

# Cometary Research in Taiwan

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# Scientific Topics

Solar System	Stars	Galaxies
<ul style="list-style-type: none"><li>•Comets</li><li>•KBOs</li><li>•Planets</li></ul>	<ul style="list-style-type: none"><li>•Planetary nebulae</li><li>•RR Lyrae variables</li></ul>	<ul style="list-style-type: none"><li>•Star formation histories</li><li>•Galactic evolution</li></ul>

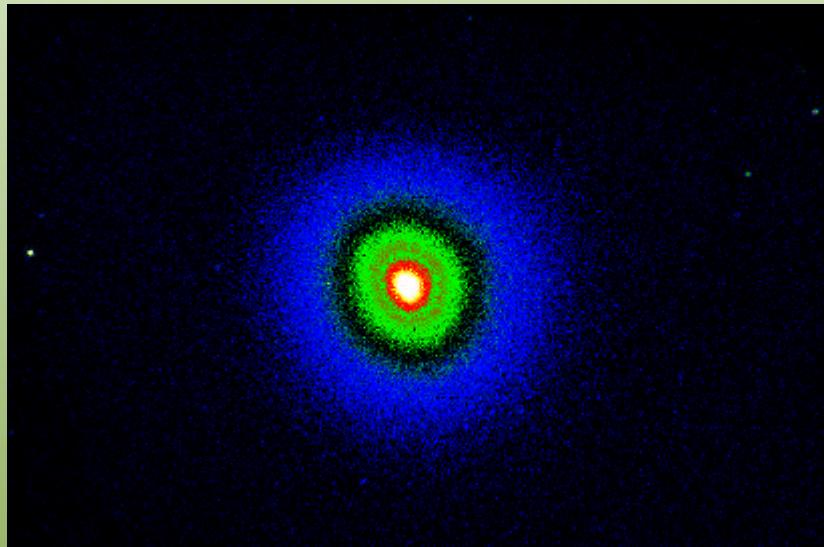
# Cometary Research

	<b>Obs</b>	<b>Th</b>	<b>Lab</b>
• <b>Origin(s)</b>			
- Chemical composition	X	X	X
- Collisional accretion and fragmentation		X	
• <b>Structure</b>			
- Surface (colour, albedo, ice/dust complex)	X	X	X
- Interior (rubble piles or monolithic bodies)		X	
• <b>Evolution</b>			
- Star cluster dynamics		X	
- Orbital scattering ~ short period comets		X	

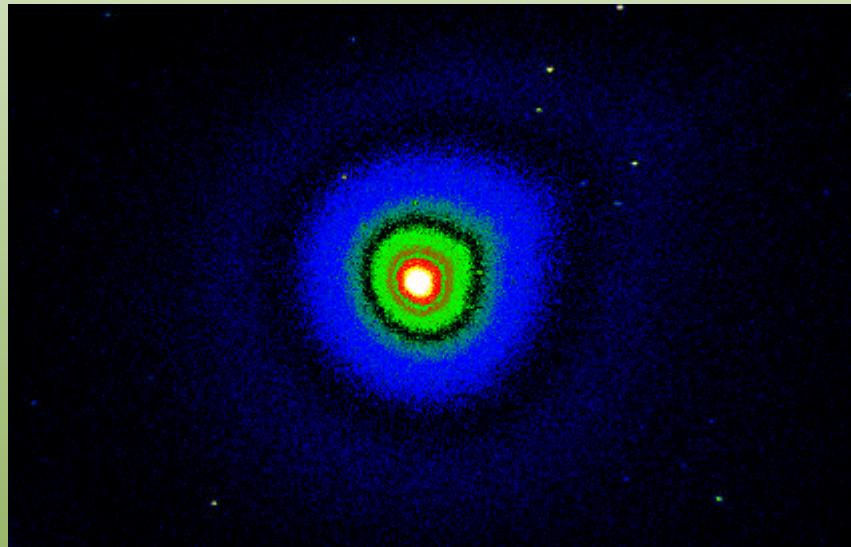
# Observational Opportunities

Obs.	1999	2000	2001	2002	2003	Objectives
Lu-Lin	V	V	V	V	V	Narrow-band filter imaging photometry
NAOC		V	V	V	V	2.16 m spectrogr.
SMT				?	?	Thermal emission
SMA				?	?	Thermal emission plus spectroscopy
Subaru				?	?	Imaging

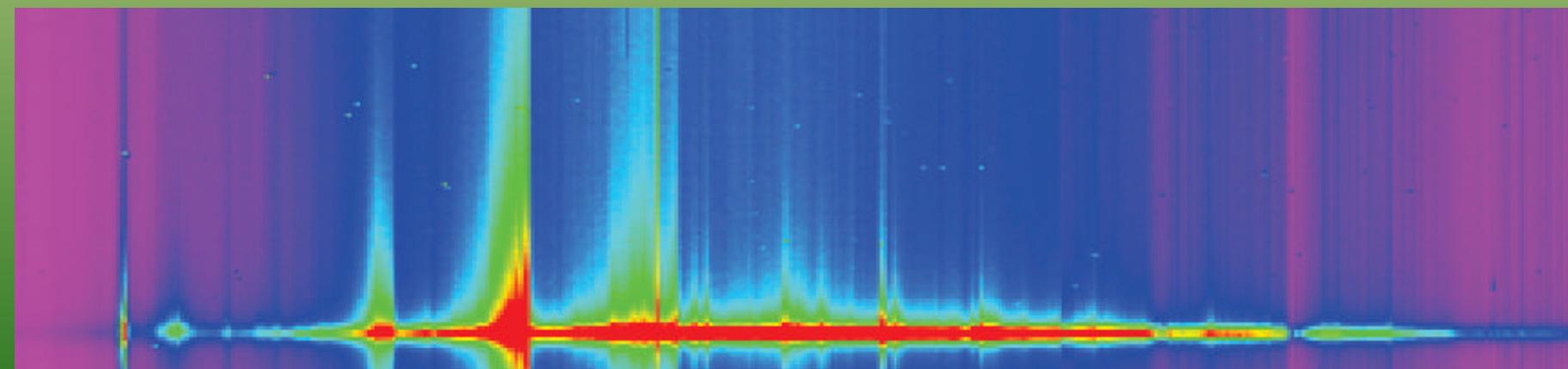
## C/2001 A2(LINEAR)



ESA C<sub>2</sub> filter, exposure time ~ 120 sec and taken on July 1, 2001

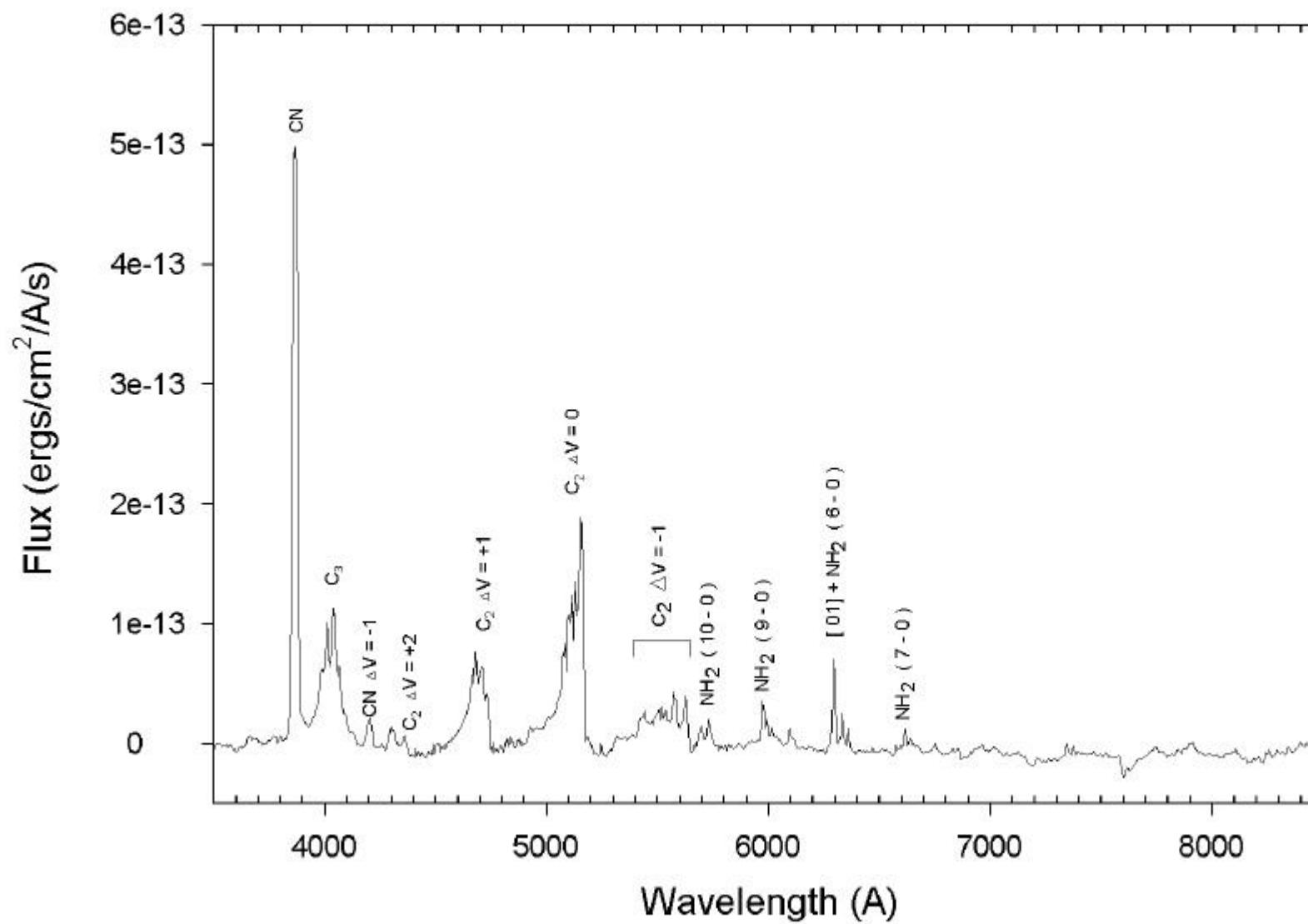


V-band filter, exposure time ~ 60 sec and taken on July 1, 2001

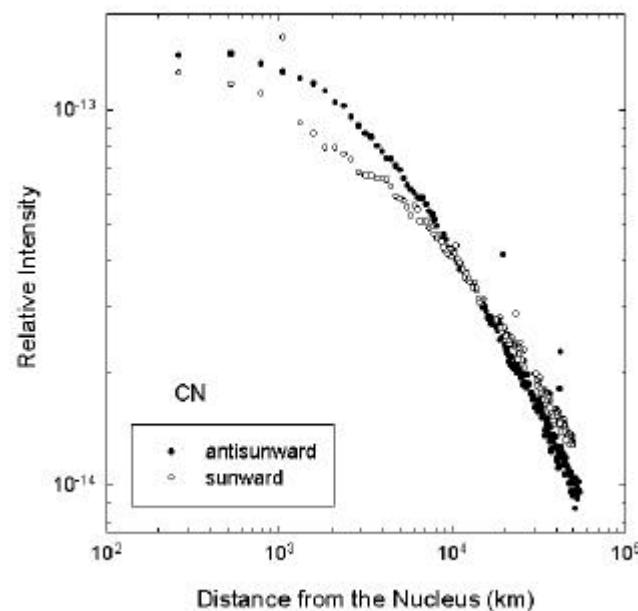
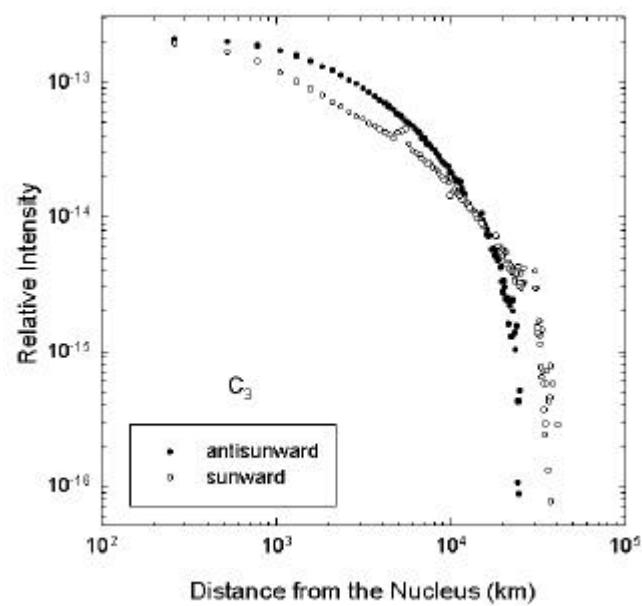
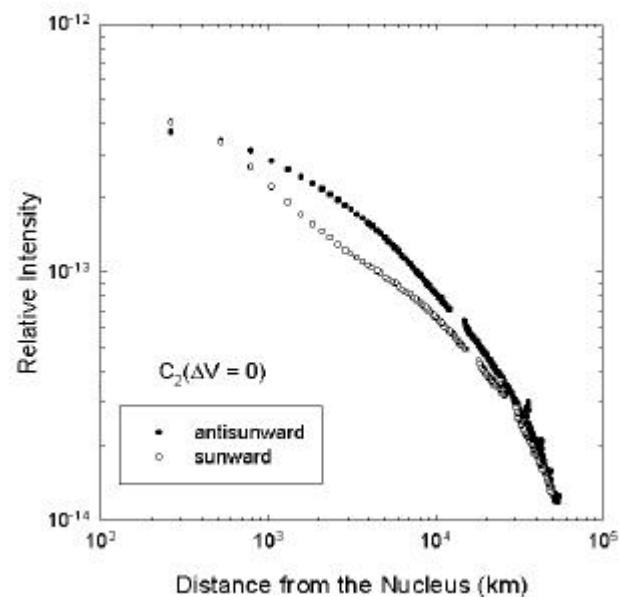
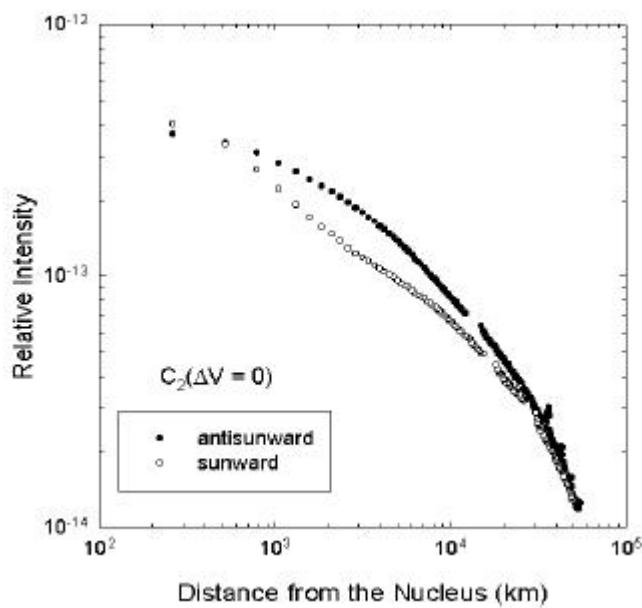


BAO 2.16m spectrograph image taken on July 11, 2001

## Comet 2001/A2 (nucleus)



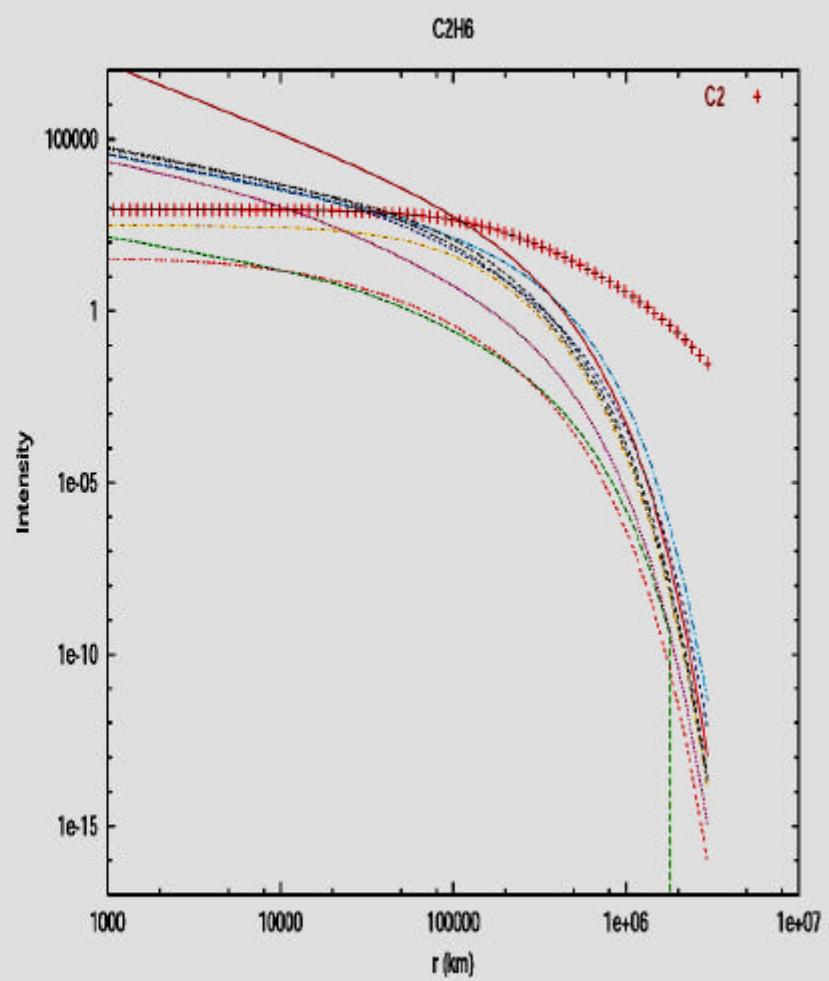
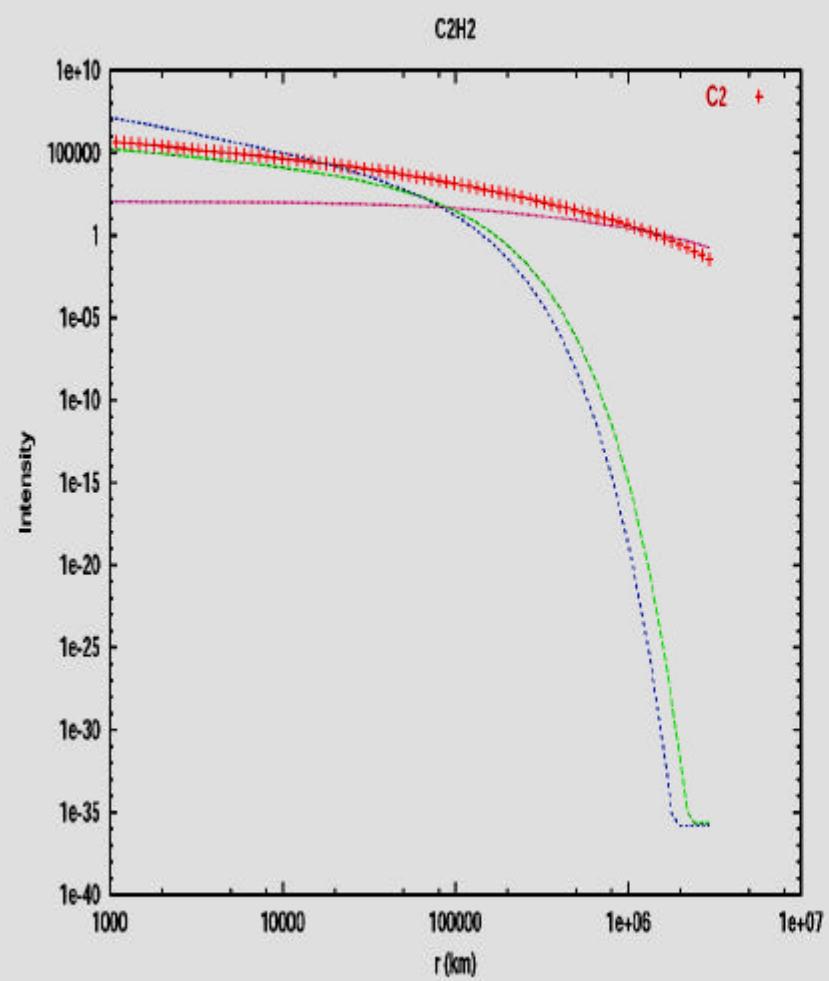
# Comet 2001/A2 2001.07.14



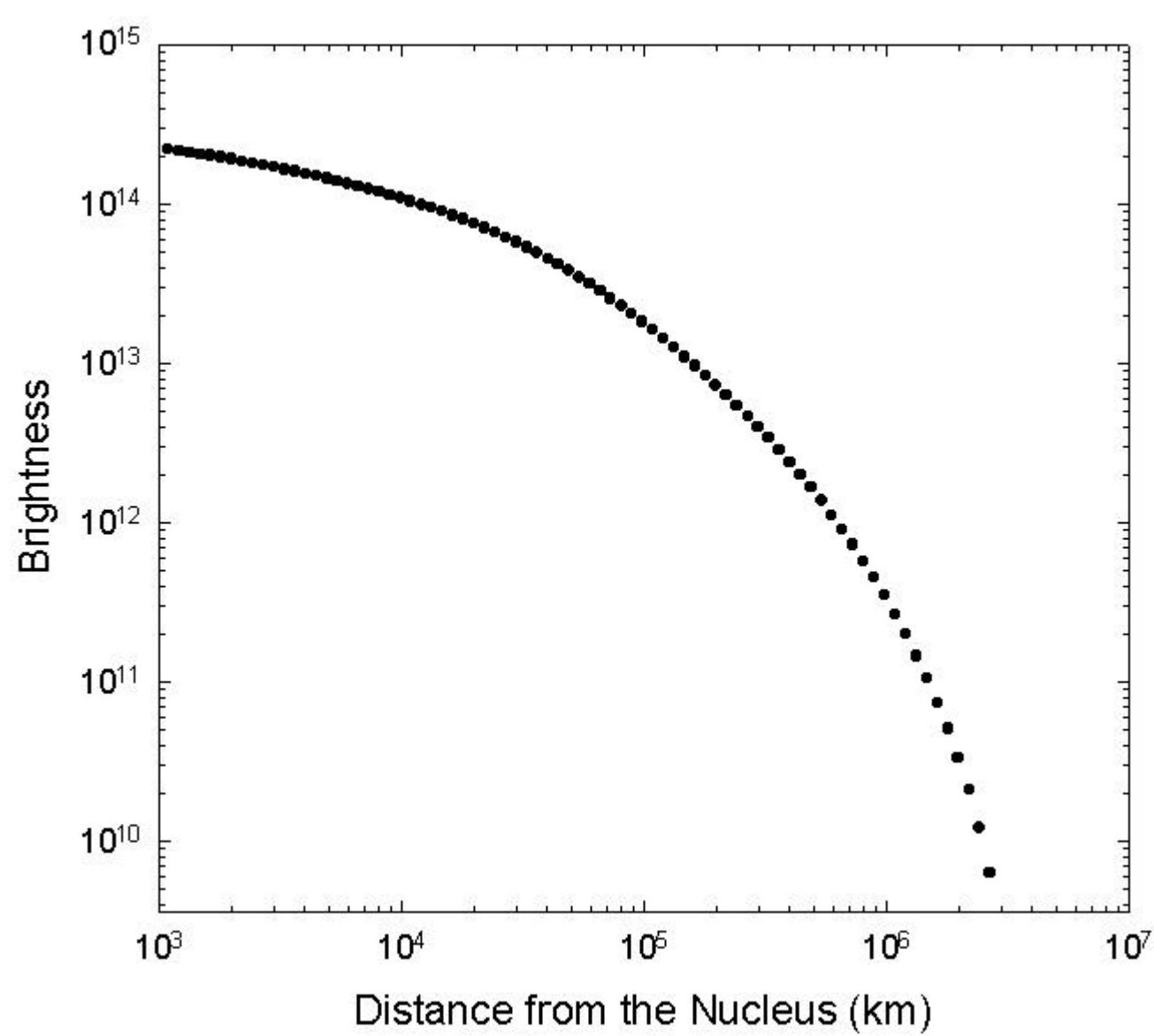
# Relative Abundances of C<sub>2</sub>, C<sub>2</sub>H<sub>2</sub> and C<sub>2</sub>H<sub>6</sub>

(H<sub>2</sub>O = 100%)

- C<sub>2</sub>: 0.20 - 0.50
- C<sub>2</sub>H<sub>2</sub>: 0.30 - 0.90
- C<sub>2</sub>H<sub>6</sub>: 0.20 - 0.45
- Are C<sub>2</sub>H<sub>2</sub> and C<sub>2</sub>H<sub>6</sub> the long-sought after parent molecules of C<sub>2</sub> ?



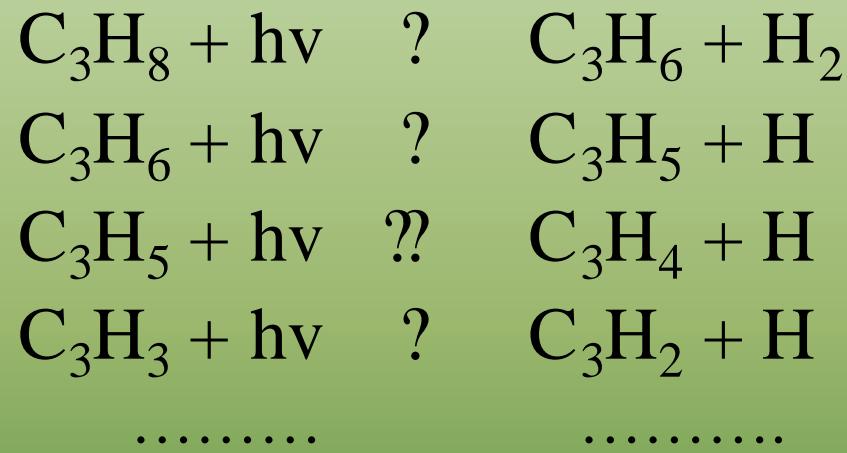
## $C_2$ Coma Model



# Photolytic Reactions

Photolytic Reactions	Observational Values (sec)	Laboratory Values (sec)
$\text{C}_2\text{H}_2 + \text{hv} \rightarrow \text{C}_2\text{H} + \text{H}$ ? $\text{C}_2 + \text{H}$ $\text{C}_2\text{H} + \text{hv} \rightarrow \text{C}_2 + \text{H}$	----- $3.1 \times 10^4$	$1.0 \times 10^5$ [ $6.9 \times 10^4$ ] $3.7 \times 10^4$ [ $2.4 \times 10^5$ ] -----
$\text{C}_2 + \text{hv} \rightarrow \text{C} + \text{C}$ ? $\text{C}_2 + \text{e}$	$1.2 \times 10^4$	$5.9 \times 10^6$
	MR Combi and AH Delsemme, Neutral Cometary Atmospheres, V. C2 and CN in comets, ApJ, 308, 472, 1986.	HU Schmidt et al. and [WF Huebner]

# $\text{C}_3$ Photodissociation Paths



Multi-step processes in the production of  $\text{C}_3$  following the photolytic chemical chain.

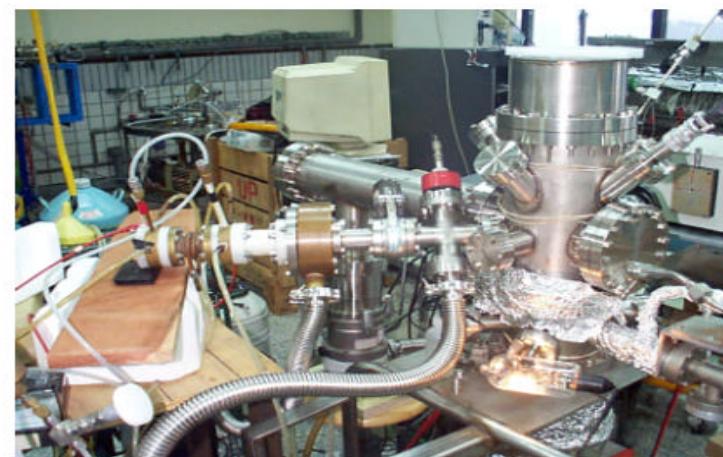
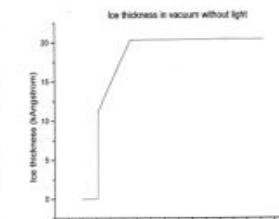
But cometary  $\text{C}_3$  intensity profiles require “direct production” of  $\text{C}_3$  parent molecules or  $\text{C}_3$ -parent radicals subject to fast dissociation.

# LARA (Laboratory Astrochemistry) to simulate icy surface interactions with ions and photons

## LABORATORY EXPERIMENTS

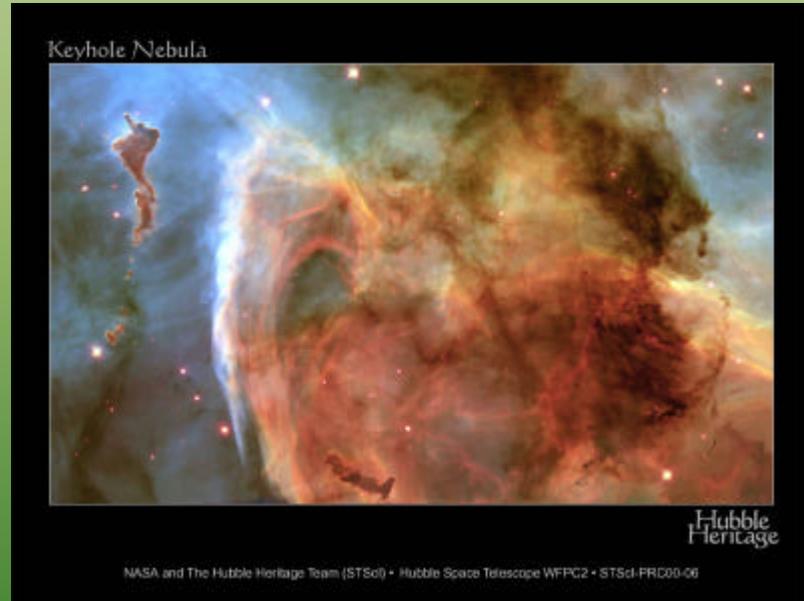
In the three-year integrated plan we will carry out laboratory experiments on photon irradiation and ion impact sputtering. Some specific ice systems to be studied are:

- Pure molecular ices:  $\text{H}_2\text{O}$ , CO,  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2$ ,  $\text{CH}_3\text{OH}$ ,  $\text{SO}_2$ ,  $\text{NH}_3$ , etc.
- Mixed ices:  $\text{H}_2\text{O}-\text{CH}_3\text{OH}$ ,  $\text{H}_2\text{O}-\text{CH}_4-\text{C}_2\text{H}_2-\text{NH}_3$ , etc.
- Clathrate hydrates:  $\text{CH}_4-\text{nH}_2\text{O}$ ,  $\text{CO}_2-\text{nH}_2\text{O}$ ,  $\text{CH}_3\text{OH}-\text{nH}_2\text{O}$ ,  $\text{C}_2\text{H}_4-\text{nH}_2\text{O}$ , etc.

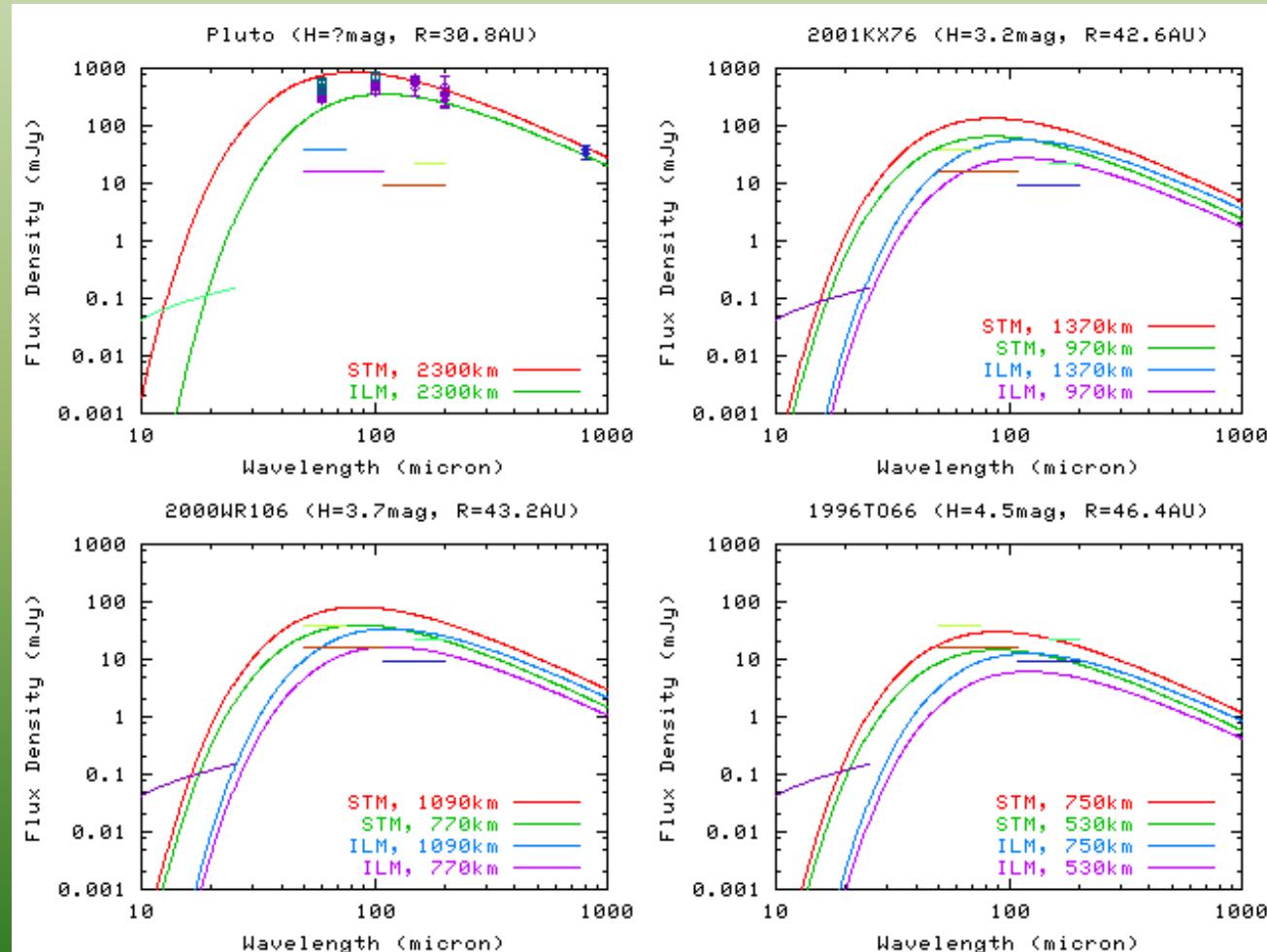


# LARA Scientific Objectives

- Laboratory simulations of comets, KBOs and other icy planetesimals in primordial solar system
- Laboratory simulations of chemical synthesis of complex organic and pre-biotic molecules in ISM and molecular clouds



# Thermal Flux of EKBO/Centaur

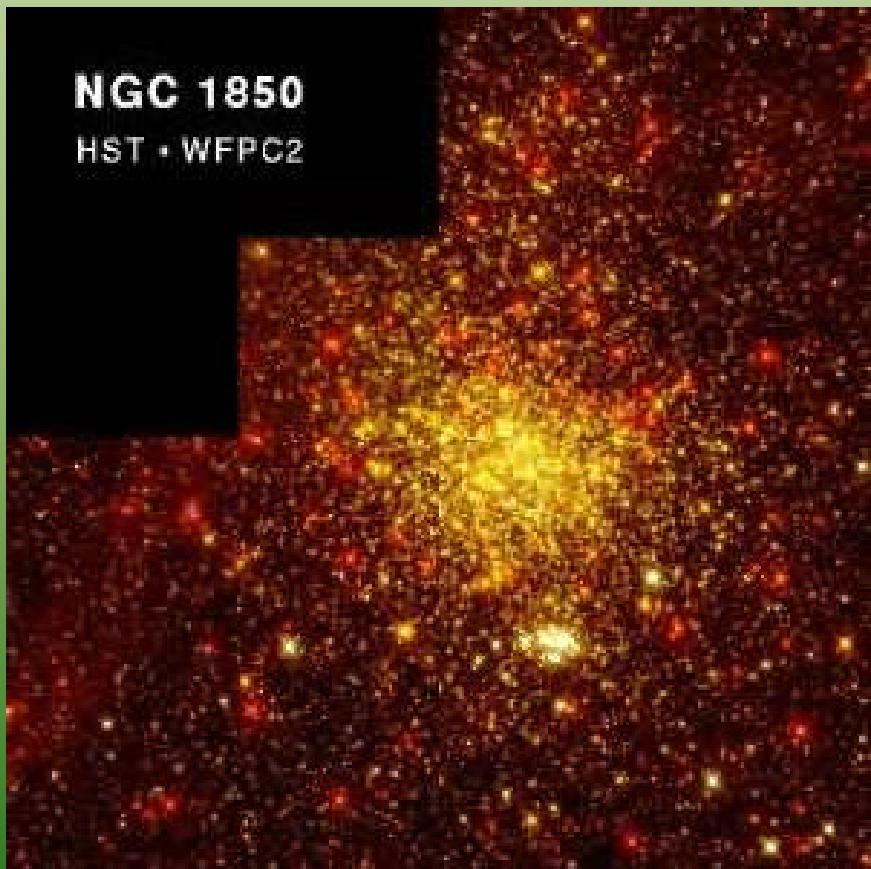


Data from D. Kinoshi (NAOJ)

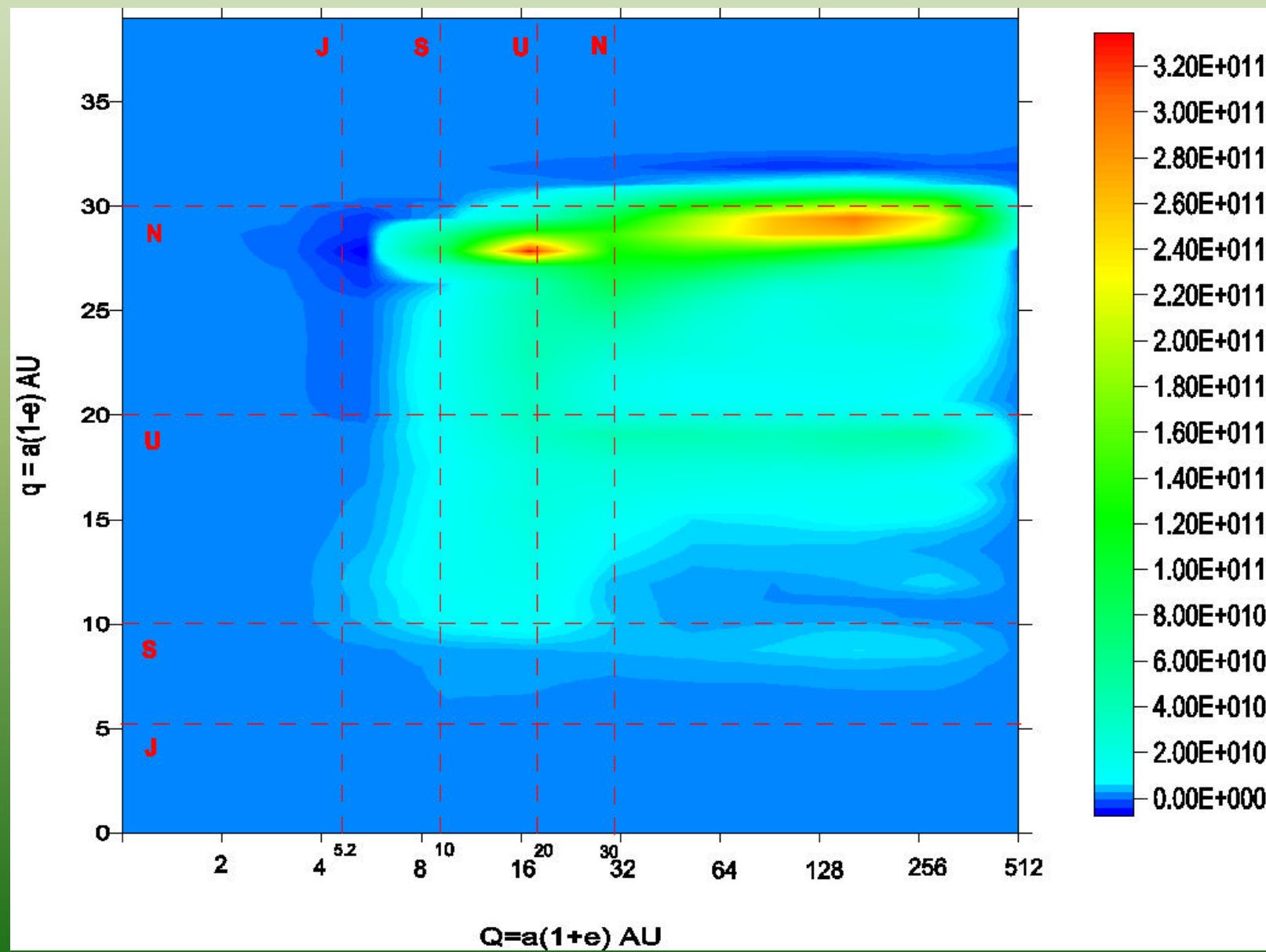
# **Observations of Thermal Emission and Dust Halo Formation of KBOs : SMT , SMA , Subaru ...**

# Dynamical Evolution

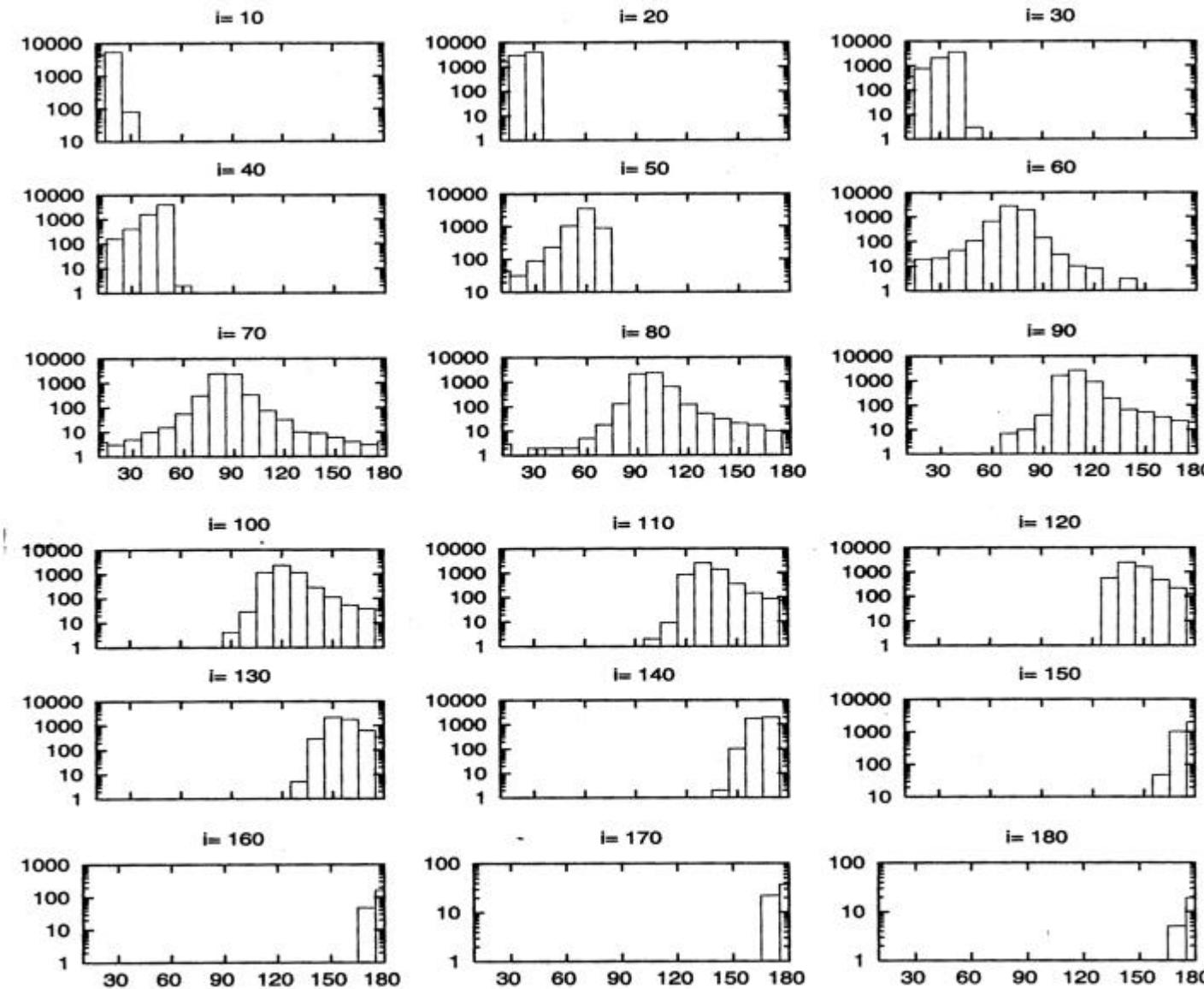
N-body Simulation  
of Inclinations of  
KBO - disks and  
Exoplanets in Young  
Star Clusters



# Q-q Distribution of Scattered KBOs



## Final Inclination Distributions of Short-Period Comets from KBOs



## Acknowledgment

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中大天文所林忠義、張建邦、張智威、許慧君、胡瑞華、吳宇立及游大立各同學在彗星及行星研究工作之熱忱打拼。