

Convex Optimization for Applications in Communications and Signal Processing

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**Wireless Communications and Signal
Processing (WCSP) Lab, NTHU**



Convex Optimization

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□ Convex Optimization problem

$$\begin{aligned} \text{(P)} \quad & \min_x f(x) \\ & \text{s.t. } x \in \mathcal{F} \end{aligned}$$

is **convex** if $f(\cdot)$ is a convex function and $\mathcal{F}$ is a convex set, i.e.,

$$\theta x + (1 - \theta)y \in \mathcal{F} \quad \forall x, y \in \mathcal{F}, \quad 0 \leq \theta \leq 1$$

$$f(\theta x + (1 - \theta)y) \leq \theta f(x) + (1 - \theta)f(y) \quad \forall 0 \leq \theta \leq 1$$

- (P) is **feasible** if the constraint set $\mathcal{F}$ is nonempty.
- **Optimal solutions** (provided that (P) is solvable) can be found either analytically, or numerically using available convex solvers (e.g., SeDuMi or CVX)
- **Applications in Communications and Networking:** Detection, space-time coding, transmit beamforming, resource allocation, secret communications, etc.
- **Applications in Signal Processing:** Blind Source Separation, Biomedical Image Analysis, Hyperspectral Image Analysis, etc.

台灣清華大學祁忠勇教授為我校師生開設“通信與信號處理之凸優化”短期

強化開放課程受到熱捧

來源：天津大學新聞網http://www.tju.edu.cn/newscenter/foreign_affairs/201109/t20110901_113243.htm 發布時間：2011-09-01



本站訊（通訊員 鄒強）應我校電子信息工程學院的邀請，台灣新竹清華大學祁忠勇教授於 8 月 22 日至 9 月 2 日來校講授“通信與信號處理之凸優化”的短期強化開放課程。

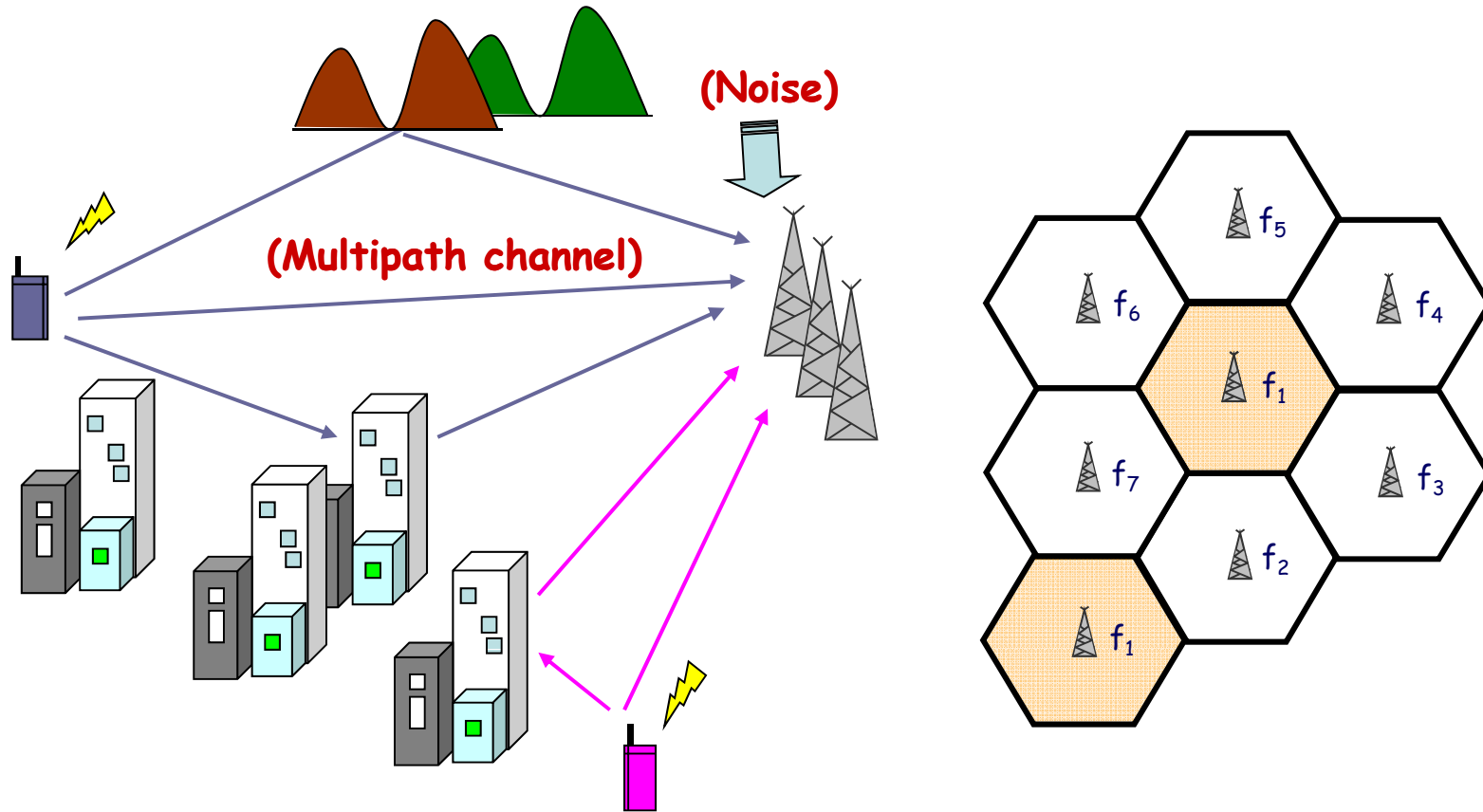
凸優化理論與方法在近二十年內一直是公認的解決科技工程問題的強有力的工具。迄今為止，祁教授及所在科研小組已將凸優化理論與方法成功應用於盲源信號分離（Blind Source Separation），生物醫學與高光譜成像分析中的信號處理，以及無線通信中相干性檢測，信道估計，空時編碼，分散式信號處理等一系列相關領域。此外，該方法正被用於其他更新的領域中，如分析化學，無線通信物理層之保密與合作。本次開放的這門課程就是介紹凸優化的理論和方法，相關軟件及其應用。

課程吸引了信息、精儀、自動化、管理、理學院和南開大學相關領域的教師、研究生 120 多人參加，大大超出預期人數，以致連續兩次調整教室規模。祁教授生動活潑的授課方式，深入淺出的教學方法以及幽默風趣的風格得到師生的廣泛好評。

祁忠勇教授於 1983 年博士畢業於南加州大學電機工程系，之後在美國加州理工學院之噴射推進實驗室工作五年，此後在台灣新竹清華大學工作二十二年，是台灣通信領域最著名的學術專家，發表高水平的論文近 170 篇，參與著書並編寫教材，現階段從事領域主要包括無線通訊系統的信號處理，盲信號源分離的凸優化處理以及生物醫學與高光譜成像中的信號處理及分析，是台灣地區下一代通信系統的研究和規劃工作的牽頭人之一。本次課程是天津大學和台灣新竹清華大學緊密合作的成果之一。本短期強化課程的開設，得到了研究生院的大力支持。



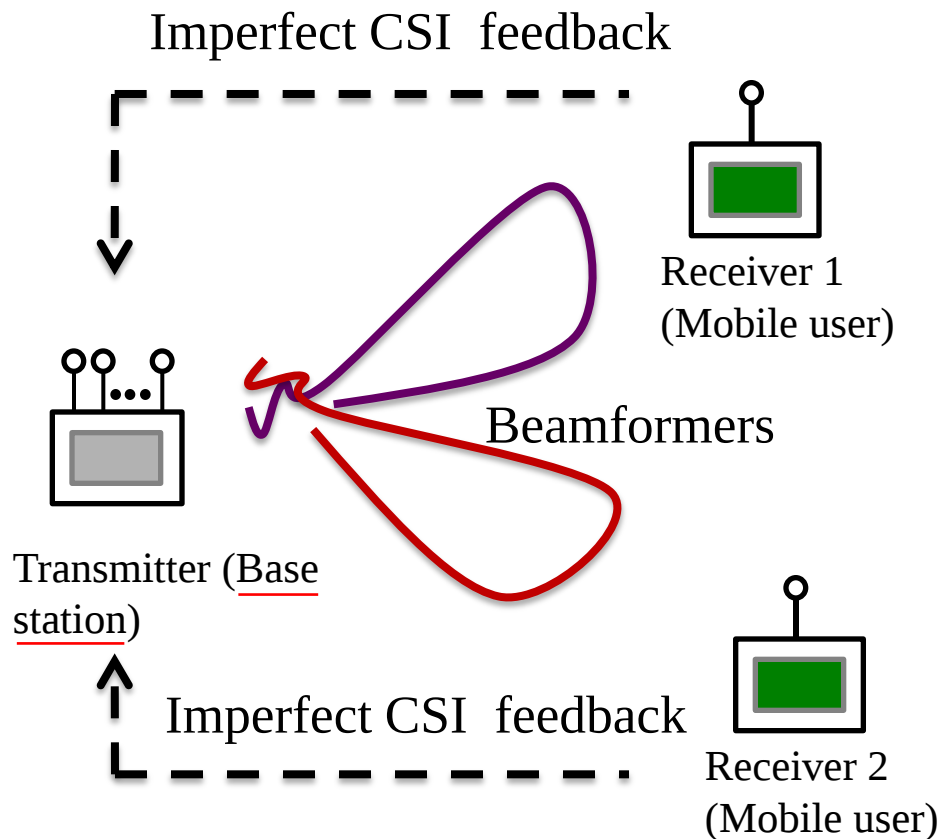
Cellular Wireless Communication System



◆ 無線通訊

❖ MIMO合作式無線通訊及通訊安全

穩健波束成形

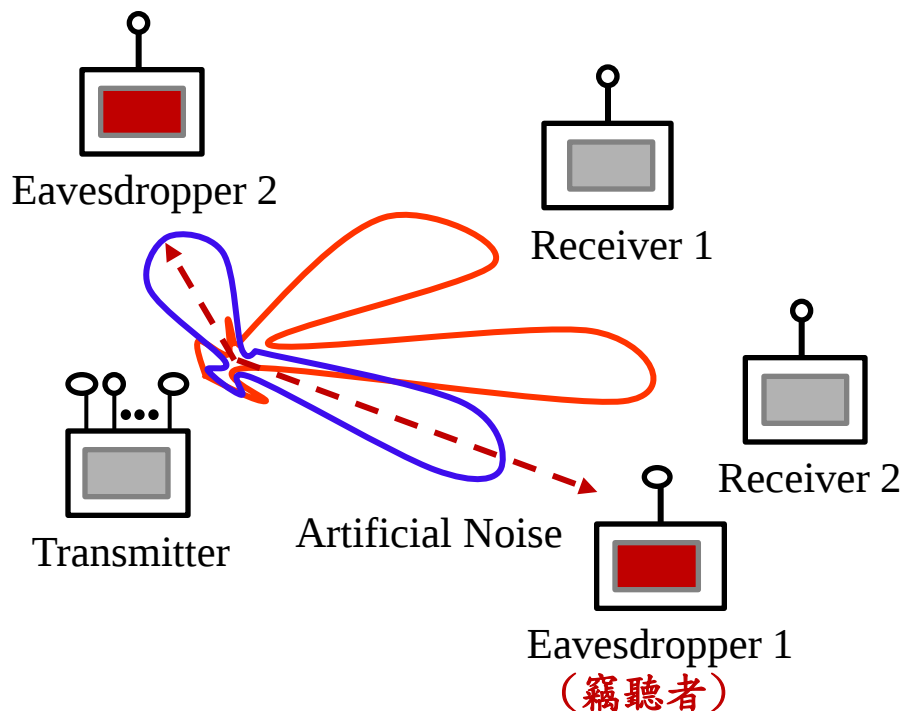


- ◆ 考慮傳送端的非理想通道訊息之穩健波束成形設計。
- ◆ 針對不同的通道訊息誤差模型，開創**凸優化理論**之低複雜度、高性能設計方法(*New fundamental theory*)。
- ◆ 目標：消耗最少的的傳輸功率，同時能夠容忍最大的通道訊息誤差，達到接收訊號品質之要求。

◆ 無線通訊

❖ MIMO合作式無線通訊及通訊安全

安全波束成形

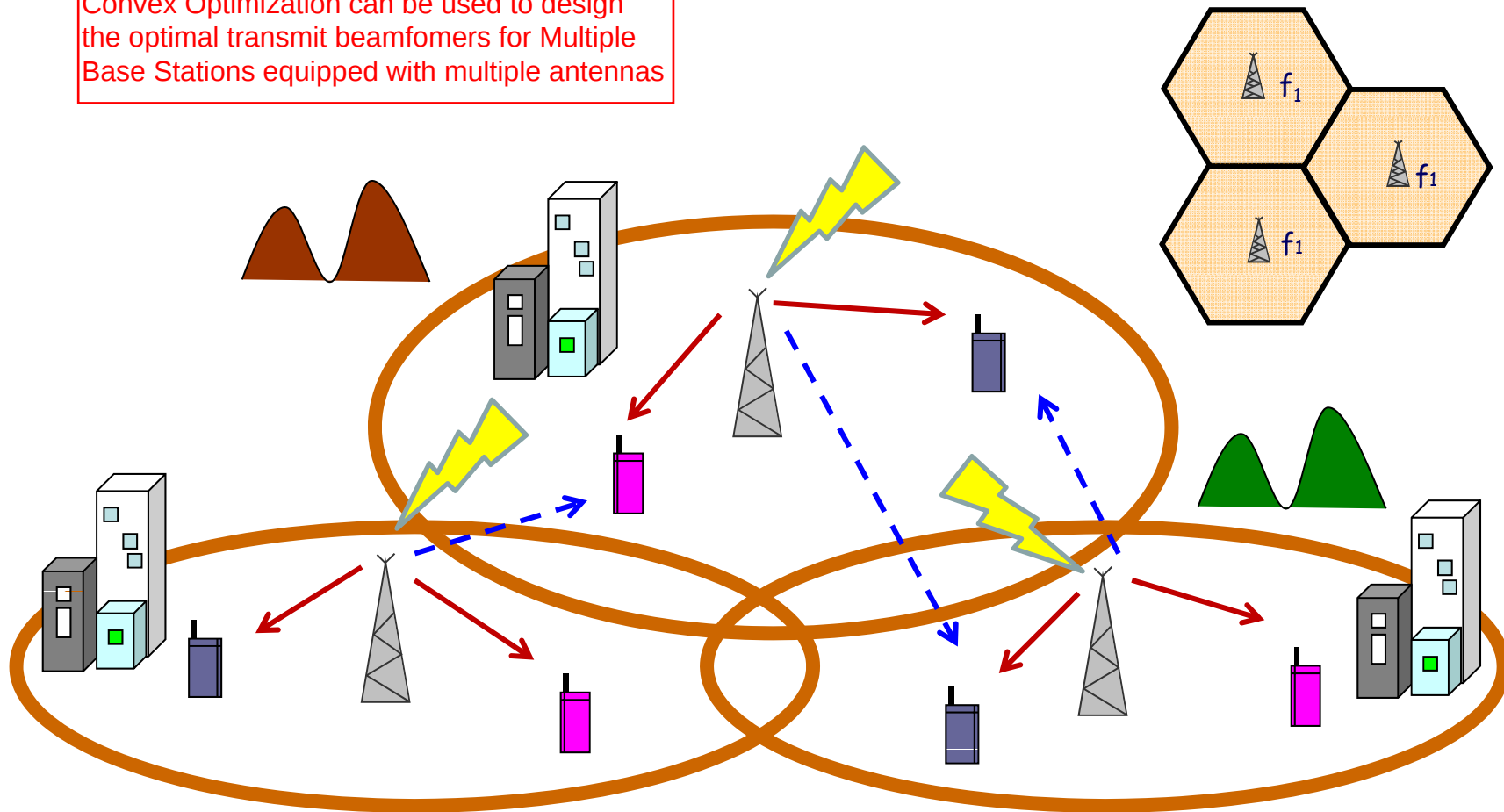


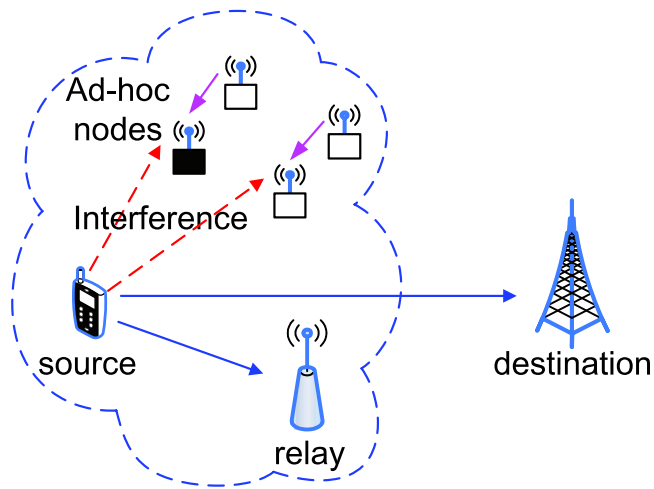
- ◆ 安全波束成形設計; 同時最佳化符和接收訊號品質要求之安全波束成形及人工雜訊之空間分佈。
- ◆ 基於凸優化理論(Convex optimization theory)之有效解決方法(*New fundamental theory*)。



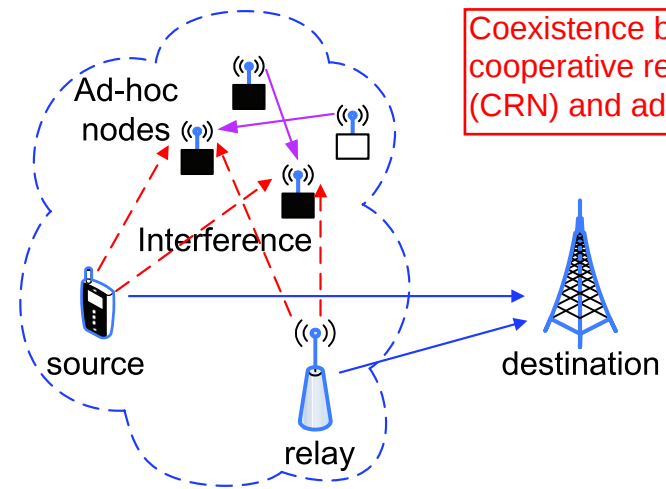
Multicell Wireless Cooperative System

Convex Optimization can be used to design the optimal transmit beamformers for Multiple Base Stations equipped with multiple antennas



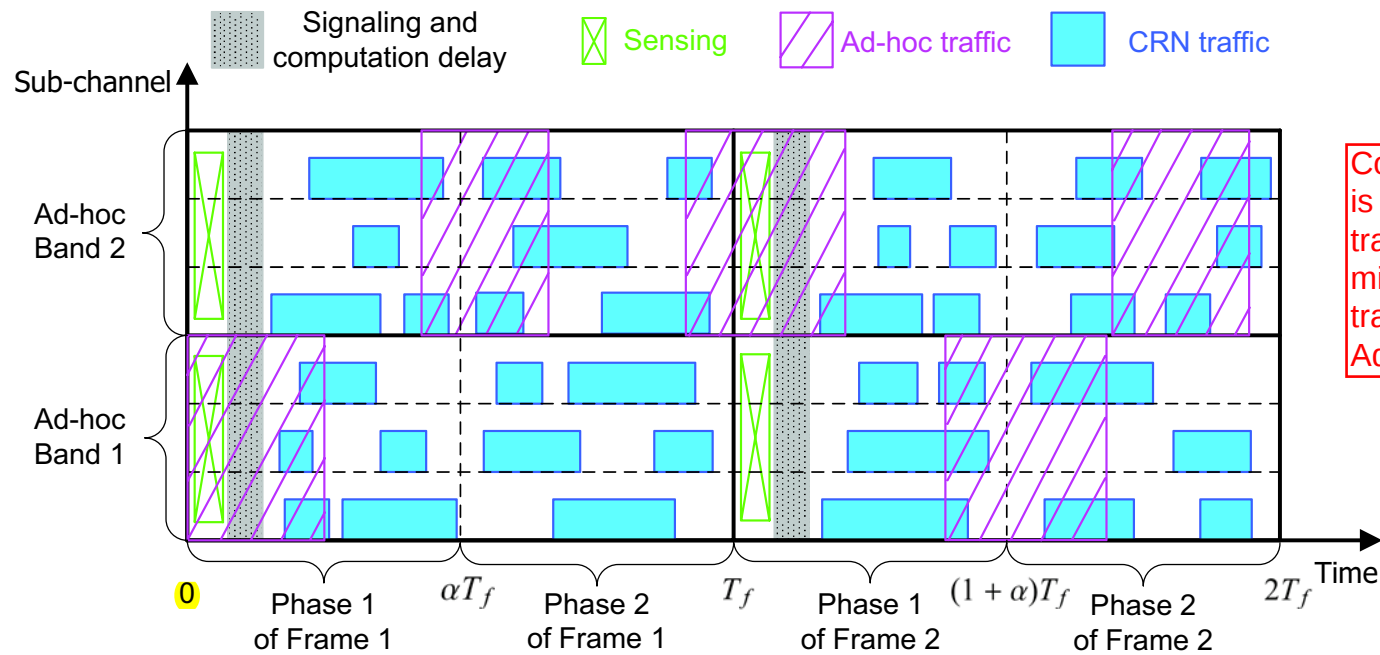


Phase 1 of the uplink CRN



Phase 2 of the uplink CRN

Coexistence between a cooperative relay network (CRN) and ad-hoc network

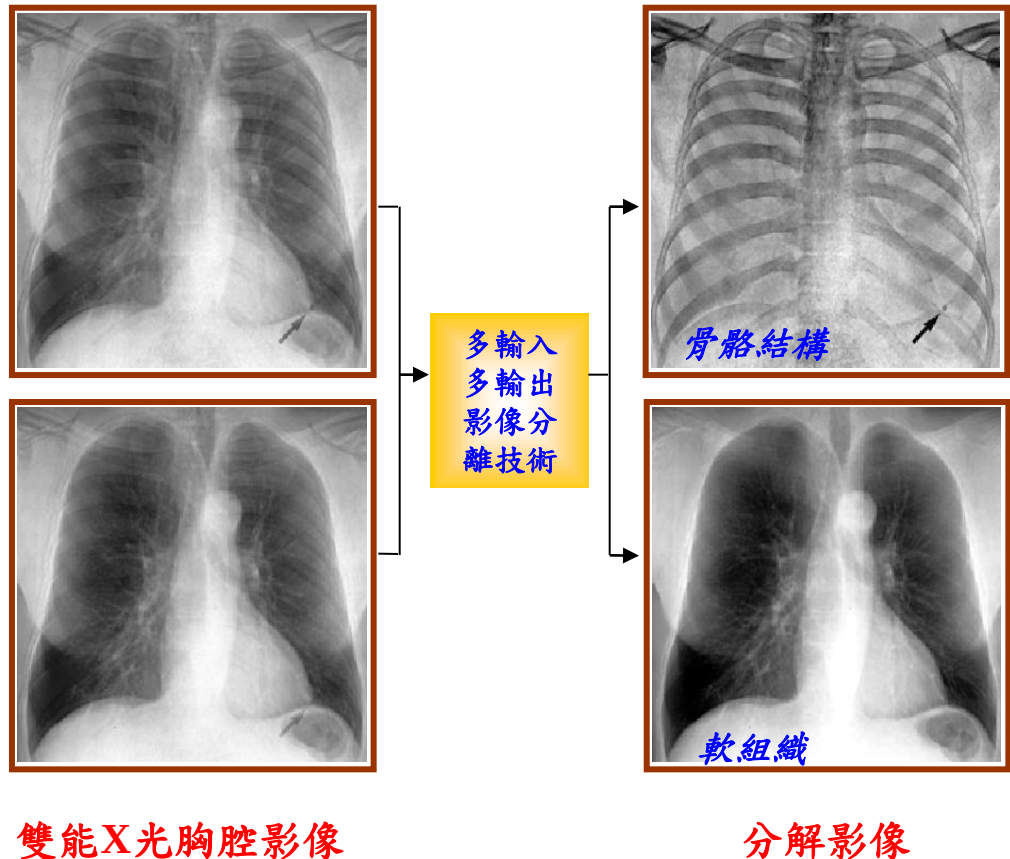


Convex Optimization is used for optimal transmission control to minimize the overlap traffic time of CRN and Ad-hoc networks

◆ 跨領域研究: 生物醫學(Biomedicine)

❖ 生醫影像分解

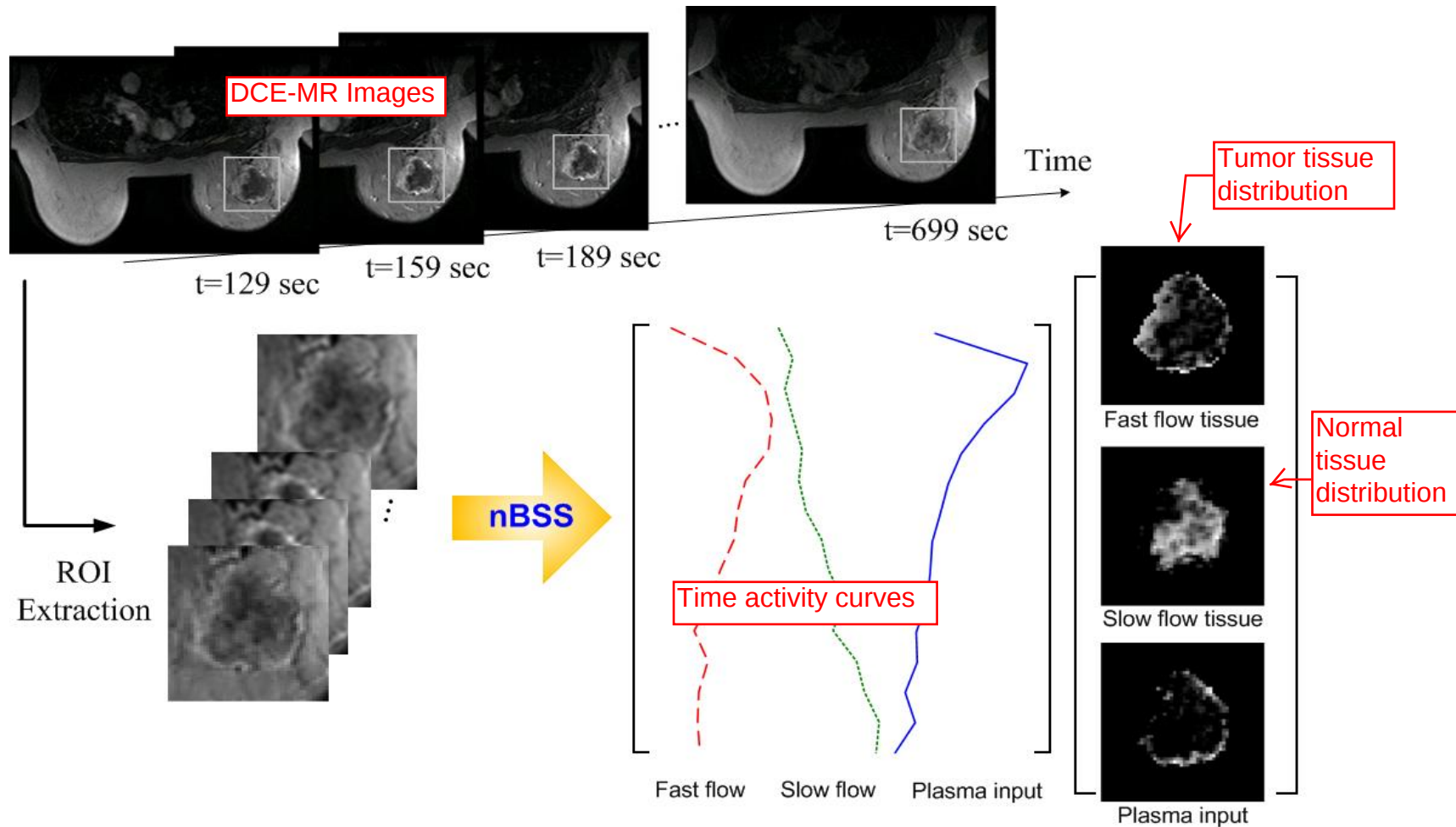
- ◆ MIMO Communications: **Non-Coherent Detection**
(多輸入多輸出通訊之非同調檢測)
↓ 凸優化理論
- ◆ Signal Processing: **Blind Source Separation** (盲訊號源分離)
↓ 凸優化理論
- ◆ **Biomedical Image Analysis** for Dual-energy X-ray images, and other images (e.g. DCE-MRI images)





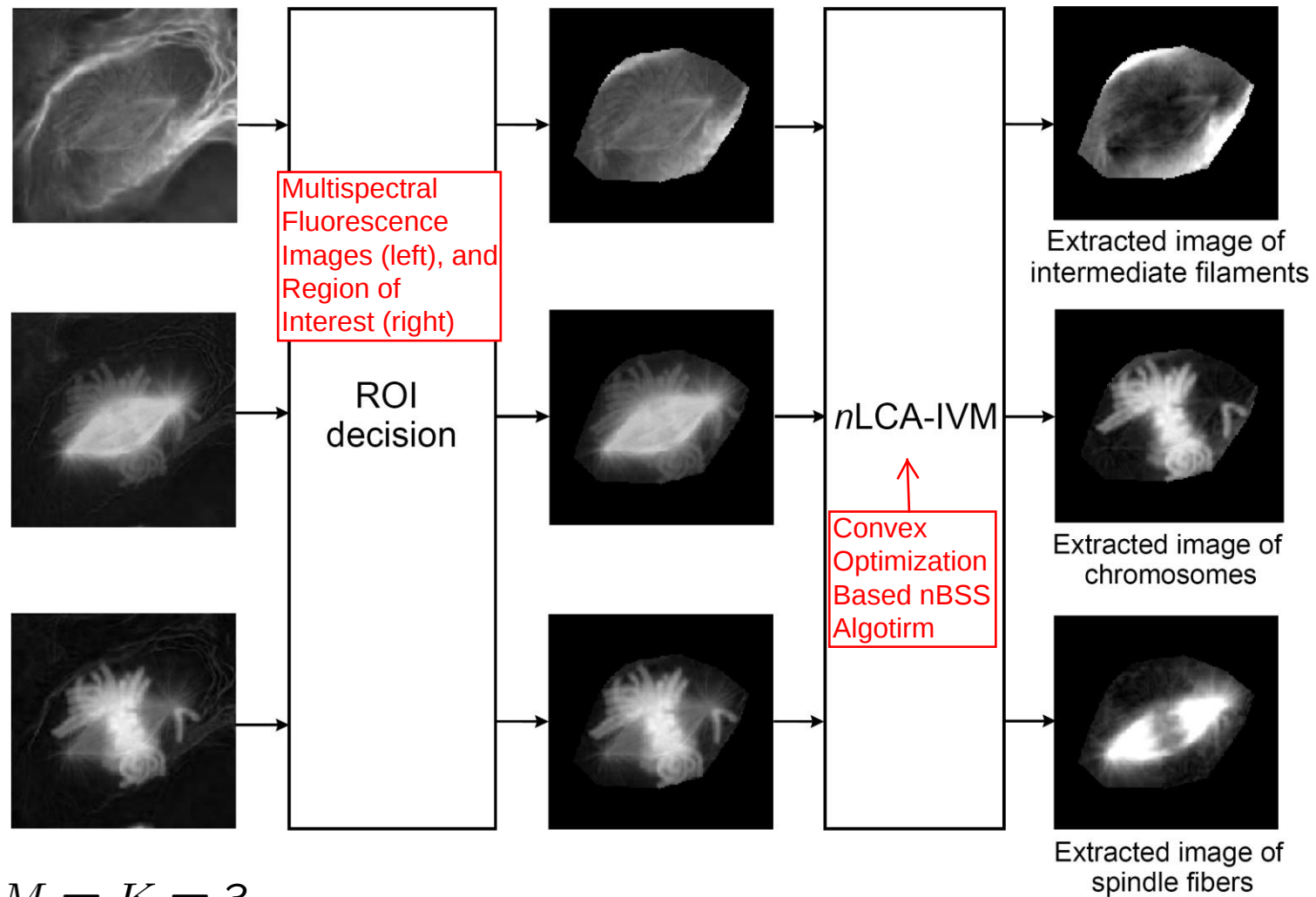
An Application of nBSS

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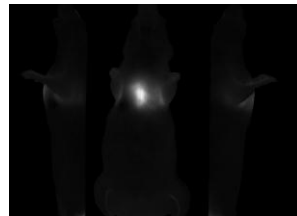
$$M = K = 3$$

The results were obtained by nLCA-IVM

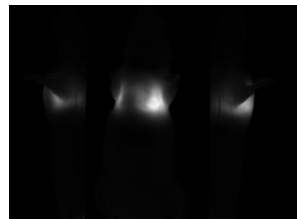


Results for DFI Data (Supine Position)

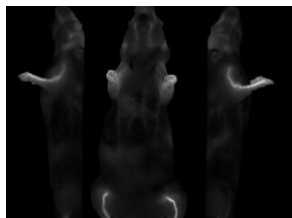
Anatomical Map obtained by processing 150 Dynamic Fluorescence Images using CAMNS (Convex Optimization Based nBSS Algorithm)



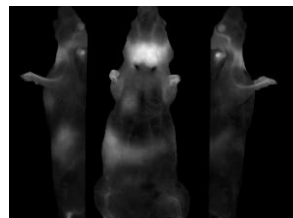
Heart (1st)



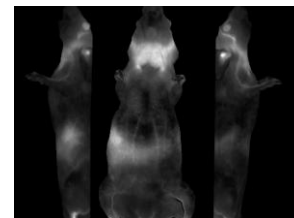
Lungs (2nd)



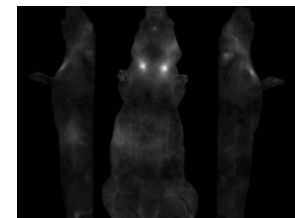
Blood vessels (3rd)



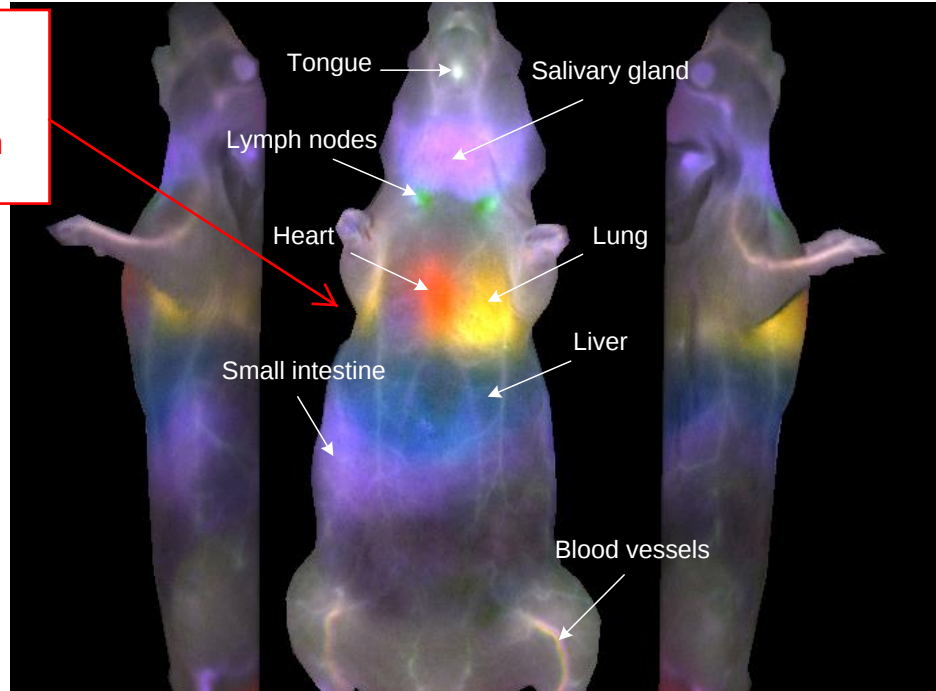
Salivary gland (4th)



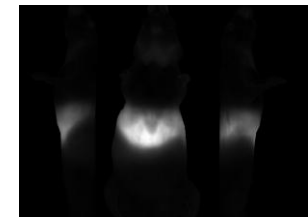
Small intestine (4th)



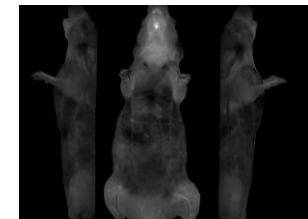
Lymph nodes (5th)



Estimated anatomical map (overlapped with the pseudo-colored estimated sources)



Liver (7th)



Tongue (6th)

$$M = 150$$

$$K = 8$$

The above results were obtained by CAMNS

◆ 跨領域研究: 遙感 (Remote Sensing)

❖ 超光譜影像分解

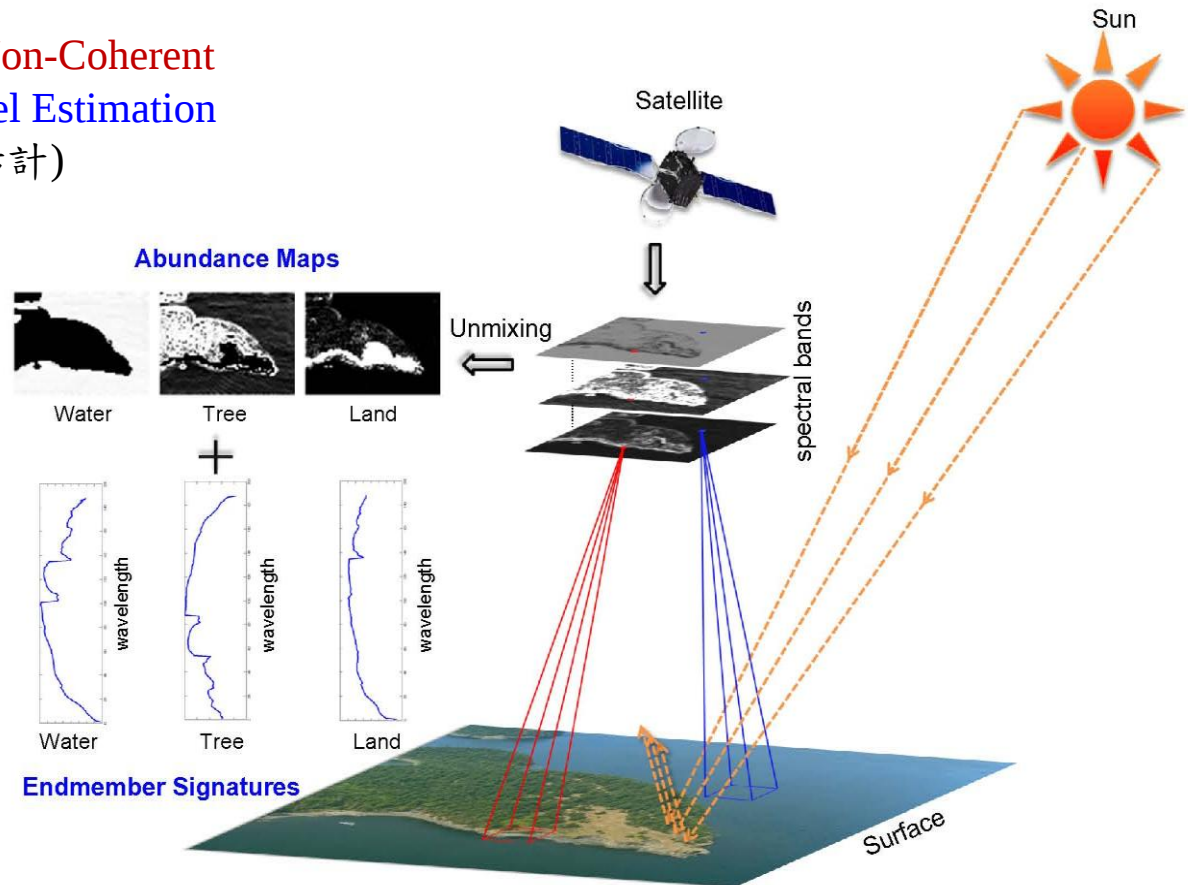
- ◆ MIMO Communications: **Non-Coherent Detection** and **Blind Channel Estimation**
(非同調檢測及盲蔽通道估計)

↓ 凸優化理論

- ◆ Signal Processing: **Blind Source Separation**
(盲訊號源分離)

↓ 凸優化理論

- ◆ Hyperspectral Unmixing: **Endmember Extraction** and **Abundance Estimation**
(超光譜分解之端源抽取及物質分佈比例估計)

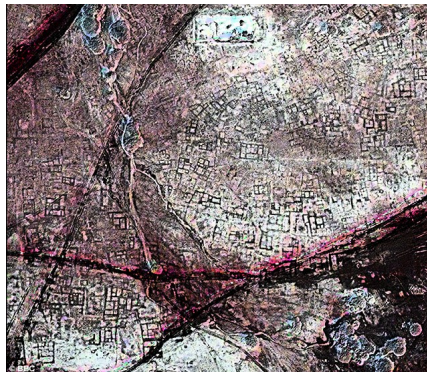


A Potential Application: Space Archaeology

- Infrared satellite images show that Tanis to be a city littered with underground tombs.



naked eye vs infrared image



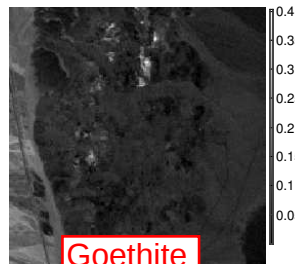
ancient streetmap

All the materials above were taken from BBS news, May 26, 2011.



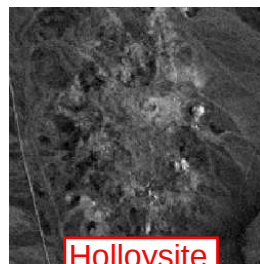
Muscovite

(a)



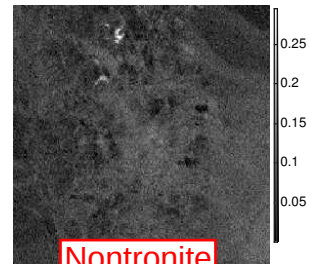
Goethite

(b)



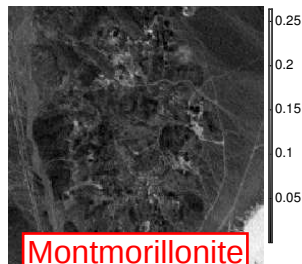
Holloysite

(c)



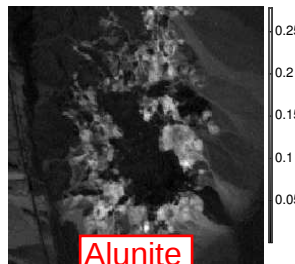
Nontronite

(d)



Montmorillonite

(e)



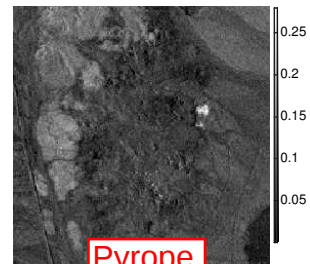
Alunite

(f)



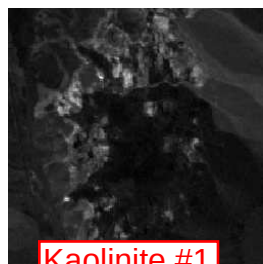
Buddingtonite

(g)



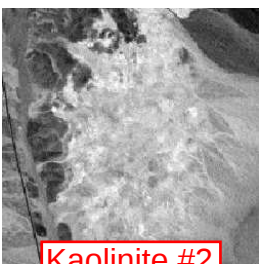
Pyrope

(h)



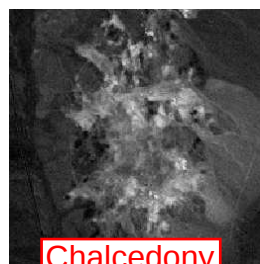
Kaolinite #1

(i)



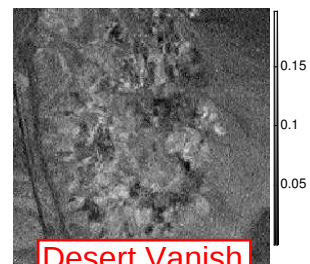
Kaolinite #2

(j)



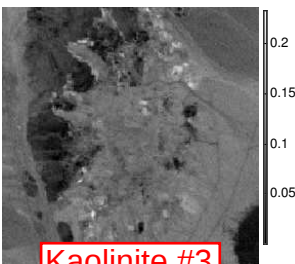
Chalcedony

(k)



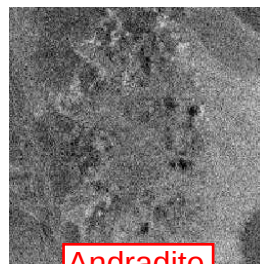
Desert Vanish

(l)



Kaolinite #3

(m)



Andradite

(n)

Convex Optimization is used to unmix Airbone Visible/Infrared Imaging Spectrometer Data (AVIRIS) Data, Cuprite mining site, Nevada 1997

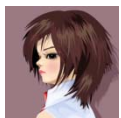


有興趣或有意願的同學，請與我們聯繫：



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