Cosmic Optical Background: The View from Pioneer 10/11

Y. Matsuoka[1], N. Ienaka[2], K. Kawara[2], S. Oyabu[1] ([1]Nagoya University, [2]The University of Tokyo)

We present new constraints on the cosmic optical background (COB) obtained from an analysis of the *Pioneer 10/11* Imaging Photopolarimeter data. An optical diffuse emission map over a quarter of the sky is created, from which the Galactic starlight (both the direct and dust-scattered components) is accurately subtracted. The derived COB brightness is 7.9 ± 4.0 and 7.7 ± 5.8 nW m^{-2} sr^{-1} at ~0.44 μm and ~0.64 μm, respectively. From comparison with the integrated brightness of galaxies, we conclude that bulk of the COB is comprised of normal galaxies which have already been resolved in the current deepest observations. (Reference: Matsuoka et al. 2011, ApJ, 736, 119)

<1. BACKGROUND>

Extragalactic Background Light (EBL)

Integrated radiation from all light sources outside the Galaxy. Dominant contribution to its optical component, the COB, comes from stellar nucleosynthesis in galaxies at redshifts $z < 10$.

The COB is IMPORTANT
since it tells us the total amount of stars (galaxies) in the universe (→ cosmic star formation history) and the presence or absence of any unknown radiation emitters (→ the nature of dark matter),
but HARD TO DETECT
due to the extremely-bright foreground emissions such as the airglow, zodiacal light (ZL), and Galactic starlight.

How do we tackle the problem of foreground removal?

(1) Usual space observations (with *HST, IRTS*, etc.) and ZL brightness models (e.g., Bernstein 2007)
(2) Estimate the foreground brightness on the surface of Galactic dark clouds (e.g., Mattila 1976)
(3) **Observations from outer solar system (this work)**

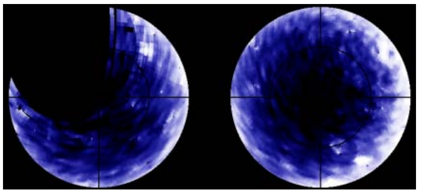
<2. DATA>

- Data source: NASA's science data archive.
- Instrument: Imaging Photopolarimeter (IPP) on board the NASA's spacecrafts *Pioneer 10/11*.
- Wave bands: blue (~0.44 μm) and red (~0.64 μm).
- Observation date: early 1970's when the spacecrafts travelled beyond Mars, i.e., outside the ZL region.

Initial data reduction:
(1) calculation of the instrument pointings,
(2) subtraction of light from bright (V < 8 mag) stars,
(3) photometric calibration from the measurements of calibration lamps and star crossings.
→ Data stored in the archive as "Background Sky Tape"

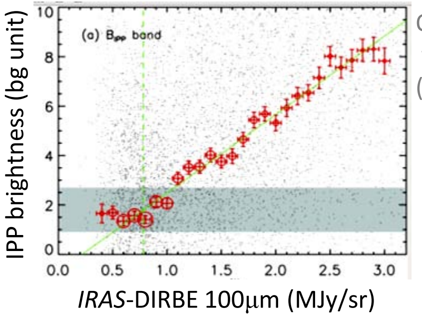
<3. ANALYSIS>

After the retrieval of the Background Sky Tape, we
(1) clean the data by applying various quality cuts (~30% of the data are rejected in this process),
(2) integrate multiple sky scans into a single map in each band,



IPP diffuse emission map in the blue band (left: Galactic latitude $b > 35^{deg}$, right: $b < -35^{deg}$)

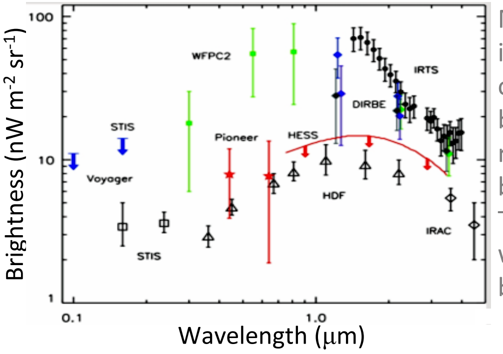
(3) subtract light from faint stars down to 32.0 mag using the *Tycho-2* catalog, the *HST* Guide Star Catalog II, and the Galactic star-count model TRILEGAL (Girardi et al. 2005),
(4) subtract diffuse Galactic light (DGL), which refers to the star-light scattered off the interstellar dust, using the empirical correlation between the DGL and far-IR dust emissions measured by *IRAS* and *COBE*/DIRBE (Schlegel et al. 1998).



Observed correlation between the IPP-blue and far-IR (100 μm) emission brightness

The final errors include both the systematic and random uncertainties in
- IPP observations,
- starlight subtraction,
- DGL subtraction.

<4. RESULTS>



Measurements of integrated brightness of galaxies (open symbols) and background radiation (filled symbols). The results of this work are represented by the red stars.

The derived COB brightness is
7.9 ± 4.0 nW m^{-2} sr^{-1} at the blue band (~0.44 μm) and
7.7 ± 5.8 nW m^{-2} sr^{-1} at the red band (~0.64 μm).
They are consistent with the integrated brightness of galaxies in the *Hubble* Deep Field, suggesting that bulk of the COB is comprised of normal galaxies. No sign of Pop. III stars is found.

References
Bernstein 2007, ApJ, 666, 663
Girardi et al. 2005, A&A, 436, 895
Mattila 1976, A&A, 47, 77
Schlegel et al. 1998, ApJ, 500, 525

For discussion and further details, see
Matsuoka et al. 2011, ApJ, 736, 119