAlO_3$) (red)	694
Nd:Yag (NIR)	1064
Carbon dioxide (FIR)	10600

Fig. 2: Tempel 2

Image: artist's concept showing impactor spacecraft approaching comet Tempel 1. Image credit: Maas Digital.

Challenges

It still is a difficult task to identify its type or chemical compounds from a full fluorescence spectrum. However the timing resolution may solve this problem due to known distance to the target objects, and filtering.

Further Applications

Natural, magnetic and magnetochiral circular dichroism are identified by (Jorissen and Cerf 2002). Natural and magnetochiral circular dichroism may cause, through asymmetric photolysis, an enantiomeric excess in a racemic mixture of chiral molecules irradiated, respectively, by circularly polarized ultraviolet light, or by unpolarized ultraviolet light in the presence of a magnetic field non-perpendicular to the light beam. This phenomena can be utilized for predicting interplanetary magnetic field in addition to the chirality study.

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