A MULTI-BAND, MULTI-RESOLUTION DEBLENDER FOR LSST (& OTHERS)

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A NEW DEBLENDER

- Star/Galaxy separation is not obvious: non-parametric
- Objects are somehow “compact”, mostly symmetric
- Color should be useful, photo-z are dangerous
BSS VIA NON-NEGATIVE MATRIX FACTORIZATION

\[
\text{scene} = \sum_{k} \text{SED}_k \times \text{Morphology}_k + \text{noise}
\]

\[
Y = A \cdot S + \text{noise}
\]

\[
\|Y - A \cdot S\|_2^2 + g(A, S)
\]
BUT: HOW?

Objective function $f(A, S)$ is quadratic in $A$ and $S$

\[ \| Y - A \cdot S \|_2^2 \]

1. solve for $A$ under constraints (at least non-negative)

2. solve for $S$ under constraints

3. repeat until convergence

Alternating Least-Squares (ALS): does not converge well (if at all)

But: $f$ is convex in every argument
EFFICIENT GENERAL SOLVER: ADMM

- Problem: \( \min_S \{ f(A, S) + g(GS) \} \)

- Enforce constraints with dual variable: \( f(A, S) + g(Z) : GS = Z \)

- Alternative Direction of Method of Multiplier (ADMM):

  \[
  S^{k+1} := \arg\min_S \left\{ f(S | A) + \lambda^k GS + \frac{1}{2\rho} \| GS - Z^k \|_2^2 \right\}
  \]

  \[
  Z^{k+1} := \arg\min_Z \left\{ g(Z) + \lambda^k T Z + \frac{1}{2\rho} \| GS^{k+1} - Z \|_2^2 \right\}
  \]

  \[
  \lambda^{k+1} := \lambda^k + \frac{1}{\rho} (GS^{k+1} - Z^{k+1})
  \]

- Often per-iteration updates are simple & analytic:

  \[
  S^{k+1} := \nabla_S \left( f(A, S) + \frac{\mu}{\rho} G^T (GS^k - Z^k + \lambda^k) \right)
  \]
EFFICIENT GENERAL SOLVER: ADMM

it 4000: (-3.123, -1.590)
def grad_f(xy):
    """Gradient of f"""
    x, y = xy
    return np.array([2*x, 2*y])

def prox_circle(xy, step):
    """Projection onto circle"""
    center = np.array([0, 0])
    dxy = xy - center
    radius = 0.5
    # exclude interior of circle
    if (dxy**2).sum() < radius**2:
        phi = np.arctan2(dxy[1], dxy[0])
        return center + radius*np.array([np.cos(phi), np.sin(phi)])
    else:
        return xy
DEBLENDING GALAXIES WITH NMF
MELCHIOR ET AL. (IN PREP)

\[ g(A, S) \rightarrow \sum_k g_k(A_k) + h_k(LS_k) \]

- per-object constraints with linear operators: gradients, symmetry, FFT …
- SED: sum=1, particular colors, distribution of observed colors

3-band RGB  
NMF: no constraint  
NMF: with monotonicity
AGN JET VS HOST GALAXY

- 5-band HSC data
- Model: Jet + 2-component host + neighbor
- PSF matching on the fly

Constraints:
- Color+
- Structure+

Found Components:

by Max Jerdee (Princeton)
NMF FOR HYPER-SPECTRAL UNMIXING

210 wavelengths
500nm to 2 micron
NMF FOR HYPER-SPECTRAL UNMIXING

Moolekamp & Melchior (2017)
CONCLUSIONS

- Whenever you have an additive mixture situation: think NMF
- Soft priors and hard constraints can be implemented
- **NMF code** public, algorithm paper [arxiv:1708.09066](https://arxiv.org/abs/1708.09066)
- Deblender: multi-band by design, multi-resolution-ready
- Standalone version available soon & integration into the LSST stack
- [Post-doc position](https://example.com) available
QUESTIONS / PROBLEMS

▸ Which quantities should be measured well?
▸ How large do we need to go?
▸ How faint do we need to go?
▸ What do we do with unrecognized blends?
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Dawson et al. (2015)

▸ What do we do with unrecognized blends?