Algorithmic Trading

PIMS Summer School 2016

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Main textbook published by Cambridge University Press (available on Amazon)...

Introduction

Introduction

- **Algorithmic Trading (AT)**: The use of computer algorithms that make trading decisions, submit orders, and manage those orders after submission.

- **High-Frequency (HF) Trading**: refers to the subset of AT trading strategies that are characterised by their reliance on speed differences relative to other traders to make profits based on short-term predictions and also by the objective to hold essentially no inventories for more than a very short period of time.

Introduction

- ▶ Why AT? One example
  - ▶ **Institutional investors** need to **trade large volume** of securities. These quantities are too large for the market to process without prices moving in the 'wrong direction' (slippage).

  - ▶ Thus, large orders are broken up in small ones and these are traded over time (minutes, hours, days, weeks, or even months) and across different venues.

  - ▶ Deciding how to break up and execute a large order can mean saving millions of dollars for large players

Introduction

- ► Why AT? Another example

- ► **Proprietary traders** devise strategies to maximise profits.
  - ► Speed based: short-lived signals, news, arbitrage across exchanges

  - ► Exploit predictable patterns: pairs trading, co-integrated prices

Exchanges

Exchanges

An exchange is a 'place' where 'people' meet to buy/sell securities: shares, commodities, derivatives, etc

- **Order Driven Market**:
  - All buyers and sellers display the prices and quantities at which they wish to buy or sell a particular security.

- **Quote Driven Market**:
  - Designated market makers and specialists display bids and asks for a specific security – e.g., even now **FX markets** are like this.

Order Driven Market

- All participants can post **limit buy or sell orders** – **provide liquidity**

- **limit orders** show an intention to buy or sell and must indicate the **amount of shares** and **price** at which the agent is willing to trade
    - limit buy order with the highest price is known as the **best bid**
    - limit sell order with the lowest price is known as the **best offer/ask**
    - The best bid/ask is also called the **touch**

- The difference between the best bid & offer is called the **spread**

- All participants can execute **market orders** for buy/selling at the best available prices – **take liquidity**

Evolution of markets

- ▶ Old days brokerage model: Ring a broker, broker sends order to the pit and after screaming and hand signalling the order is executed.

- ▶ Electronic market: Ring or use internet to contact broker who sends the order to the electronic exchange (no screaming)

- ▶ Direct Access Market: clients send orders directly to market

There are a multitude of exchanges... IEX (approved June 2016), ARCA-NYSE: electronic platform of NYSE, BATS (Kansas), BEX: Boston Equity Exchange, CBSX (CBOE Stock Exchange), CSXZ (Chicago Stock Exchange), DRCTEDGE (Direct Edge, Jersey City, NJ), ISE (International Securities Exchange), ISLAND (Acquired by Nasdaq in 2003), LAVA (Citigroup), NSX (National Stock Exchange, Chicago) TRACKECN (Track ECN), ChiX, LSE (London Stock Exchange), BM&F BOVESPA (Braizl) etc, etc

Limit Order Books

Algo Trading

Limit Order Book

- **Limit orders** are accumulated in the limit order book (**LOB**) until they find a counterparty for execution or are cancelled

- The counterparty is a **market order** which is an order to buy or sell an amount of shares, regardless of the price, and is **immediately executed** against the **best prices**
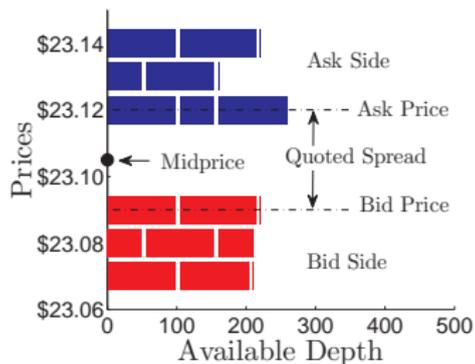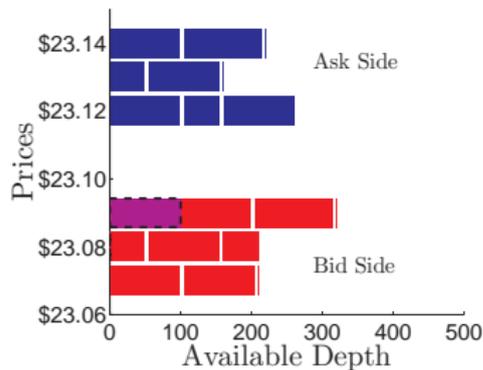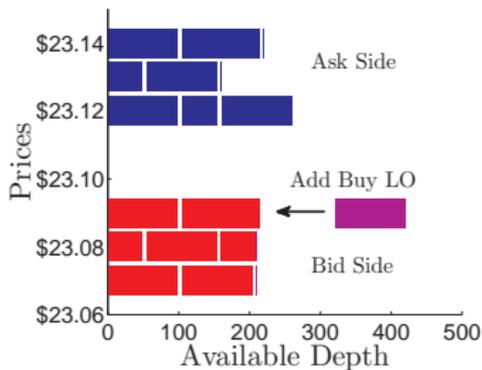

ORCL on Nov 1, 2013
at 09:38:00.072
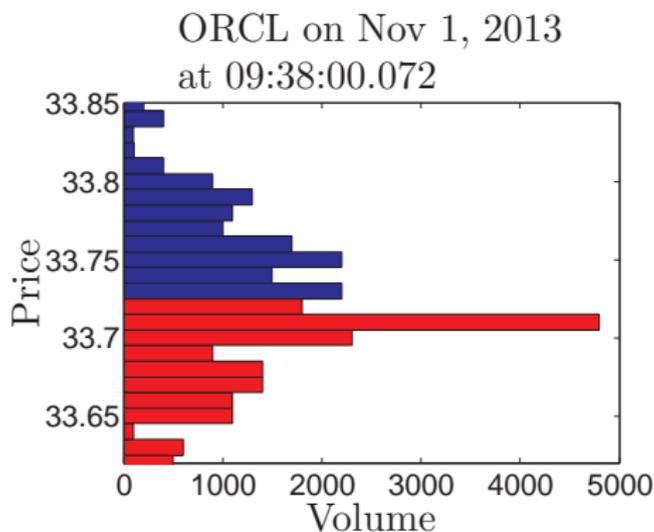
Limit Order Book

Figure : LOB illustration of a buy LO added to the queue at the best bid.

Limit Order Book
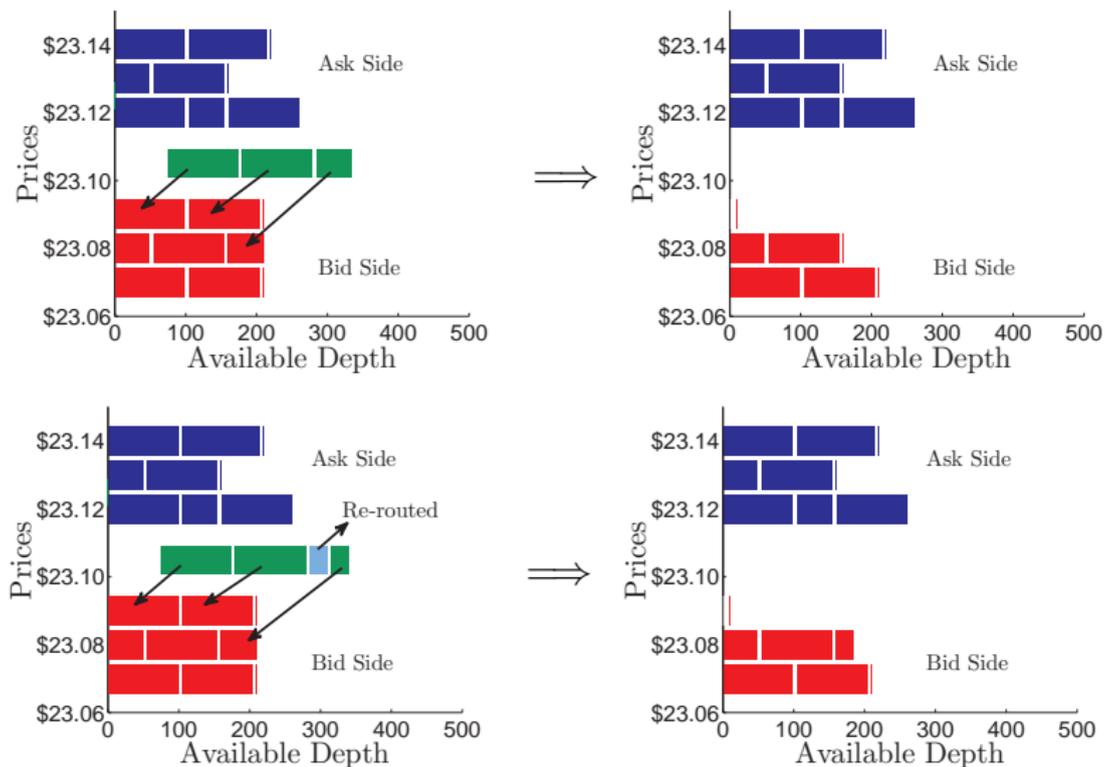
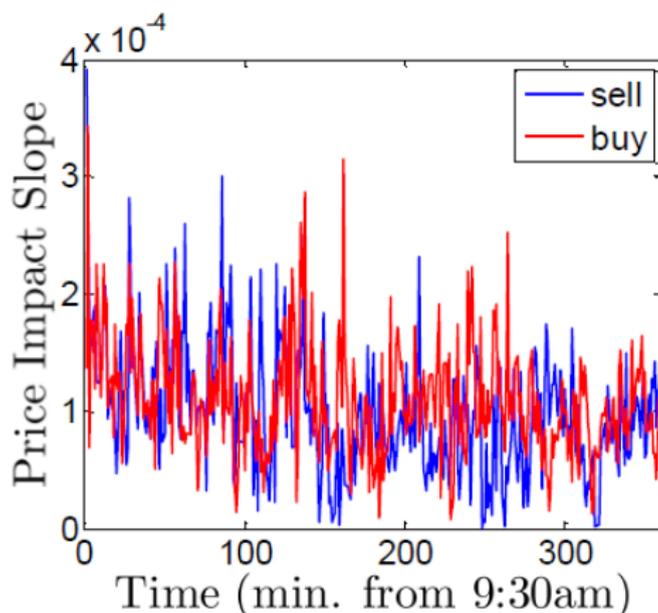Figure : LOB: a sell MO walking the LOB with and without re-routing.

Limit Order Book

Market orders can **walk the LOB** and incur **immediate execution costs**
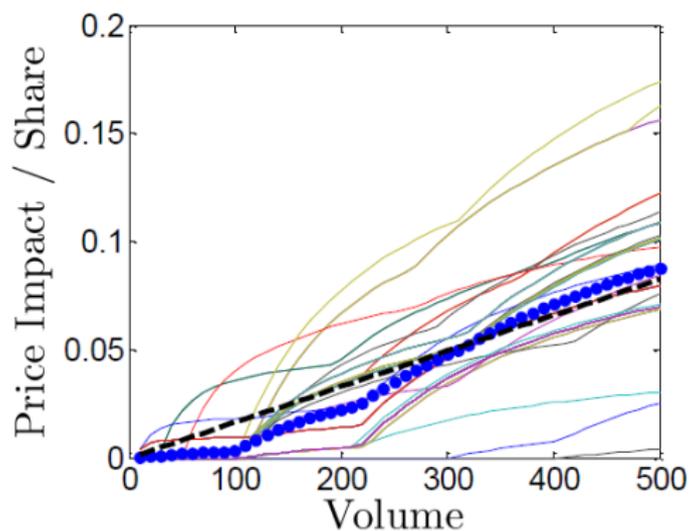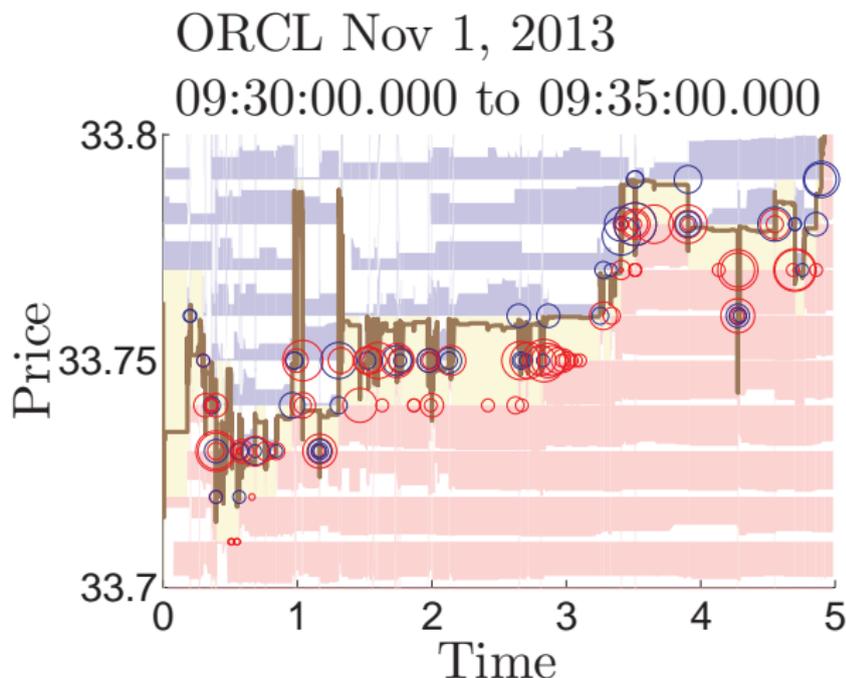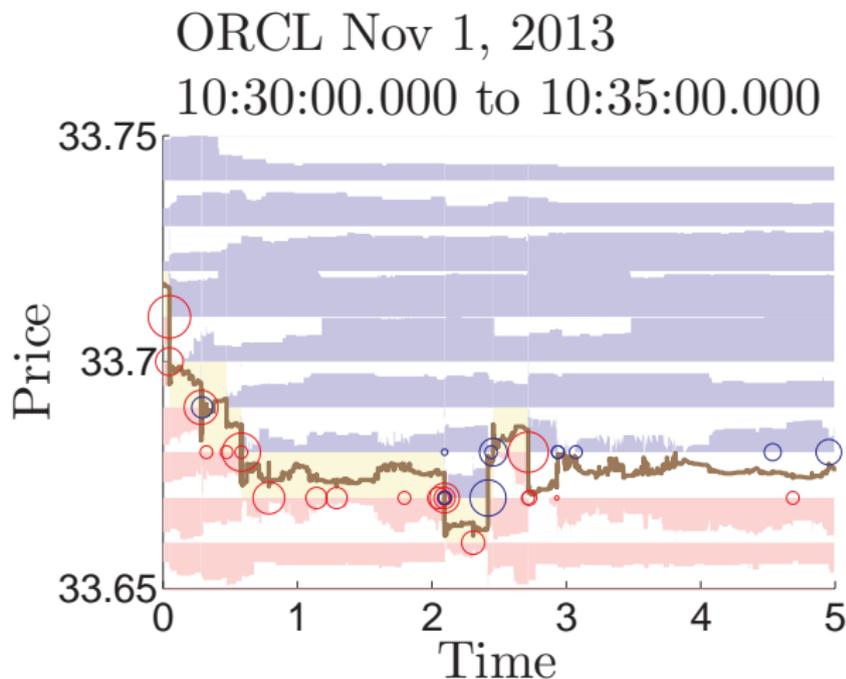
Limit Order Book

Impact dynamics throughout the day
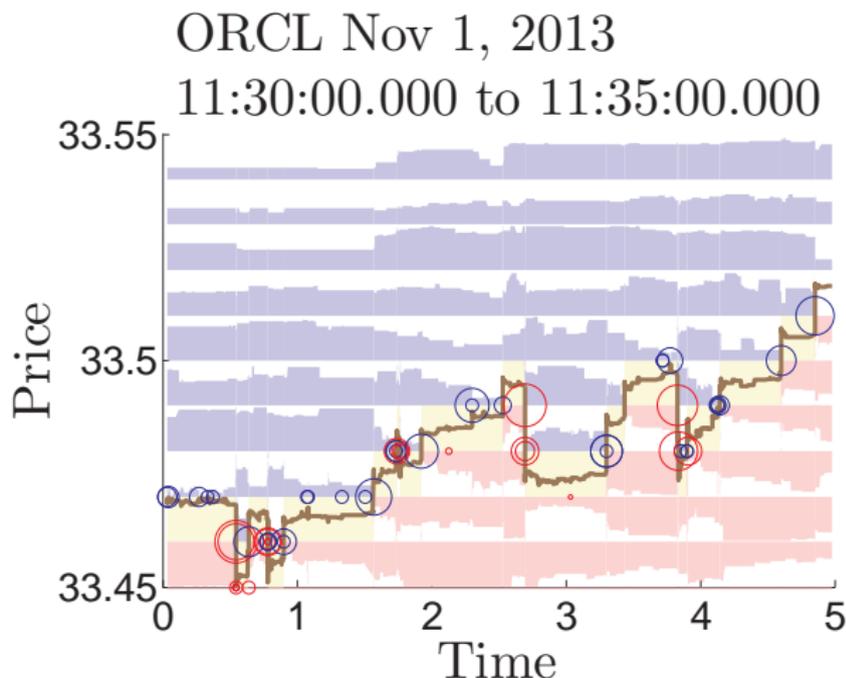
Limit Order Book

Trade Activity

ORCL Nov 1, 2013
09:30:00.000 to 09:35:00.000

Limit Order Book

Trade Activity

ORCL Nov 1, 2013
10:30:00.000 to 10:35:00.000

Limit Order Book

Trade Activity

ORCL Nov 1, 2013
11:30:00.000 to 11:35:00.000

Limit Order Book

Trade Activity

ORCL Nov 1, 2013
12:30:00.000 to 12:35:00.000

Limit Order Book

Trade Activity

ORCL Nov 1, 2013
13:30:00.000 to 13:35:00.000

Limit Order Book

Trade Activity

ORCL Nov 1, 2013
14:30:00.000 to 14:35:00.000

Limit Order Book

Trade Activity

ORCL Nov 1, 2013
15:30:00.000 to 15:35:00.000

Algo Trading

Limit Order Book

Trade Activity

ORCL Nov 1, 2013
15:55:00.000 to 16:00:00.000
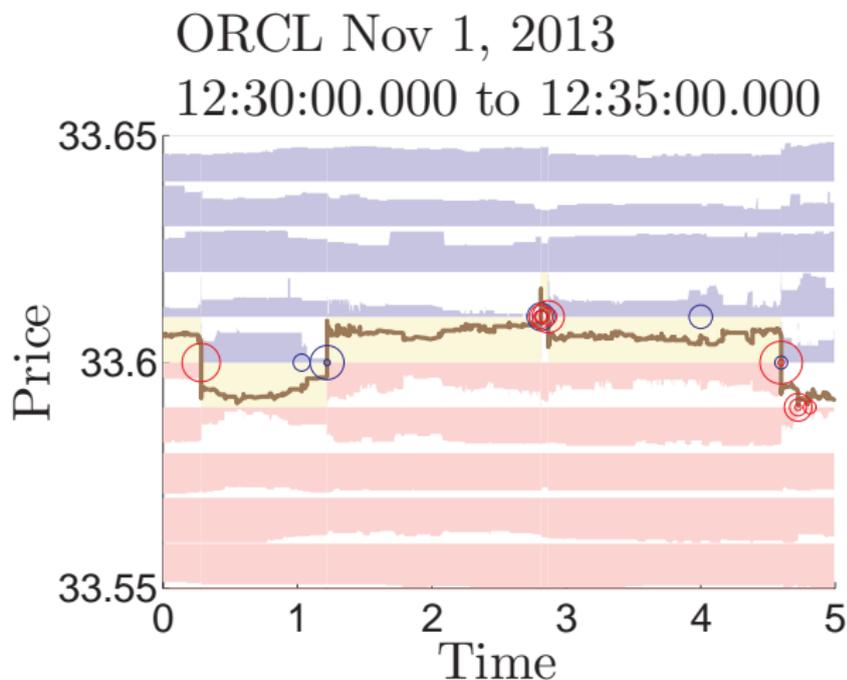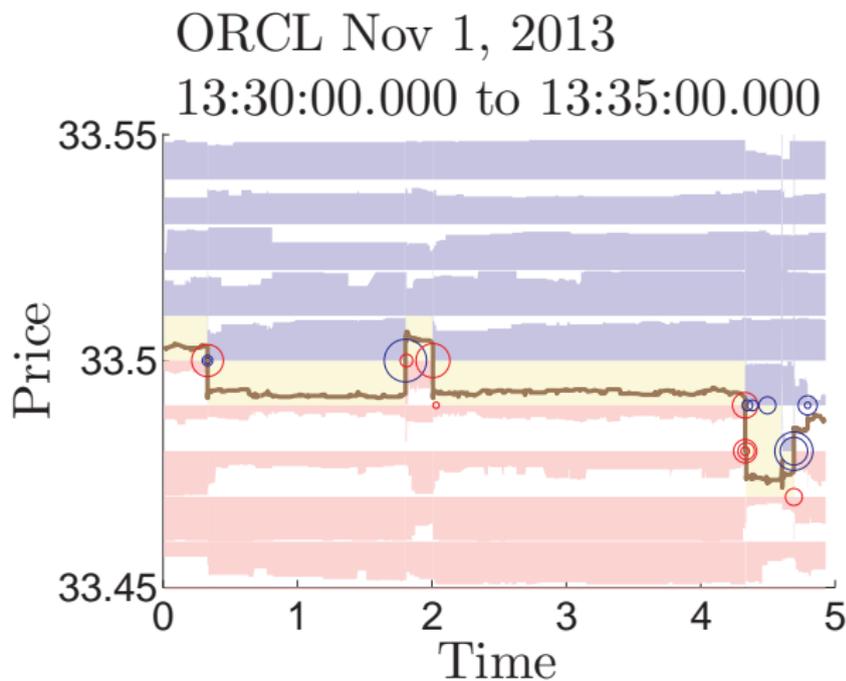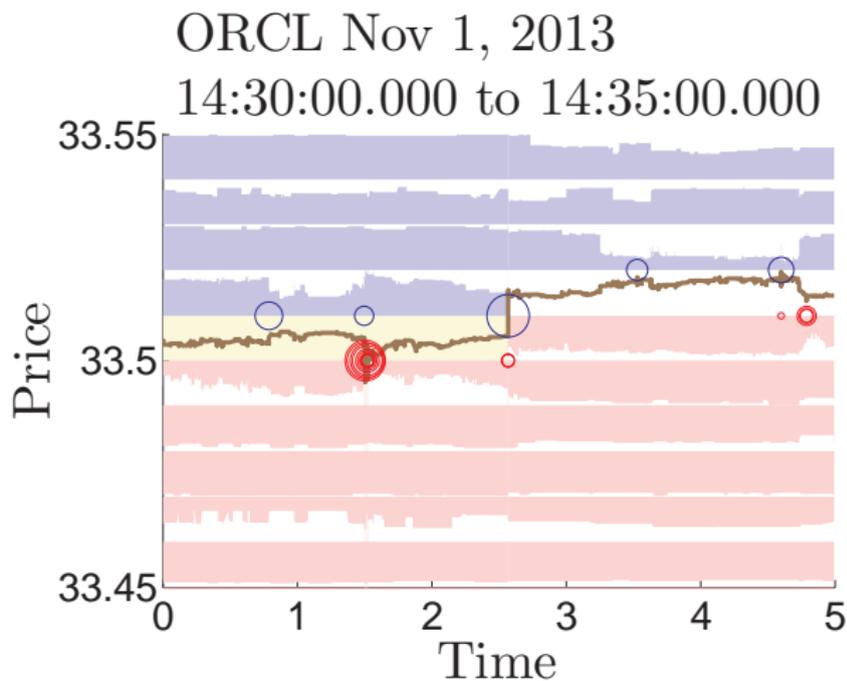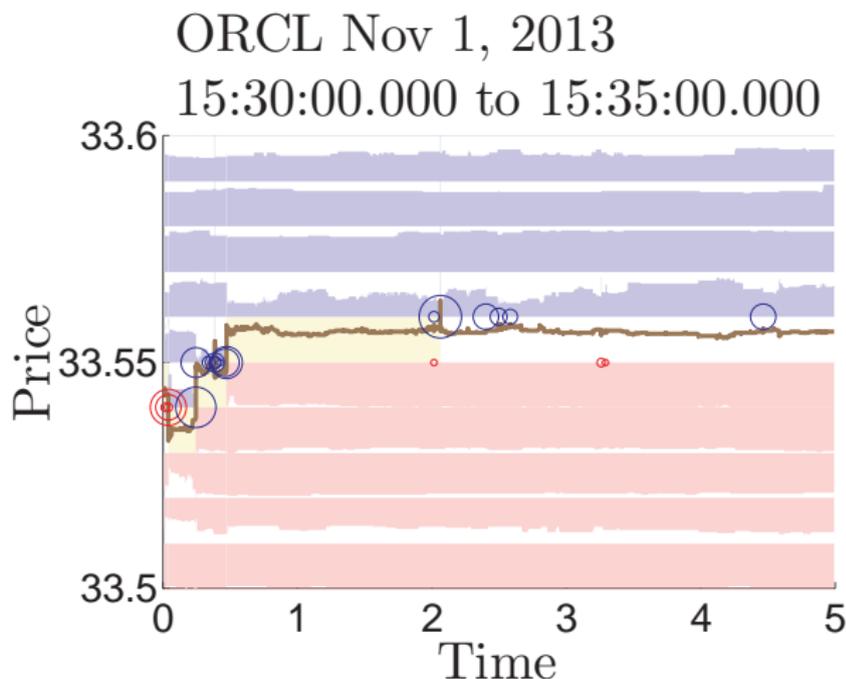
Limit Order Book
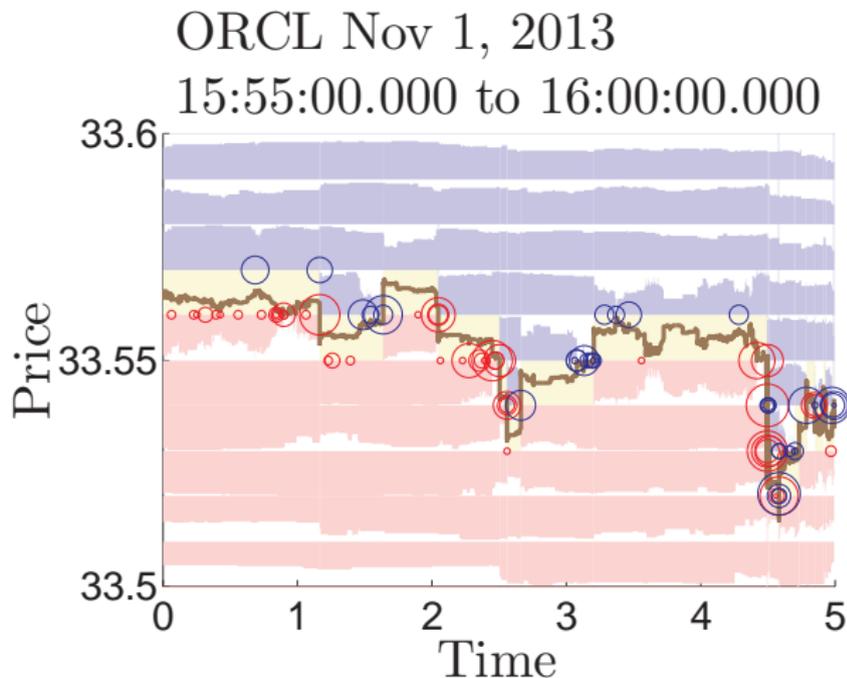
Trade Activity: INTC for Oct-Dec, 2014 (5min)

Limit Order Book
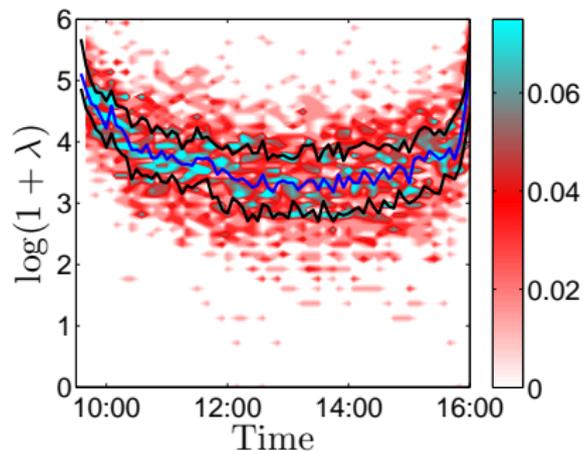
Trade Volume: INTC for Oct-Dec, 2014 (5min)
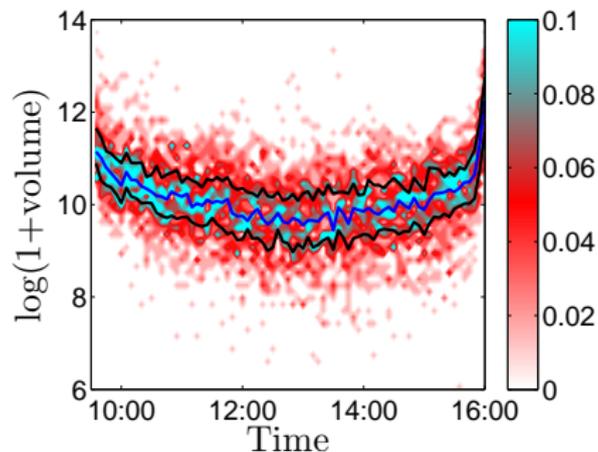
Order Imbalance

Order Imbalance

- **Order Imbalance** measures whether the LOB is buy or sell heavy
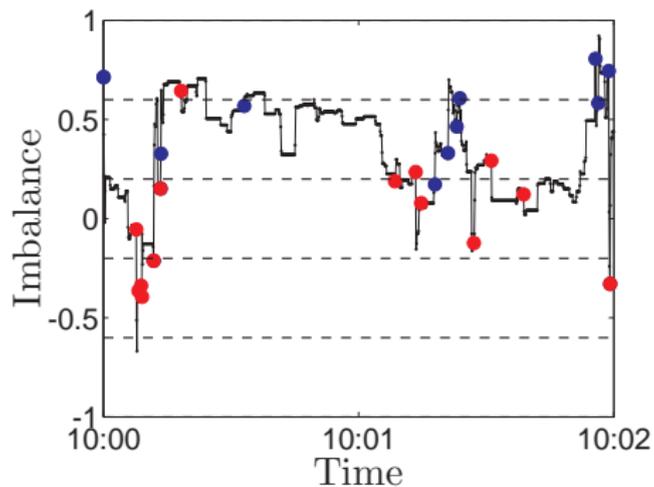
$$\rho_t = \frac{V_t^b - V_t^a}{V_t^a + V_t^b} \in [-1 \, , \, +1]$$

- Order imbalance is a good **predictor of trade direction**

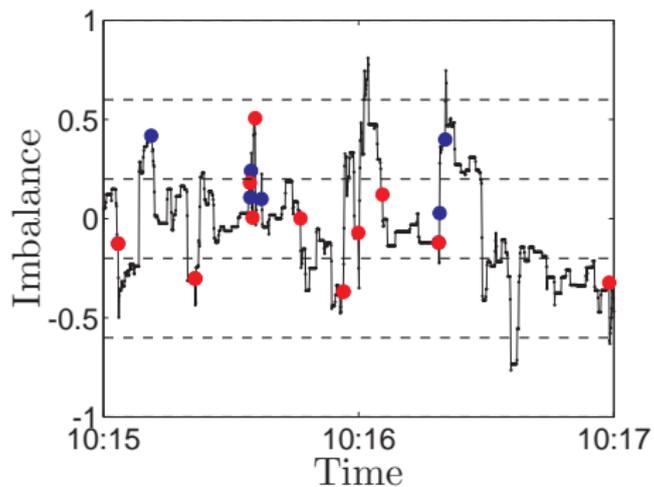|		ORCL Nov 1, 2013				
		buys		sells		Total
ρ	direction	num	perc.	num	perc.	
all		**1699**	**53%**	1526	47%	3225
< -0.5	sell heavy	67	12%	**506**	**88%**	573
< 0	sell	313	23%	**1059**	**77%**	1372
> 0	buy	**1385**	**75%**	462	25%	1847
$> +0.5$	buy heavy	**745**	**89%**	91	11%	836

Order Imbalance

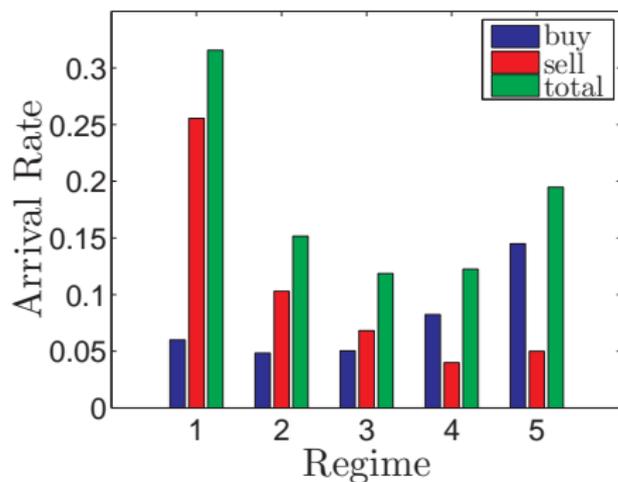A slice of OI for ORCL 10:00am to 10:02am on Nov 1, 2013

Order Imbalance

A slice of OI for ORCL 10:15am to 10:17am on Nov 1, 2013

Order Imbalance

MO arrival rates conditional on OI: ORCL on Nov 1, 2013

Order Imbalance

- Distribution of midprice change 10*ms* after a market order.

Figure : ORCL: one month of NASDAQ trades. Imbalance ranges are $[-1, -0.33)$, $[-0.33, 0.33]$, and $(0.33, 1]$.

Order Imbalance

- Distribution of midprice change 10*ms* after a market order.
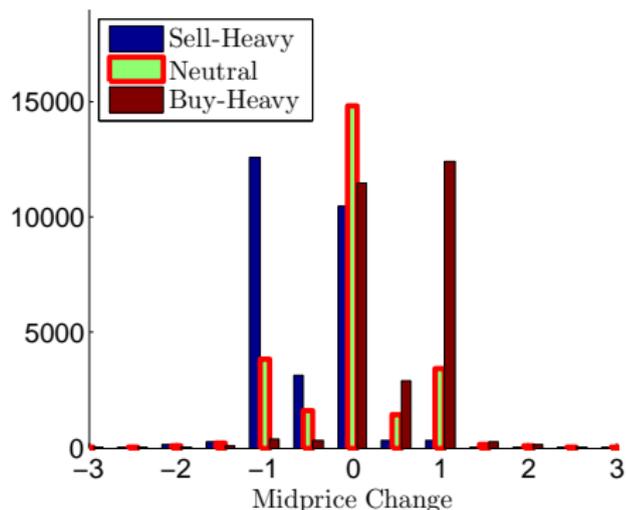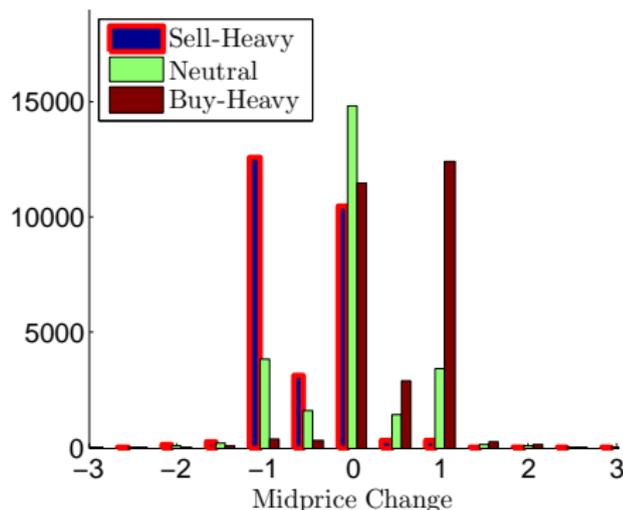

Figure : ORCL: one month of NASDAQ trades. Imbalance ranges are
$[-1, -0.33)$, $[-0.33, 0.33]$, and $(0.33, 1]$.

Order Imbalance

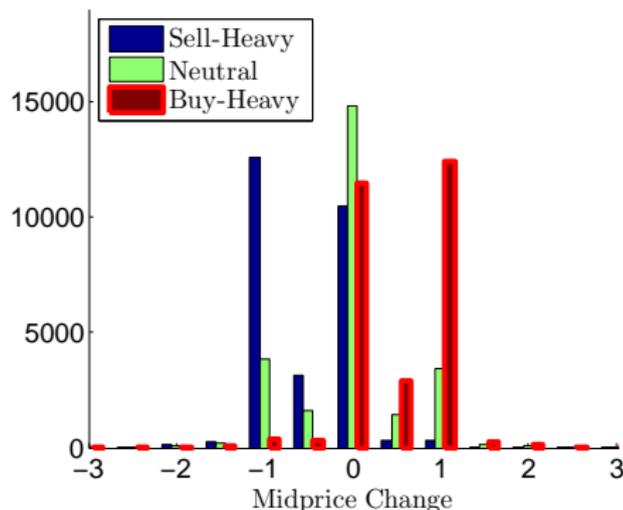▶ Distribution of midprice change 10*ms* after a market order.

Figure : ORCL: one month of NASDAQ trades. Imbalance ranges are
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Glosten-Milgrom Model

Imagine that you are a market maker... (part I)

Glosten-Milgrom model

- An asset is worth either $\overline{V}$ or $\underline{V}$ with prob $\frac{1}{2}$

- MM sets the bid and ask prices

- A trader arrives and buys OR sells the asset to the MM

- The trader is informed with probability α

- **Informed traders** know the asset outcome before trading

- **Uniformed traders** buy/sell with probability $\frac{1}{2}$

Imagine that you are a market maker... (part II)

Glosten-Milgrom model

▶ What are the rational prices that a risk-neutral MM sets?

▶ Naive answer is simply to set

$$ask = bid = \mathbb{E}[\, V \,]$$

▶ The MM will then be **adversely selected**...

▶ When trading with uninformed trader... no losses on average.

▶ When they sell... they sometimes sell to an informed trader who knows the price was going up

▶ When they buy... they sometimes buy from an informed trader who knows the price was going down

Imagine that you are a market maker... (part III)

Glosten-Milgrom model

- ▶ To account for the potential of being adversely selected, the MM sets instead

$$ask = \mathbb{E}[\ V \mid \text{MO is buy}\ ]$$
$$bid = \mathbb{E}[\ V \mid \text{MO is sell}\ ]$$

- ▶ After some simple computations one finds

$$ask = \mathbb{E}[\ V\ ] + \frac{\alpha}{2}\left(\overline{V} - \underline{V}\right)$$
$$bid = \mathbb{E}[\ V\ ] - \frac{\alpha}{2}\left(\overline{V} - \underline{V}\right)$$

- ▶ Therefore

$$\boxed{spread = \alpha\left(\overline{V} - \underline{V}\right)}$$