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(3<sup>rd</sup> grade PhD. course of  
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- ✦ ID:S13B-08 (PI: Shinnaka)
- ✦ Instruments: HDS
- ✦ Target: Comet ISON
- ✦ Date: 2013 Nov. 15  
(during its outburst)
- ✦ **First detection of  $^{15}\text{NH}_2$**   
from a single comet &  
inferred  $^{14}\text{N}/^{15}\text{N}$  ratio in  
cometary Ammonia.  
→ **Now printing to ApJL**

## Comet C/2012 S1 (ISON) Observed with HDS during an Outburst in the middle of November 2013

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On UT 2013 November 15.6, we performed high-dispersion spectroscopic observation of comet C/2012 S1 (ISON), using the High-Dispersion Spectrograph (HDS) mounted on the Subaru Telescope in Hawaii. We successfully observed comet ISON during an outburst starting at around UT November 14. The obtained spectrum showed many emission lines from gaseous molecules and atoms ( $\text{C}_2$ ,  $\text{NH}_2$ ,  $\text{H}_2\text{O}^+$ ,  $\text{CN}$ ,  $\text{O}$ ,  $\text{Na}$ , and unidentified species). Our observation will play an important role in shedding light on the mechanisms of the outburst and the origin of comet ISON.

Credit: D. Peach

### 1. Introduction

**Comet**

- ✦ Most pristine icy bodies in the Solar system.
- ✦ The remnants of planetesimals formed in the solar nebula 4.6 Gyrs ago.
- ✦ When a cometary nucleus approaches the sun, coma and tail appear.

**Comet C/2012 S1 (ISON)**

- ✦ Discovered on 2012 Sep. 21, by the ISON group.
- ✦ A **sungrazing comet** from the Oort cloud.
- ✦ Disintegrated by approaching the sun (Perihelion: 2013 Nov. 28,  $q=0.012$  AU).

**Ortho/Para abundance Ratio of  $\text{NH}_2$  in Comets**

- ✦ There is a relationship between OPRs and formation temperatures of the molecule.
- ✦ Obtained OPRs clustered at around 1.15 (30K).

Left: CCD image of comet ISON. Right:  $\text{NH}_2$  OPRs in 17 comets. This figure shows almost comets clusters a similar formation temperature ( $\sim 30\text{K}$ ).

### 2. Observations with Subaru / HDS

- ✦ Date: UT 2013 Nov. 15.6 (EL  $\sim 20.6$  deg)
- ✦ Heliocentric distance: 0.601 AU
- ✦ Geocentric distances: 0.898 AU
- ✦ Exposure time: 1200 s ( $R=72000$ )
- ✦ The outburst: UT Nov. 14.  $0 \pm 0.2$  (10 times by 4-8 hrs)

Left: The light curve of comet ISON. Green line indicate our observing time (2013 November 15.6). Center: Raw data of the high-dispersion optical spectrum (called an "Echelle format") of comet ISON. Right: Observed spectrum of comet ISON (after corrected solar reflected light and telluric absorption). This spectrum showed a lot of gaseous emission lines from molecules and atoms ( $\text{C}_2$ ,  $\text{NH}_2$ ,  $\text{H}_2\text{O}^+$ ,  $\text{CN}$ ,  $\text{O}$ ,  $\text{Na}$ , and unidentified species).

### 3. Preliminary Results

- ✦ Estimated a OPRs of ammonia from three  $\text{NH}_2$  bands ( $\text{NH}_2$  is a photo dissociation product of  $\text{NH}_3$  in the coma, B.R  $\sim 95\%$ ).
- ✦ Our results are consistent with each other and similar to the value ever observed ( $\sim 30\text{K}$  for formation temperature).

Table: OPRs and  $T_{\text{spin}}$  of  $\text{NH}_2$  of Comet ISON.

$\text{NH}_2$ Bands	$\text{NH}_2$ OPR	$\text{NH}_2$ $T_{\text{spin}}$ (K)
(0,9,0)	$1.09 \pm 0.09$	$33 +17/-6$
(0,8,0)	$1.14 \pm 0.04$	$29 +3/-2$
(0,7,0)	$1.15 \pm 0.03$	$29 \pm 2$
<b>Weighted mean</b>	<b><math>1.14 \pm 0.02</math></b>	<b><math>29 \pm 1</math></b>

### 4. Future Works

**Plan to pursue the researches**

- ✦ The origin of Comet ISON.
- ✦ The mechanisms of the outburst.
- ✦ The formation history of the Solar system.

**Concrete examples of studies**

- ✦ Emission line atlas for comet ISON.
- ✦ Isotopic ratios of Carbon and Nitrogen.
- ✦ Molecular abundance ratios relative to water.
- ✦ Origin of forbidden lines of [OI].
- ✦ Ortho-to-para abundance ratios of  $\text{NH}_3 \nsubseteq \text{H}_2\text{O}$ .

**Please contact us, if you would like to collaborate with us to cometary study.**

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