Another try at explaining Gutermuth color cuts

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Find me the blue peanut M&Ms!

How are you going to do this?

- You can't touch (or taste) them.
- Size?
- What if your camera isn't high enough spatial resolution?
- And what if one of the peanut ones has a small peanut, or is edge-on (to be compared with a face-on plain one)?
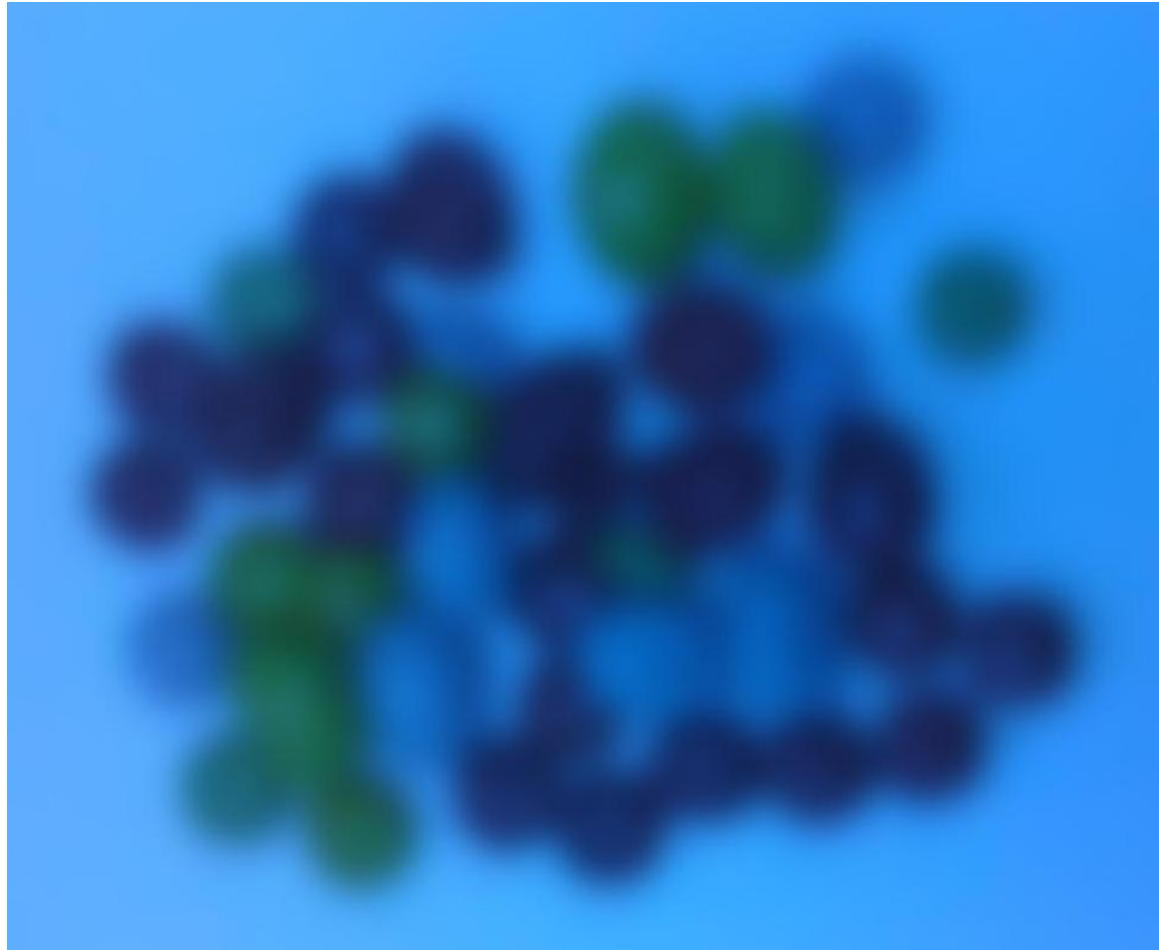
What your camera sees

How are you going to do this?

- Color?

- Flip back and forth among the following views. Notice how the different colors look different in the different filters.

- Remember that your camera really sees the blurry view.

Blue (reality)

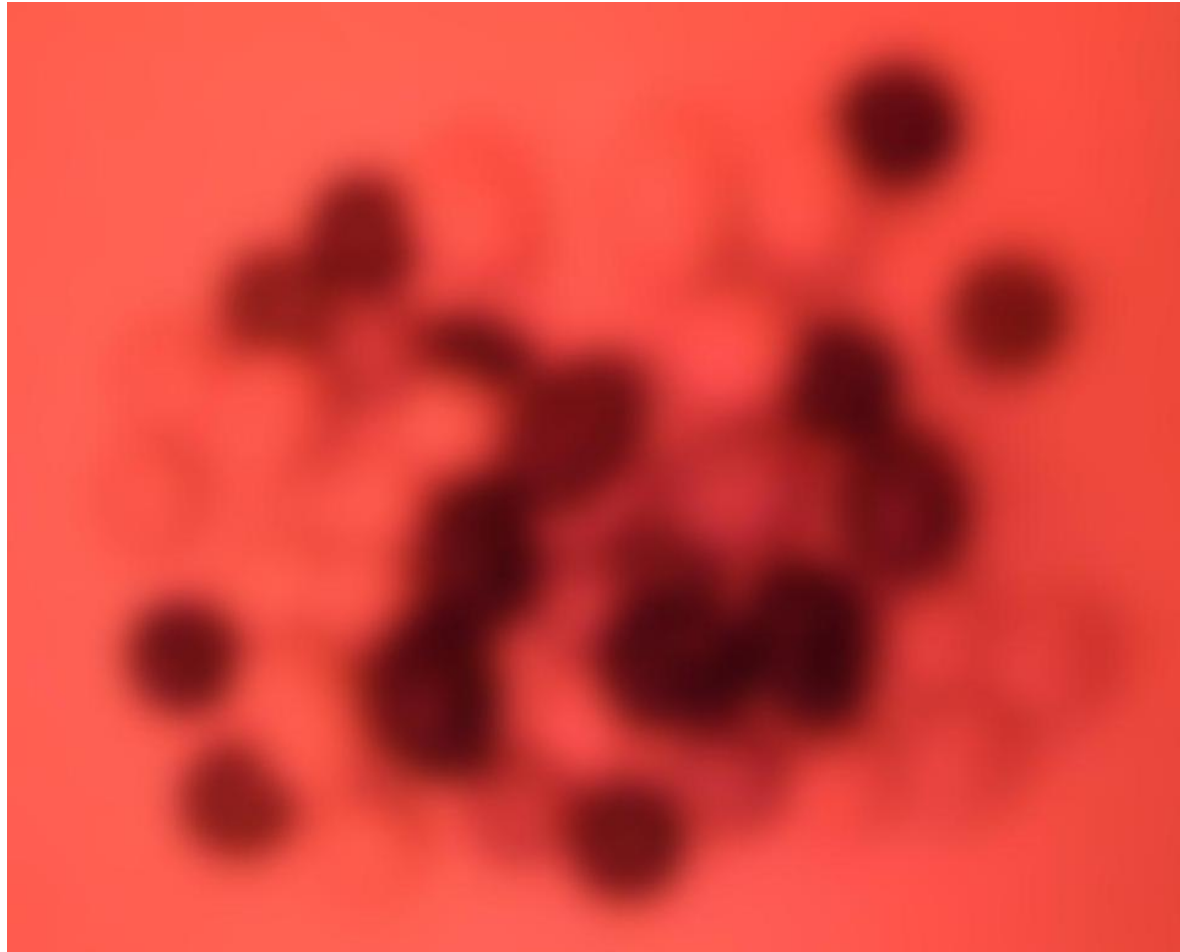# Blue (what your camera sees)

Red (reality)

Red (what your camera sees)

Green (reality)

Green (what your camera sees)

How are you going to do this?

- Now, maybe, you have a way of picking out the blue ones.

- How are you going to find the peanut ones?

- Remember, size is not enough (and NASA won't give you enough money to build a better/bigger camera).

- You need to find a "peanut wavelength" that can see inside the object.

Simulated "peanut" view

"Peanut" wavelength (camera)

Now…

- For each object in the field of view, you have an estimated brightness in each of the four colors (blue, red, green, and "peanut").

- You can compare the relative brightnesses in each combination. How many combinations are there? (I get six…)

How many combinations?

Red & Green	Red & Blue
Red & Peanut	Green & Blue
Green & Peanut	Blue & Peanut

Now…

- For each combination, can compare colors for each object (==make a plot).

- For each object, note properties of that object in that comparison.

- Then, have a big table, one entry per object, with properties of each object in each combination.

- You can then make an educated guess, based on properties in all available bands, which are the blue peanut M&Ms.

THIS is what we did in our project!

- We measured the properties of each object in all available bands.
- We made plots and compared them in many different color-color spaces. (You can do this manually, or let the computer do the comparison.)
- We made educated guesses as to which objects were likely YSOs or contaminants in each space, keeping track of which objects were which and which had which properties. (This bookkeeping is all done within the computer.)

Gutermuth method, broken down

- **Technically,** should deredden the photometry for some of these steps, but we don't have enough information to to that, and we didn't talk about this at all anyway. Should not matter too much.
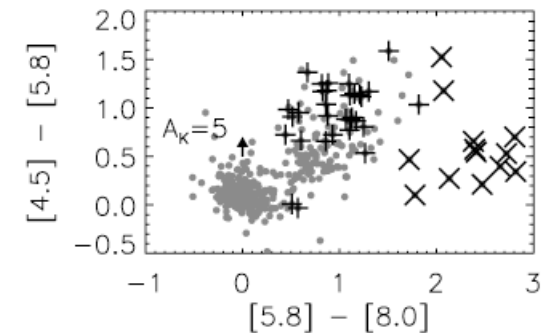
Gutermuth method, broken down

- **Drop** things that meet all of these 3 criteria

$$[4.5] - [5.8] < \frac{1.05}{1.2}([5.8] - [8.0] - 1),$$

$$[4.5] - [5.8] < 1.05,$$

$$[5.8] - [8.0] > 1.$$

Things that meet these criteria are galaxies with PAH emission.

Gutermuth method, broken down
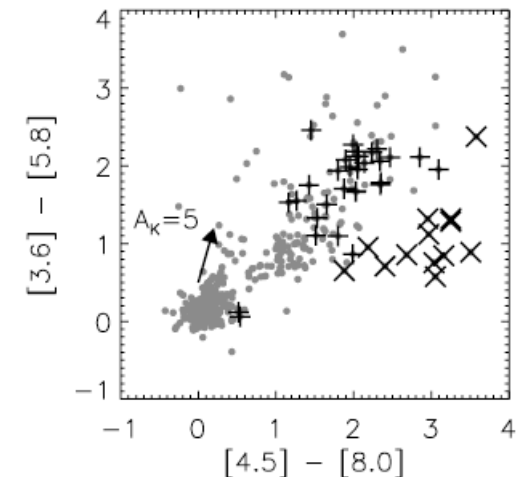
- **Drop** things that meet all of these 3 criteria

$$[3.6] - [5.8] < \frac{1.5}{2}([4.5] - [8.0] - 1),$$

$$[3.6] - [5.8] < 1.5,$$

$$[4.5] - [8.0] > 1.$$

Things that meet these criteria are also galaxies with PAH emission.

Gutermuth method, broken down

- **Drop** things that meet all of these criteria

$$[4.5] - [8.0] > 0.5,$$

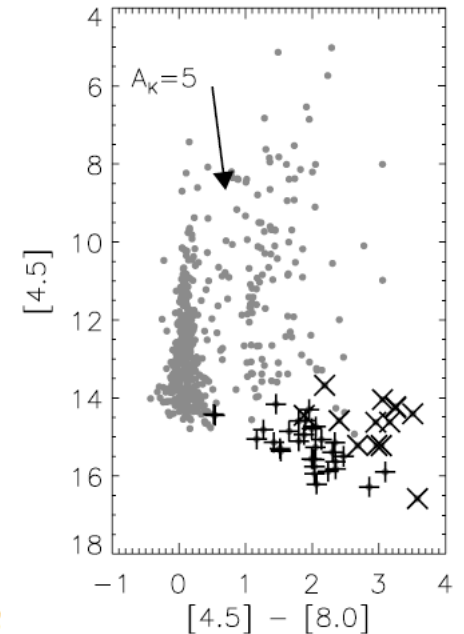$$[4.5] > 13.5 + ([4.5] - [8.0] - 2.3)/0.4,$$

$$[4.5] > 13.5.$$

- AND these as well:

$$[4.5] > 14 + ([4.5] - [8.0] - 0.5),$$

$$[4.5] > 14.5 - ([4.5] - [8.0] - 1.2)/0.3$$

$$[4.5] > 14.5.$$

Things that meet these criteria are AGN.

Gutermuth method, broken down

- **Drop** things that meet all of these 3 criteria

$$[3.6] - [4.5] > \frac{1.2}{0.55}([[4.5] - [5.8]] - 0.3) + 0.8,$$

$$[4.5] - [5.8] \leq 0.85,$$

$$[3.6] - [4.5] > 1.05.$$

Things that meet these criteria are likely unresolved blobs of dust, whose colors are dominated by shock emission.

Gutermuth method, broken down

- **Keep** things that meet all of these 3 criteria and don't fail the earlier tests.

$$[4.5] - [8.0] > 0.5,$$

$$[3.6] - [5.8] > 0.35,$$

$$[3.6] - [5.8] \leq \frac{0.14}{0.04}([[4.5] - [8.0]] - 0.5) + 0.5.$$

Things that meet these criteria are likely Class II young stars.

Gutermuth method, broken down

- **Keep** things that meet all of these 3 criteria and don't fail the earlier tests.

Flaherty et al. 2007). Sources are likely protostars if they have an extremely red discriminant color ($[4.5] - [5.8] > 1$). In addition, any sources with a moderately red discriminant color ($0.7 < [4.5] - [5.8] \leq 1.0$) that also have $[3.6] - [4.5] > 0.7$ are likely protostars (see Fig. 7), although in rare cases a highly reddened Class II source could have these colors as well.

Things that meet these criteria are likely Class 0 or I young stars.

Gutermuth method, broken down

- You can keep going. (I didn't.)
- Rest of his method provided here for completeness.
- Go to slide 32 for summary.

First we measure the line of sight extinction to each source as represented by the E_{J-H}/E_{H-K} color excess ratio, using baseline colors based on the classical T Tauri star (CTTS) locus of Meyer et al. (1997) and standard dwarf-star colors (Bessell & Brett 1988). To accomplish the latter task, we force $[J-H]_0 \geq 0.6$, a simplifying approximation for the intrinsic colors of low-mass dwarfs. These are the equations used to derive the adopted intrinsic colors from the photometry we have measured:

$$[J-H]_0 = 0.58[H-K]_0 + 0.52,$$

$$[H-K]_0 = [H-K]_{\mathrm{meas}} - \left([J-H]_{\mathrm{meas}} - [J-H]_0\right)\frac{E_{H-K}}{E_{J-H}},$$

$$[H-K]_0 = \frac{[J-H]_{\mathrm{meas}} - [E_{J-H}/E_{H-K}][H-K]_{\mathrm{meas}} - 0.52}{0.58 - [E_{J-H}/E_{H-K}]}.$$

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Once we have measured the component of the $H - K$ color excess that is caused by reddening, we compute the dereddened $K - [3.6]$ and $[3.6] - [4.5]$ colors using the color excess ratios presented in Flaherty et al. (2007), specifically $E_{J-H}/E_{H-K} = 1.73$, $E_{H-K}/E_{K-[3.6]} = 1.49$, and $E_{H-K}/E_{K-[4.5]} = 1.17$:

$$[K - [3.6]]_0 =$$

$$[K - [3.6]]_{\mathrm{meas}} - ([H - K]_{\mathrm{meas}} - [H - K]_0) \frac{E_{K-[3.6]}}{E_{H-K}},$$

$$[[3.6] - [4.5]]_0 =$$

$$[[3.6] - [4.5]]_{\mathrm{meas}} - ([H - K]_{\mathrm{meas}} - [H - K]_0) \frac{E_{[3.6]-[4.5]}}{E_{H-K}},$$

$$\frac{E_{[3.6]-[4.5]}}{E_{H-K}} = \left(\left[\frac{E_{H-K}}{E_{K-[4.5]}} \right]^{-1} - \left[\frac{E_{H-K}}{E_{K-[3.6]}} \right]^{-1} \right)^{-1}.$$

Gutermuth method, broken down

- Having done the prior two steps, add things meeting all of these criteria to the YSO list.

$$\sigma_1 = \sigma[[3.6] - [4.5]]_{\mathrm{meas}},$$

$$\sigma_2 = \sigma[[K] - [3.6]]_{\mathrm{meas}};$$

$$[[3.6] - [4.5]]_0 - \sigma_1 > 0.101,$$

$$[K - [3.6]]_0 - \sigma_2 > 0,$$

$$[K - [3.6]]_0 - \sigma_2 > -2.85714\big([[3.6] - [4.5]]_0 - \sigma_1 - 0.101\big) + 0.5.$$

All sources classified as Class II with this method must have $[3.6]_0 < 14.5,$

Things that meet these criteria are likely Class II young stars.

Gutermuth method, broken down

- Add objects that meet all criteria on prior slide, plus these criteria, to the YSO list.

$$[K - [3.6]]_0 - \sigma_2 > -2.85714([[3.6] - [4.5]]_0$$
$$- \sigma_1 - 0.401) + 1.7.$$

All sources classified as protostars must have $[3.6]_0 < 15$.

Things that meet these criteria are likely Class 0/I young stars.

Gutermuth method, broken down

- Add objects that meet all criteria on prior slide, plus these criteria, to the YSO list.

dominated sources flagged in § 4.1. We reinclude flagged sources as likely protostars if they have both bright MIPS 24 μm photometry ($[24] < 7$, as before) and convincingly red IRAC/MIPS colors ($[3.6] - [5.8] > 0.5$ and $[4.5] - [24] > 4.5$ and $[8.0] - [24] > 4$).

Gutermuth method, broken down

- Check everything on the YSO list.

Finally, all previously identified protostars that have 24 μm detections are checked to ensure that their SEDs do indeed continue to rise from IRAC to MIPS wavelengths. All protostars that have MIPS detections must have $[5.8] - [24] > 4$ if they possess 5.8 μm photometry, otherwise they must have $[4.5] - [24] > 4$.

What we did

- We did the Gutermuth method up to slide 26.
- This provides an IRAC-based selection.
- We cannot deredden (we don't have enough information), so we can't do his JHK steps.
- We did not add things that are MIPS-only; they just fell out of the IRAC selection.
- We took that initial, automatic cut that produced a short list of objects and looked at each and every one of those objects.
- The ones we dropped were computer glitches of one sort or another (duplicate sources, sources in galaxy).
- We looked at the SED for each one, and assessed it for quality (like Gutermuth does too).