Constraining the structure of the Milky Way through 3D extinction mapping of molecular clouds

Tom Wilson

Introduction

Introduction

ESA/NASA

Introduction

Bruno Gilli/ESO

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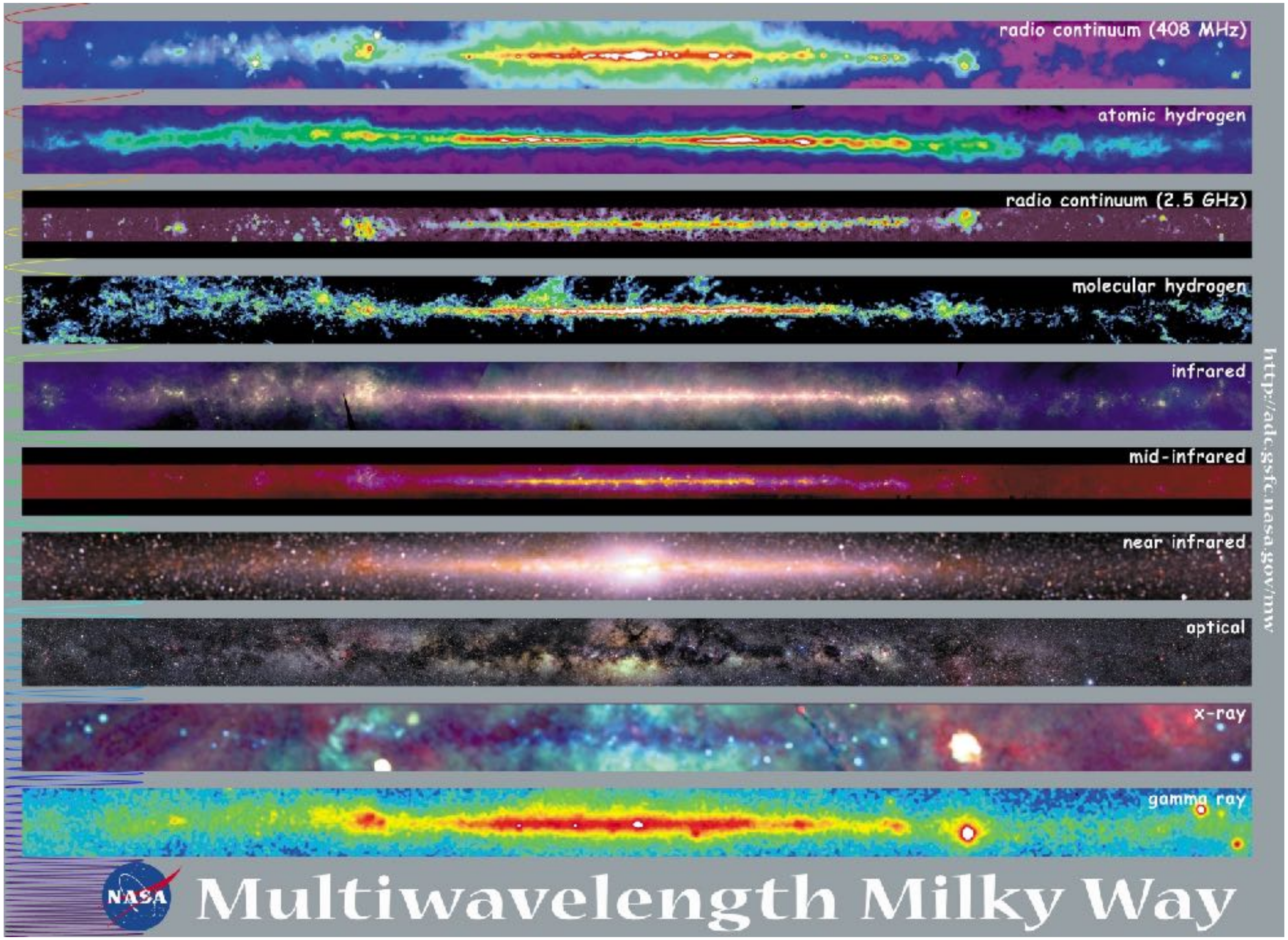

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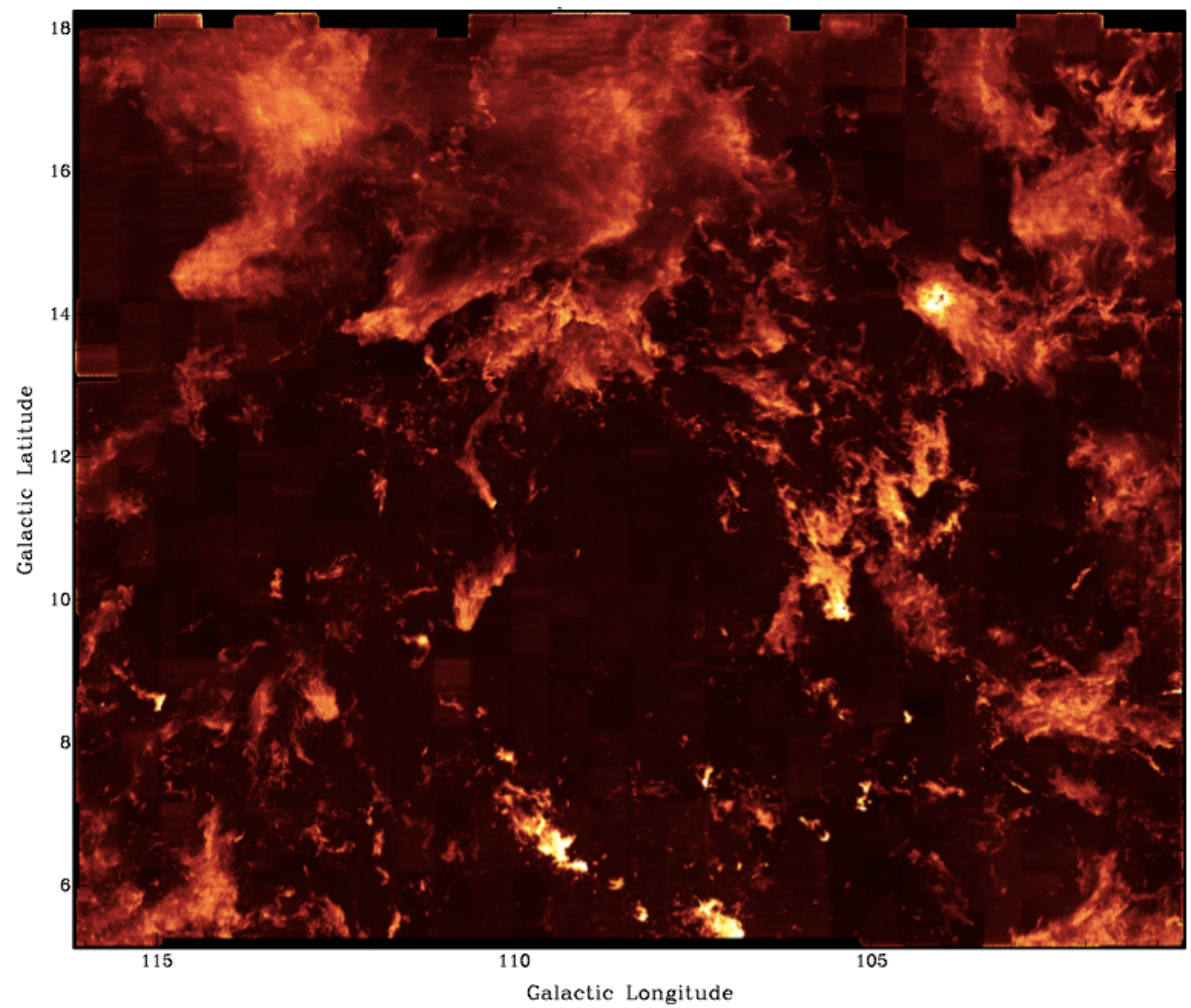

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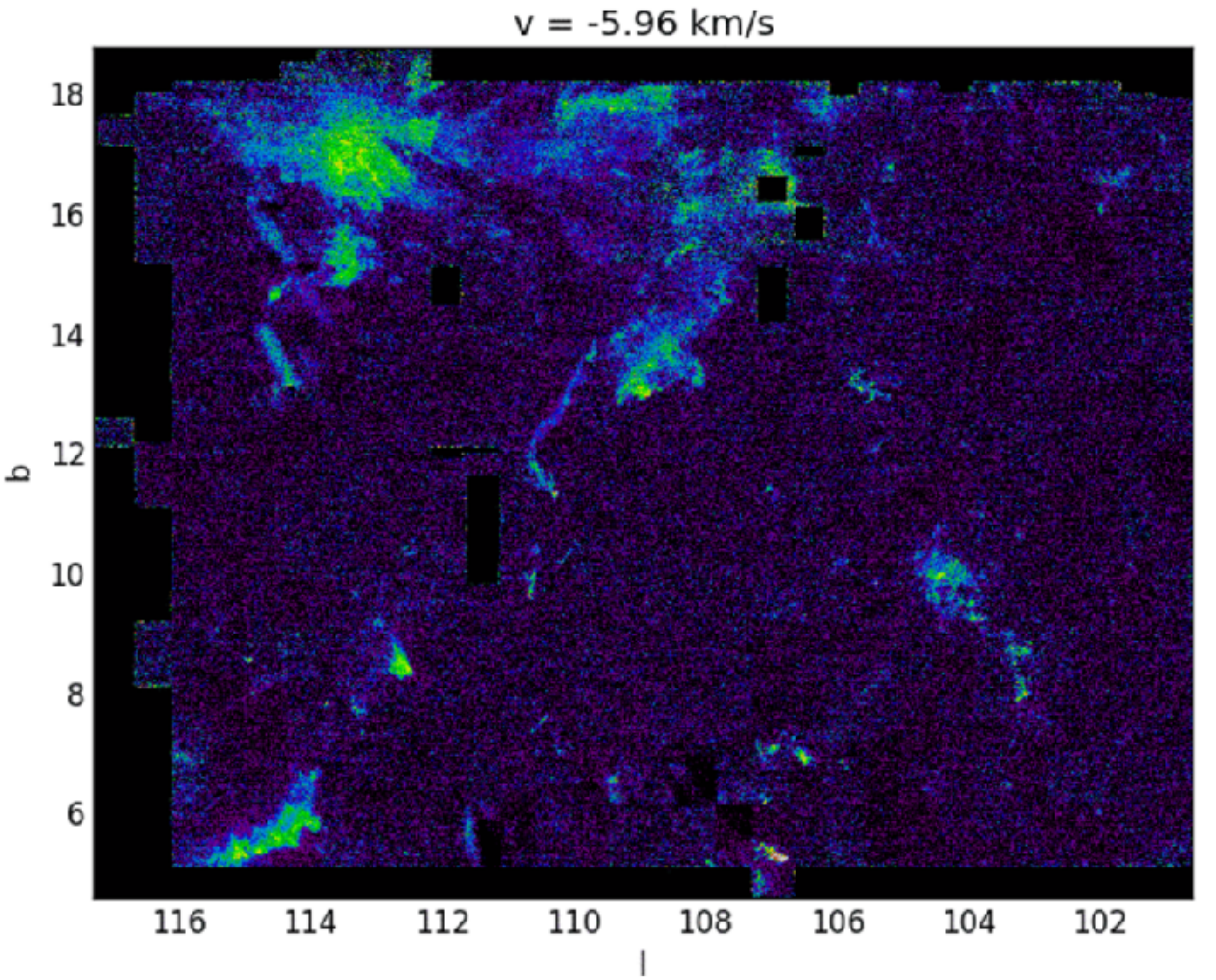

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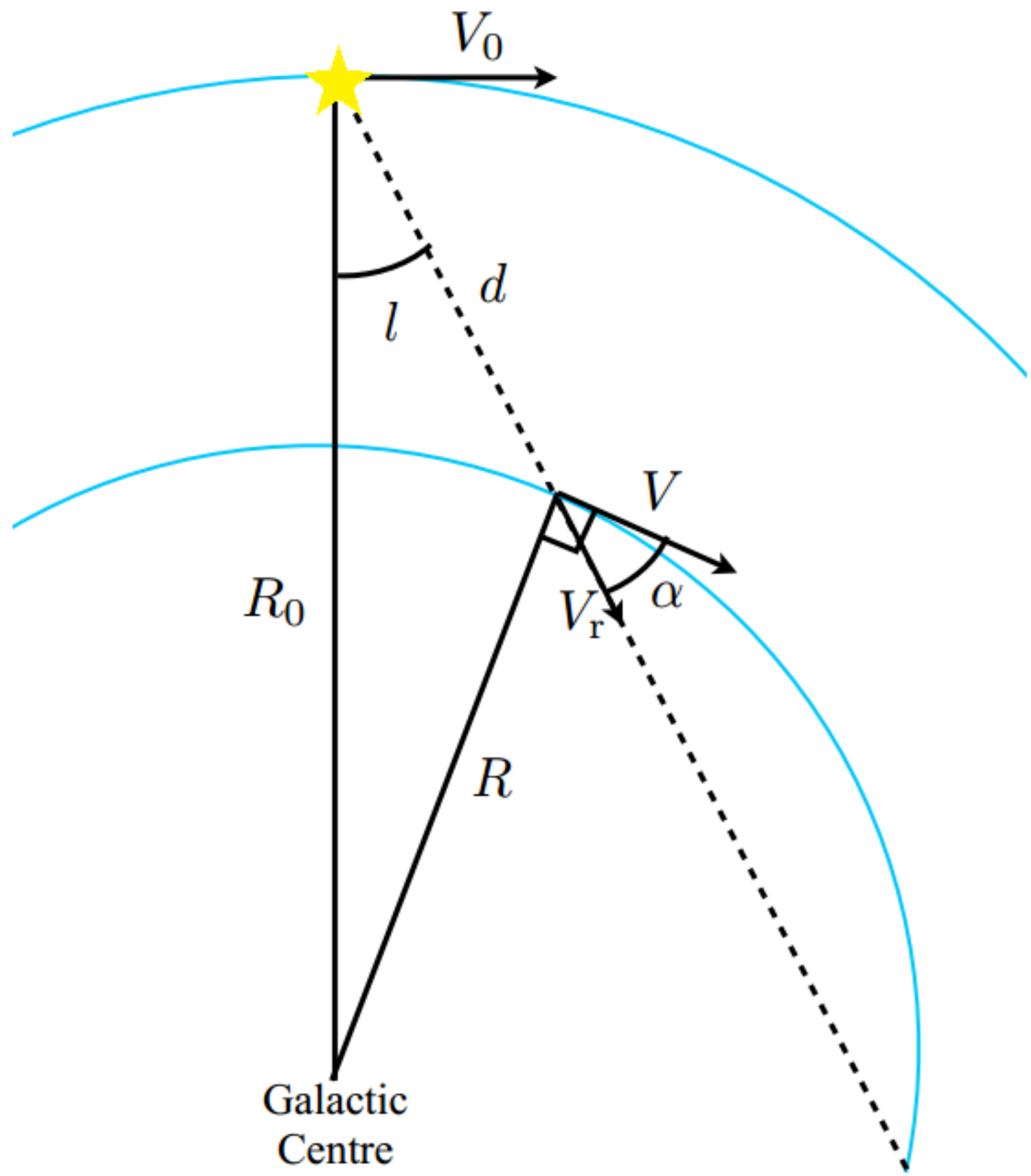

Jenny Hatchell,
PHY3066

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  Small fraction of clouds
  Require knowledge of association

APOD/NASA

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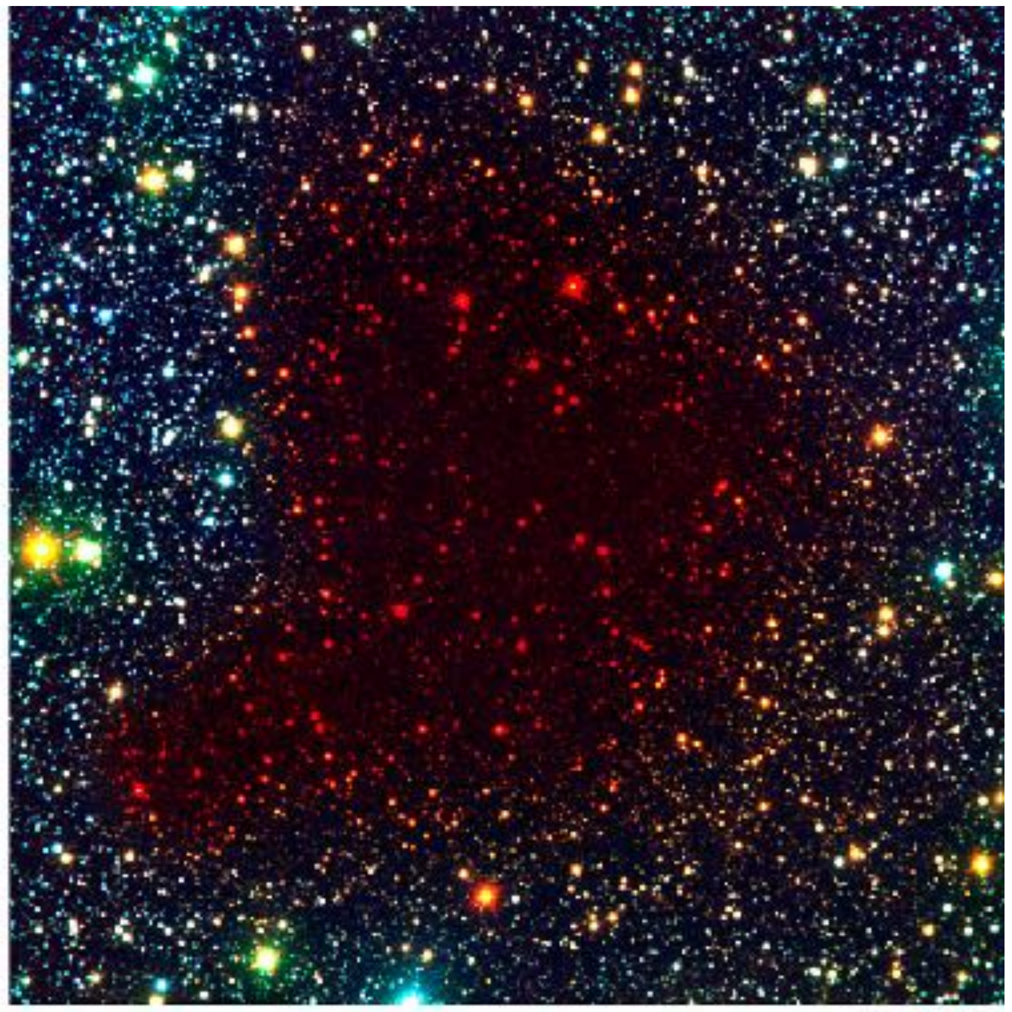

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ESO

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- 3D extinction distance

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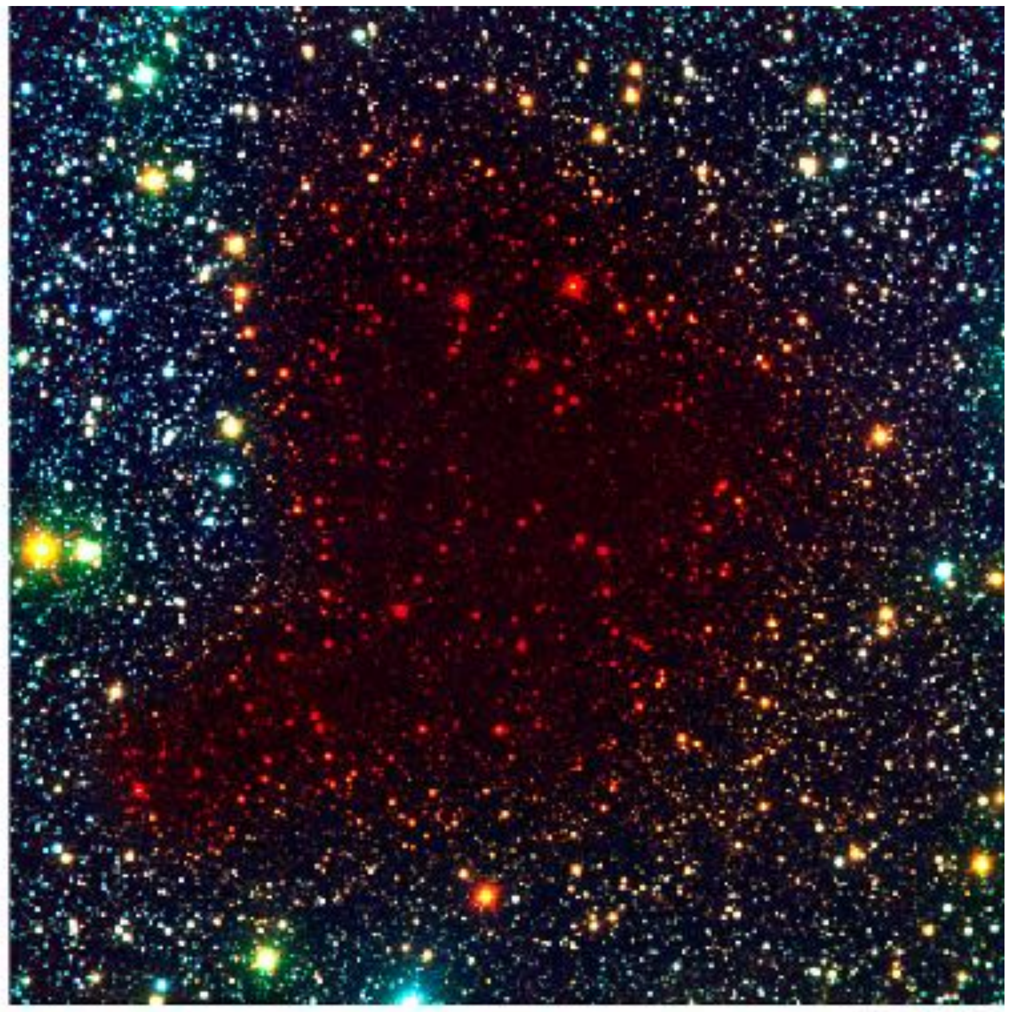

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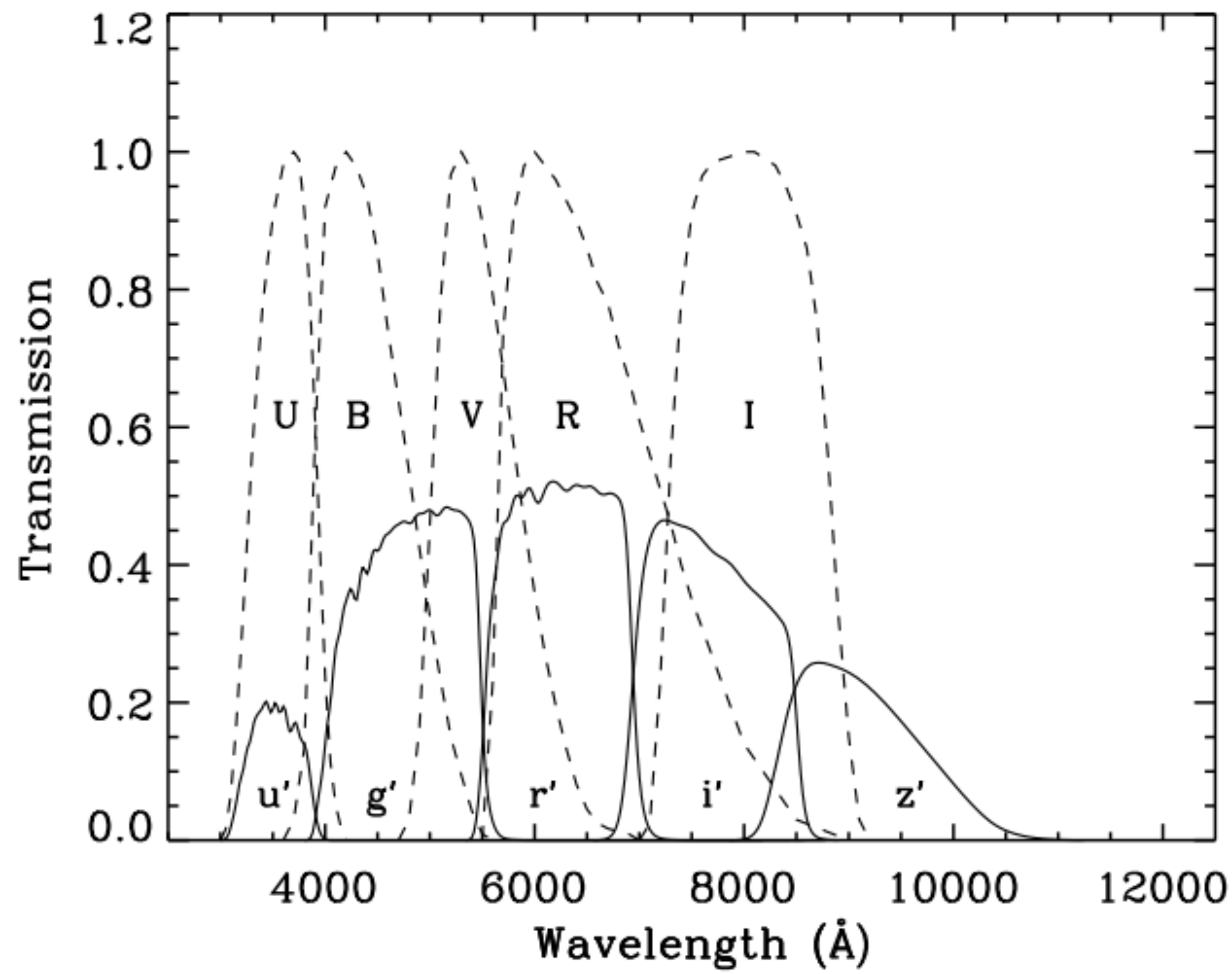

Lenz et al., 1998, ApJS, 119, 121

3D Extinction

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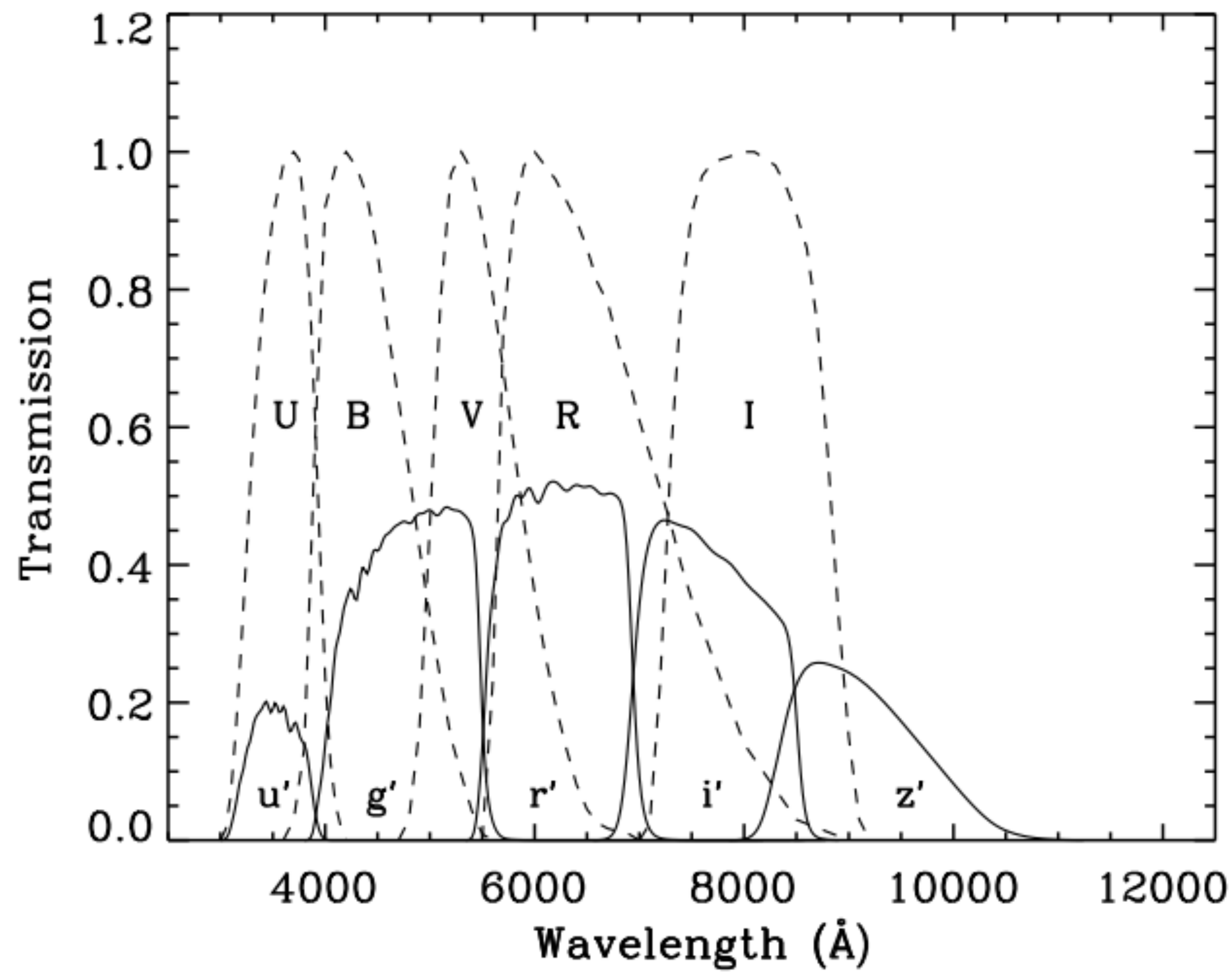

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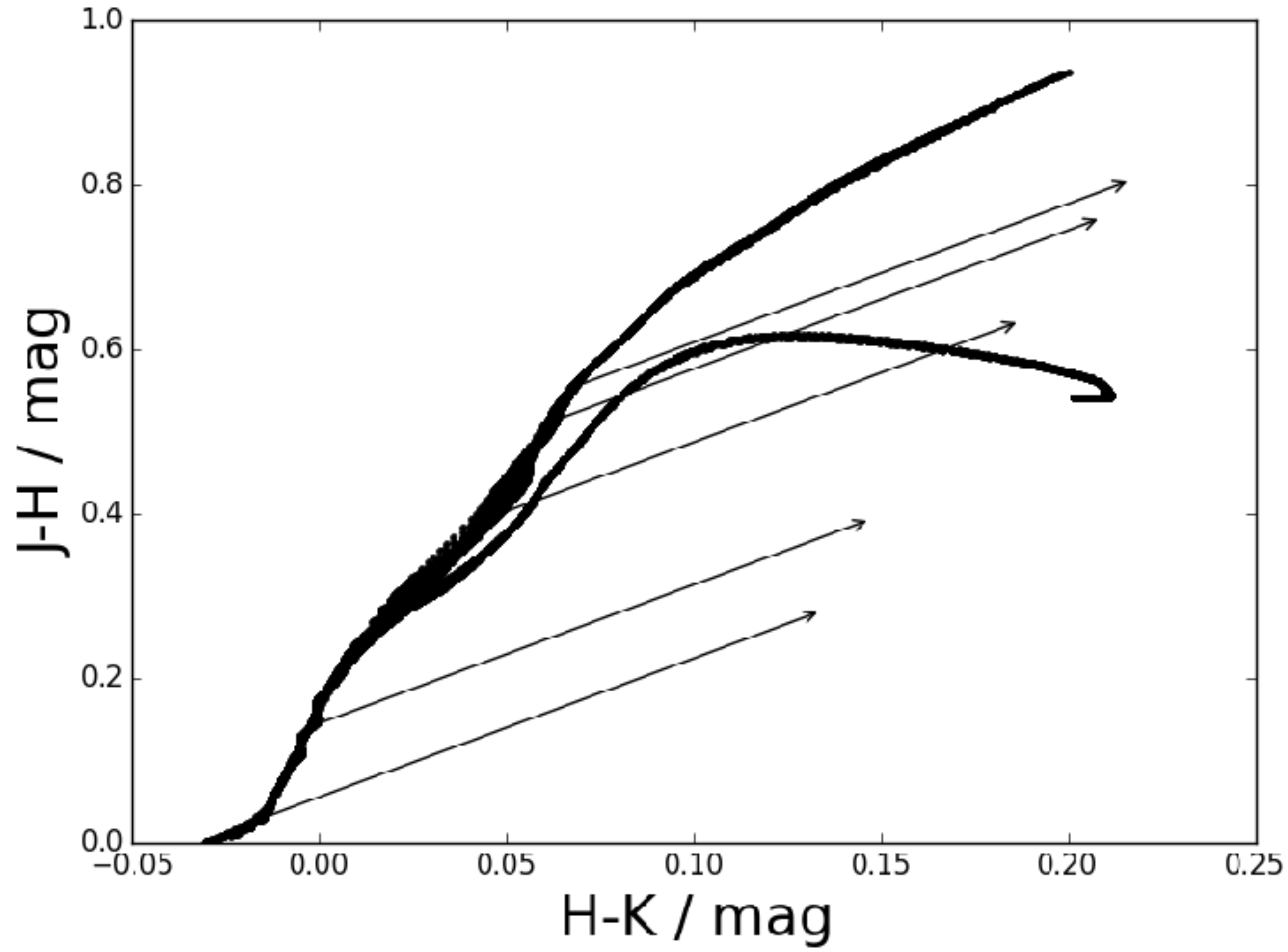

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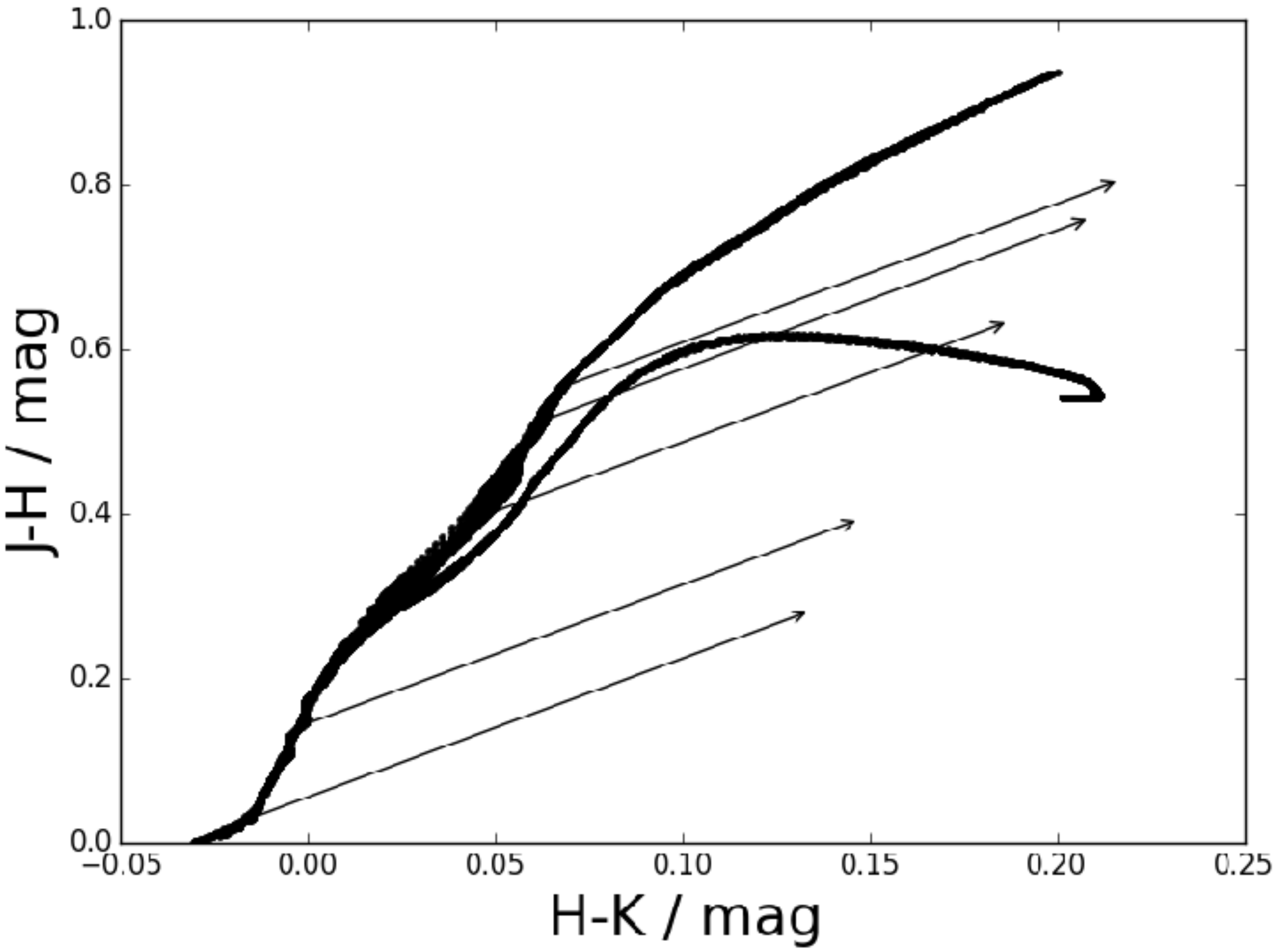
- Dereddened stars allow d to be calculated from m-M



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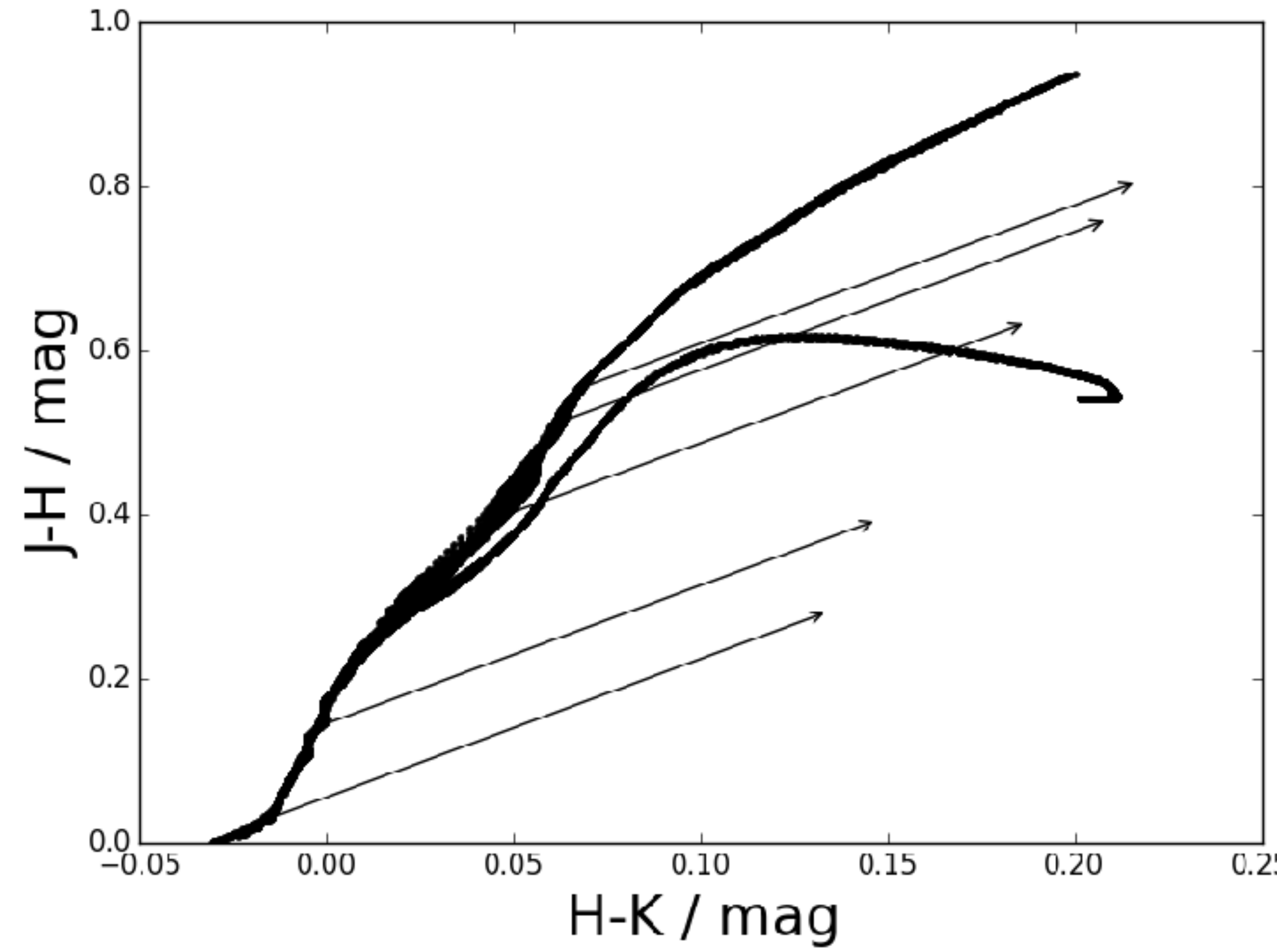

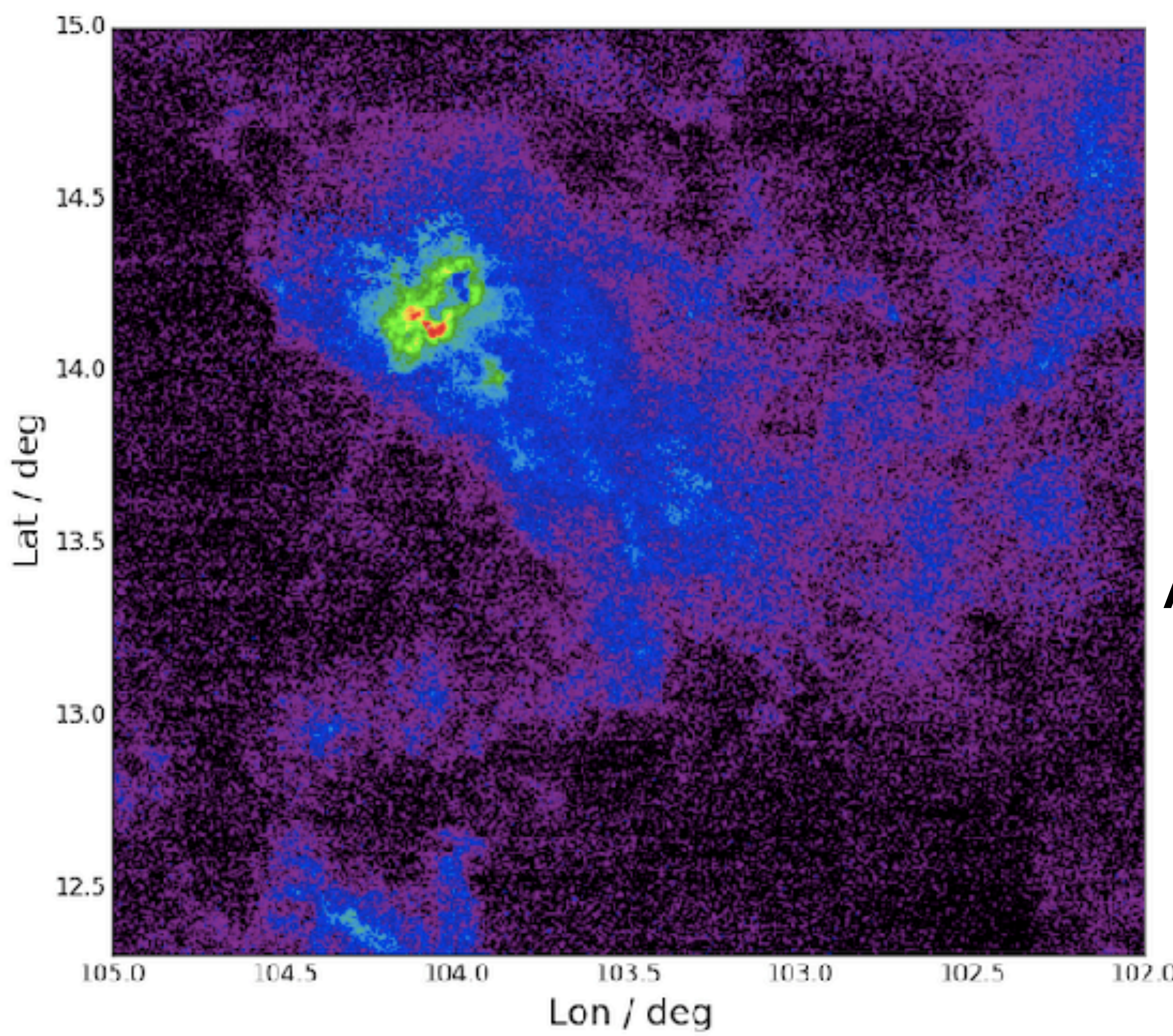

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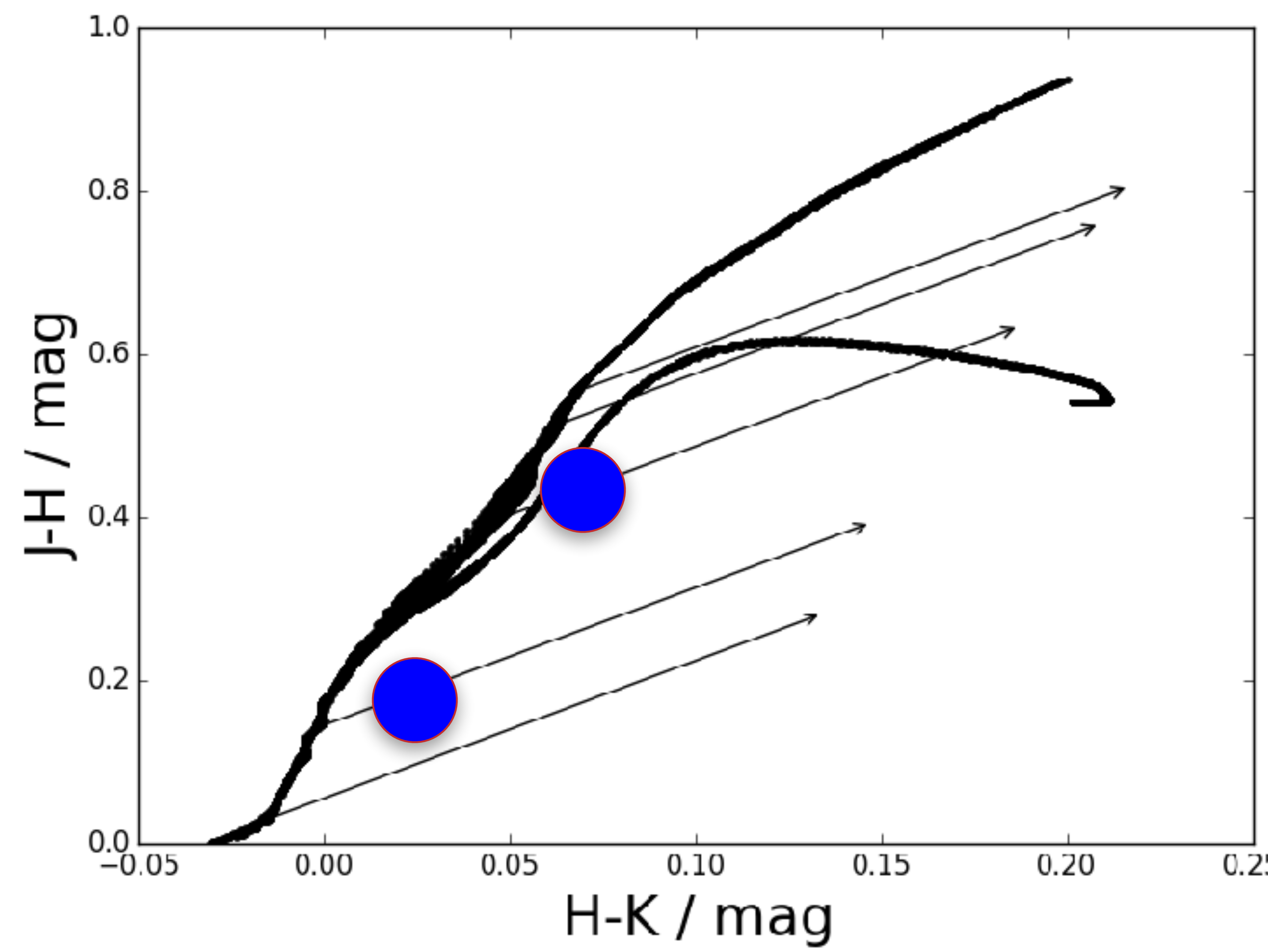

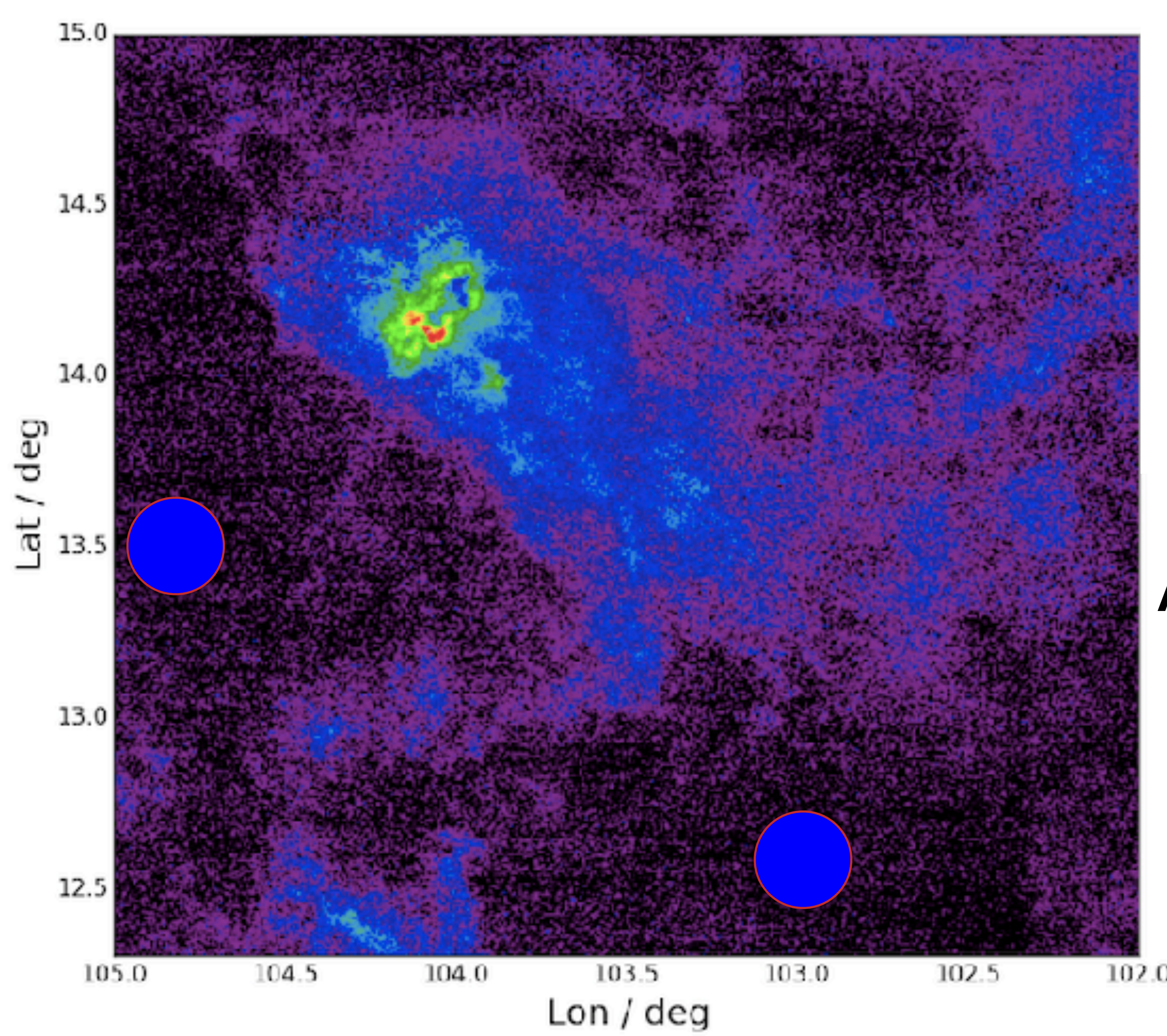

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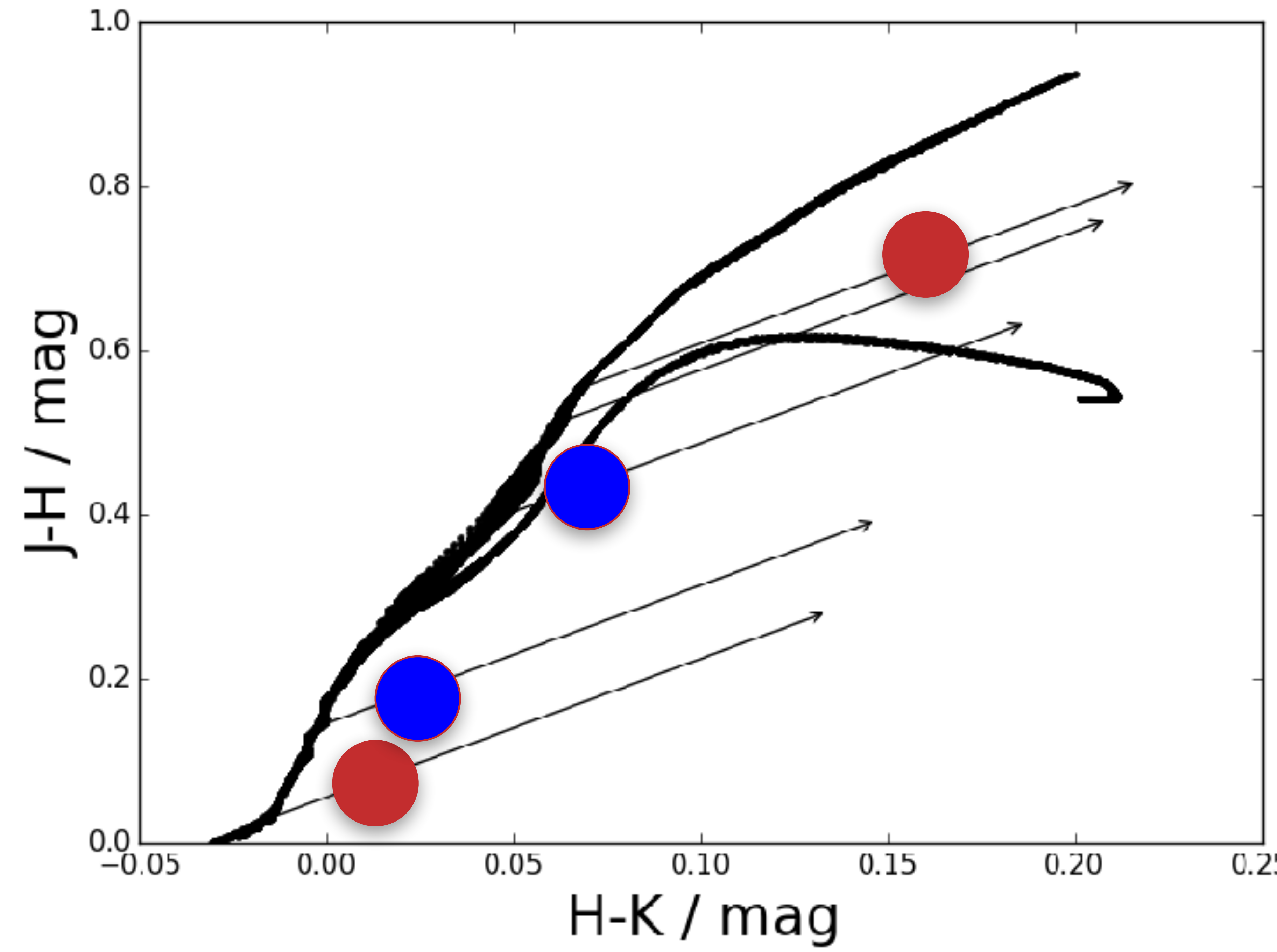

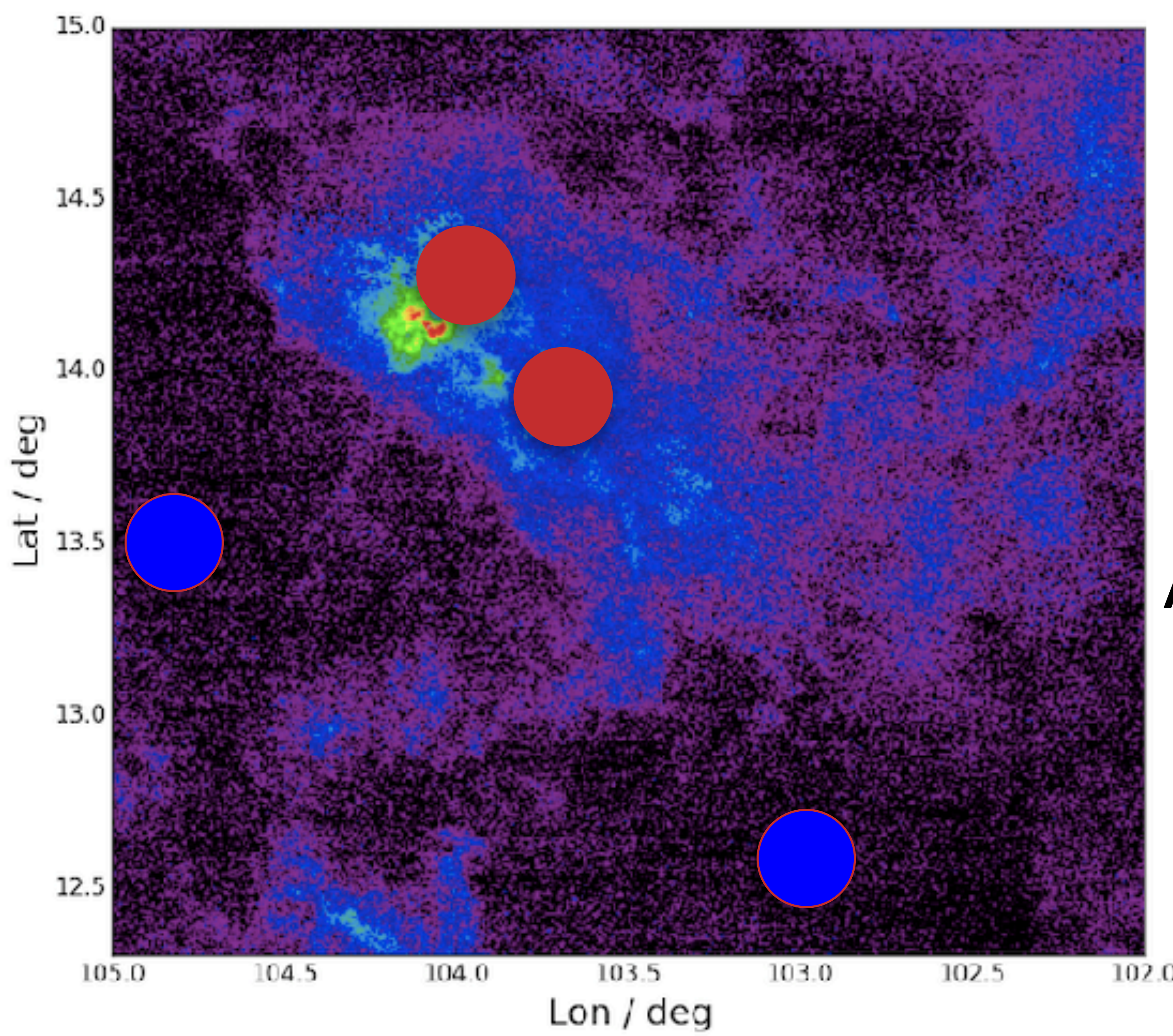

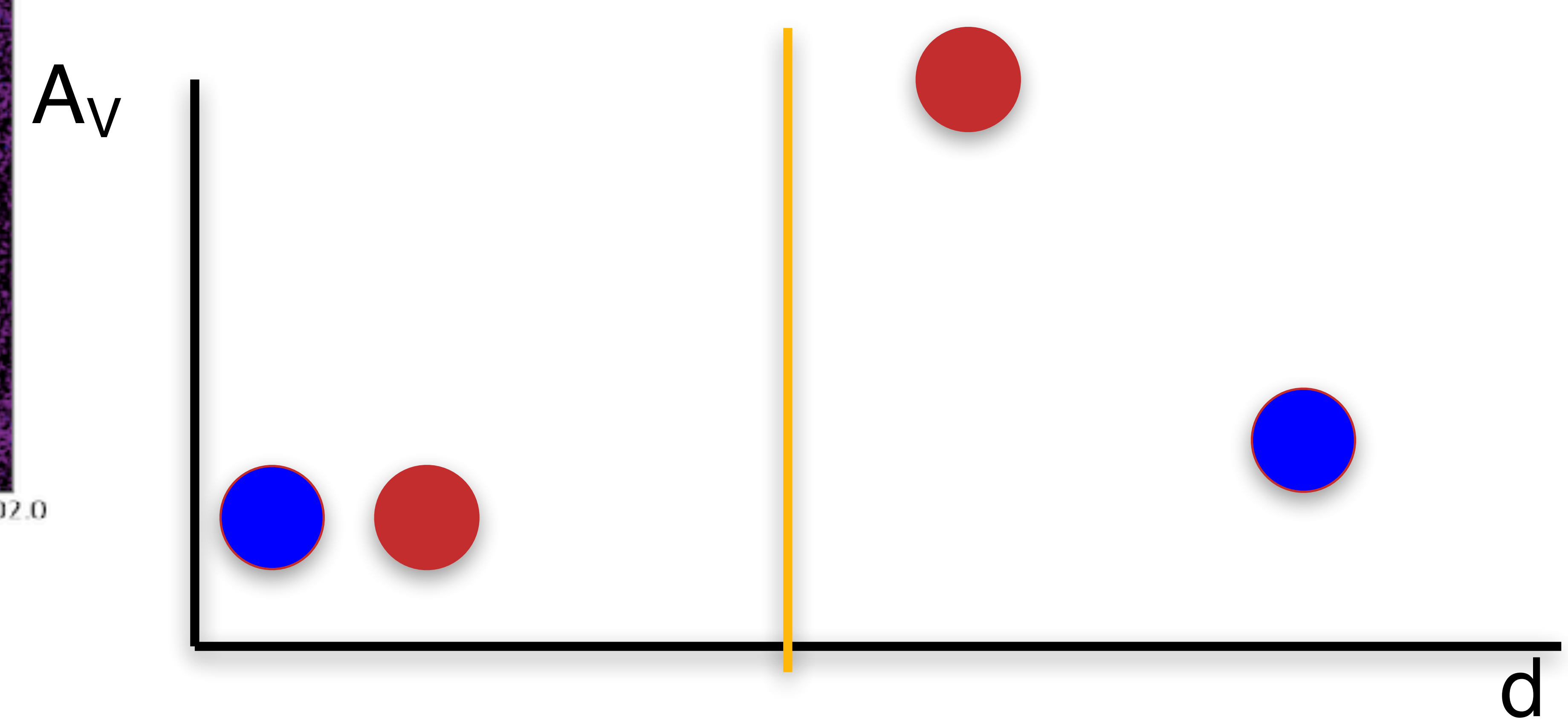

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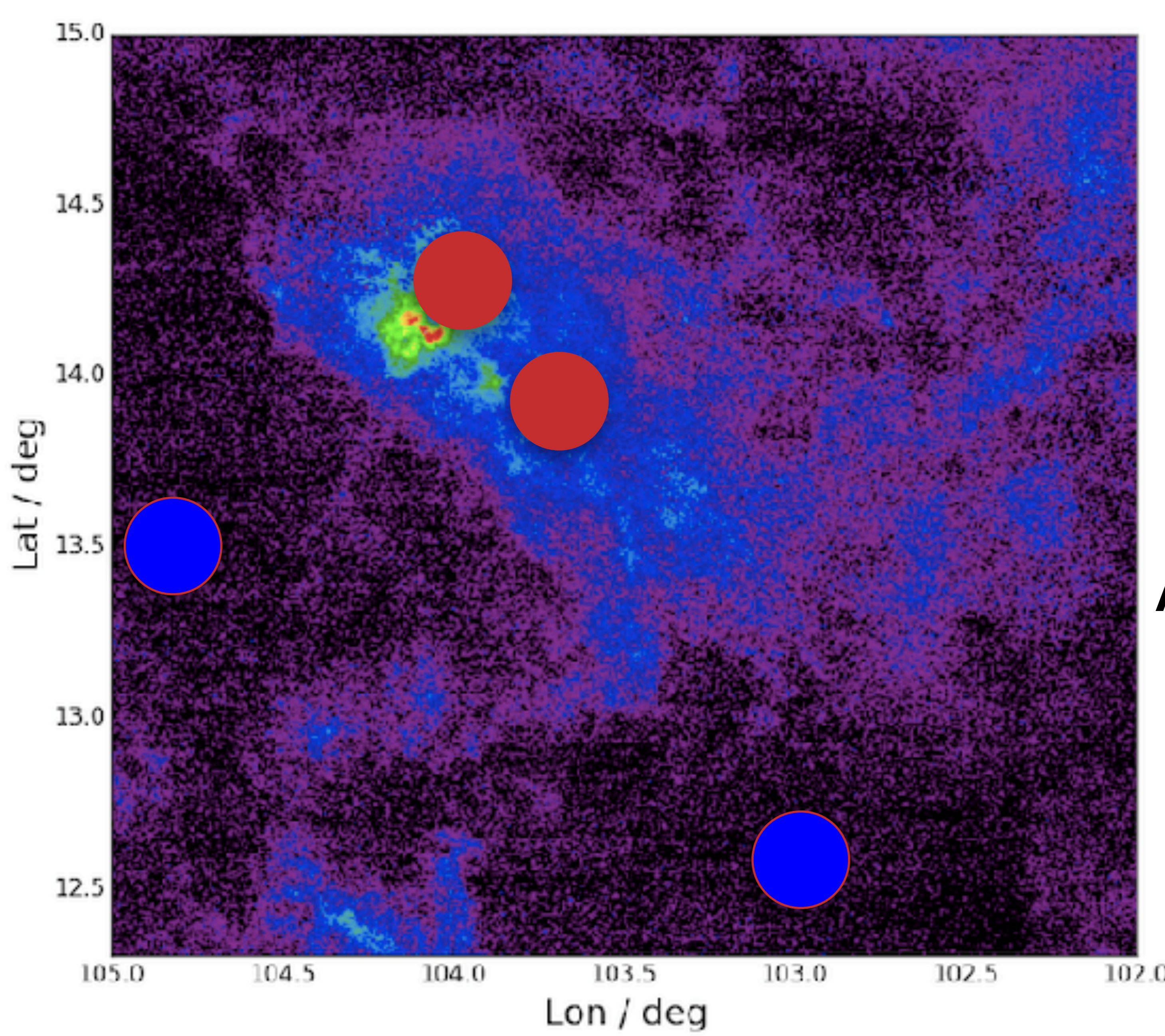

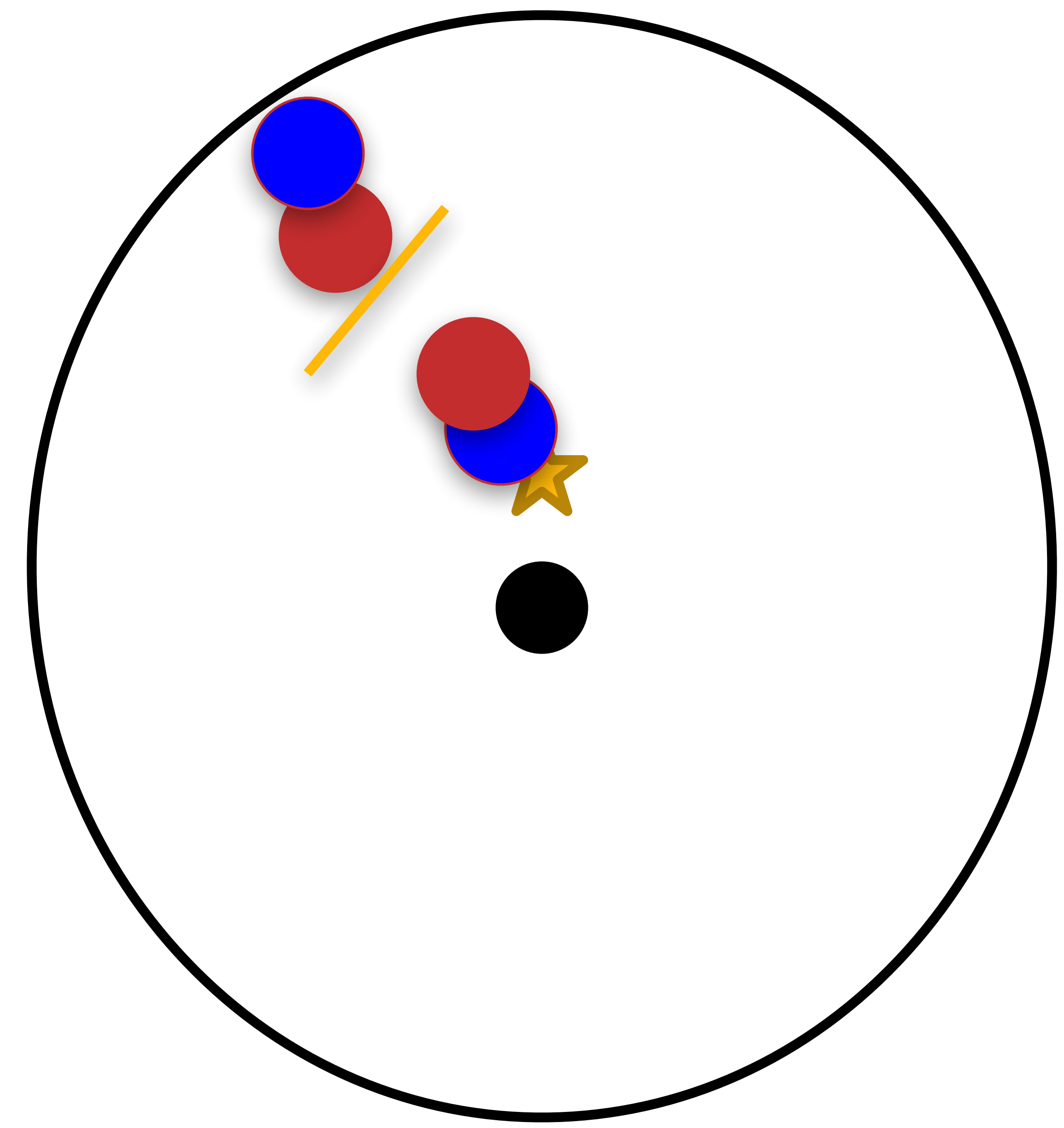

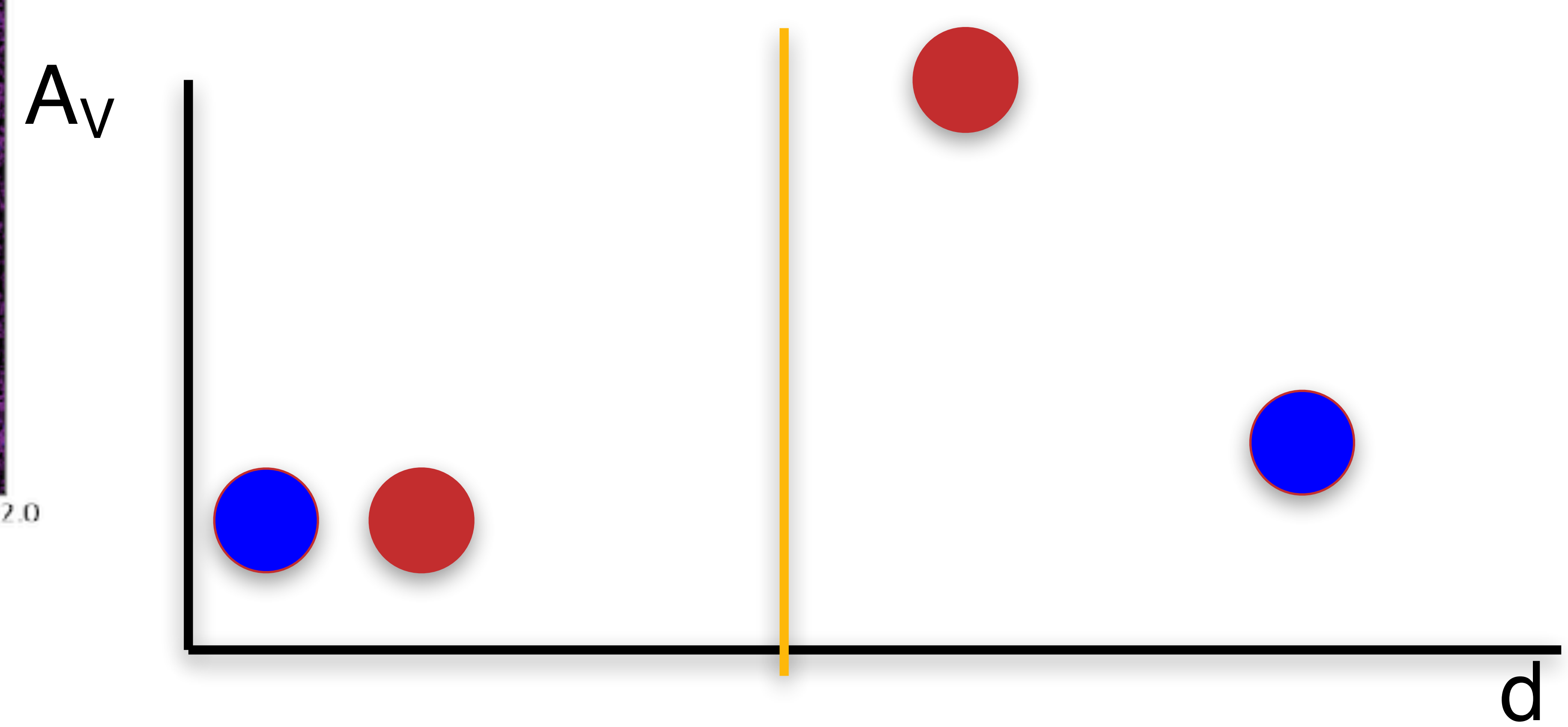

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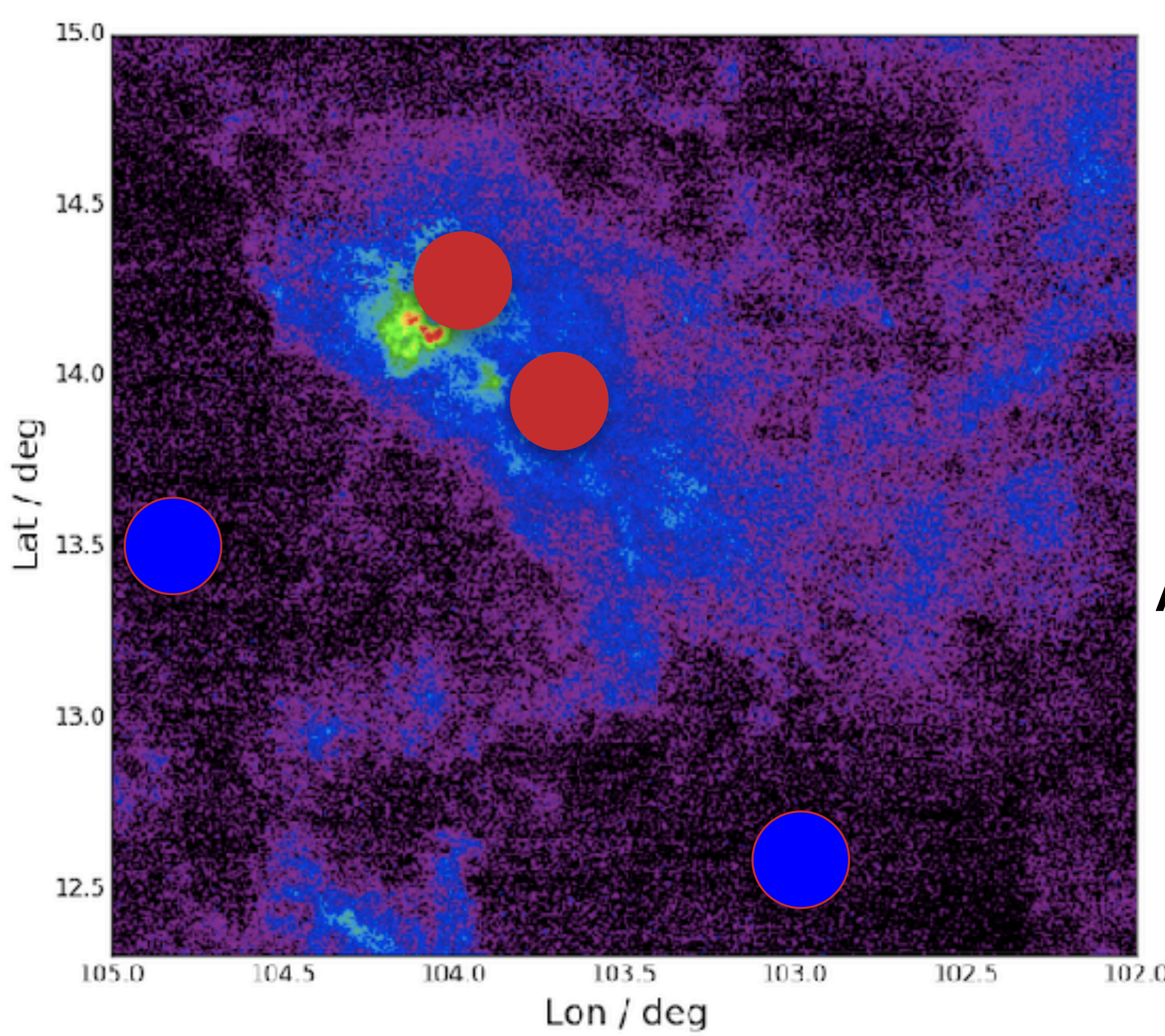

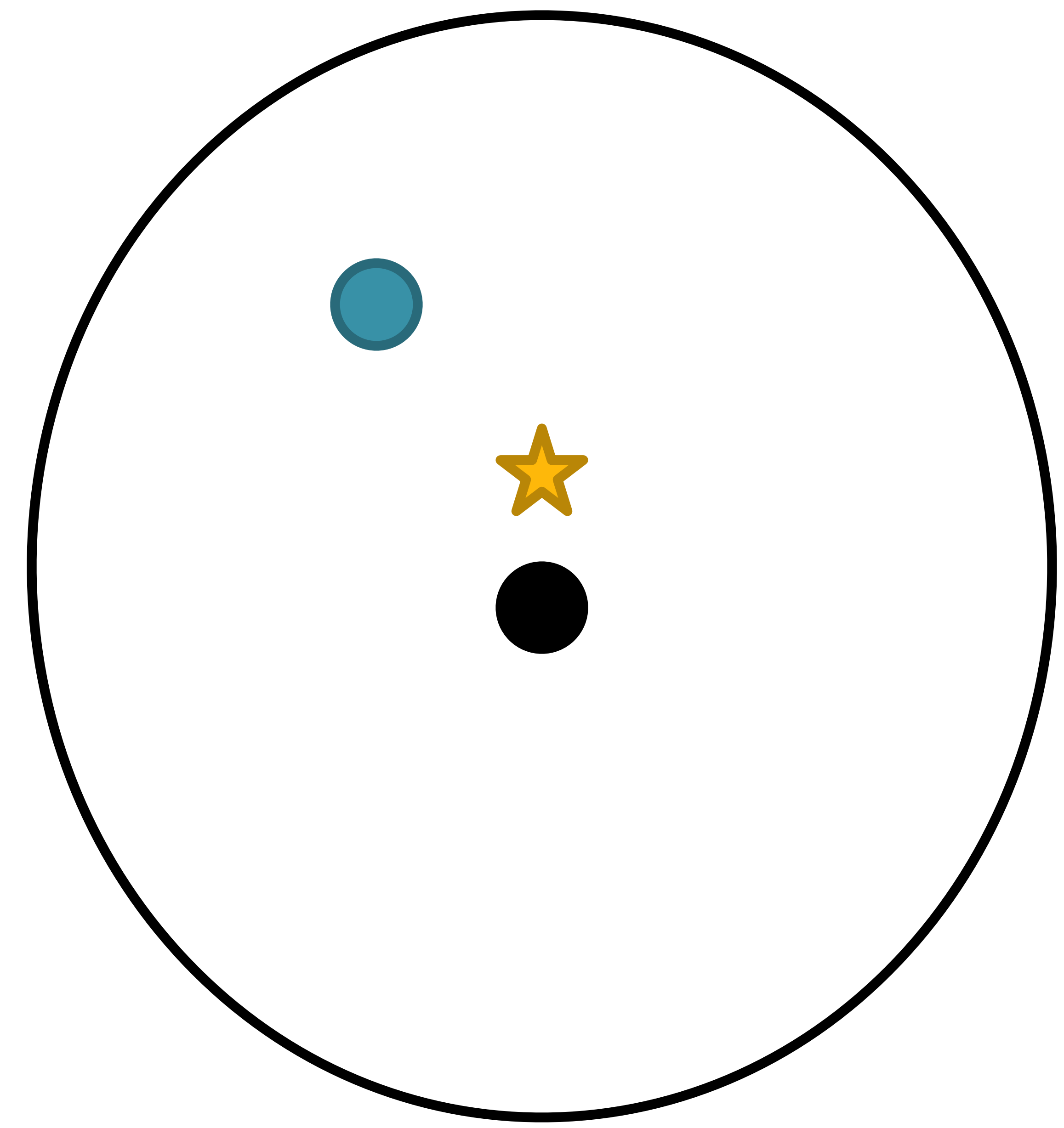

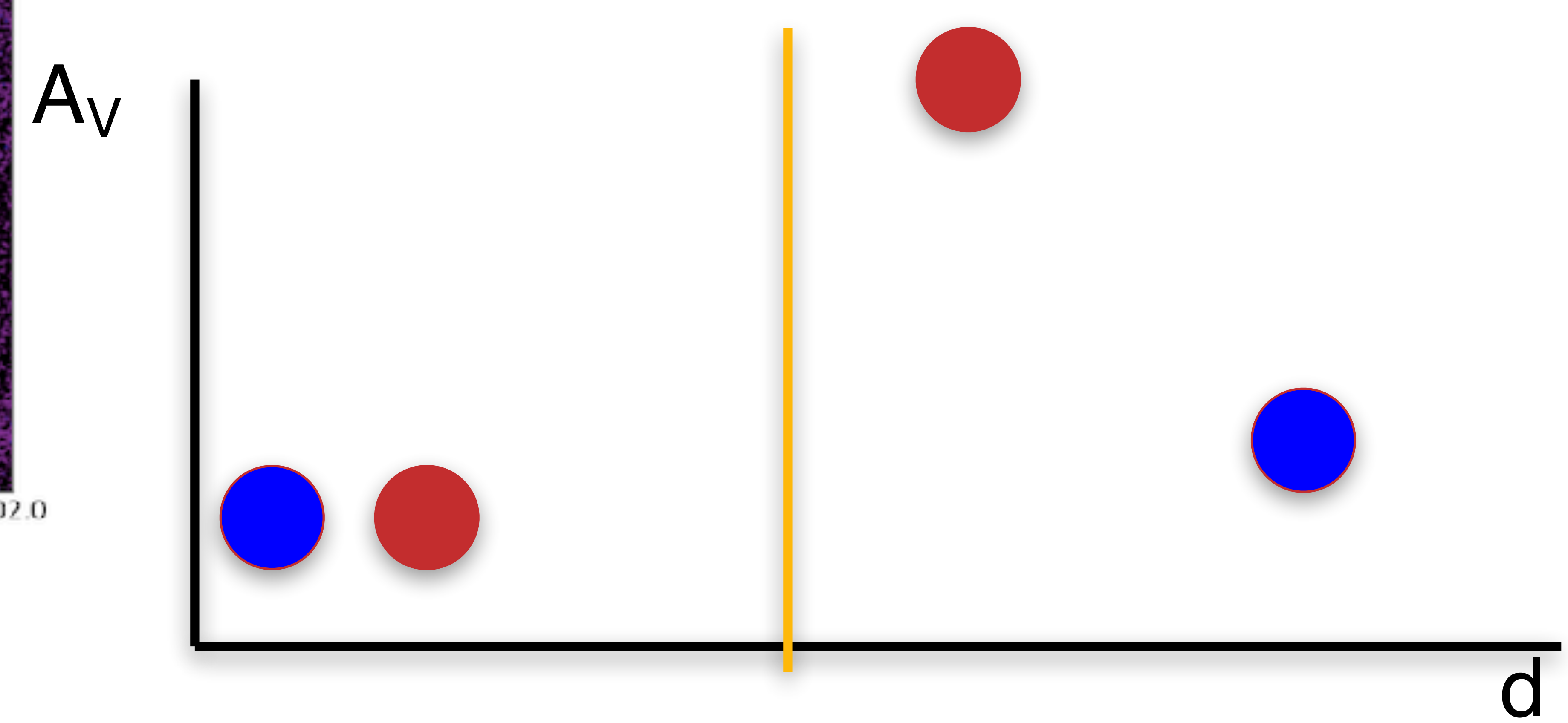

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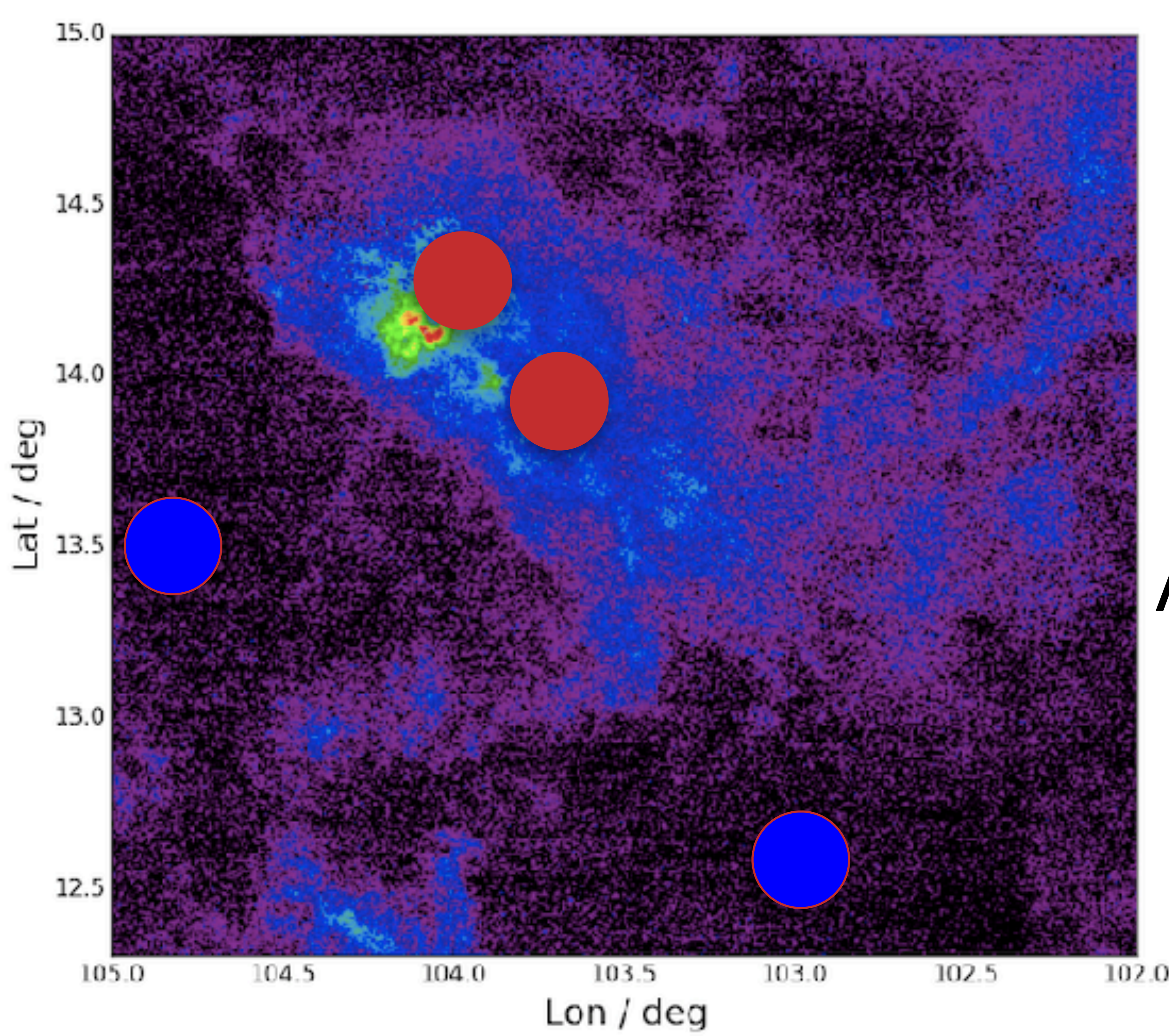

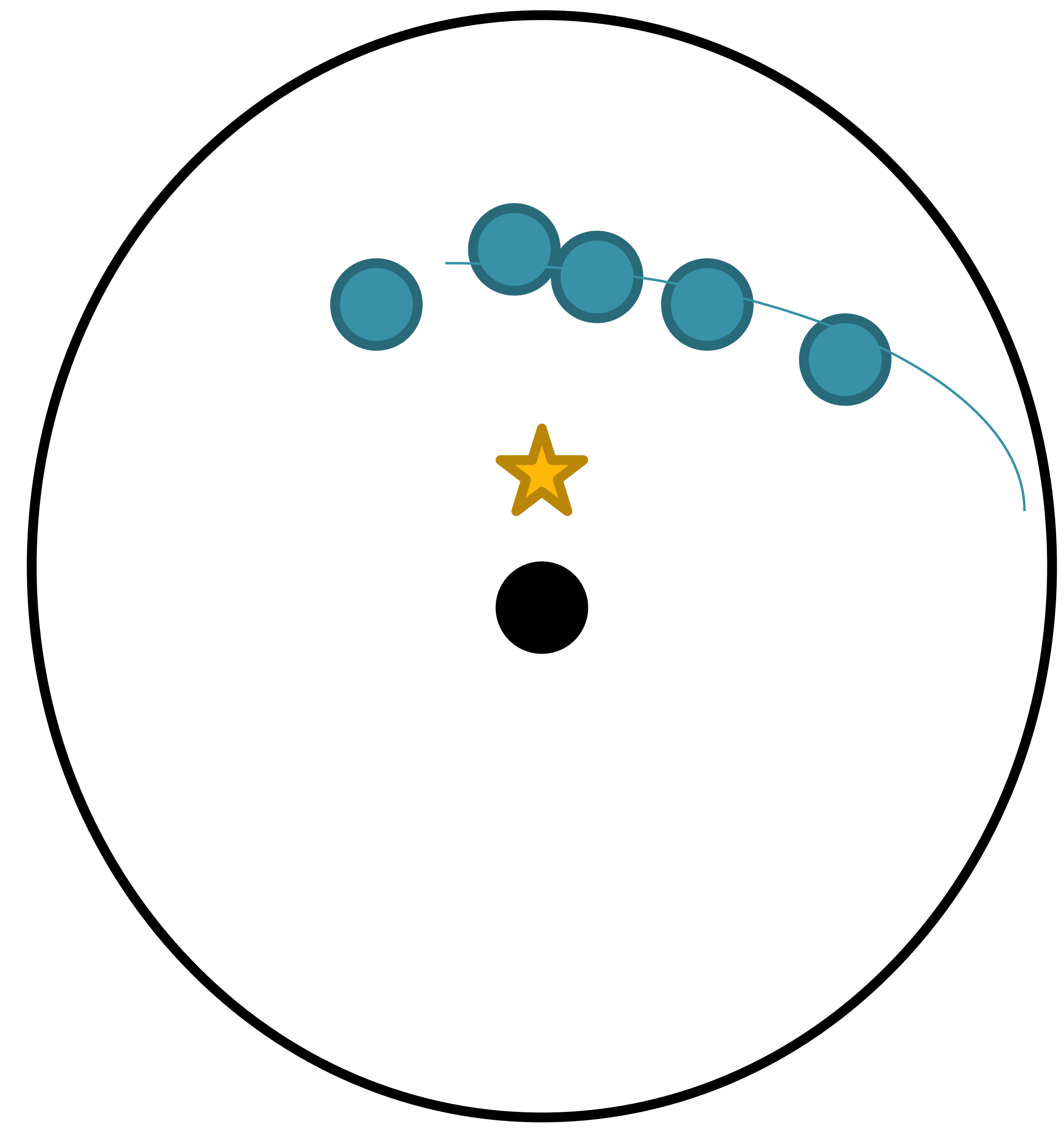

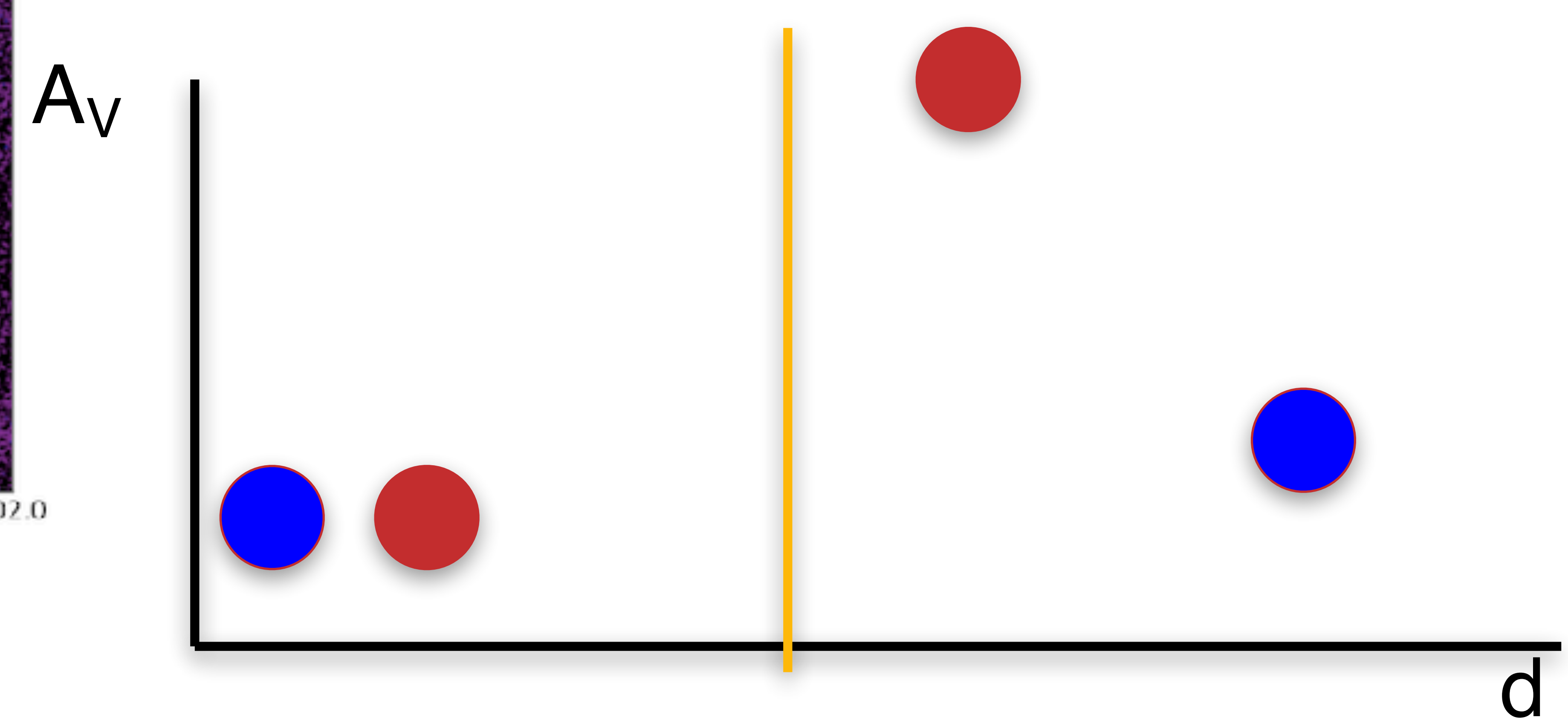

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Brunier, ESO

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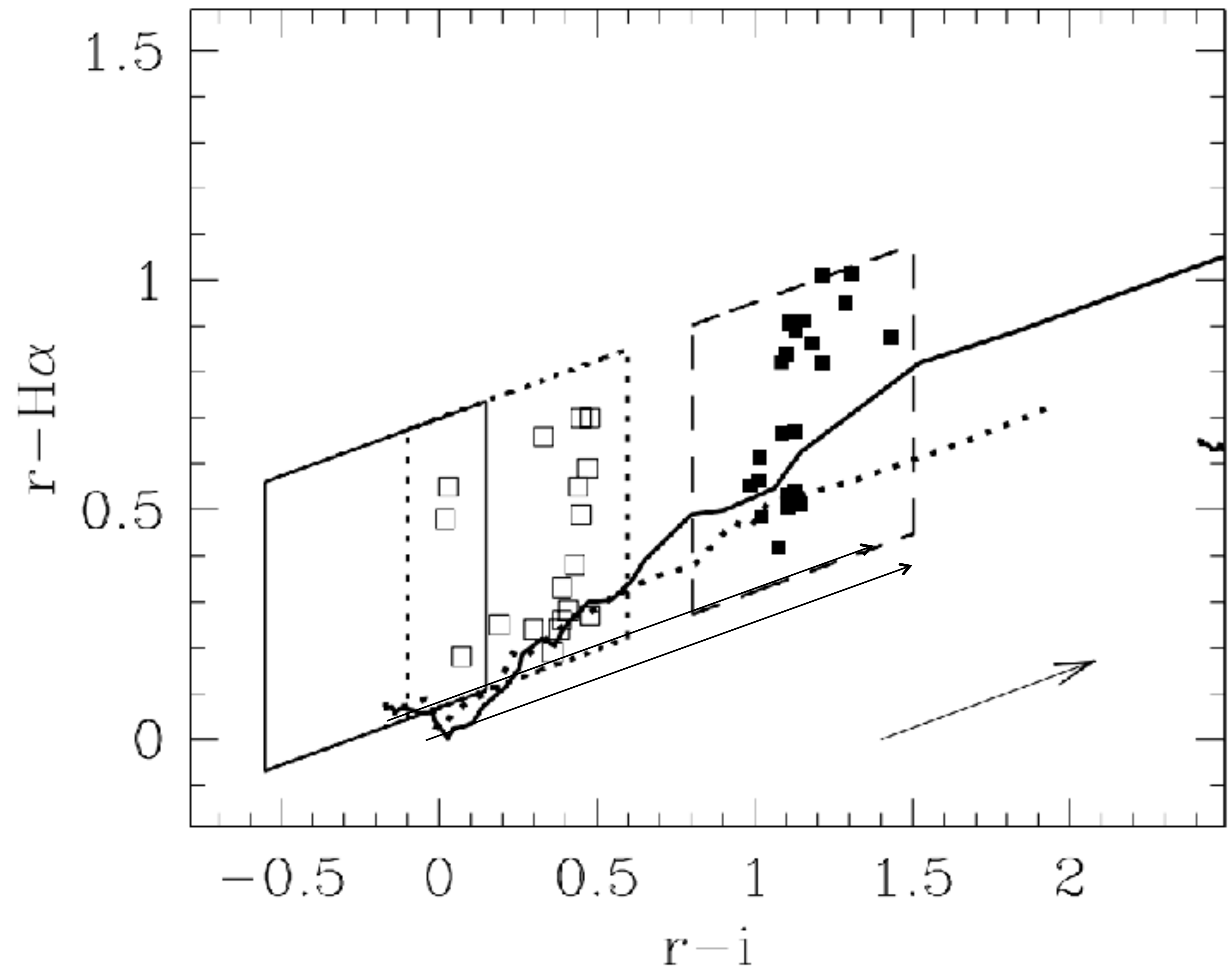

Corradi et al., 2008, A&A, 480, 409

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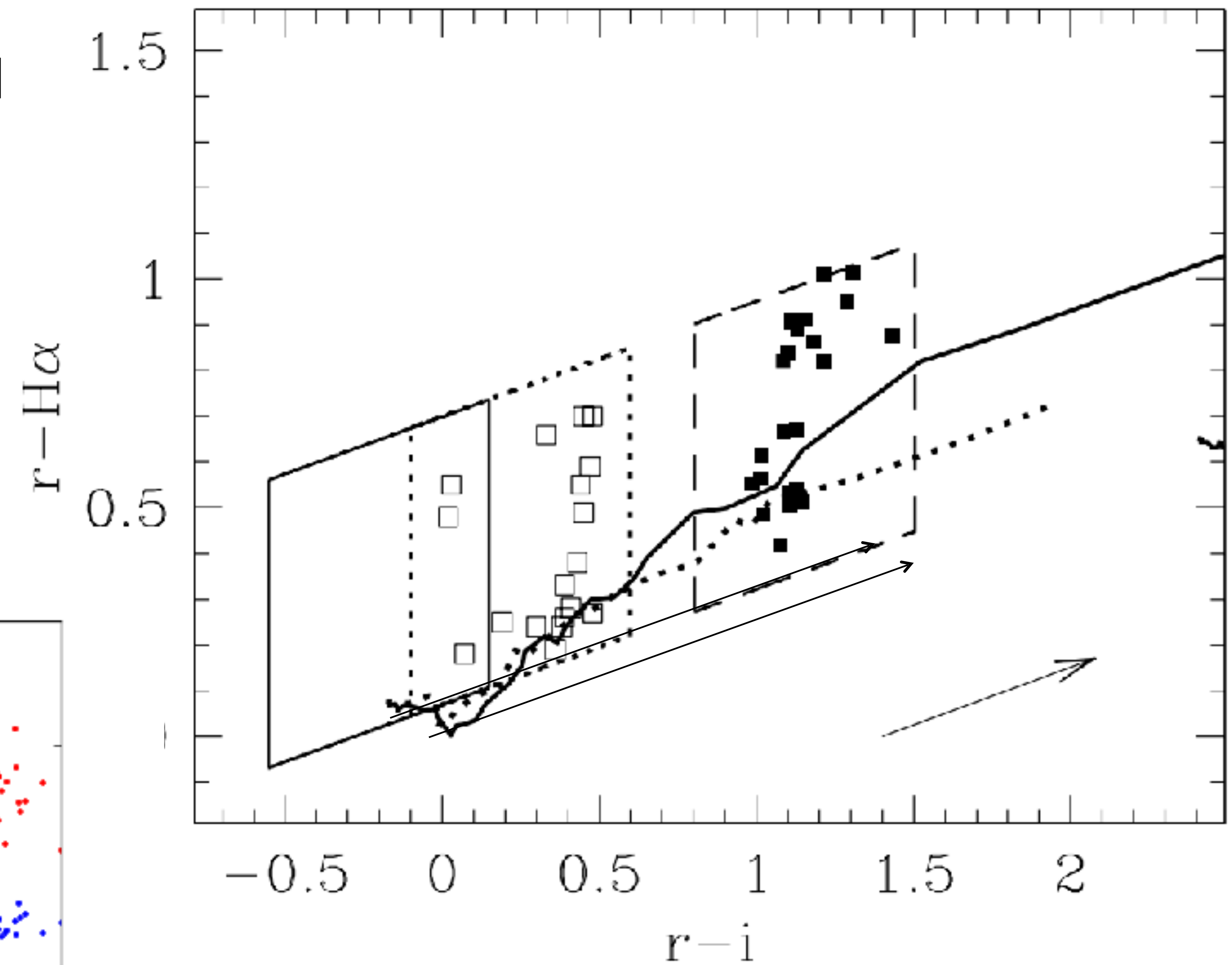
- Not accurate below ~500pc



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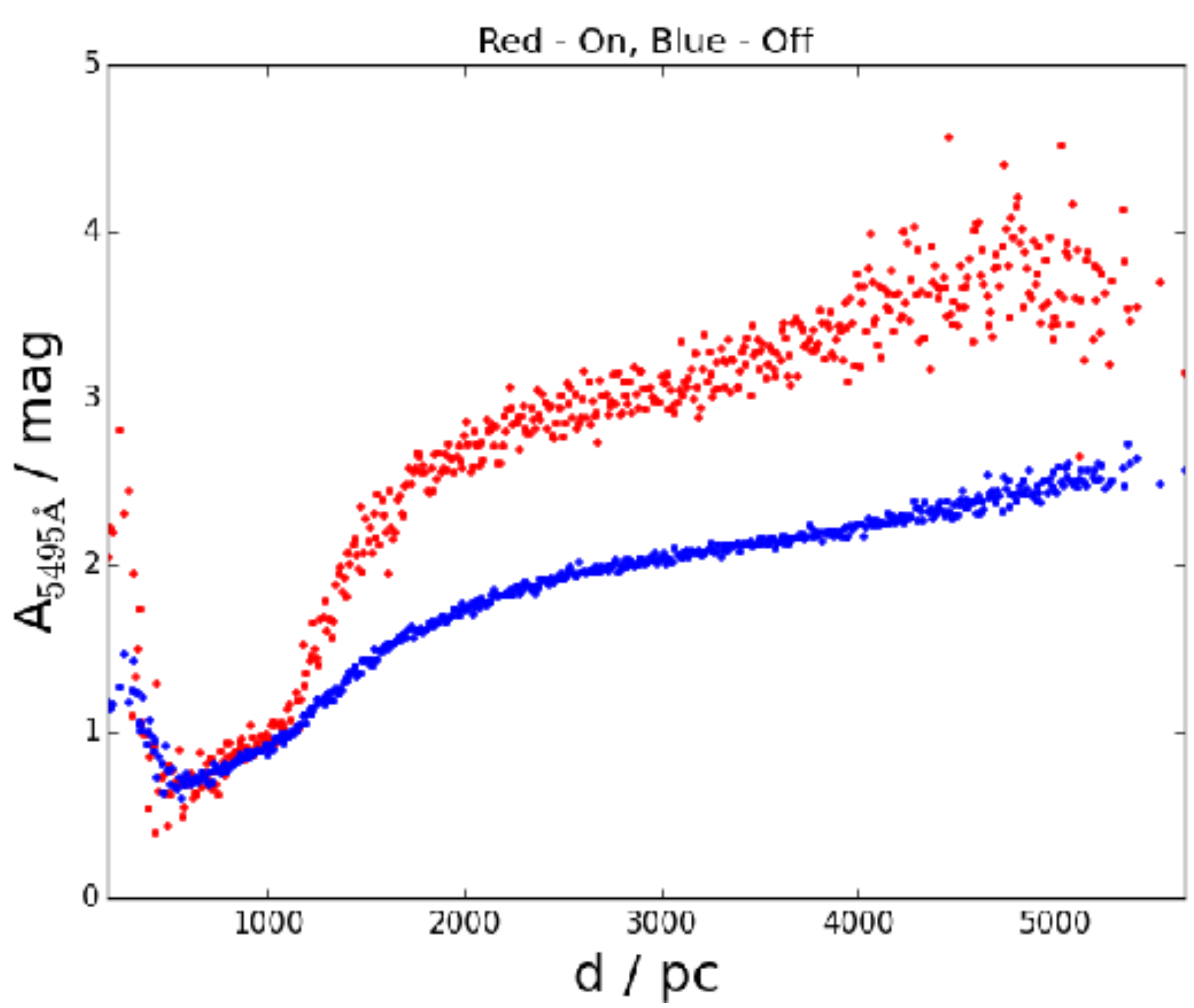

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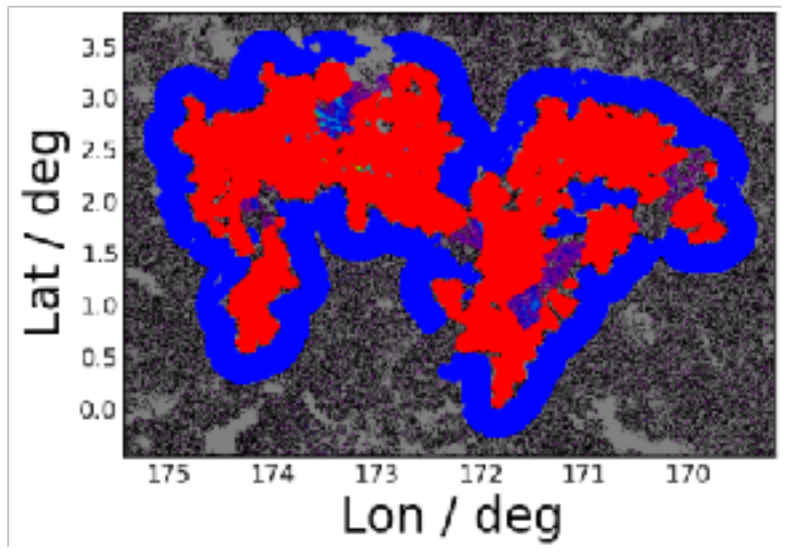

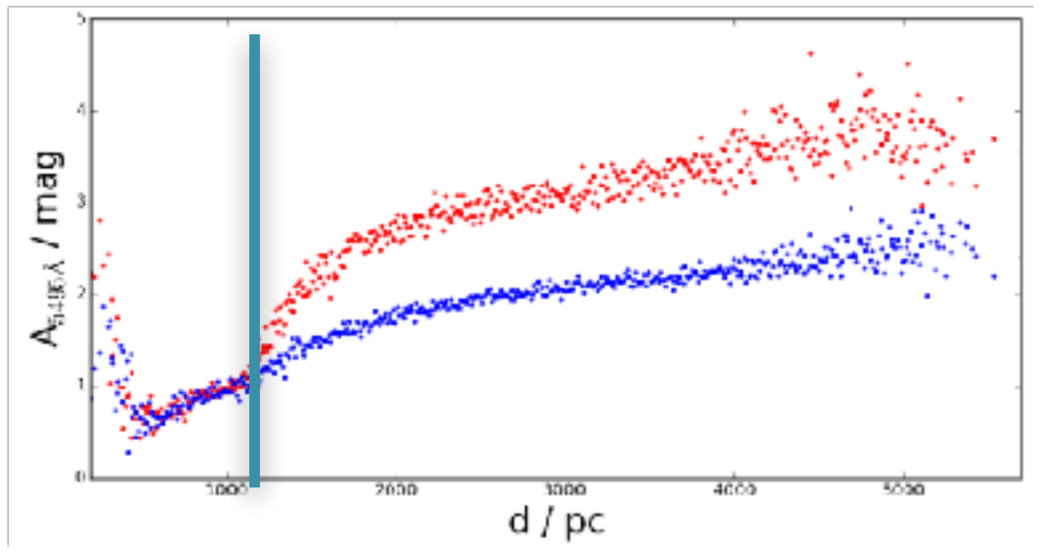

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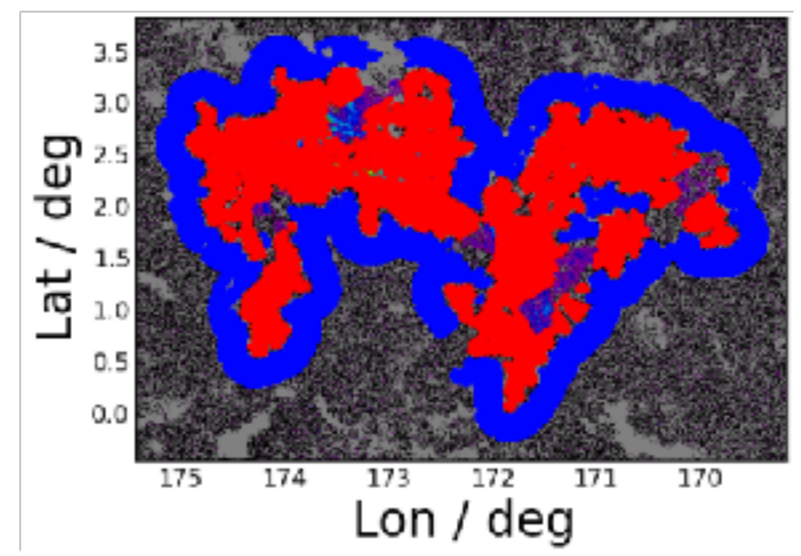

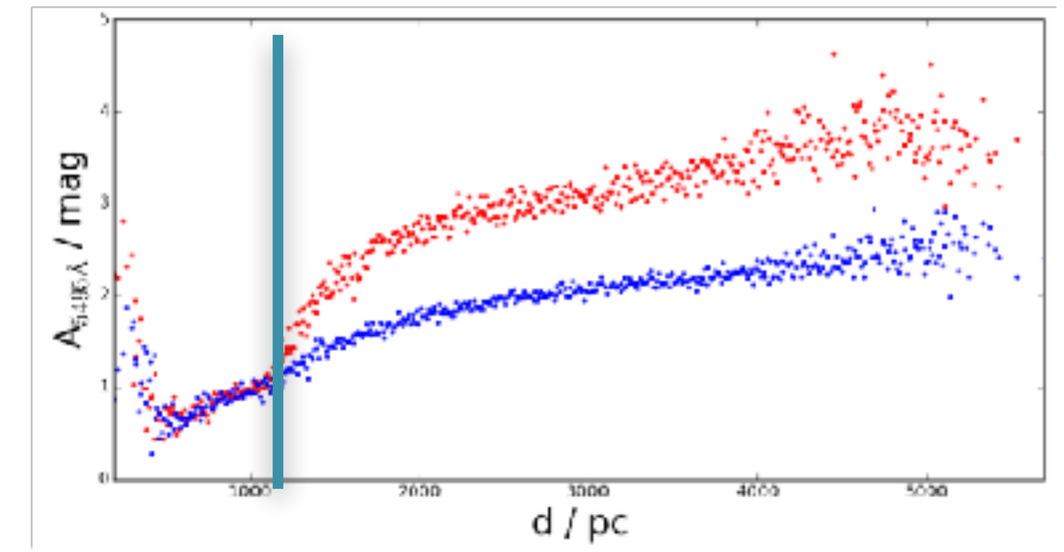

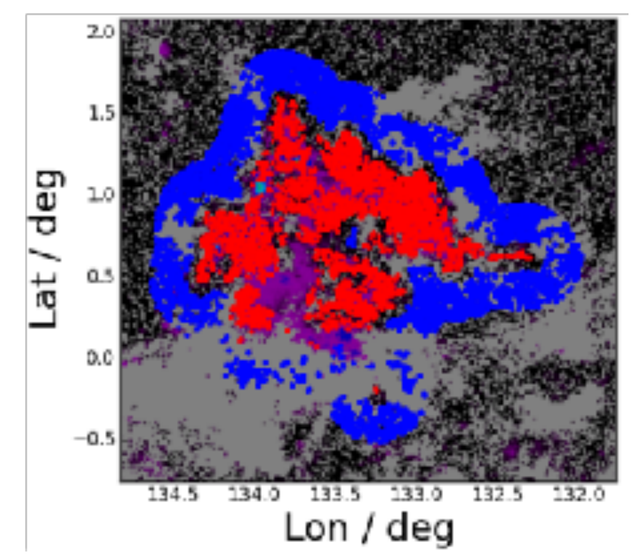

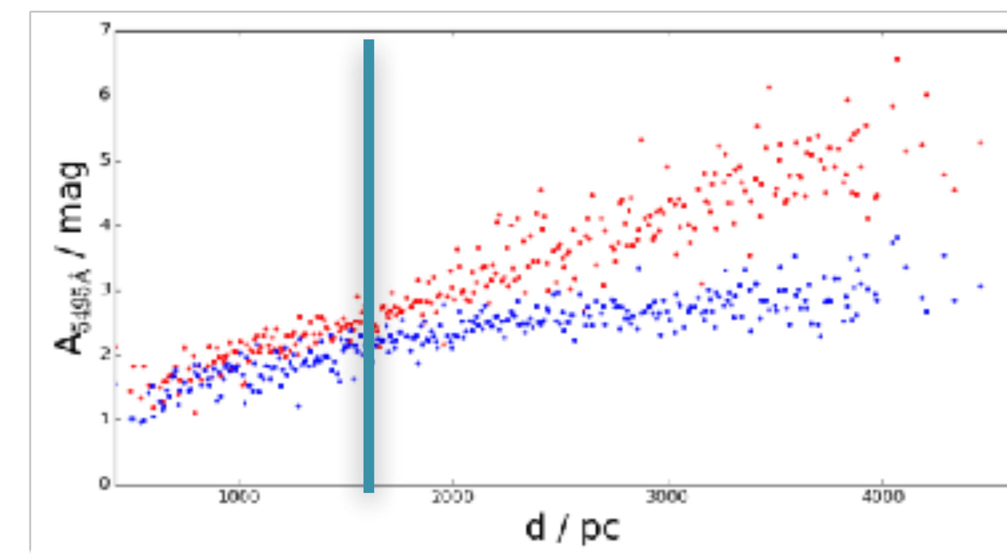

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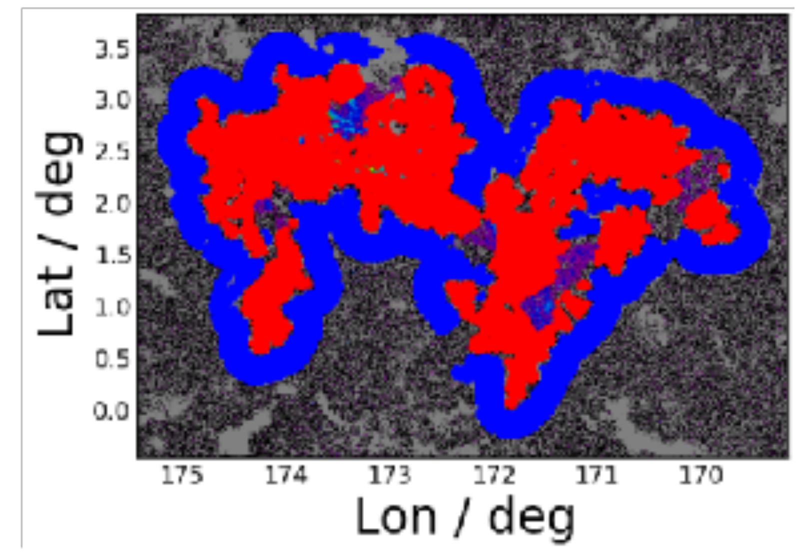

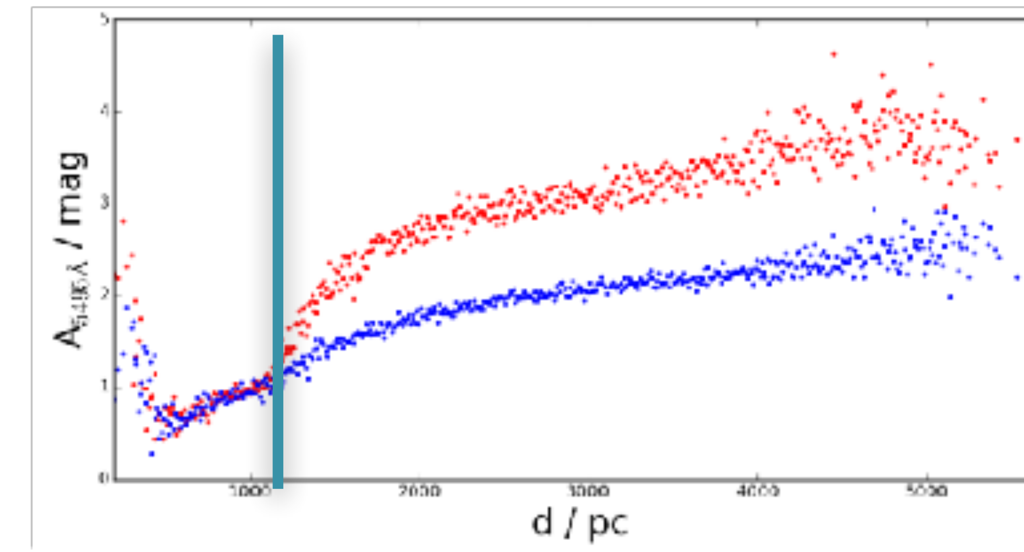

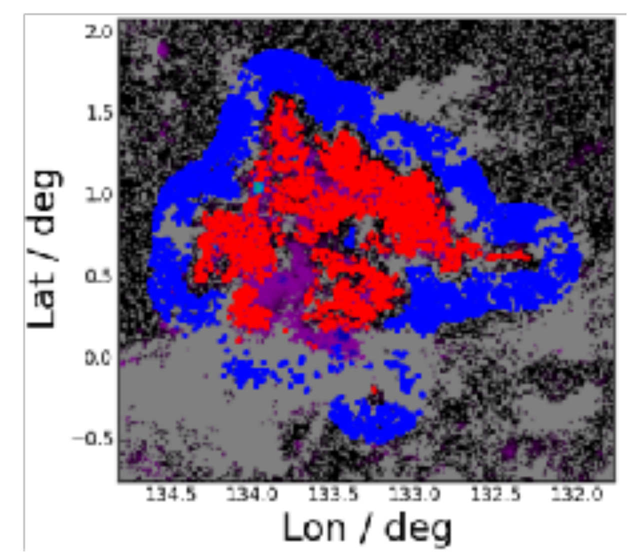

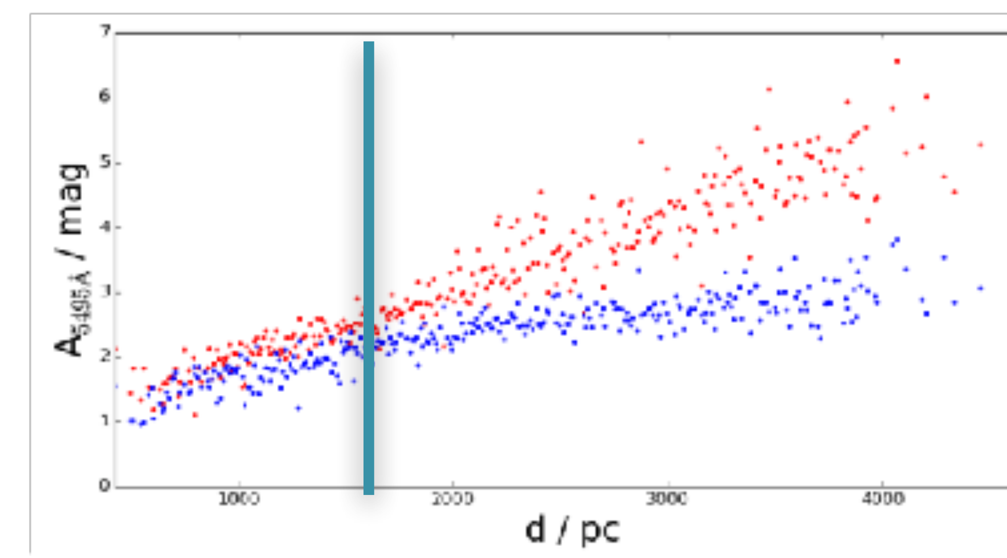

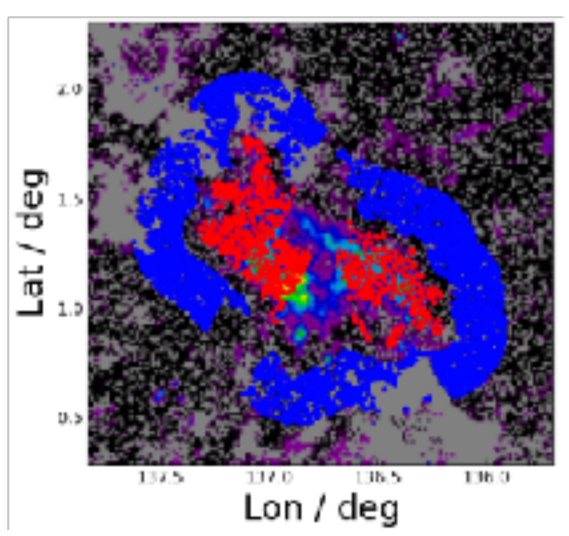

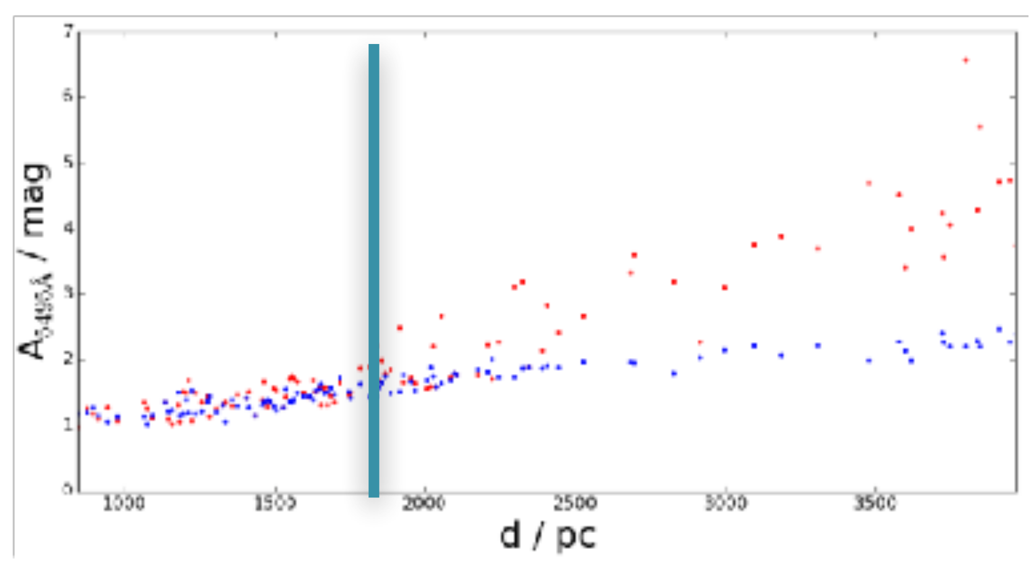

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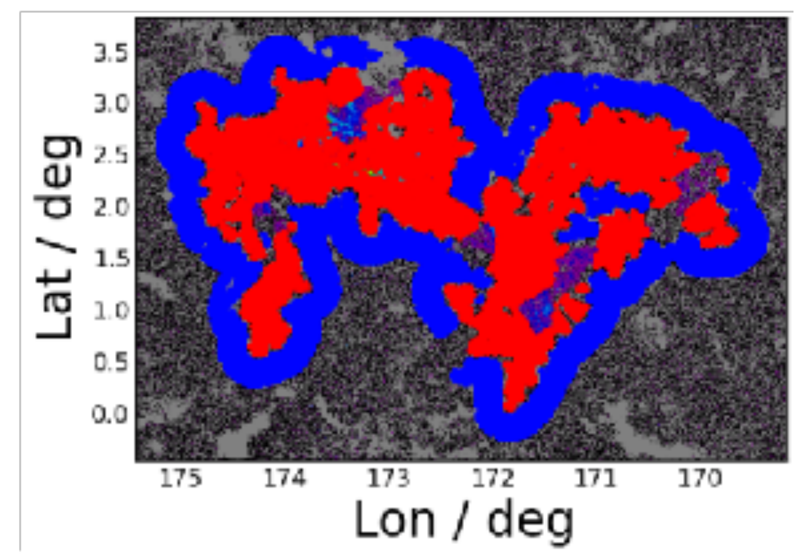

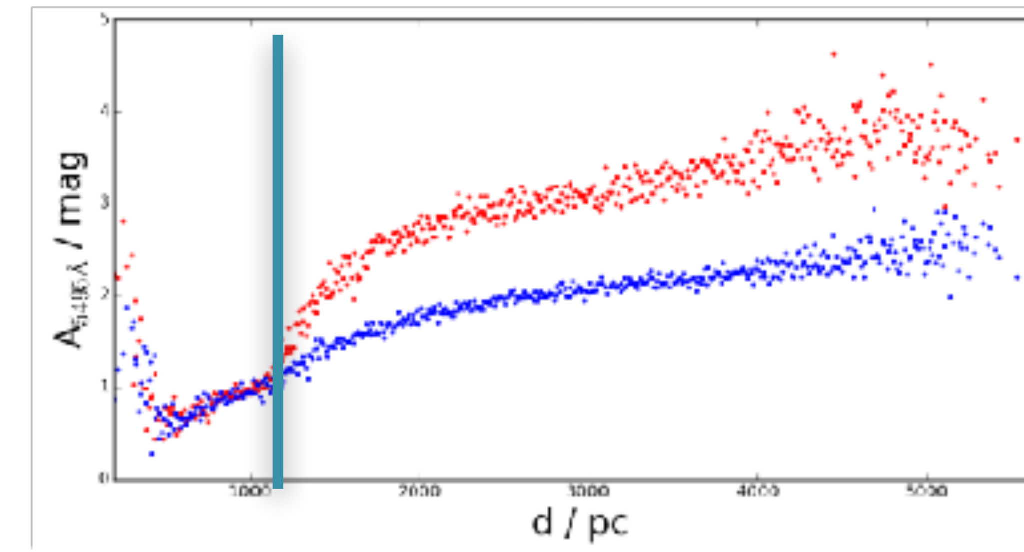

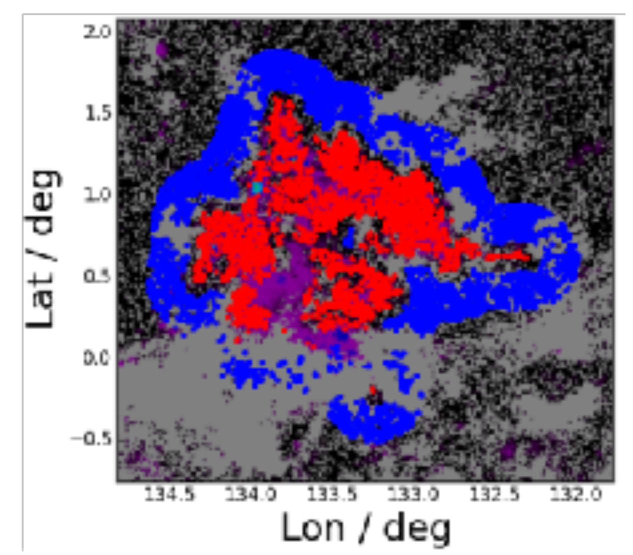

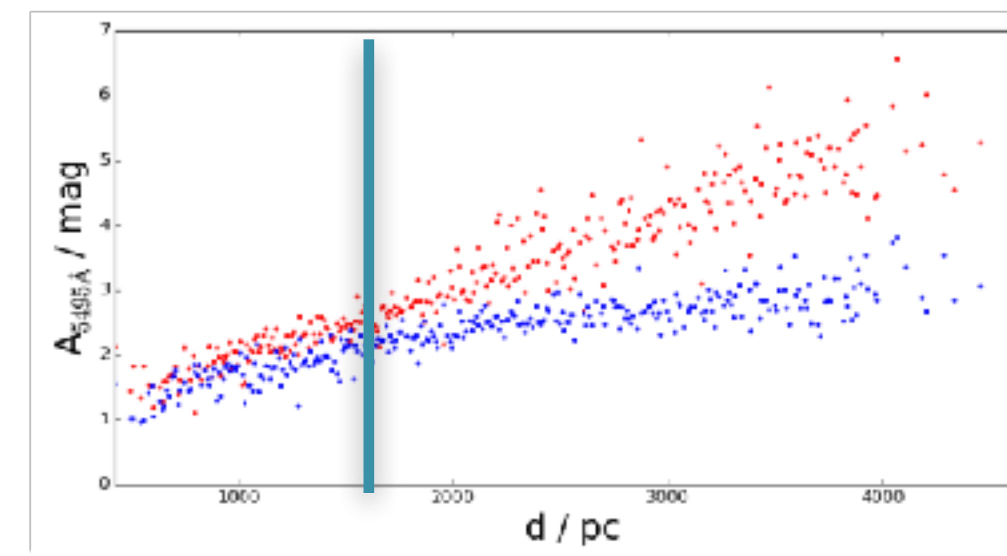

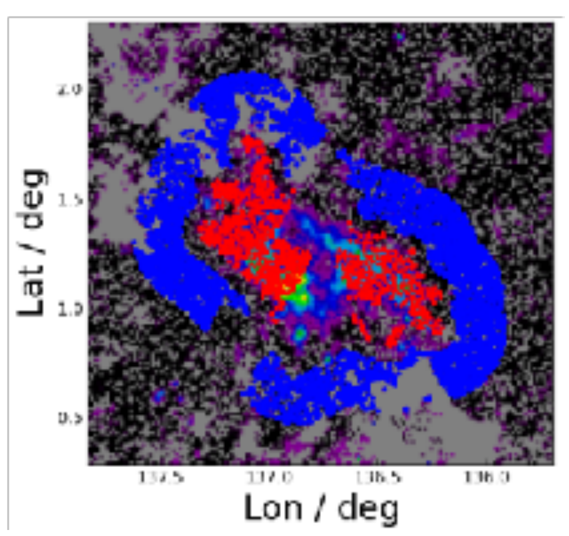

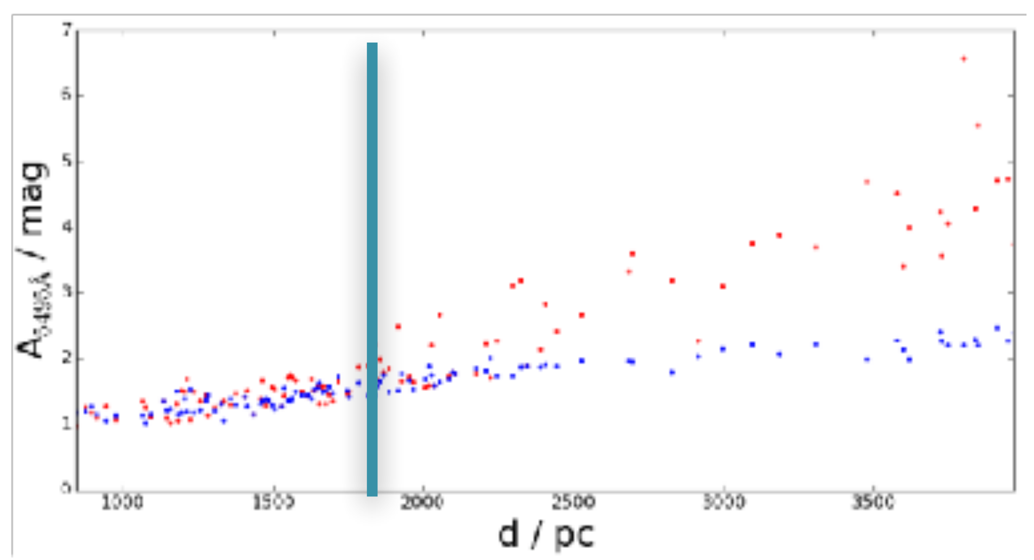

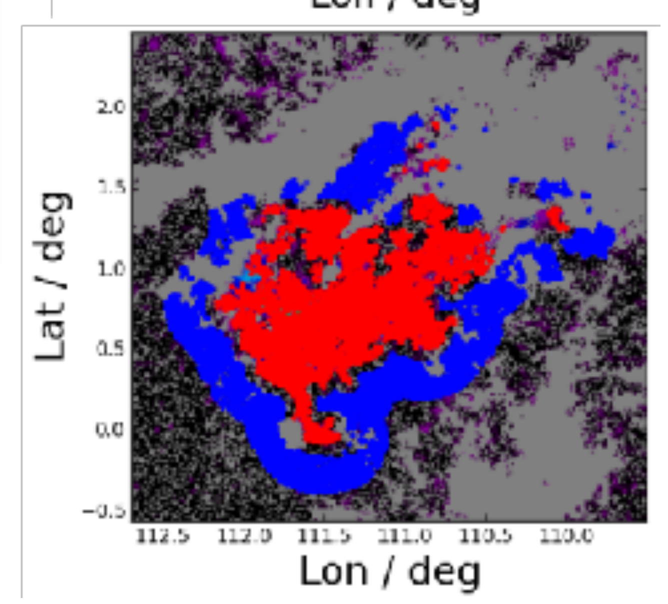

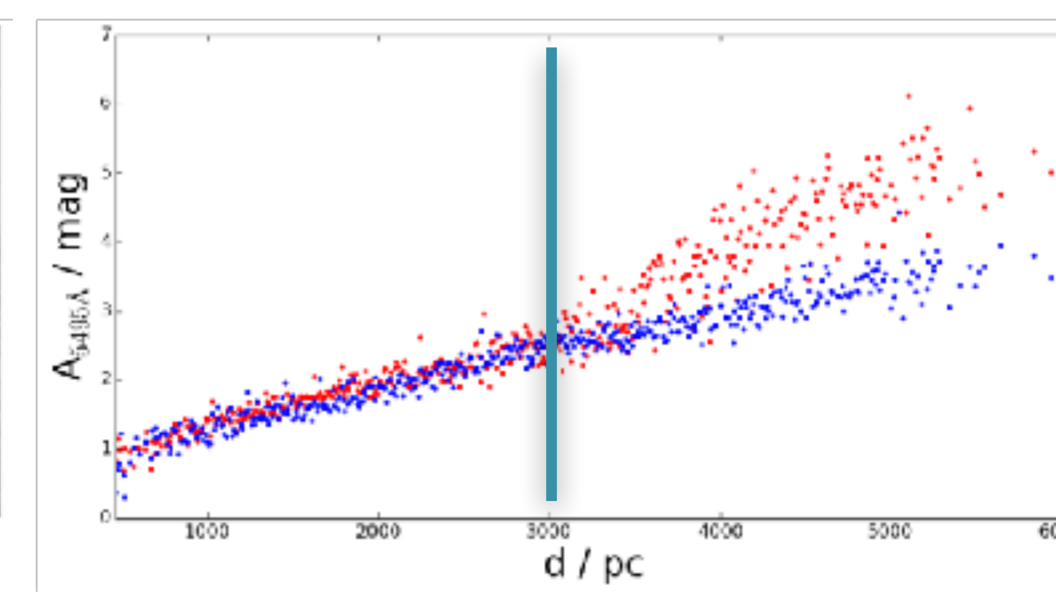

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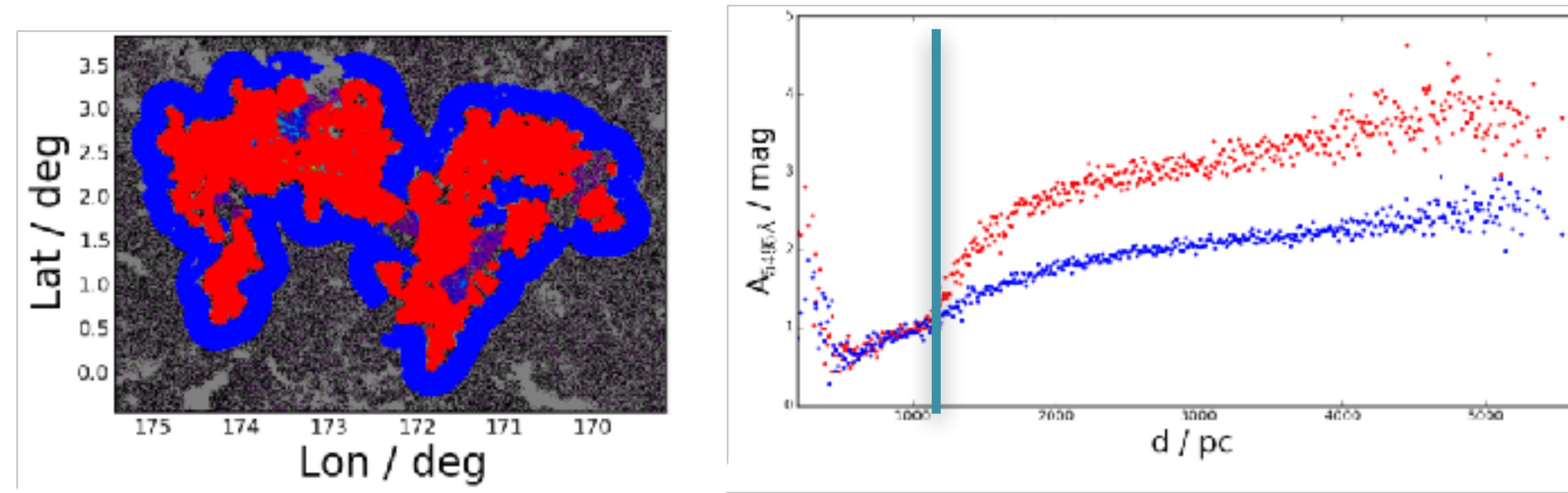

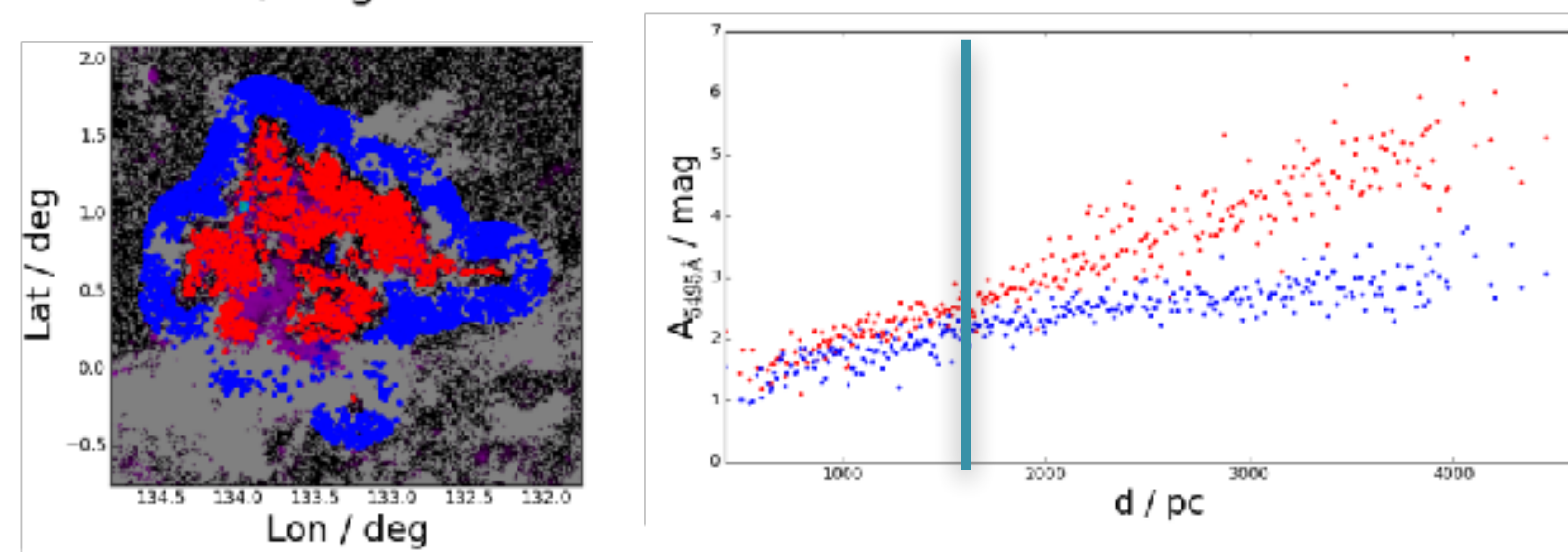

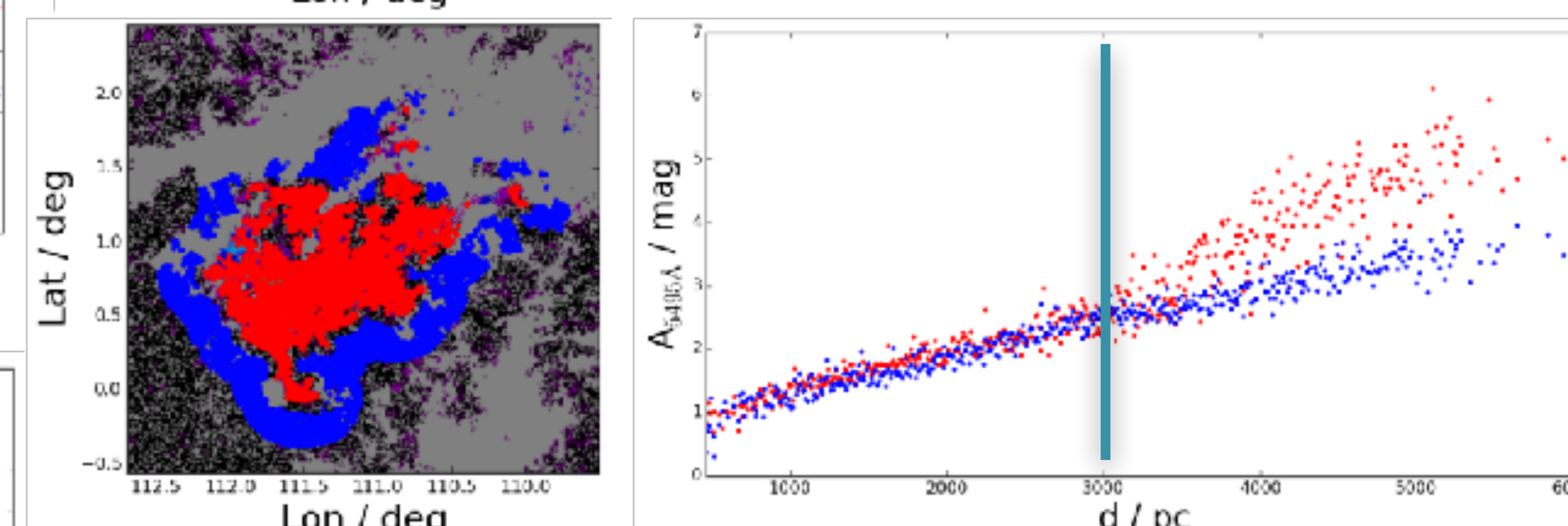

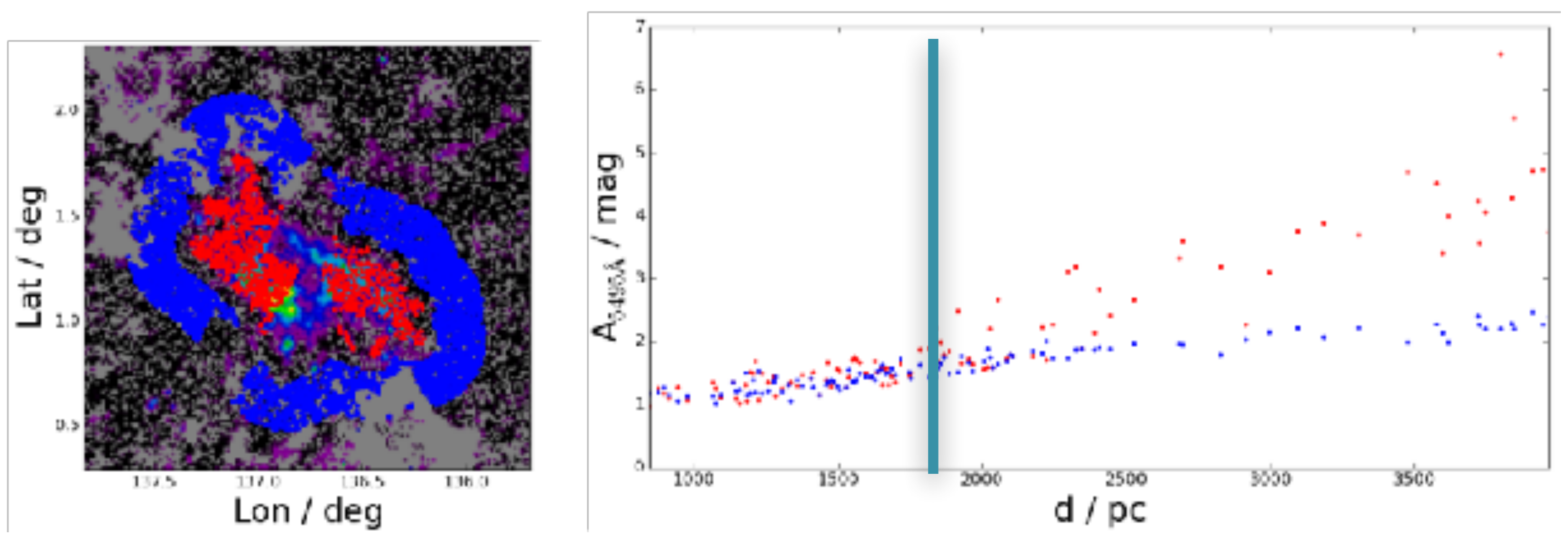

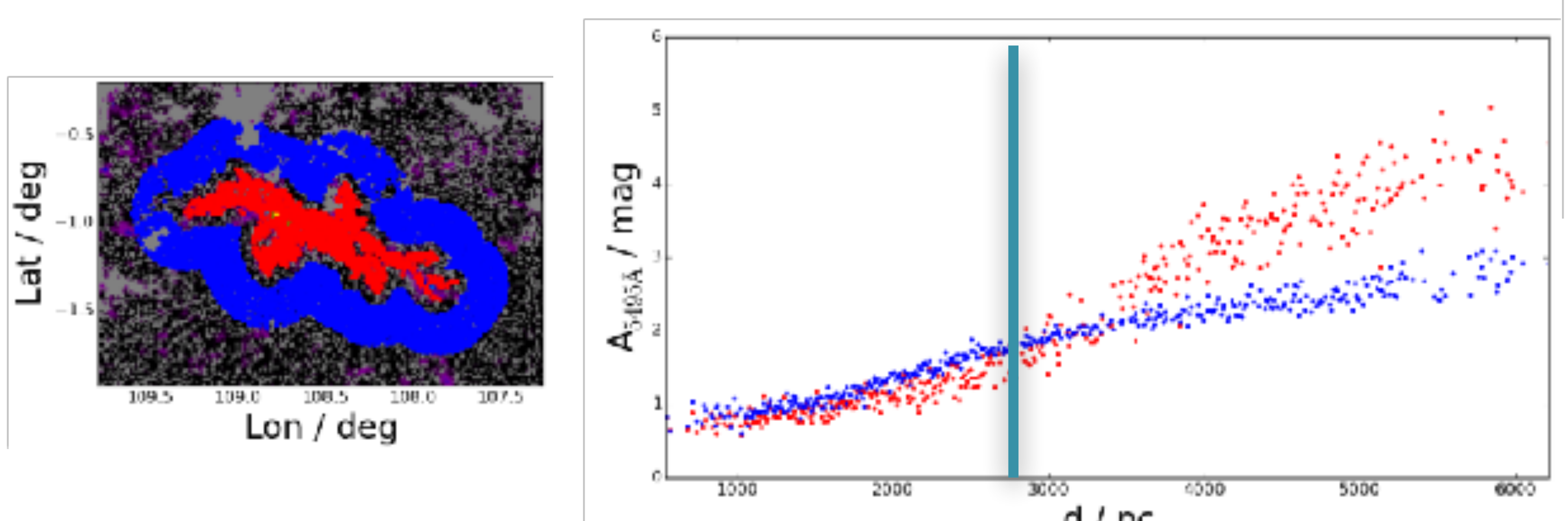

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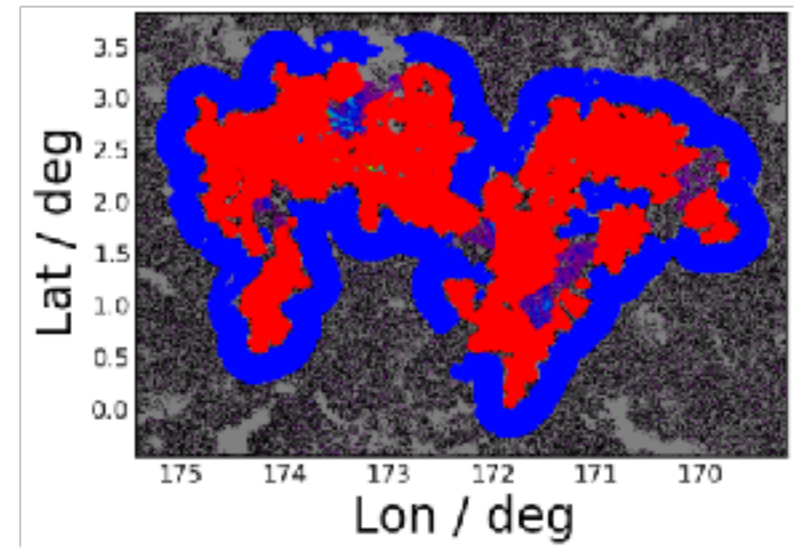

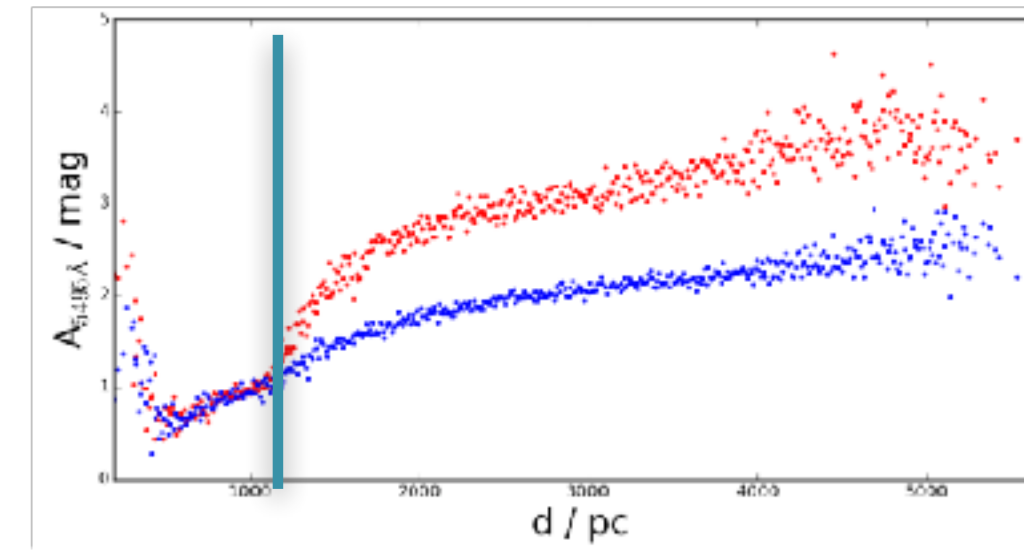

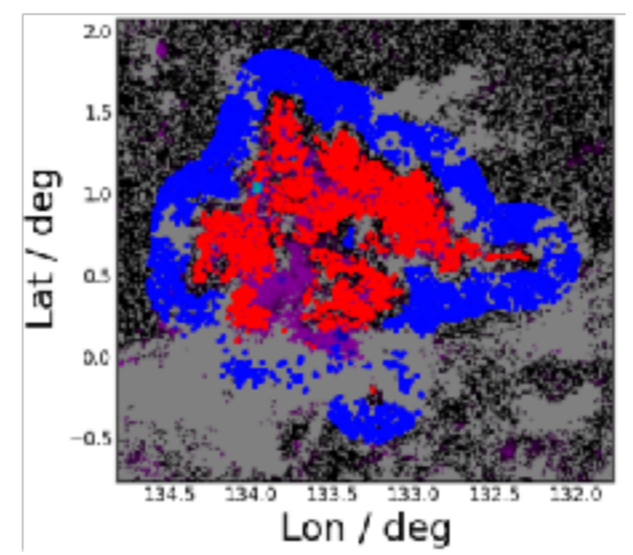

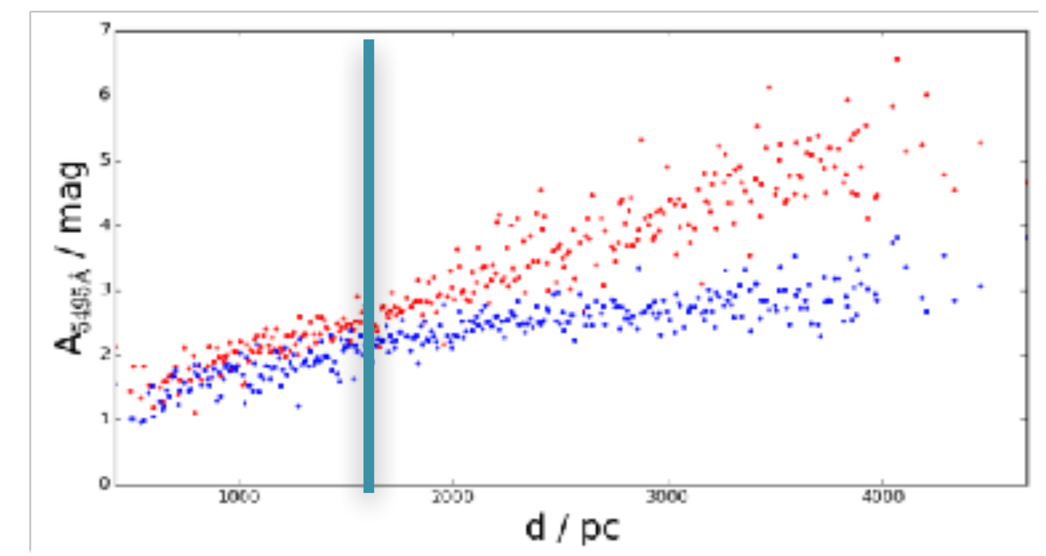

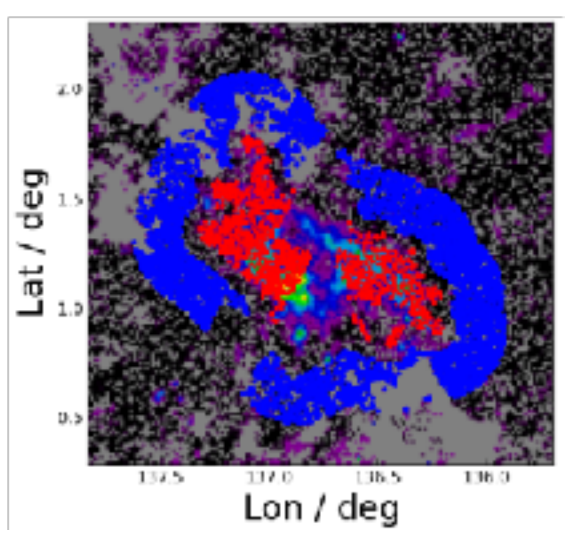

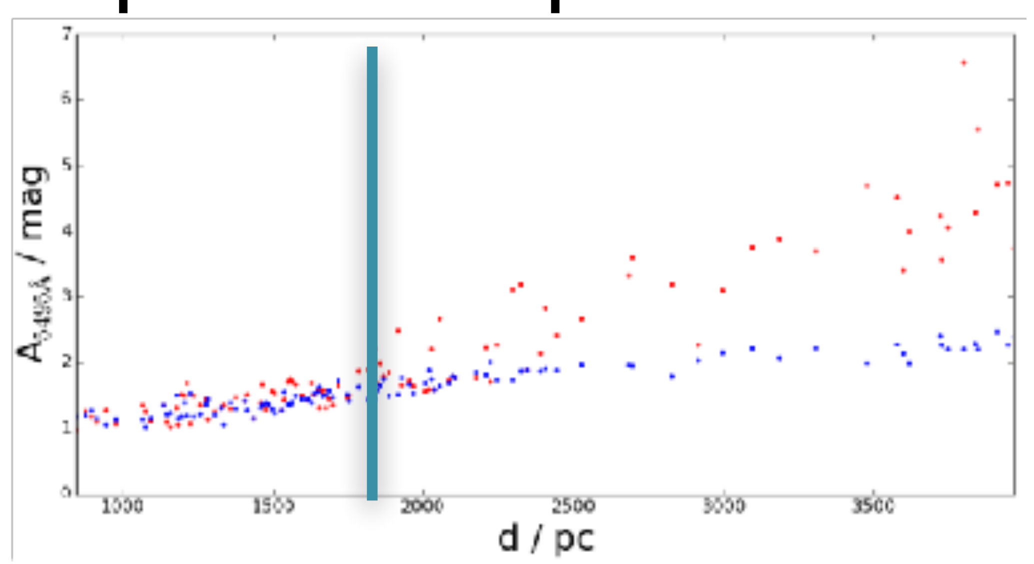

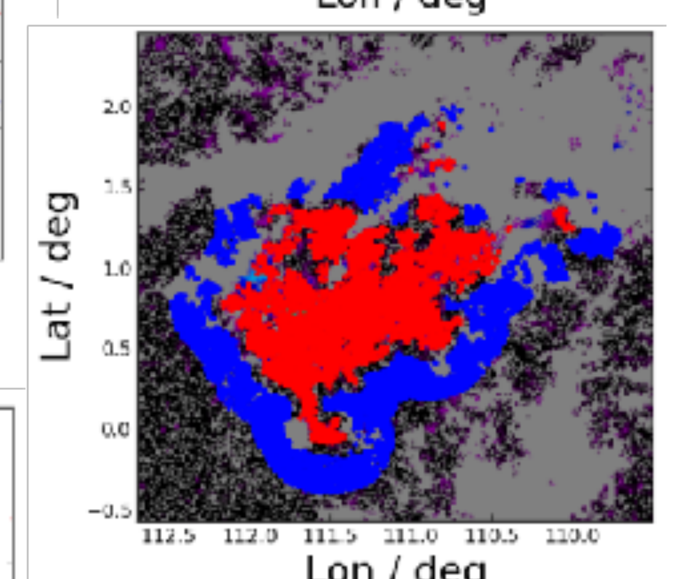

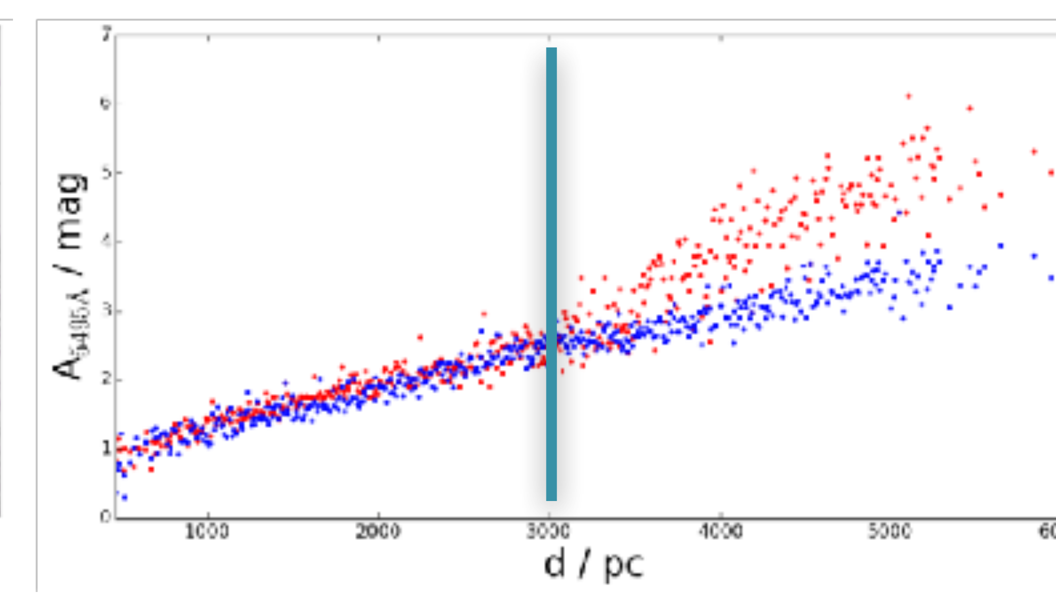

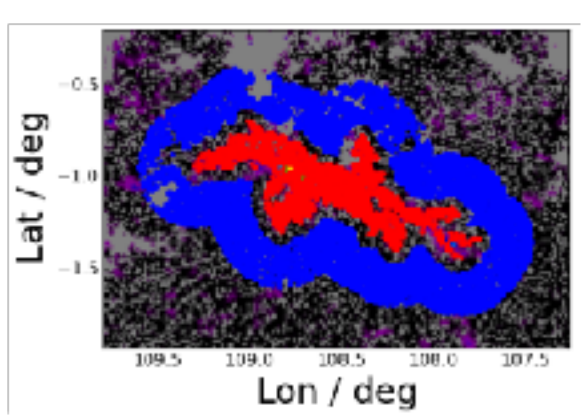

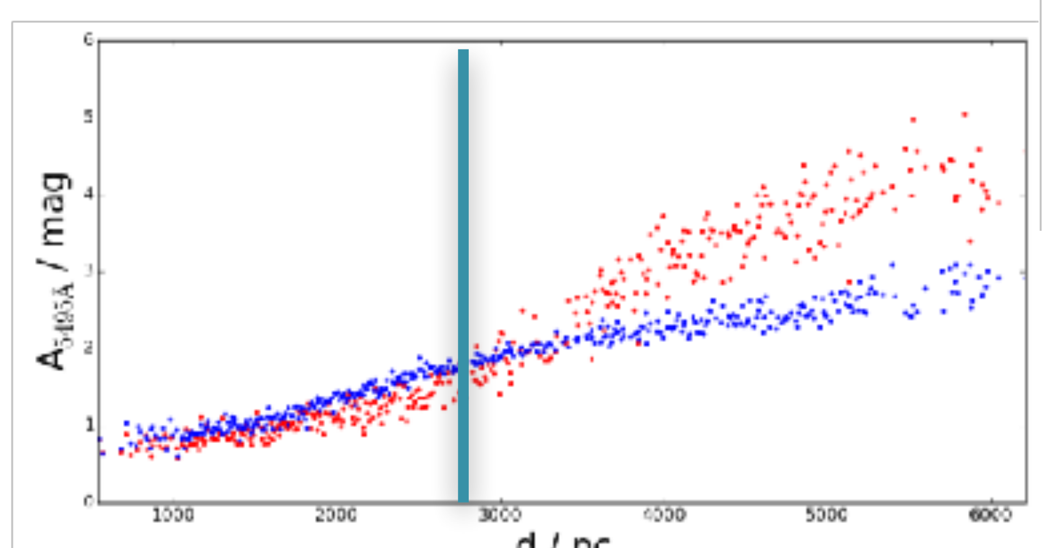

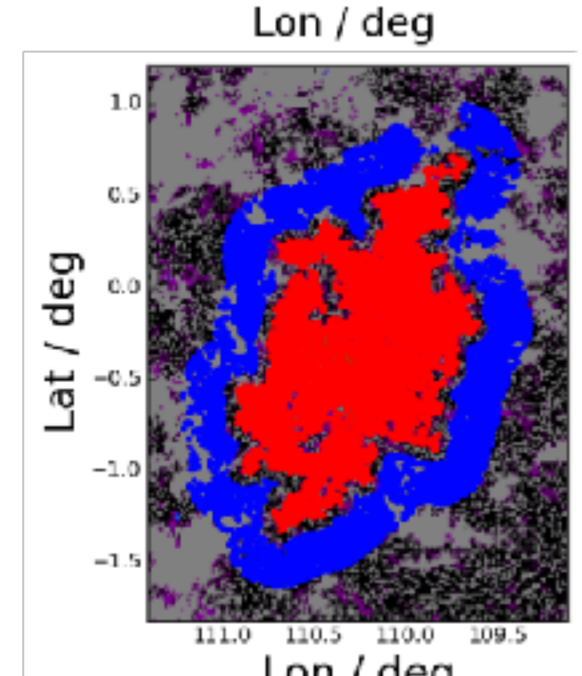

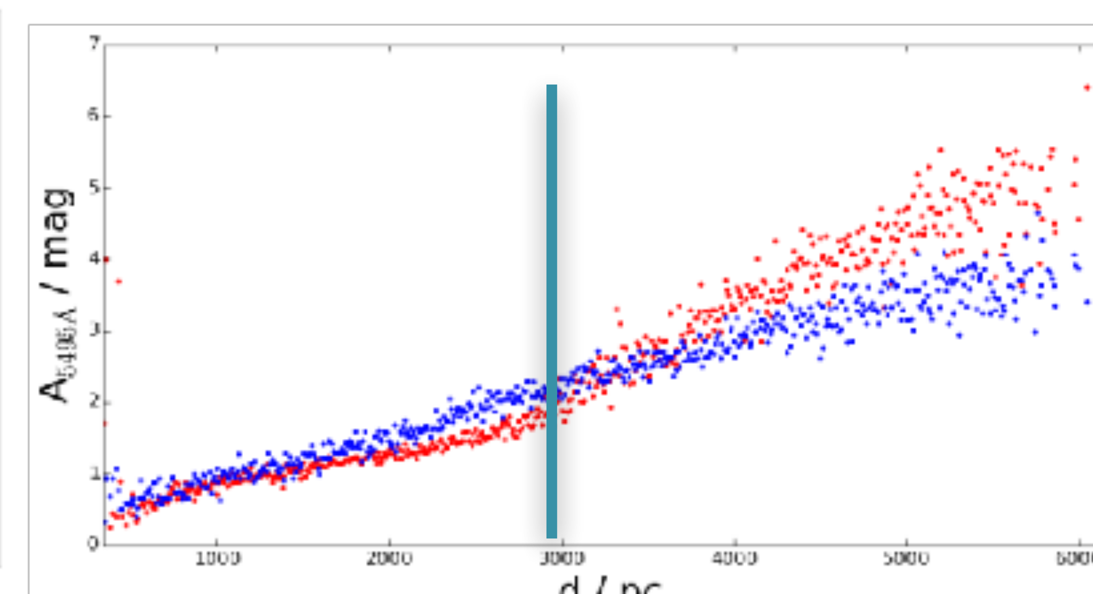

1. Evans N.J. II, Blair G. N., 1981, ApJ, 246, 394
2. Xu Y. et al., 2006, Science, 311, 54
3. Koenig X. P. et al., 2008, ApJ, 688, 1142
4. Moscadelli L. et al., 2009, ApJ, 693, 406
5. Ramirez Alegria S. et al., 2011, A&A, 535, 8
6. Foster T., Routledge D., 2003, ApJ, 598, 1005

3D Extinction – IPHAS

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- Expect jump in extinction at specific distance, then a continuation of ISM extinction

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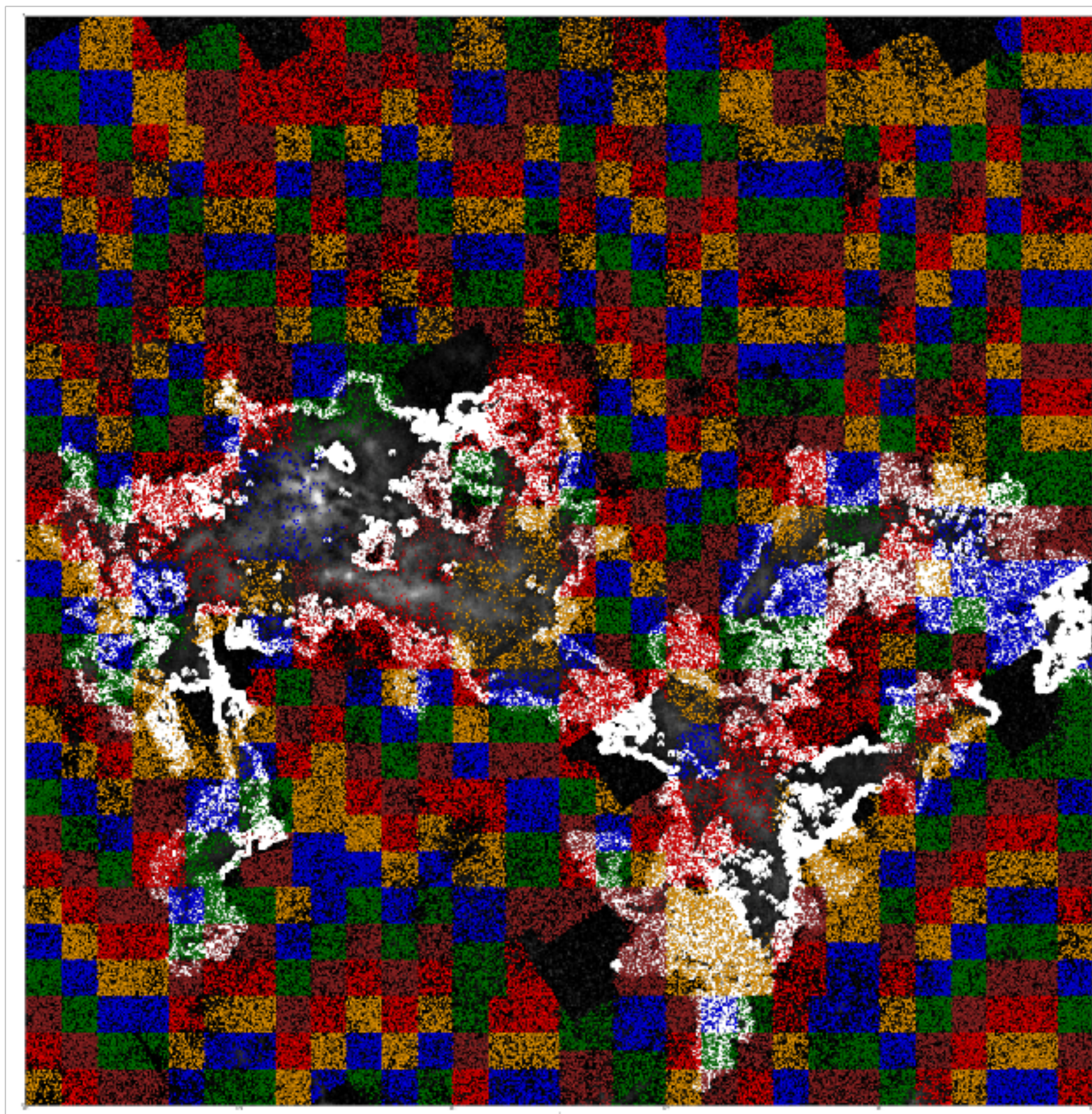
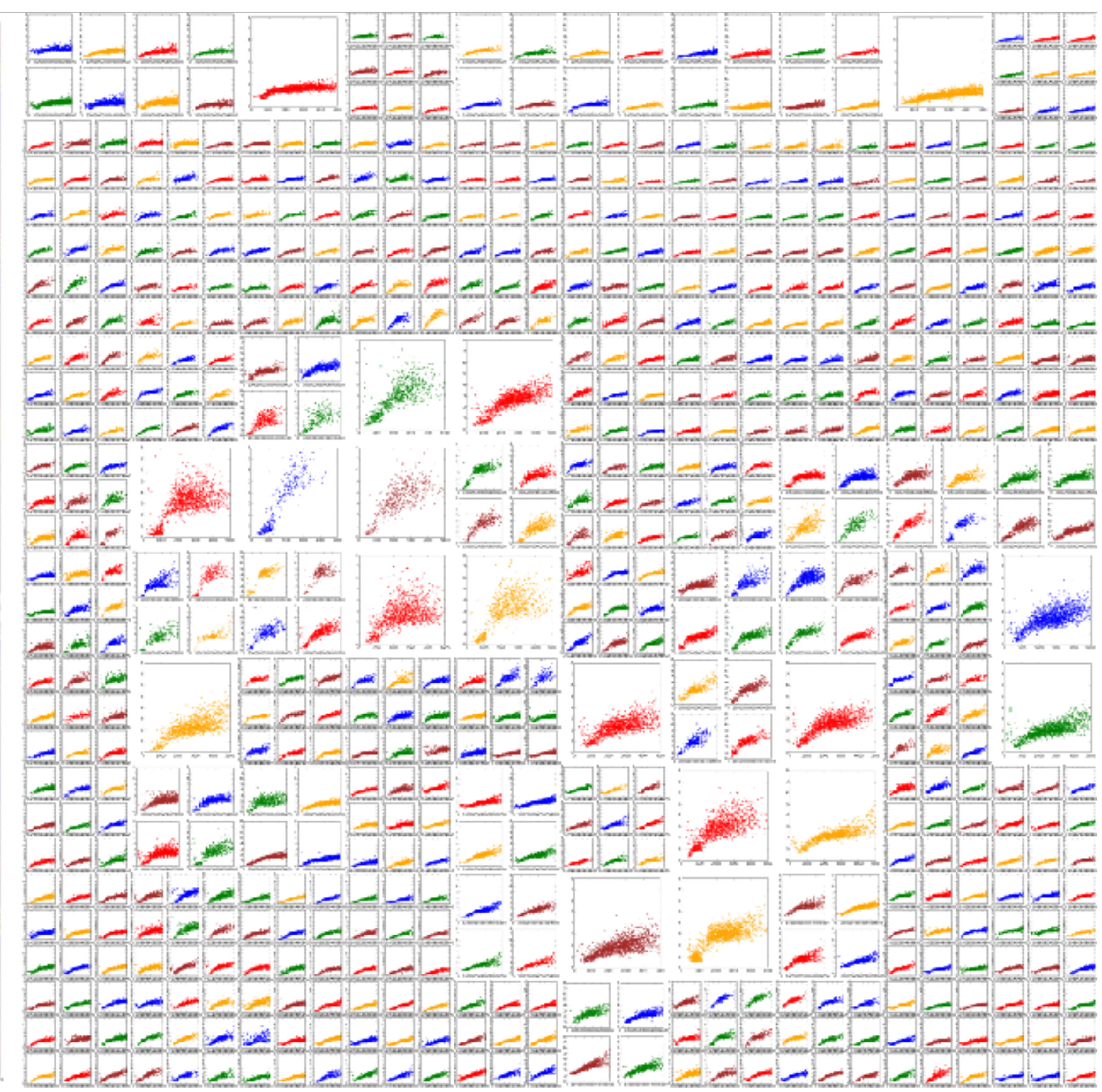
- Expect jump in extinction at specific distance, then a continuation of ISM extinction
- Individual sightlines split cloud

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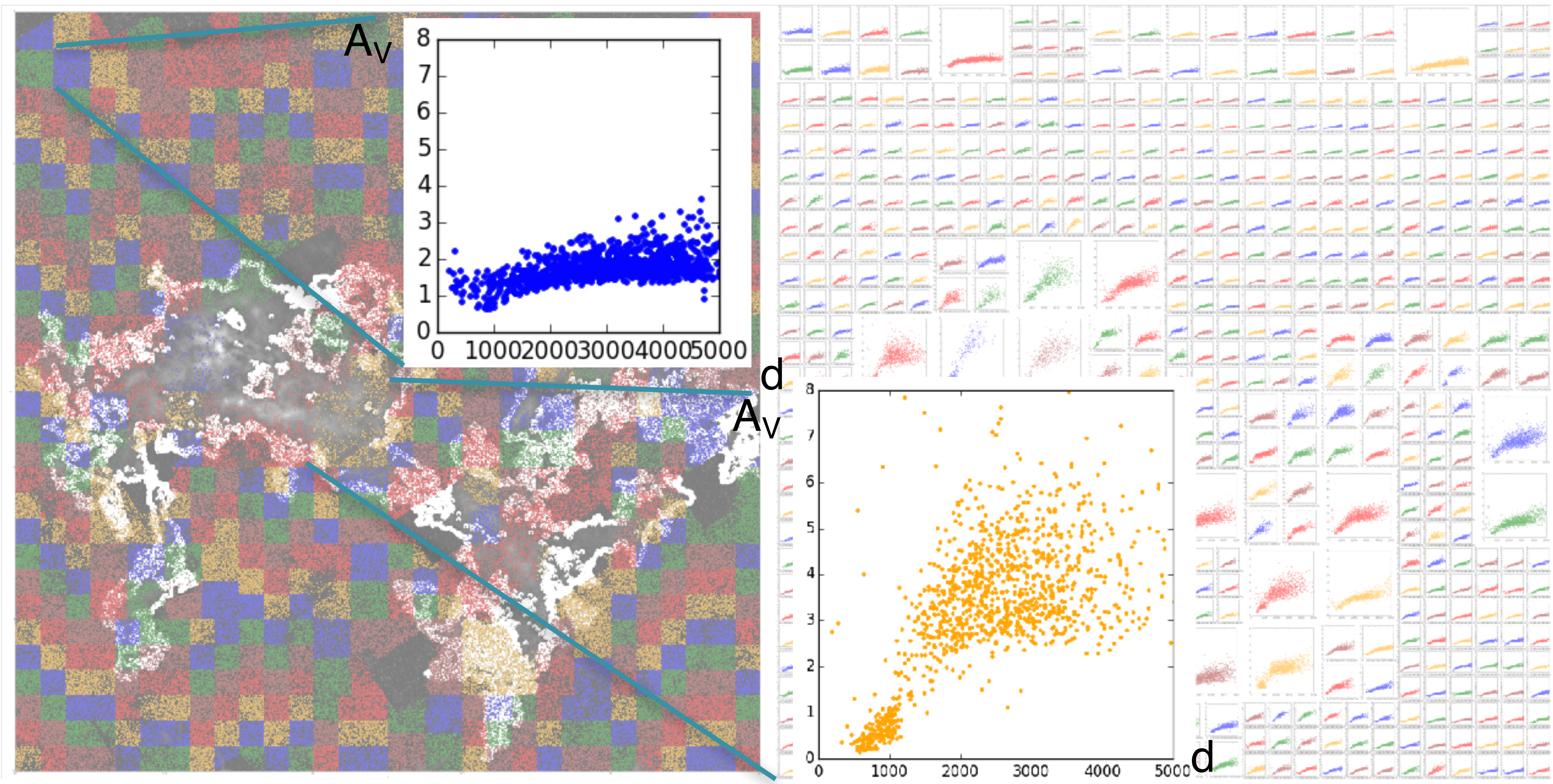

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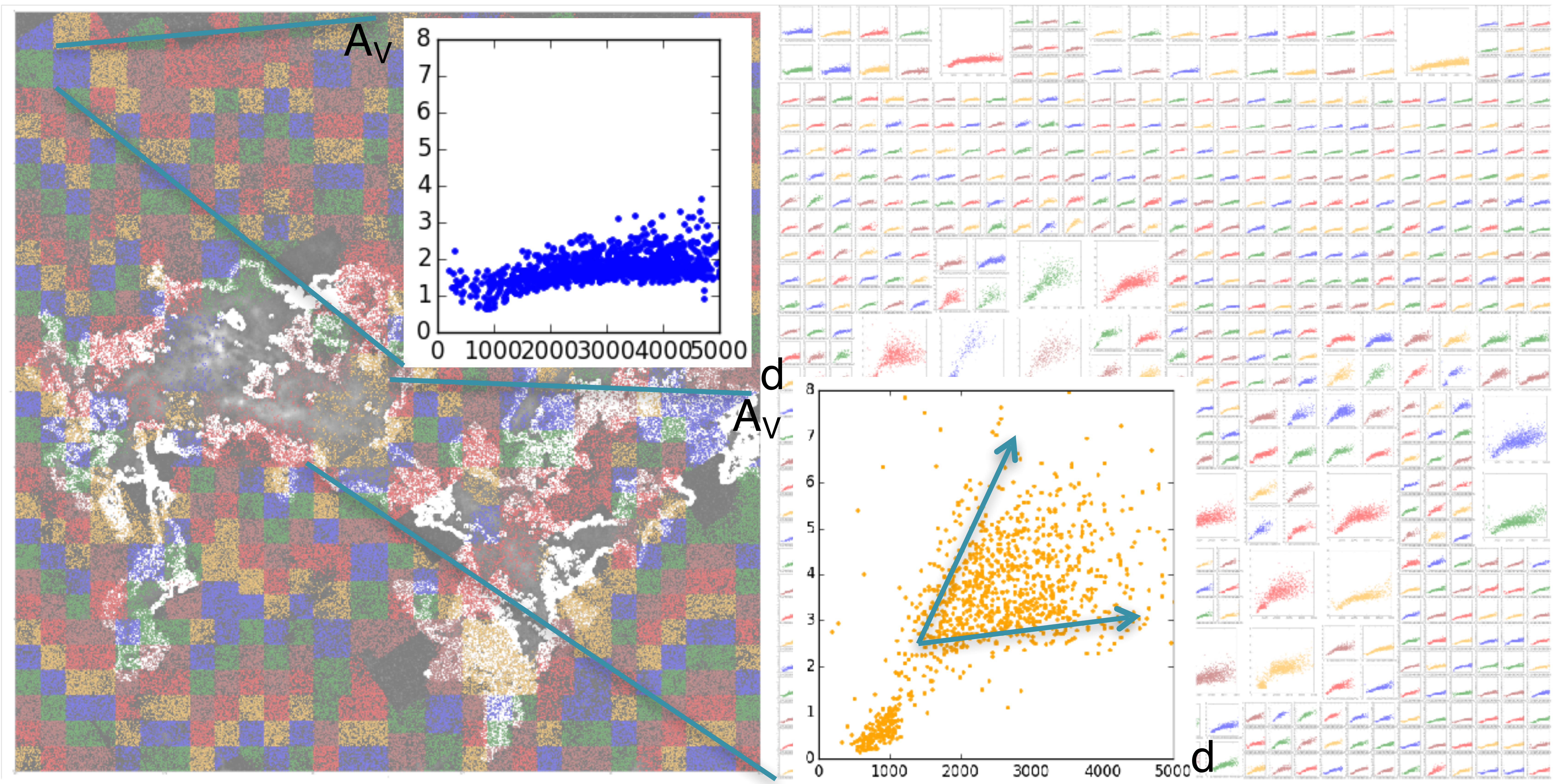
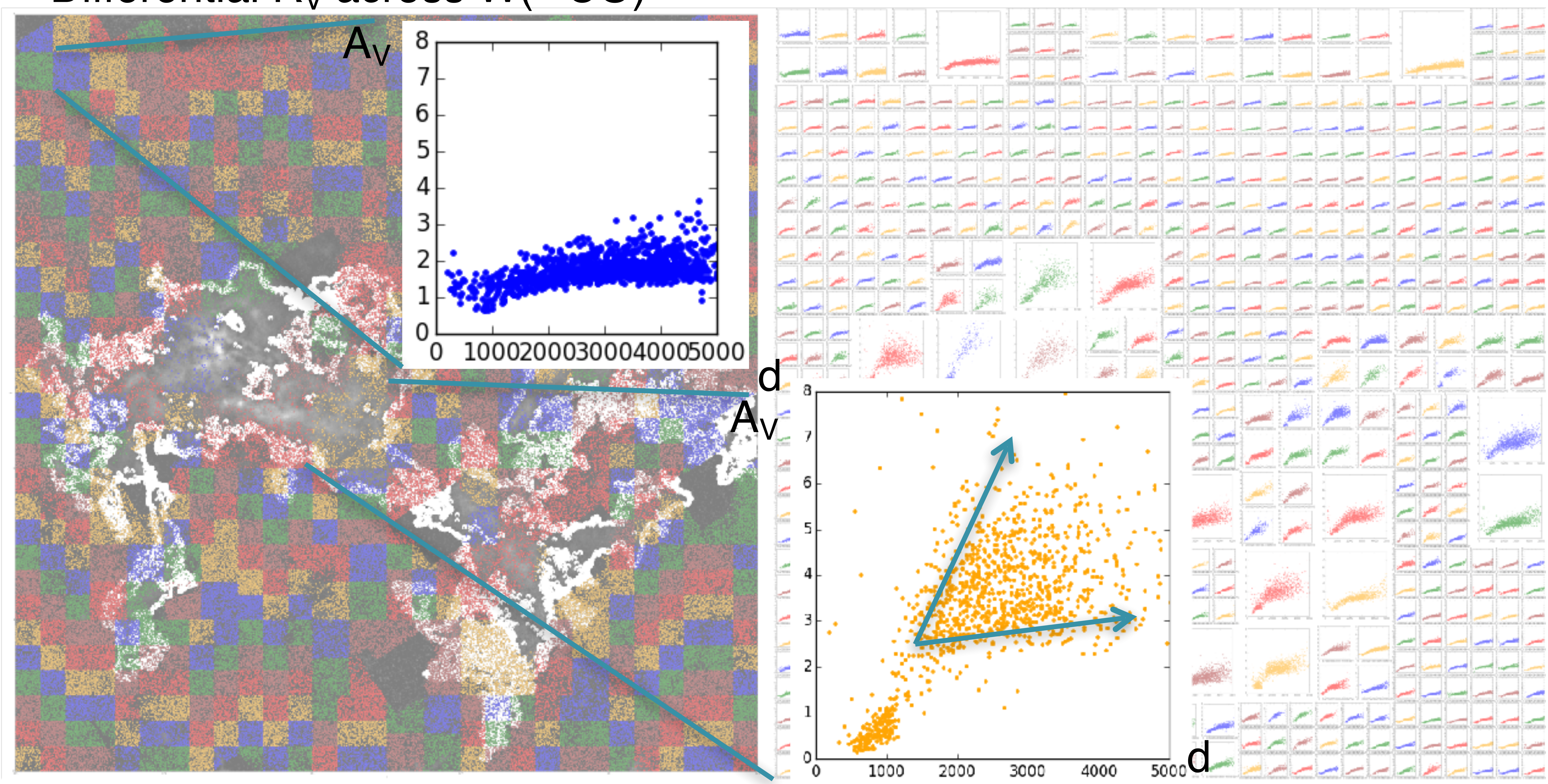
- Extinction gradient across cloud



3D Extinction – IPHAS

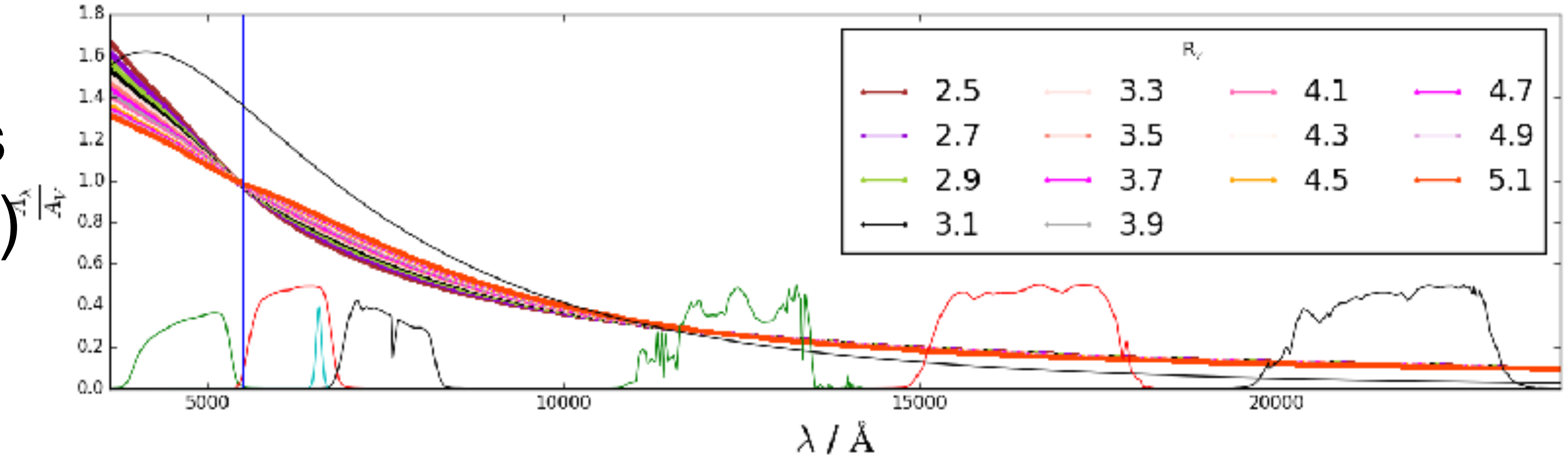
- Expect jump in extinction at specific distance, then a continuation of ISM extinction
- Individual sightlines split cloud
- Extinction gradient across cloud
- Differential R_V across $W(^{12}CO)$



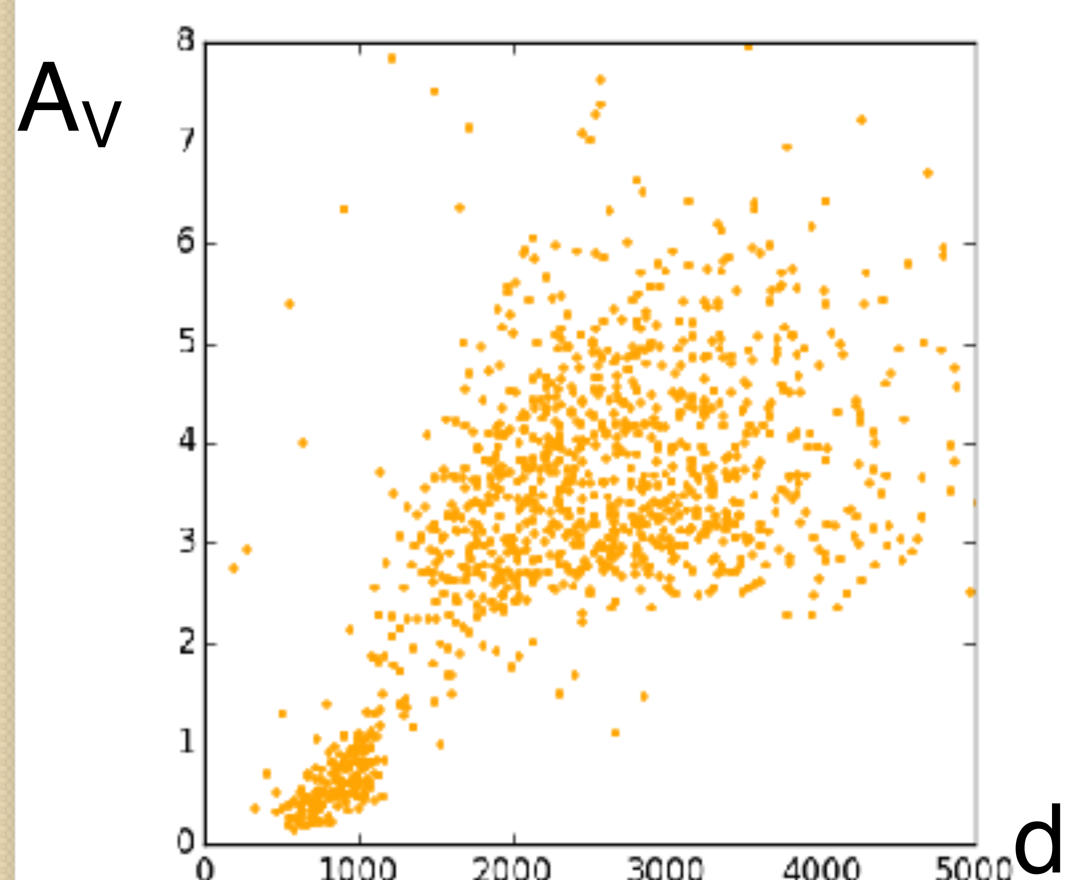
3D Extinction – IPHAS

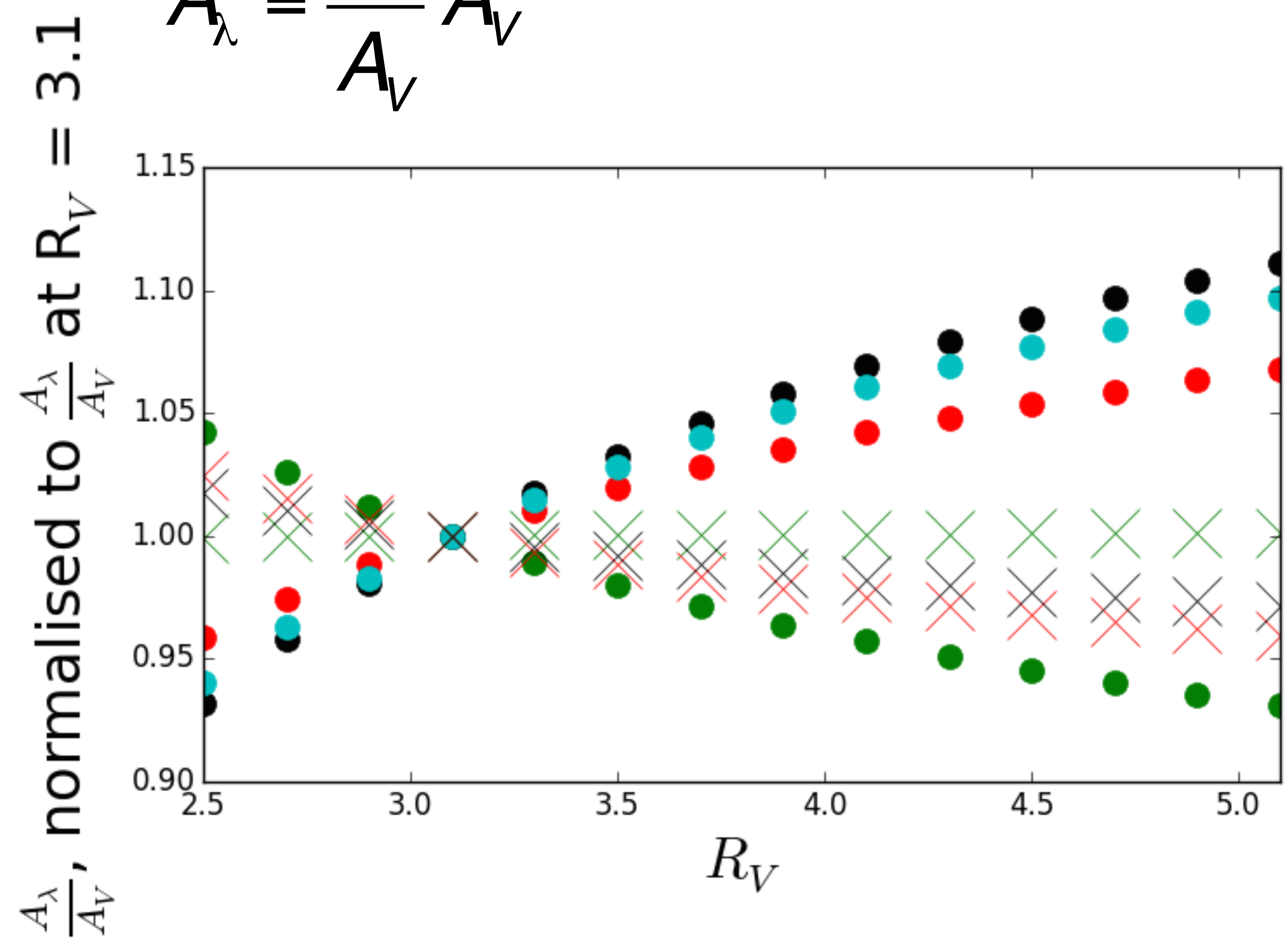
3D Extinction – IPHAS

- Reddening laws assume constant ratio between filters
- $R_V = A_V/E(B-V) = A_V/(A_B-A_V)$



$$A_\lambda = \frac{A_\lambda}{A_V} A_V$$





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- Reddening laws assume constant ratio between filters
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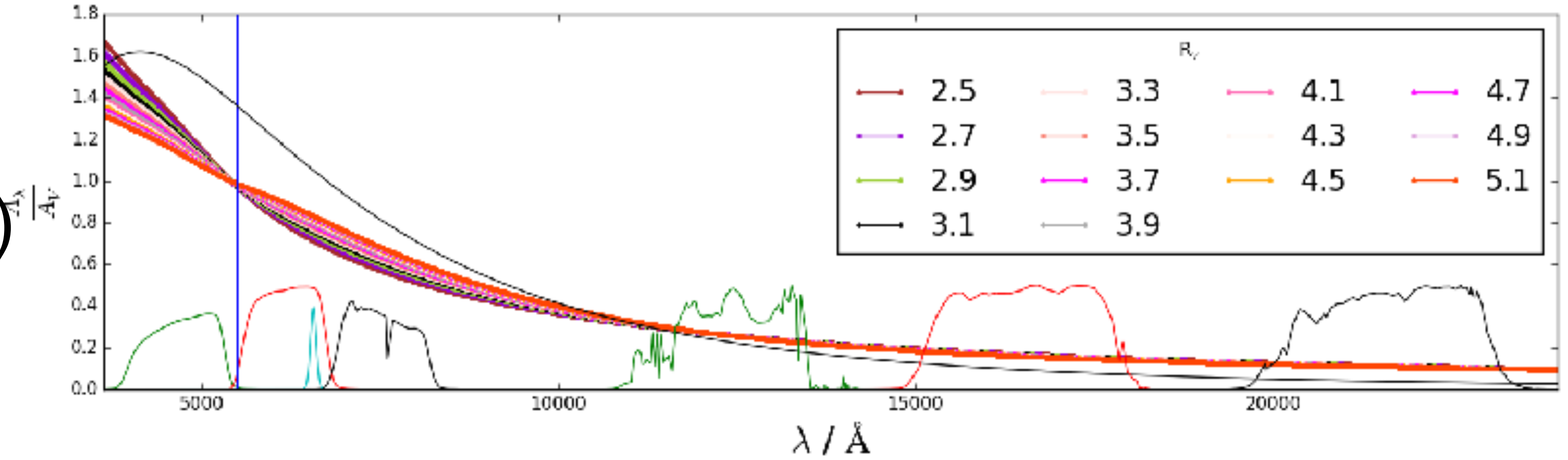
- Increasing R_V changes amount of extinction derived



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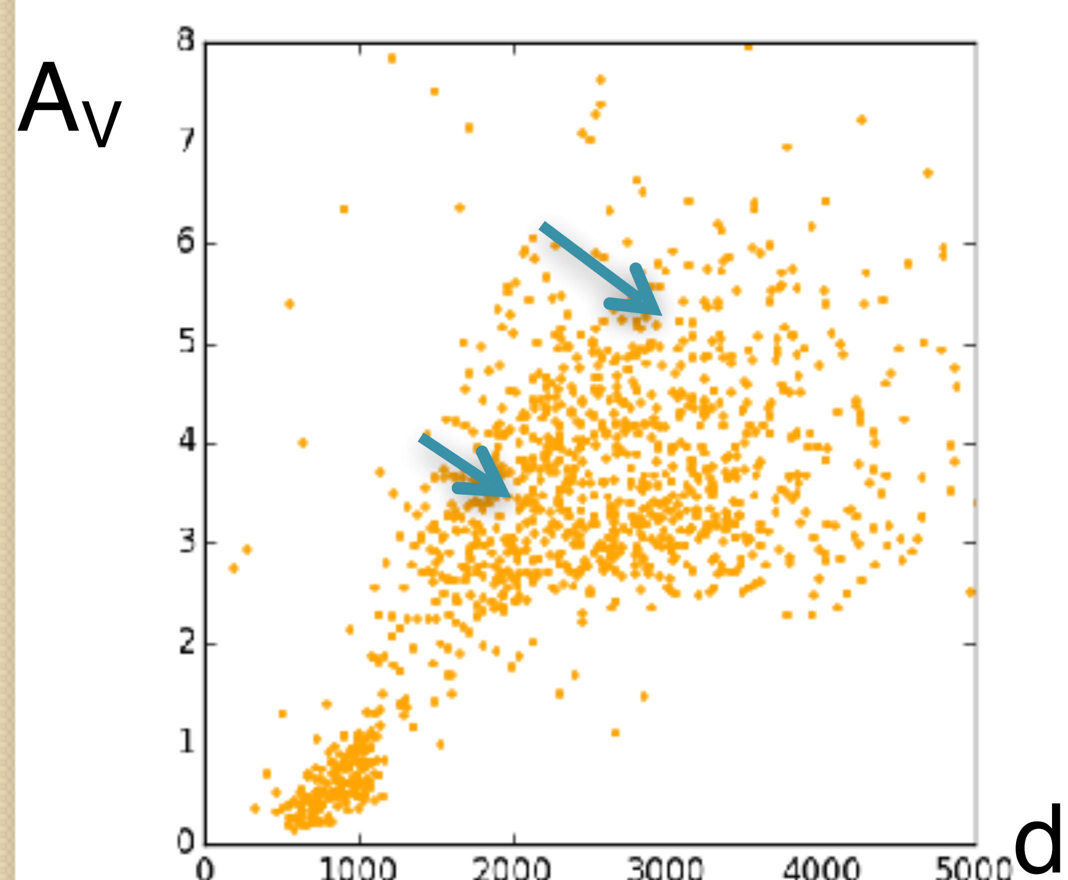
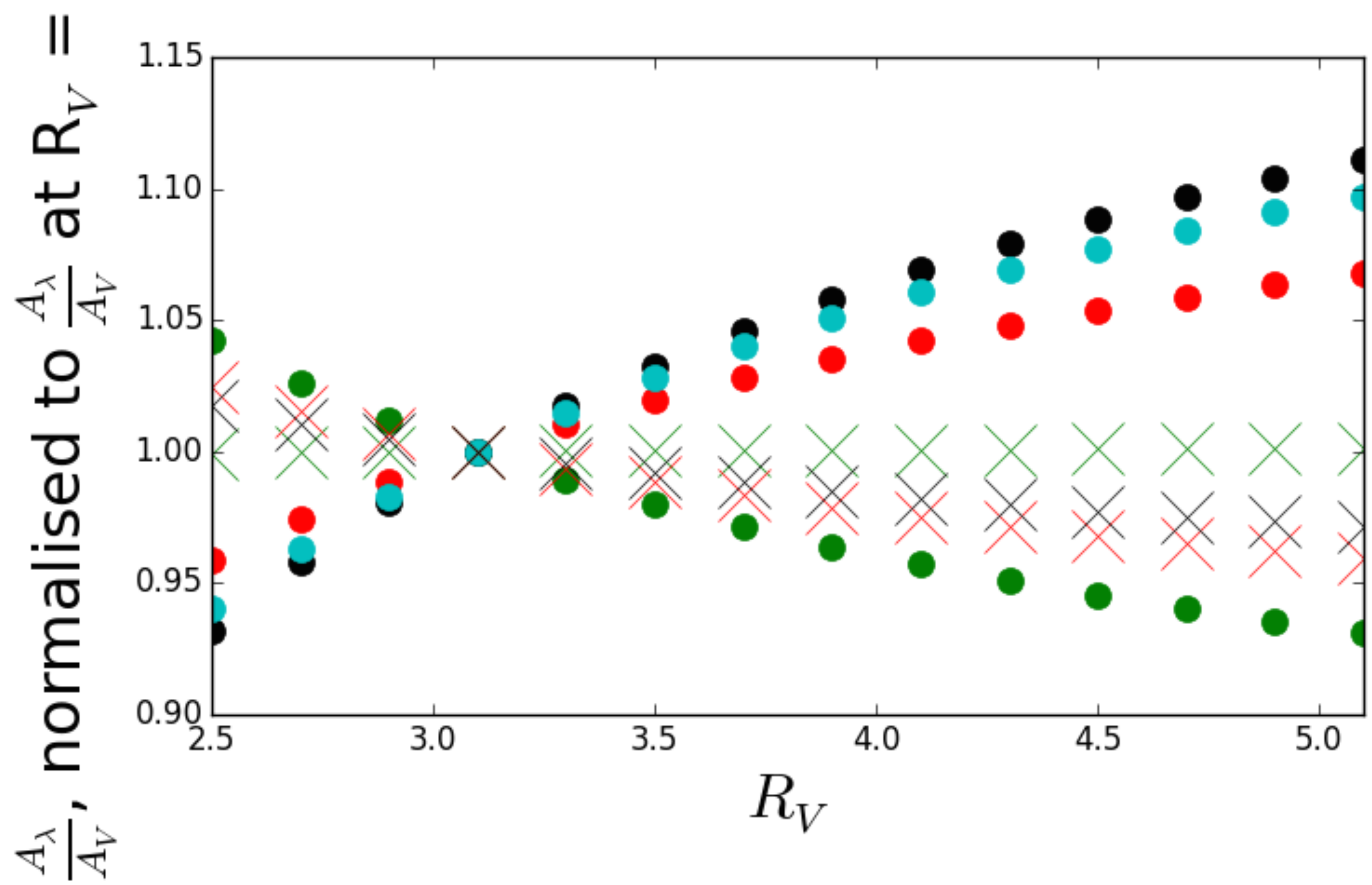
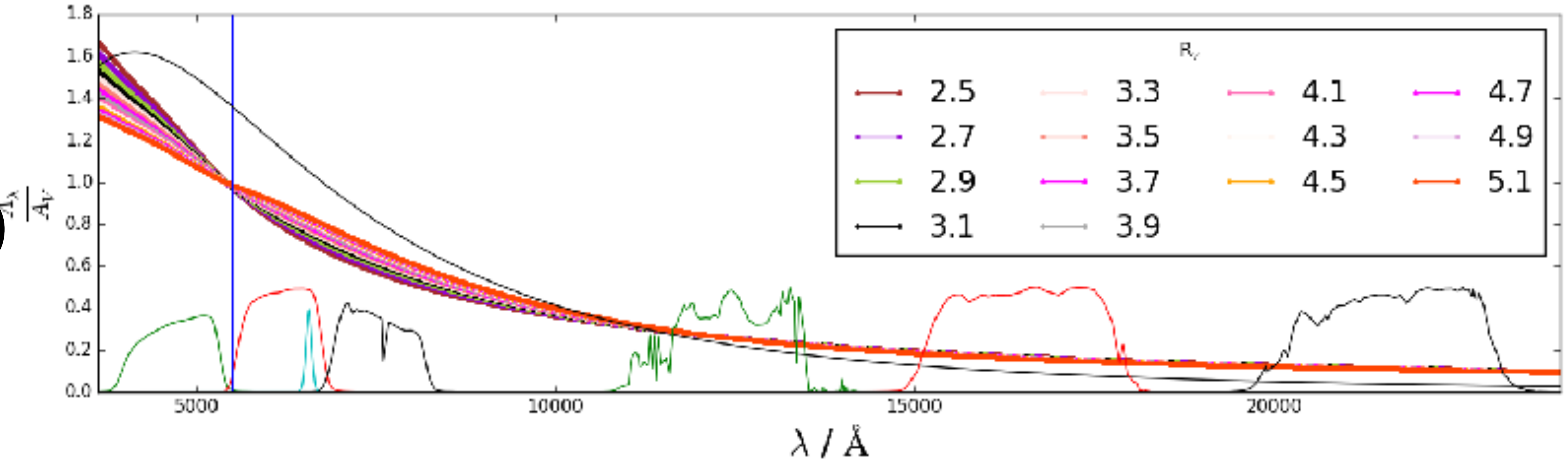




3D Extinction – IPHAS

- Reddening laws assume constant ratio between filters
- $R_V = A_V/E(B-V) = A_V/(A_B-A_V)$
- Increasing R_V changes amount of extinction derived
- Increase in $W(^{12}CO)$ across cloud increases extinction as well



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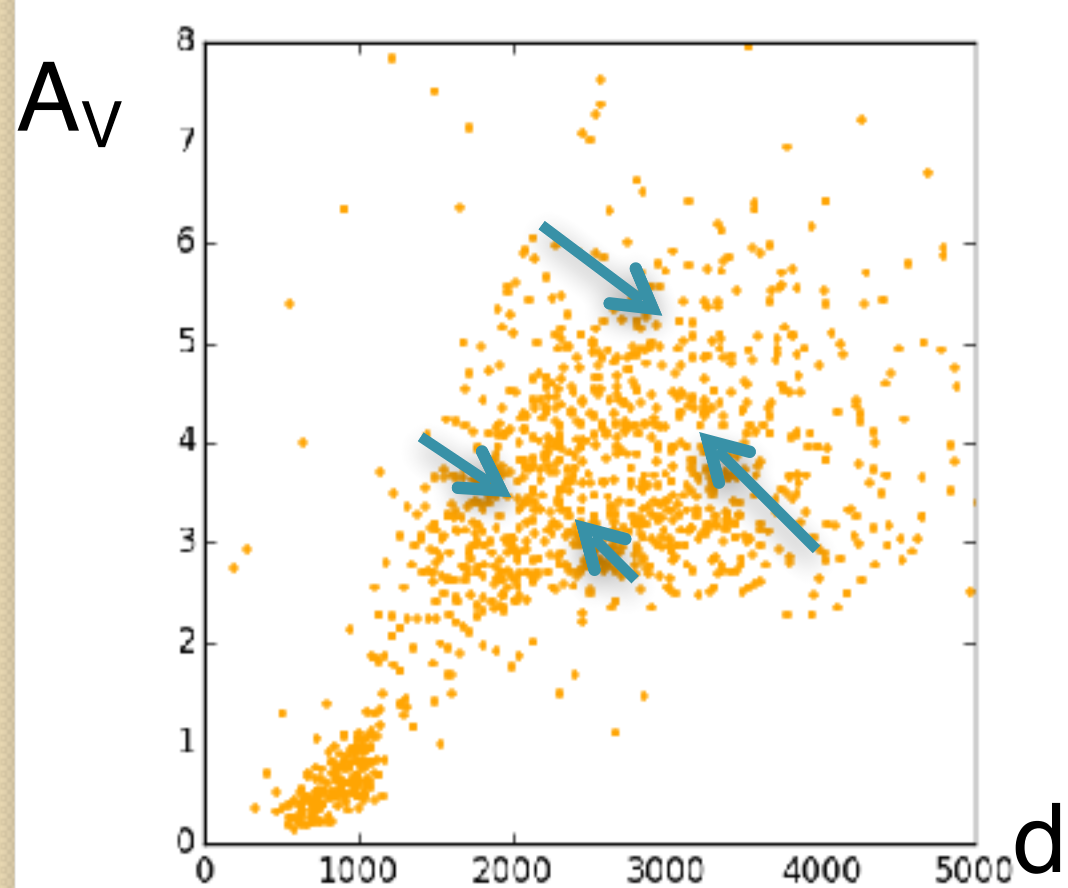
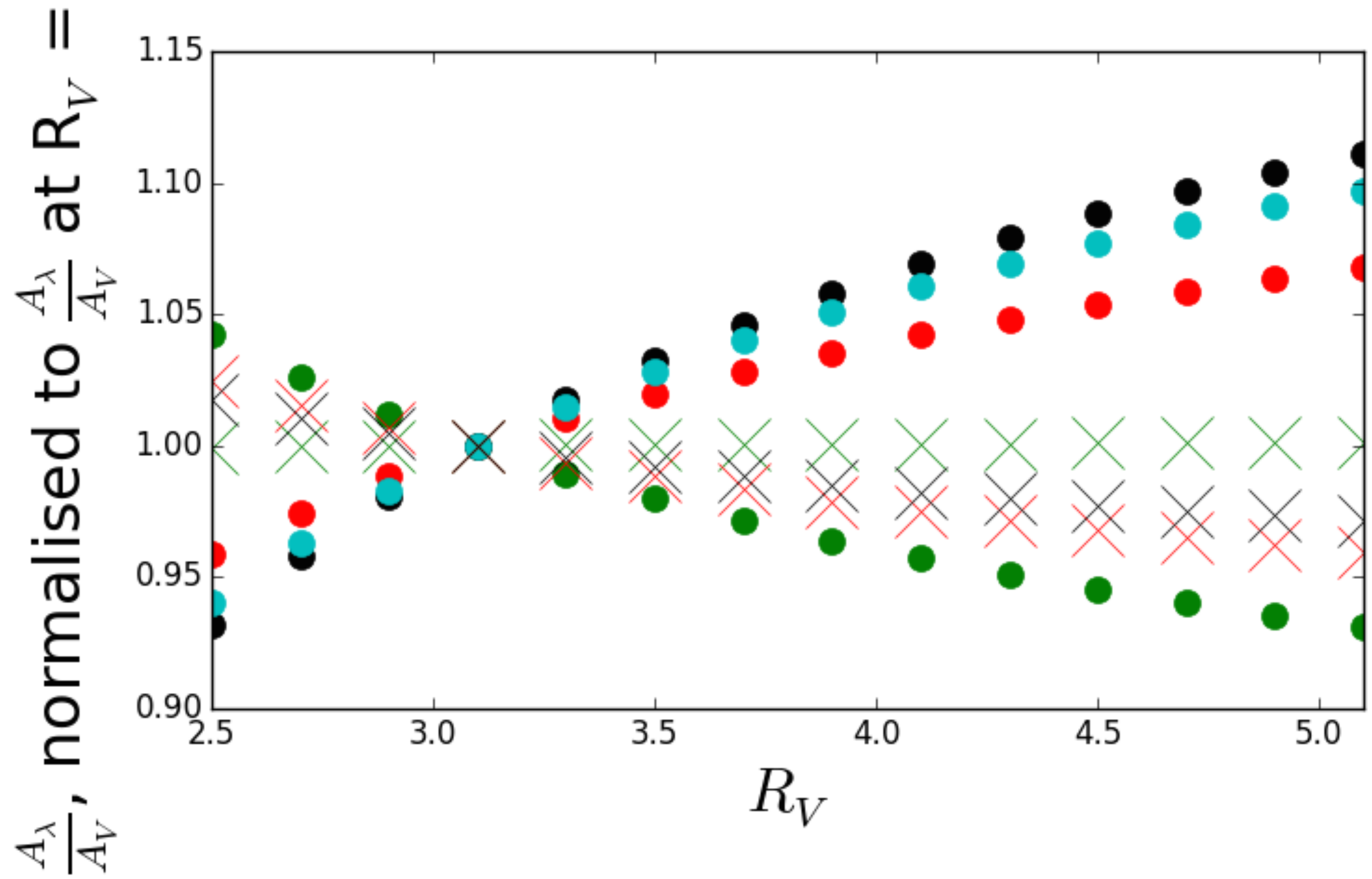
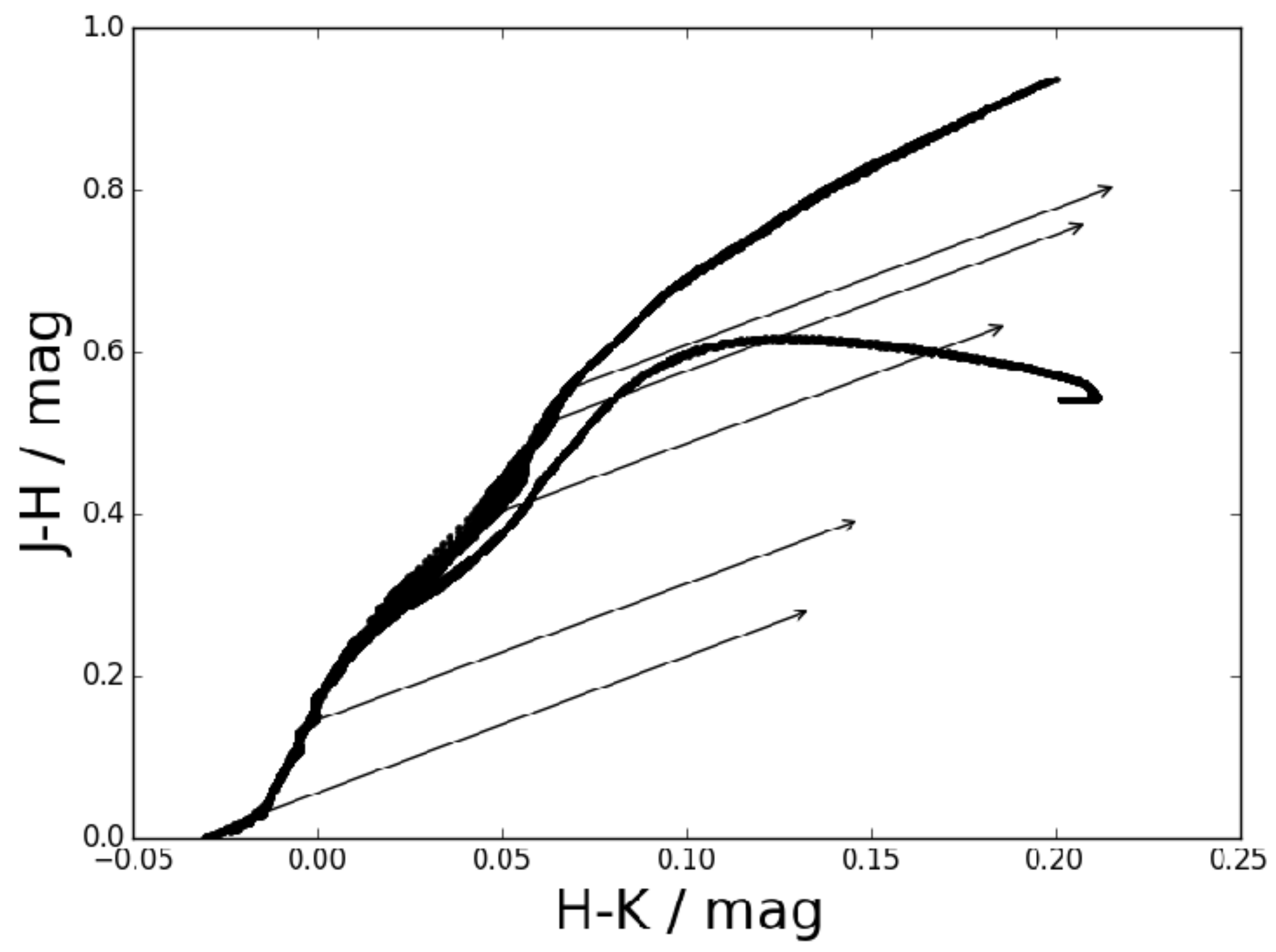




3D Extinction – Bayesian

3D Extinction – Bayesian

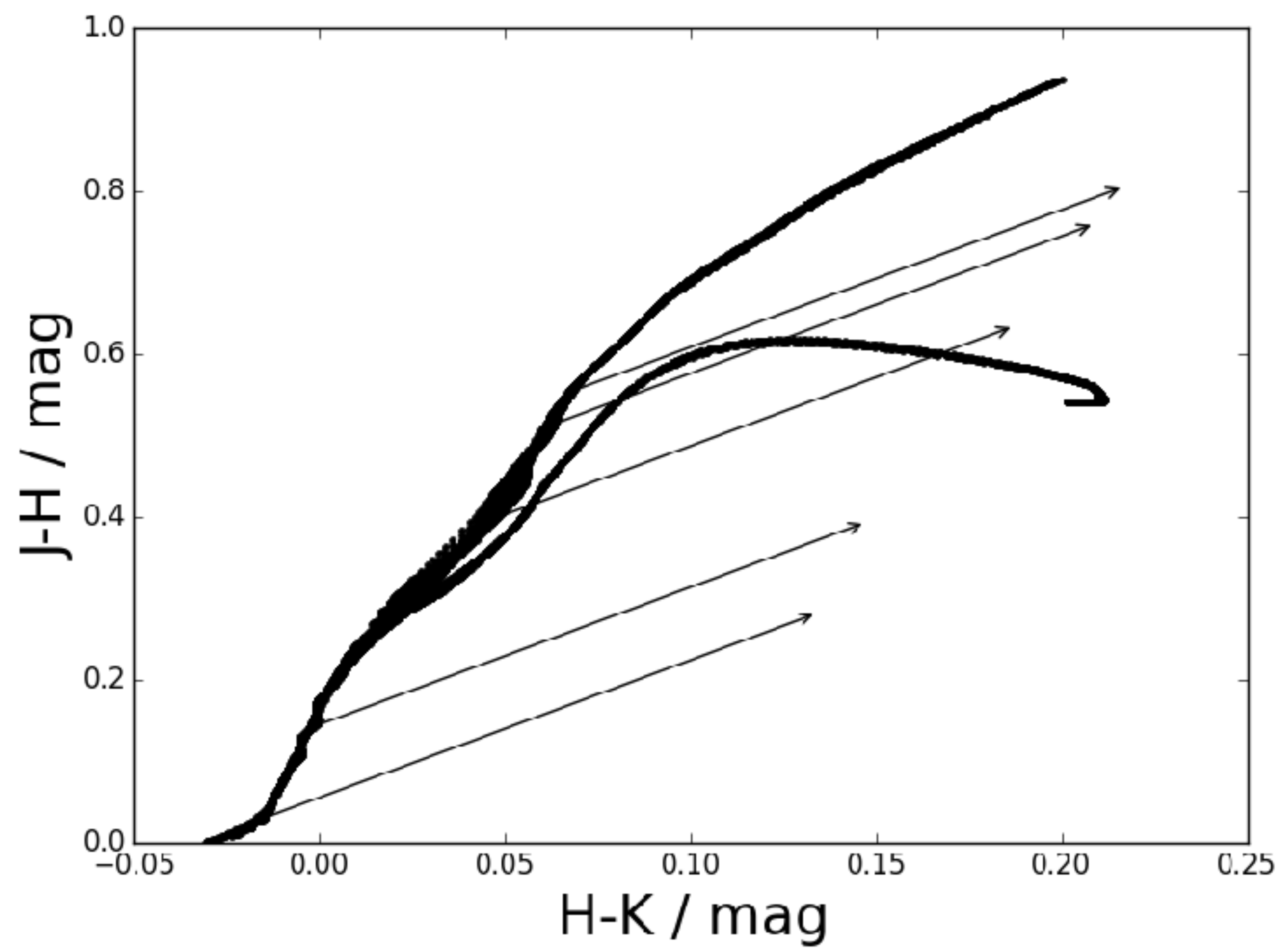
- Flexible method to find most probable outcome



3D Extinction – Bayesian

- Flexible method to find most probable outcome
- p(M) – the prior
- p(M I D) – the posterior
- p(D I M) – the likelihood
- p(D) – normalisation
- Advantageous due to ability to construct more detailed models

$$p(M \mid D) = \frac{p(D \mid M)\, p(M)}{p(D)}$$



3D Extinction – Bayesian

$$p(\alpha \mid \{\mathbf{m}\}) = p(\alpha) \prod_i \iint p(\mathbf{m}_i \mid \mu, A_V(\alpha, \mu), \Theta)\, p(\mu)\, p(\Theta)\, \mathrm{d}\Theta\, \mathrm{d}\mu$$

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3D Extinction – Bayesian

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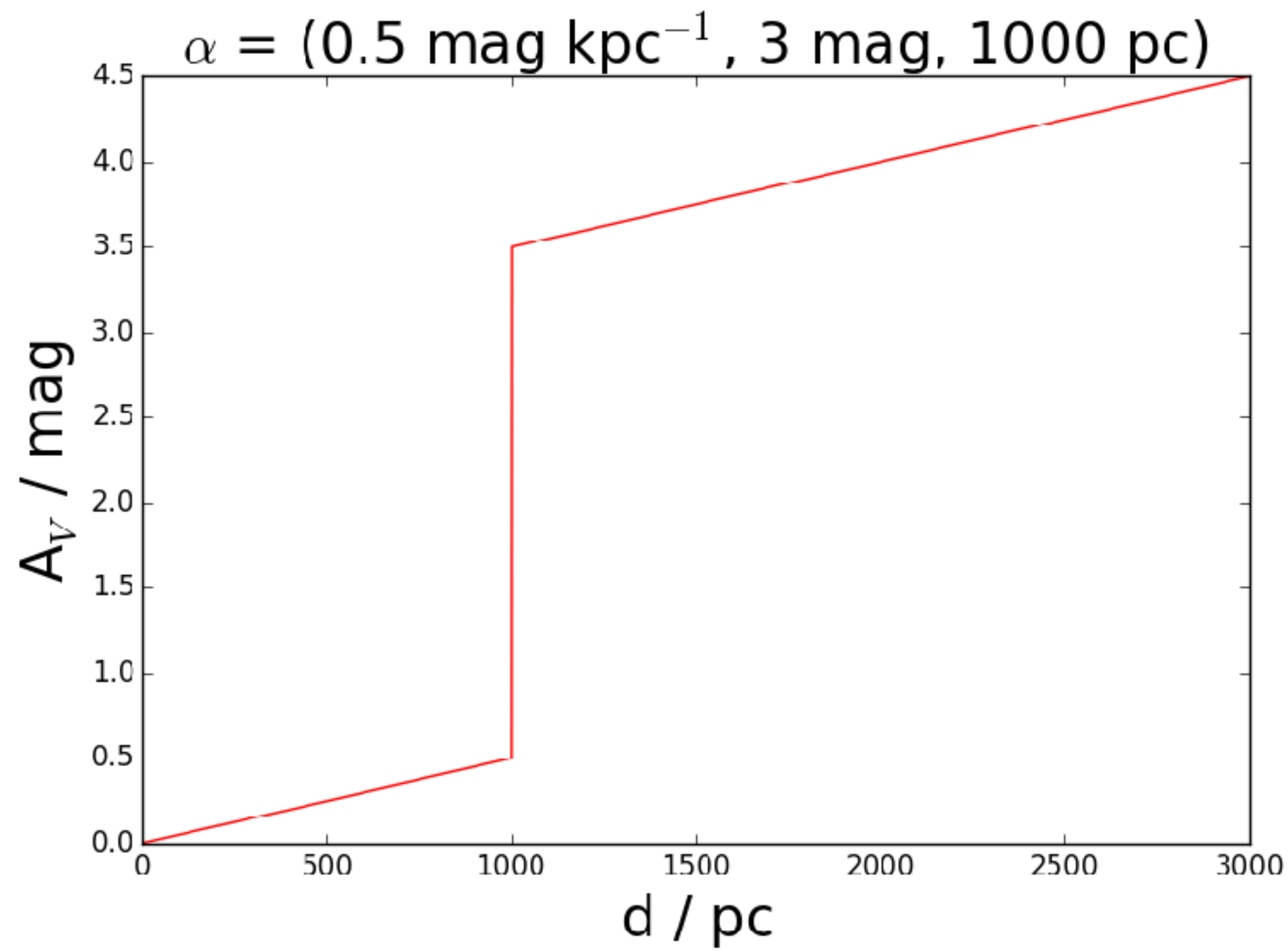
- α is the distance-extinction relationship
- Background extinction, cloud extinction jump + distance



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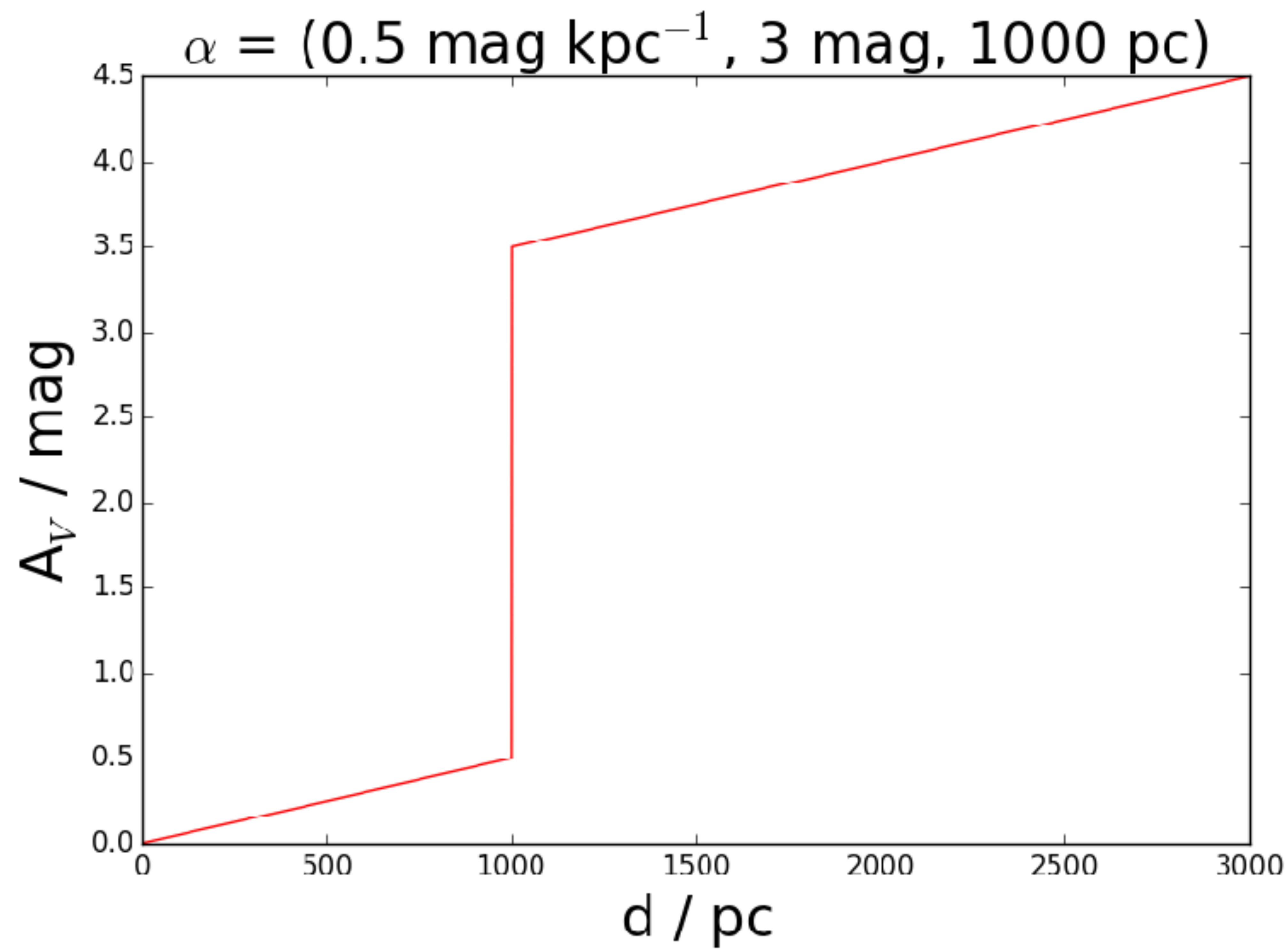
- α is the distance-extinction relationship
- Background extinction, cloud extinction jump + distance
- Require galactic model to calculate priors [1]
- Large scale galactic structure used as input model



1. Green et al, 2014, ApJ, 783, 114

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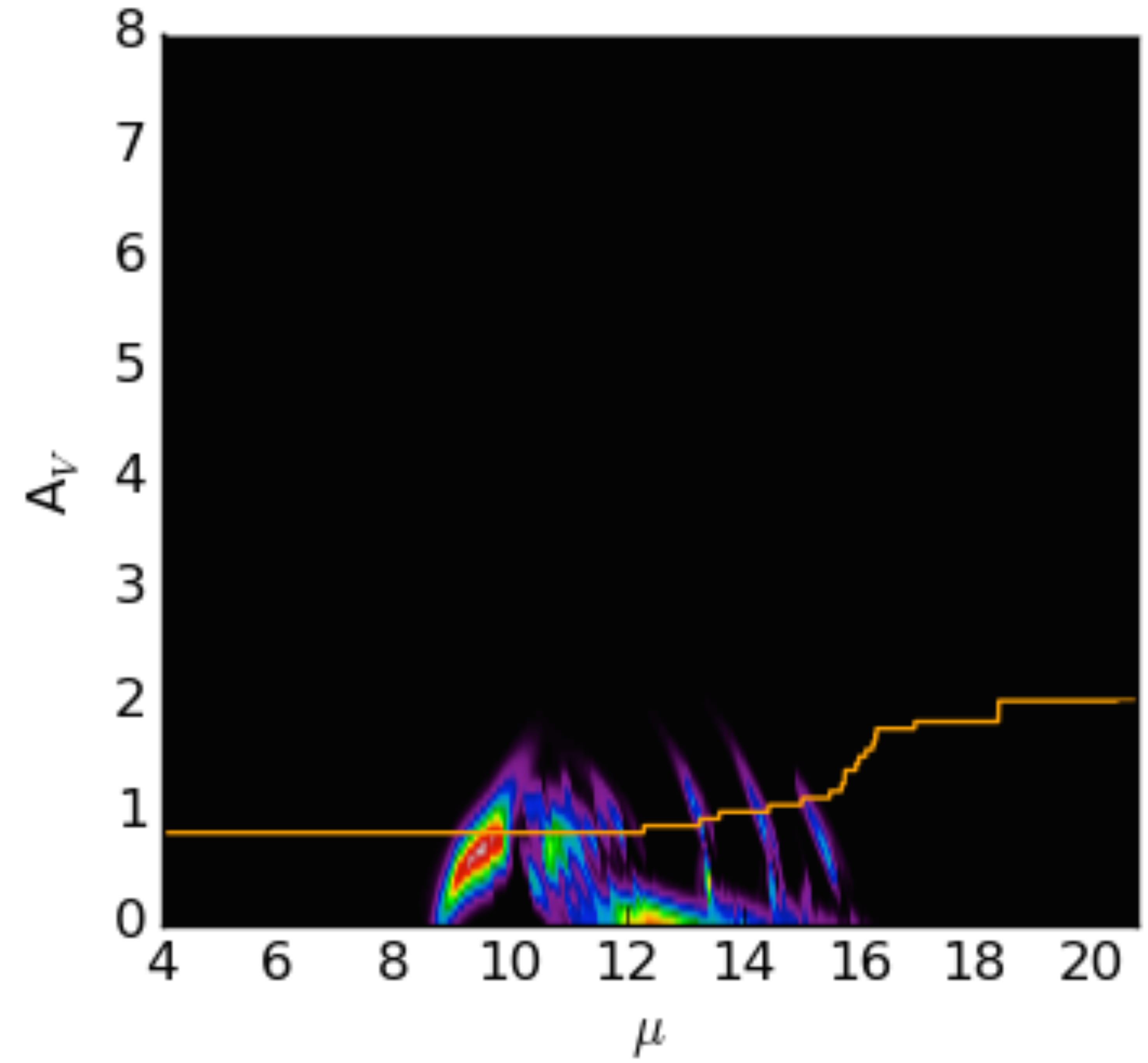
- $p(\Theta) = p([Fe/H]|\mu)\ p(\mathrm{age})\ p(M/M_\odot)$

3D Extinction – Bayesian

$$p(\alpha\,|\,\{\mathbf{m}\}) = p(\alpha)\prod_i \iint p(\mathbf{m}_i\,|\,\mu, A_V(\alpha,\mu),\Theta)\,p(\mu)\,p(\Theta)\,\mathrm{d}\Theta\,\mathrm{d}\mu$$

- $p(\Theta) = p([Fe/H]|\mu)\ p(age)\ p(M/M_\odot)$
- Marginalise over stellar parameters



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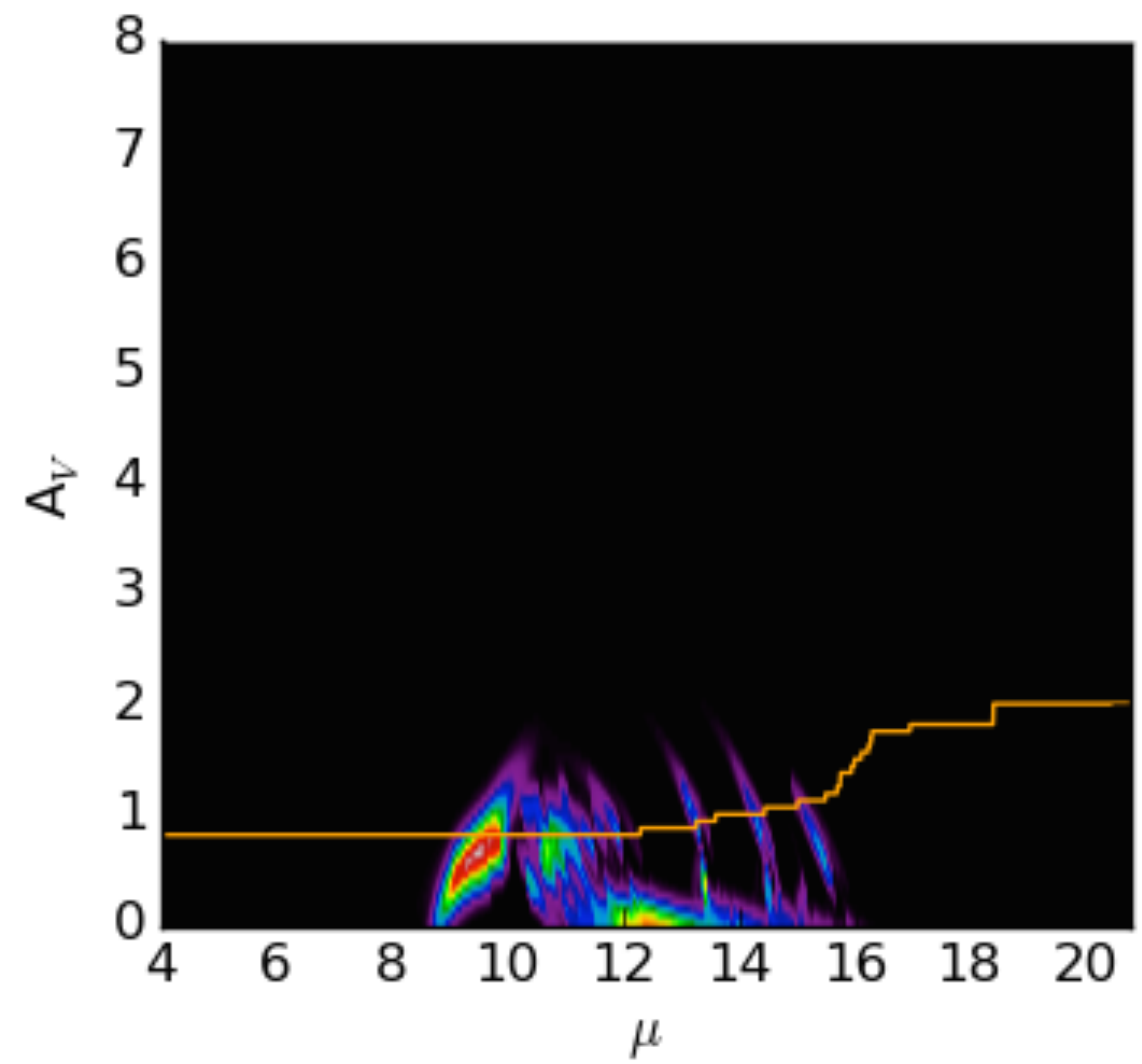
- Marginalise over stellar parameters
- Marginalise over distance, fitting for α



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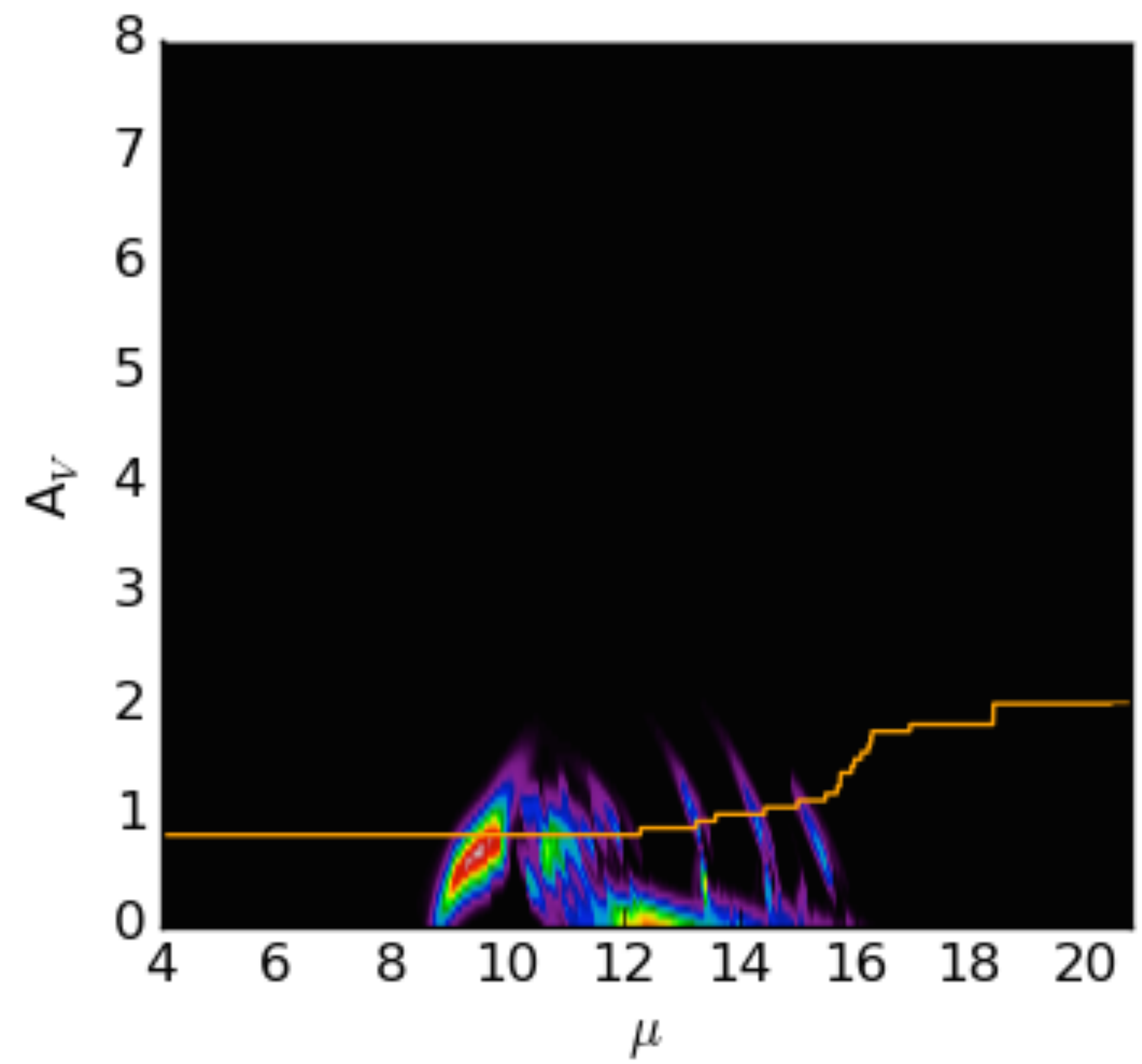
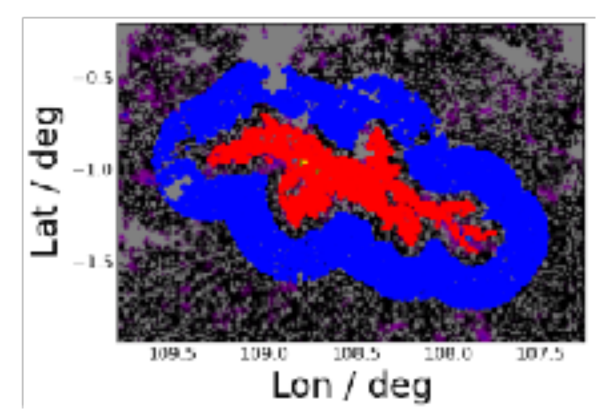
- $p(\Theta) = p([Fe/H]|\mu)\ p(age)\ p(M/M_\odot)$
- Marginalise over stellar parameters
- Marginalise over distance, fitting for α
- Multiply all stars for final probability

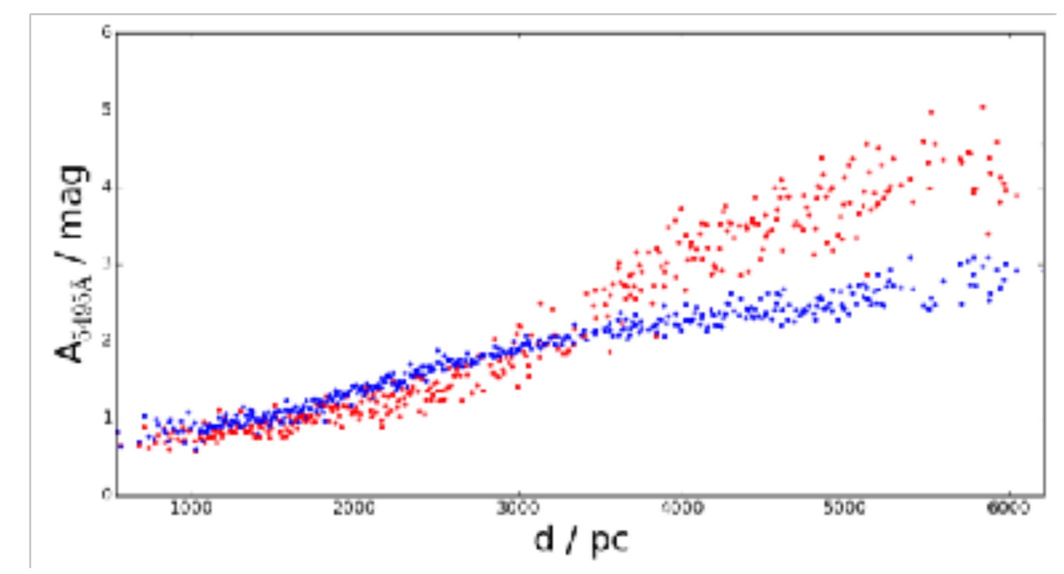


Conclusions

Conclusions

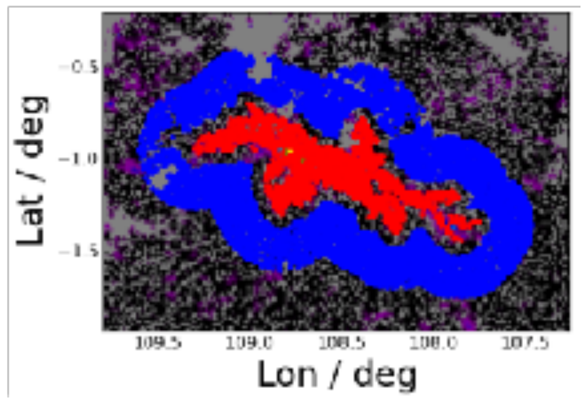
- Powerful technique to analyse galactic structure

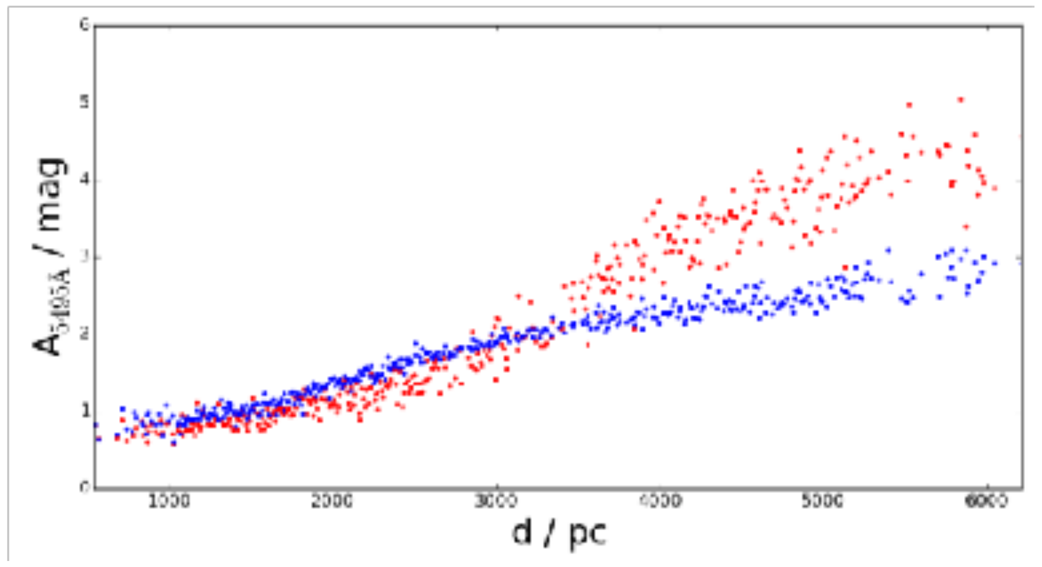




Conclusions

• Powerful technique to analyse galactic structure
• Allows for kinematics and distances simultaneously





Conclusions

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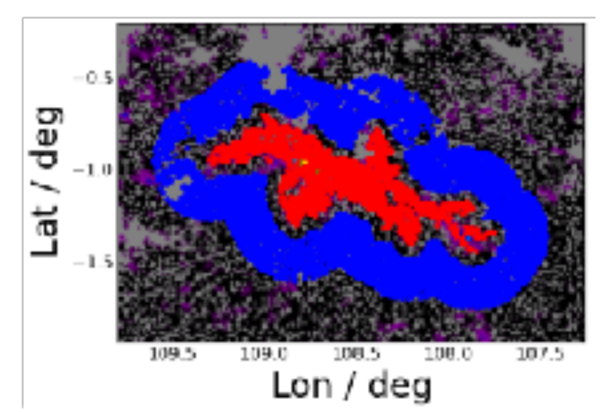

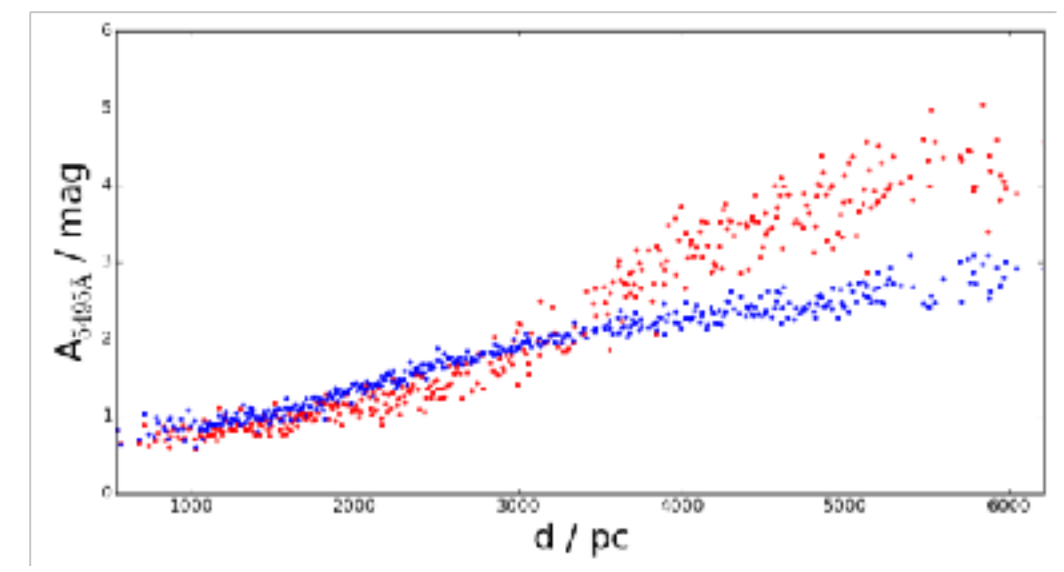

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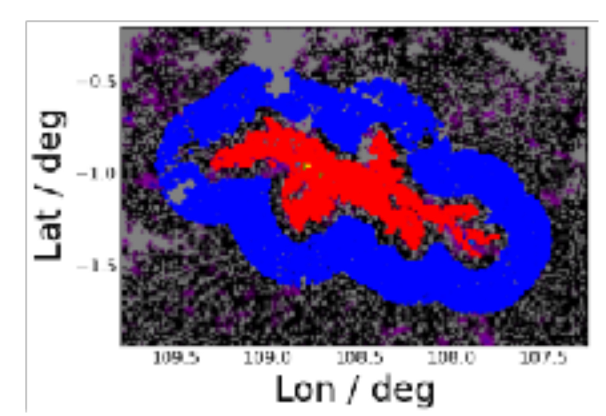

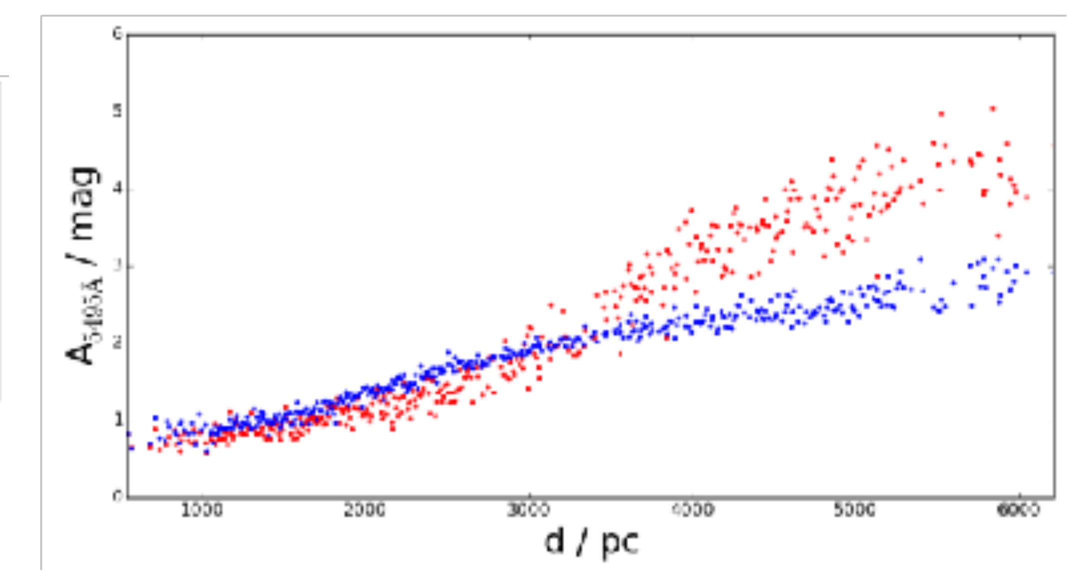

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