

**Workshop and Summer School on  
Lie Theory and  
Representation Theory (II)**

**PROGRAM**



July 13 - July 31, 2009

Department of Mathematics,  
East China Normal University  
Shanghai, China

**Workshop and Summer School on  
Lie Theory and Representation Theory II (WSSLTRT-II)**

July 13-July 31, 2009

(<http://math.ecnu.edu.cn/academia/li2009/>)

**Supported by**

Department of Mathematics, ECNU

International Exchange Division, ECNU

Graduate School, ECNU

Natural Science Found of China (NSFC)

PCSIRT

**Organized by**

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Jianyi Shi (时俭益)

Bin Shu (Coordinator, 舒斌),

Jianpan Wang (王建磐),

Youyi Wu (吴酉毅),

Hongyan Zhang (张红艳)

**Time of Workshop and Summer School**

July 13 - July 31, 2009 (*workshop is on July 20-July 22*)

**Venue of Workshop and Summer School**

Science Building (理科大楼) A 504 for Workshop

Wen-Shi Building (文史楼) 215 for Summer School

Campus of Zhongshan Road (North), East China Normal University

**WSSLTRT-II** is the second one of the series “Workshop and Summer School on Lie Theory and Representation Theory.” The first one was held in 2006. The present one will provide advanced mini-courses on Lie theory and representation theory of the topics listed in the program for graduate students and young teachers, and will host the workshop on the same theme. The graduate students and young teachers will be encouraged to give research presentations during the summer school.

### **Lecturers of Summer School**

Iain Gordon (The University of Edinburgh)

Alexander Kleshchev (University of Oregon)

Daniel K. Nakano (University of Georgia)

Toshiyuki Tanisaki (Osaka City University)

Weiqiang Wang (University of Virginia)

### **Invited Speakers of Workshop**

Tomoyuki Arakawa (Nara Women’s University)

Shun-Jen Cheng (Academia Sinica at Taiwan)

Chongying Dong (University of California at Santa Cruz)

Jie Du (The University of New South Wales)

Iain Gordon (The University of Edinburgh)

Yi-Zhi Huang (University of Rutgers)

Cuibo Jiang (Shanghai Jiaotong University)

Alexander Kleshchev (University of Oregon)

Daniel K. Nakano (University of Georgia)

Yucai Su (University of Science and Technology of China)

Toshiyuki Tanisaki (Osaka City University)

Weiqliang Wang (University of Virginia)

Chaowen Zhang (China University of Mining and Technology)

Pu Zhang (Shanghai Jiaotong University)

Ruibing Zhang (University of Sydney)

## Part I. Workshop

### 1. Schedule of Workshop

(Venue: Science Building A 504 理科大楼)

July 20-22	July 20, Monday	July 21, Tuesday	July 22, Wednesday
8:45-9:00	Register		
9:00-9:10	Welcome Speeches		
9:10-10:10	T. Tanisaki	A. Kleshchev	Weiqliang Wang
10:30-11:30	D. Nakano	I. Gordon	Shun-Jen Cheng
11:30-11:40	Group Photo		
13:30-14:30	Chongying Dong	Yi-Zhi Huang	Jie Du
14:50-15:50	Ruibin Zhang	Pu Zhang	Cuibo Jiang
16:10-17:10	Yucai Su	T. Arakawa	Chaowen Zhang

### 2. Program of Workshop

#### July 20 (Mon)

8:45 - 9:00 Register

9:00 - 9:10 Welcome Speeches by Professors Jianpan Wang, Feng Zhou and Danping Yang

9:10- 10:10 T. Tanisaki (Osaka City University)

D-modules on quantized flag manifolds at roots of 1

10:10-10:30 **Tea Time**

10:30-11:30 D. Nakano (University of Georgia)

Complexity and Module Varieties for Classical Lie Superalgebras

11:30-11:40 **Group Photo**

**Lunch Time**

13: 30-14:30 Chongying Dong (University of California at Santa Cruz)

C<sub>2</sub>-cofinite vertex operator algebras

14:30-14:50 **Tea time**

14:50 -15:50 Yucai Su (University of Science and Technology of china)

(TBA)

15:50-16:10 **Tea Time**

16:10 - 17:10 T. Arakawa (Nara Women's University)

Varieties of nilpotent orbits, Kac-Moody algebras, and W-algebras

18:00 **Banquet**

## **July 21 (Tue)**

9: 10– 10:10 A. Kleshchev (University of Oregon)

Graded representation theory of symmetric groups

10:10-10:30 **Tea Time**

10:30-11:30 I. Gordon (University of Edinburgh)

Symplectic Reflection Algebras

**Lunch Time**

13: 30-14:30 Yi-Zhi Huang (University of Rutgers)

Automorphisms of infinite orders and logarithmic twisted vertex operators

14:30-14:50 **Tea time**

14:50 -15:50 Ruibin Zhang (University of Sydney)

Equivariant K-theory of quantum group actions

15:50-16:10 **Tea Time**

16:10 - 17:10 Pu Zhang (Shanghai Jiaotong University)

Gorenstein algebras of finite Cohen-Macaulay type

## **July 22 (Wed)**

9: 10– 10:10 Weiqiang Wang (University of Virginia)

Representations of Lie superalgebras in prime characteristic

10:10-10:30 **Tea Time**

10:30-11:30 Shun-Jen Cheng (Academia Sinica at Taiwan)

Irreducible characters of general linear superalgebra and super duality

**Lunch Time**

13: 30-14:30 Jie Du (The University of New South Wales)

The quantum Schur superalgebra

14:30-14:50 **Tea time**

14:50 -15:50 Cuibo Jiang (Shanghai Jiaotong University)

A Characterization of Vertex Operator Algebra  $L(\frac{1}{2},0) \otimes L(\frac{1}{2},0)$  a joint work with Chongying Dong

15:50-16:10 **Tea Time**

16:10 - 17:10 Chaowen Zhang (China University of Mining and Technology)

On the simple modules for the restricted Lie superalgebra  $gl(m,n)$  and  $W(m,n,1)$ .

### 3. Abstracts of Workshop Talks

Tomoyuki Arakawa (Nara Women's University)

**Title:** Varieties of nilpotent orbits, Kac-Moody algebras, and W-algebras

**Abstract:** Some varieties of nilpotent orbits in finite dimensional simple Lie algebras are related with the corresponding Kac-Moody algebras and (affine) W-algebras. In my talk I will explain how they are related.

As a consequence the  $C_2$  cofiniteness of all the (non-principal) exceptional W-algebras are proved. This gives a (new and huge) family of  $C_2$  cofinite vertex (operator) algebras. In fact, we will show that  $C_2$  cofinite W-algebras forms a bigger family than exceptional W-algebras.

Shun-Jen Cheng (Academia Sinica at Taiwan)

**Title:** Irreducible characters of general linear superalgebra and super duality

**Abstract:** We develop a new method to solve the irreducible character problem for a wide class of modules over the general linear superalgebra, including all the finite-dimensional modules, by directly relating the problem to the classical Kazhdan-Lusztig theory. Our method allows us to verify a parabolic version of a conjecture of Brundan on the irreducible characters in the BGG category  $O$  of the general linear superalgebra. As a further application we give a proof of the super duality conjecture. This is a joint work with Ngau Lam.

Chongying Dong (University of California at Santa Cruz)

**Title:**  $C_2$ -cofinite vertex operator algebras

Jie Du (The University of New South Wales)

**Title:** The quantum Schur superalgebra

**Abstract:** We introduce the notion of quantum Schur superalgebras. These algebras share certain nice properties with quantum Schur algebras such as base change property, existence of canonical  $\mathbb{Z}[v, v^{-1}]$ -bases, and the duality relation with quantum supermatrix algebra  $M(m|n)$ . We also construct a cellular  $\mathbb{Q}(v)$ -basis and determine its associated cells, called supercells, in terms of a super version of the Robinson--Schensted correspondence. In this way, we classify all irreducible representations via supercell modules. This is joint work with Hebing Rui.

## Iain Gordon (University of Edinburgh)

**Title:** Symplectic Reflection Algebras

**Abstract:** I will explain some current work on these algebras, their links to resolutions of singularities and Lie theory.

## Yi-Zhi Huang (University of Rutgers)

**Title:** Automorphisms of infinite orders and logarithmic twisted vertex operators

**Abstract:** We introduce a suitable notion of twisted representation for a vertex operator algebra associated to an automorphism of infinite order. Such a representation in general is graded by the generalized eigenspaces of  $L(0)$  and by an additional horizontal grading. More importantly, the twisted vertex operators in general involve the logarithm of the formal or complex variable. We construct examples of such twisted representations from a weight 1 element of the vertex operator algebra satisfying suitable conditions.

## Cuibo Jiang (Shanghai Jiaotong University)

**Title:** A Characterization of Vertex Operator Algebra  $L(\frac{1}{2}, 0) \otimes L(\frac{1}{2}, 0)$  a joint work with Chongying Dong

**Abstract:** We show that any simple, rational and  $\mathbb{C}_2$ -cofinite vertex operator algebra whose weight 1 subspace is zero, the dimension of weight 2 subspace is greater than or equal to 2 and with central charge  $c=1$ , is isomorphic to  $L(\frac{1}{2}, 0) \otimes L(\frac{1}{2}, 0)$ .

## Alexander Kleshchev (University of Oregon)

**Title:** Graded representation theory of symmetric groups

**Abstract:** Brundan and the speaker have defined a  $\mathbb{Z}$ -grading on blocks of symmetric groups and cyclotomic Hecke algebras. This opens up a way for studying graded representation theory of these objects. We will

explain how to grade Specht modules and what can be said about graded decomposition numbers.

## Daniel K. Nakano (University of Georgia)

**Title:** Complexity and Module Varieties for Classical Lie Superalgebras

**Abstract:** Let  $\mathfrak{g} = \mathfrak{g}_{\{0\}} \oplus \mathfrak{g}_{\{1\}}$  be a classical Lie superalgebra and  $\mathcal{F}$  be the category of finite dimensional  $\mathfrak{g}$ -supermodules which are semisimple over  $\mathfrak{g}_{\{0\}}$ . In this paper we investigate the homological properties of the category  $\mathcal{F}$ . In particular we prove that  $\mathcal{F}$  is self-injective in the sense that all projective supermodules are injective. We also show that all supermodules in  $\mathcal{F}$  admit a projective resolution with polynomial rate of growth and, hence, one can study complexity in  $\mathcal{F}$ . If  $\mathfrak{g}$  is a Type-I Lie superalgebra we introduce support varieties which detect projectivity and are related to the associated varieties of Duflo and Serganova. If in addition  $\mathfrak{g}$  has a (strong) duality then we prove that the conditions of being tilting or projective are equivalent.

## Yucai Su (University of Science and Technology of China)

**Title:** TBA

## Toshiyuki Tanisaki (Osaka City University)

**Title:** D-modules on quantized flag manifolds at roots of 1

**Abstract:** I will describe the category of D-modules on quantized flag manifolds, and give an analogue of some results by Bezrukavnikov-Mirkovic-Rumynin on D-modules on flag manifolds in positive characteristics.

## Weiqiang Wang (University of Virginia)

**Title:** Representations of Lie superalgebras in prime characteristic

**Abstract:** We will discuss part of Lei ZHAO's Virginia dissertation, which initiates the study of representation theory of Lie superalgebras in characteristic  $p > 2$ . A superalgebra generalization of the celebrated Kac-Weisfeiler Conjecture is formulated and established for Lie superalgebras of type A and type Q among many others, which exhibits a mixture of  $p$ -power and  $2$ -power divisibilities of dimensions of modules. We describe connections between modular Lie algebras and superalgebras. The typical blocks for super type A are shown to be equivalent to the corresponding blocks in the usual type A, where Lusztig's conjecture applies.

## Chaowen Zhang (China University of Mining and Technology)

**Title:** On the simple modules for the restricted Lie superalgebra  $gl(m,n)$  and  $W(m,n,1)$ .

**Abstract:** The presentation is divided into two parts. The first part is about the simple modules for the restricted general linear superalgebra. It covers the simplicity of Verma modules, Kac modules, also the Kac-Weisfeiler Theorem for  $gl(m,n)$ . The second part is about a joint work with Shu Bin, in which we classified all the simple modules with typical weights for the restricted Witt type Lie superalgebra  $W(m,n,1)$  constructed by Liu and Zhang.

## Pu Zhang (Shanghai Jiaotong University)

**Title:** Gorenstein algebras of finite Cohen-Macaulay type

**Abstract:** Gorenstein—projective modules have been used in several branches of mathematics. However there are few information on some basic problems, such as

1 How to judge the CM-finiteness of Gorenstein algebras; and then to obtain "non-trivial" CM-finite Gorenstein algebras  $A$ ?

2 Given an algebra, how to construct explicitly all the Gorenstein-projective modules ?

In this talk, we study the CM-finiteness, and constructions of Gorenstein-projective modules, of Gorenstein algebras.

First, we give a sufficient and necessary condition for CM-finite Gorenstein algebras. We determine all the Gorenstein-projective modules over the  $T_2$ -extension of a Gorenstein algebra, and over  $\left(\begin{matrix} A & M \\ 0 & B \end{matrix}\right)$

where  $A$  and  $B$  are self-injective algebras, and  $M$  is an  $A$ - $B$  bimodule with  $M_A$  and  $M_B$  projective. Finally, we obtain a criterion for the CM-finiteness of the  $T_2$ -extensions of CM-finite Gorenstein algebras; as an application we get non-trivial examples of CM-finite Gorenstein algebras.

## Ruibin Zhang (University of Sydney)

**Title:** Equivariant K-theory of quantum group actions

## Part II. Summer School

### 1. Lecturers

- . Iain Gordon (G): 8 Lectures
- . Alexander Kleshchev (K): 6 Lectures
- . Daniel Nakano (N): 6 Lectures
- . Toshiyuki Tanisaki (T): 20 Lectures
- . Weiqiang Wang (W): 8 Lectures
- . Research Presentations (RP): 30 minutes for each

### 2. Lecture Schedule of Summer School

(Lecture Room: Hall 215, Wen-Shi Building 文史楼)

Jul. 13 -Jul. 17	13 Mon	14 Tue	15 Wed	16 Thu	17 Fri
9:30- 10:30	T	N	T	T	T
10:50- 11:50	T	N	T	T	T
14:00- 15:00	RP by Dong Liu	T	RP by Yiyang Li	N	N
	RP by Yiyang Li		RP by Lisun Zheng		
15:20- 16:20	RP by Lei Zhao	T	RP by Yufeng Yao	N	N
	RP by Jinkui Wan		RP by Lisun Zheng		

Jul. 23 -Jul. 31	23 Thu	24 Fri	27 Mon	28 Tue	29 Wed	30 Thu	31 Fri
8:30- 9:30	K	K	T	G	W	G	G
9:45- 10:45	W	W	T	G	W	G	G
11:00- 12:00	G	G	K	K	T	T	
14:30- 15:30	T	T	W	T	K	W	
15:45- 16:45	T	T	W	T	K	W	

### 3. Contents of Lectures of Summer School

#### (1) Modular representations of Lie algebras (8 lectures)

---by I. Gordon (University of Edinburgh)

DESCRIPTIONS: We will cover the fundamentals of the theory, starting with the work of Kac-Weisfeiler and the geometry of the centre of the enveloping algebras; we will then move on to reduced enveloping algebras and Premet's confirmation of the Kac-Weisfeiler conjecture and support varieties; following this we will discuss recent work of Bezrukavnikov-Mirkovic-Rumynin on a more geometric description of the representation theory. If time allows we will then discuss something from either quantum groups or finite W-algebras.

#### (2) Representation theory of symmetric groups and cyclotomic Hecke algebras (6 lectures)

---by A. Kleshchev (University of Oregon)

CONTENTS: The subjects to be covered are:

- Representation theory of symmetric groups  
and cyclotomic Hecke algebras.
- Connections with W-algebras.
- The graded aspects of the theory which are quite new

#### (3) Cohomology of Algebraic Groups, Finite Groups, and Lie Algebras: Connections and Interactions (6 Lectures)

---by Daniel Nakano (University of Georgia)

CONTENTS :

- Representation Theory of Reductive Groups, Finite Groups of Lie Type, Frobenius Kernels
- Construction of Spectral Sequences and Uses of Line Bundle Cohomology
- Applications
- formulas for  $\text{Ext}^1$  between simple modules
- vanishing of self-extensions
- locating the first non-trivial cohomology class
- Support Varieties
- Parshall Conjecture
- Bounds on complexities
- Construction of maps between support varieties

#### (4) Representations of Lie Super algebras (8 Lectures)

---by Weiqiang Wang (University of Virginia)

CONTENTS: This mini-course on Lie superalgebras is intended to cover:

- Lie superalgebra ABC
- Schur-Sergeev-Howe duality for Lie superalgebras and infinite-dimensional Lie algebras
- Kostant  $u$ -homology for Lie superalgebras
- Super duality: an equivalence of category  $\mathcal{O}$  between Lie algebras and superalgebras

#### (5) D-modules and Representation Theory (20 Lectures)

---by T. Tanisaki (Osaka City University)

CONTENTS: The subjects to be covered are;

- various operations on D-modules,
- coherent D-modules,
- holonomic D-modules,
- Riemann-Hilbert correspondence,
- D-module on flag manifolds,
- Kazhdan-Lusztig conjecture.

DESCRIPTIONS: The aim of this series of lectures is to give an overview of the theory of D-modules and its application to representation theory along the line of [HTT] R. Hotta, K. Takeuchi, T. Tanisaki, *D-modules, perverse sheaves, and representation theory, Progress in Mathematics 236, Birkhauser 2008.*

with emphasis on various examples. I assume that the audience are familiar with

- basic concepts of abelian categories like those in 1.1 and 1.2 of [KS] M. Kashiwara, P. Schapira, *Sheaves on manifolds, Springer, 1990.*
- and

- basic notions on algebraic varieties (see Appendix A of [HTT]), or complex manifolds. It will also be better that the audience have some familiarity with the following subjects although I will give some account of them in the lectures;
- the language of sheaves (see 2.1, 2.2, 2.3 of [KS]),
- homological algebras and derived categories (see 1.3-1.8 of [KS]).

## 4. Abstracts of Research Presentations

### Yiyang Li (Shanghai University of Engineering Science)

**Title:** Filtrations in Modular Representations of Reductive Lie Algebra

**Abstract:** Let  $G$  be a connected reductive group over an algebraically closed field  $k$  of prime characteristic  $p$ , and  $\mathfrak{g} = \text{Lie}(G)$ . In this presentation, we study representations of the reductive Lie algebra  $\mathfrak{g}$  with  $p$ -character  $\chi$  of standard Levi-form associated with an index subset  $I$  of simple roots. With aid of support variety theory we prove a theorem that a  $U_\chi(\mathfrak{g})$ -module is projective if and only if it is a strong "tilting" module, i.e. admitting both  $Z_Q$ - and  $Z^{w^I}_Q$ -filtrations. Then by analogy of the arguments of Andersen-Kaneda for  $G_1T$ -modules, we construct so-called Andersen-Kaneda filtrations associated with each projective  $\mathfrak{g}$ -module of  $p$ -character  $\chi$ , and finally obtain sum formulas from those filtrations.

### Dong Liu (Huzhou Teachers College)

**Title:** Classification of Harish-Chandra modules over the Schrödinger-Virasoro algebra.

**Abstract:** In this talk, we classify all irreducible weight modules with finite dimensional weight spaces over the Schrödinger-Virasoro algebra  $\mathfrak{sv}$ . Meanwhile, all indecomposable modules with one dimensional weight spaces over the Schrödinger-Virasoro algebra  $\mathfrak{sv}$  are also determined.

### Jinkui Wan (University of Virginia)

**Title:** Completely splittable representations of affine Hecke-Clifford algebras

**Abstract:** We classify and construct irreducible completely splittable representations of affine and finite Hecke-Clifford algebras over an algebraically closed field of characteristic not equal to 2.

### Yufeng Yao (East China Normal University)

**Title:** Support Varieties for Lie algebras of Cartan type

**Abstract:** In this presentation, we study support varieties for Lie algebras  $L$  of Cartan type. We give some description for the support varieties of any finite dimensional  $L$ -module with character  $\chi$ , whenever the height of  $\chi$  is not too big. Moreover, we can make a concrete computation for a class of modules with semisimple characters parallel to the arguments by Lin-Nakano on restricted modules and Shu on generalized restricted modules early.

### Lei Zhao (University of Virginia)

**Title:** Modular representations of Lie superalgebras.

**Abstract:** Earlier, a superalgebra generalization of the Kac-Weisfeiler conjecture was formulated and established by Wang and the speaker for basic classical Lie superalgebras (which are the most important classes of Lie superalgebras) over characteristic  $p$ . We will present a new proof of this result by adapting the deformation arguments of Premet and Skryabin to reduced enveloping superalgebras. The new proof allows us to improve optimally the assumption on  $p$  from our original proof. We will also establish a semisimplicity criterion using the technique of odd reflections for the reduced enveloping superalgebras associated with semisimple  $p$ -characters for all basic classical Lie superalgebras.

Participants outside ECNU

Name	Affiliation	Location
T. Arakawa	Nara Women's University	Nara
Ru Chen (陈茹)	Shandong University of Technology	Shandong
Shun-Jen Cheng (程舜仁)	Academia Sinica at Taiwan	Taipei
Weideng Cui (崔为登)	Chinese Academy of Sciences	Beijing
Chongying Dong (董崇英)	University of California at Santa Cruz	California
Jie Du (杜杰)	The University of New South Wales	Sydney
Ming Fang (方明)	Chinese Academy of Sciences	Beijing
Yucai Su (苏育才)	The University of Science of Technology of China	Anhui
Iain Gordon	The University of Edinburgh	Edinburgh
Yizhi Huang (黄一知)	University of Rutgers	New Jersey
Cuibo Jiang (姜翠波)	Shanghai Jiaotong University	Shanghai
Zhihong Jiang (蒋志洪)	Tongji University	Shanghai
Alexander Kleshchev	University of Oregon	Oregon
Xiaochao Li (李小朝)	Tongji University	Shanghai
Yiyang Li (李宜阳)	Shanghai University of Engineering Science	Shanghai
Ngau Lam (林牛)	National Cheng Kung University	Tainan
Dong Liu (刘东)	Huzhou Teachers College	Zhejiang
Daniel K. Nakano	University of Georgia	Georgia
Si'an Nie (聂思安)	Chinese Academy of Sciences	Beijing
Yufeng Pei (裴玉峰)	Shanghai Normal University	Shanghai
Shaodong Tai (邵昭东)	Tongji University	Shanghai
Xiaomin Tang (唐孝敏)	Heilongjiang University	Harbin
Toshiyuki Tanisaki (谷崎俊之)	Osaka City University	Osaka
Jinkui Wan (万金葵)	University of Virginia	Virginia
Meiyan Wang (王美艳)	Shandong Institute of Business and Technology	Shandong
Weiqliang Wang (王伟强)	University of Virginia	Virginia
Xiaoshaung Wang (王小双)	Zhejiang Ocean University	Zhejiang
Zhaoting Wei (韦兆汀)	University of Pennsylvania	Pennsylvania

Tao Xie (谢涛)	Hubei Normal University	Hubei
Chengkang Xu (徐诚慷)	China University of Mining and Technology	Jiangsu
Hengyun Yang (杨恒云)	Shanghai Maritime University	Shanghai
Hongyu Yu (于红雨)	Shanghai University	Shanghai
Chaowen Zhang (张朝文)	China University of Mining and Technology	Jiangsu
Ruibin Zhang (张瑞斌)	University of Sydney	Sydney
Shizhuo Zhang (张诗卓)	Kansas State University	Kansas
Shulin Zhang (张树林)	China University of Mining and Technology	Jiangsu
Pu Zhang (章璞)	Shanghai Jiaotong University	Shanghai
Lei Zhao (赵磊)	University of Virginia	Virginia
Lishun Zheng (郑立笋)	Shanghai Institute of Technology	Shanghai
Jingjing Jiang (姜敬敬)	Shanghai Jiaotong University	Shanghai
Song Wang (王松)	Shanghai Jiaotong University	Shanghai

Participants inside ECNU

Name	Affiliation	Location
hao Chang (常浩)	East China Normal University	Shanghai
Junguang Chen (陈俊光)	East China Normal University	Shanghai
Xiaoyu Chen (陈晓煜)	East China Normal University	Shanghai
Hui Du (杜卉)	East China Normal University	Shanghai
Zhengzheng Feng (冯铮铮)	East China Normal University	Shanghai
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Jun Lu (陆俊)	East China Normal University	Shanghai
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Shanshan Wang (王珊珊)	East China Normal University	Shanghai
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