

A photograph of two lion cubs in a savanna setting. One cub is on the left, facing right, and the other is on the right, facing left. They are both on their hind legs, reaching towards each other with their front paws. The background is a blurred green field with some taller grass. The text 'AST0212 – 2016-1' is overlaid in large yellow letters across the middle of the image.

# AST0212 – 2016-1

Introducción al análisis de datos

Instituto de Astrofísica

Facultad de Física

Pontificia Universidad Católica de Chile

# Nuestro Semestre 2016-1

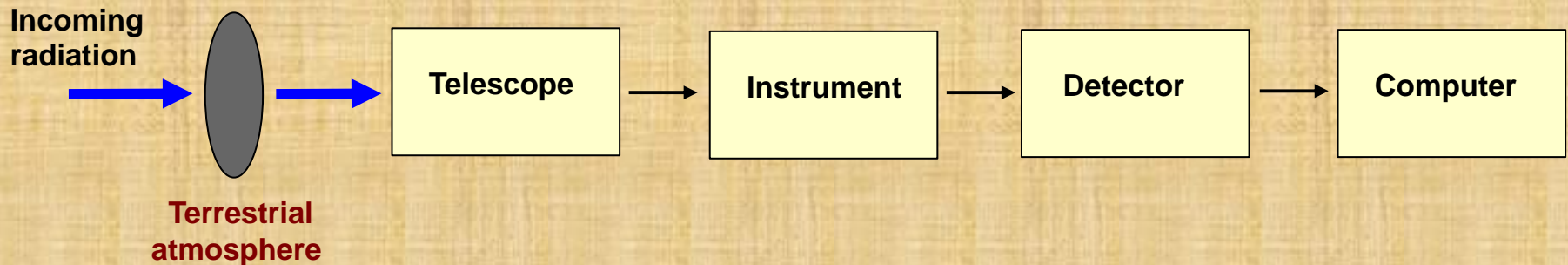
| AST0212   |            |  |                    | C0 ✓      |                   |                                      |
|---|------------|--|--------------------|-----------|-------------------|--------------------------------------|
| Sunday  | Monday     | Tuesday  | Wednesday          | Thursday  | Friday            | Saturday                             |
| 6 Mar 2016<br>Semana 1                                  | 7          | 8  | 9                  | 10        | 11<br>C1 ✓        | 12                                   |
| 13<br>Semana 2  | 14<br>TL1  | 15<br>TM1  | 16                 | 17        | 18<br>C2 ✓        | 19<br>← Control 1<br>Reparto Tarea 1 |
| 20<br>Semana 3  | 21<br>TL2  | 22<br>TM2  | 23                 | 24        | 25<br>Feriado     |                                      |
| 27<br>Semana 4  | 28<br>TL3  | 29<br>TM3  | 30                 | 31        | 1 Apr<br>C3 ✓     |                                      |
| 3<br>Semana 5   | 4<br>TL4   | 5<br>TM4   | 6                  | 7         | 8<br>C4 ✓         |                                      |
| 10<br>Semana 6  | 11<br>TL5  | 12<br>TM5  | 13                 | 14        | 15<br>C5 ✓        | 16<br>← Control 2                    |
| 17<br>Semana 7  | 18<br>TL6  | 19<br>TM6  | 20                 | 21        | 22<br>C6 ✓ – SM ✗ | 23<br>← Reparto T2                   |
| 24<br>Semana 8  | 25<br>TL7  | 26<br>← Entrega T1                                       | 27                 | 28        | 29<br>C7 ✓ – SM ✗ |                                      |
| 1 May<br>Semana 9                                       | 2<br>TL8   | 3<br>TM8   | 4                  | 5         | 6<br>C8 ✓ – SM ✗  | 7                                    |
| 8<br>Semana 10  | 9<br>TL9   | 10<br>Entrega T2 →                                       | 11                 | 12        | 13<br>C9 ✓ – SM ✗ | 14                                   |
| 15<br>Reparto T3 →                                      | 16<br>TL10 | 17<br>TM10   | 18                 | 19        | 20<br>C10         | 21<br>← Control 3                    |
| 22<br>Semana 12   | 23<br>TL11 | 24<br>TM11   | 25<br>Entrega T3 → | 26<br>C11 | 27<br>Feriado     | 28                                   |
| 29<br>Semana 13   | 30<br>TL12 | 31<br>TM12   | 1 Jun              | 2         | 3<br>C12          | 4<br>← Control 4                     |
| 5<br>Semana 14  | 6<br>TL13  | 7<br>TM13  | 8                  | 9         | 10<br>C13         | 11                                   |
| 12<br>Semana 15   | 13<br>TL14 | 14<br>TM14   | 15                 | 16        | 17                | 18                                   |
| 19  | 20         | 21   | 22                 | 23        | 24                | 25                                   |
| 26<br>Tutorías día lunes<br>Módulo 4:<br>Nicolás Castro | 27         | 28<br>Tutorías día martes<br>Módulo 6:<br>Francisco Aros | 29                 | 30        | 31<br>Notas       | 1 Jul<br>← Examen                    |

# Esta clase (Clase 11):

## 1. Imágenes Astronómicas



## Structure of an **observing system**



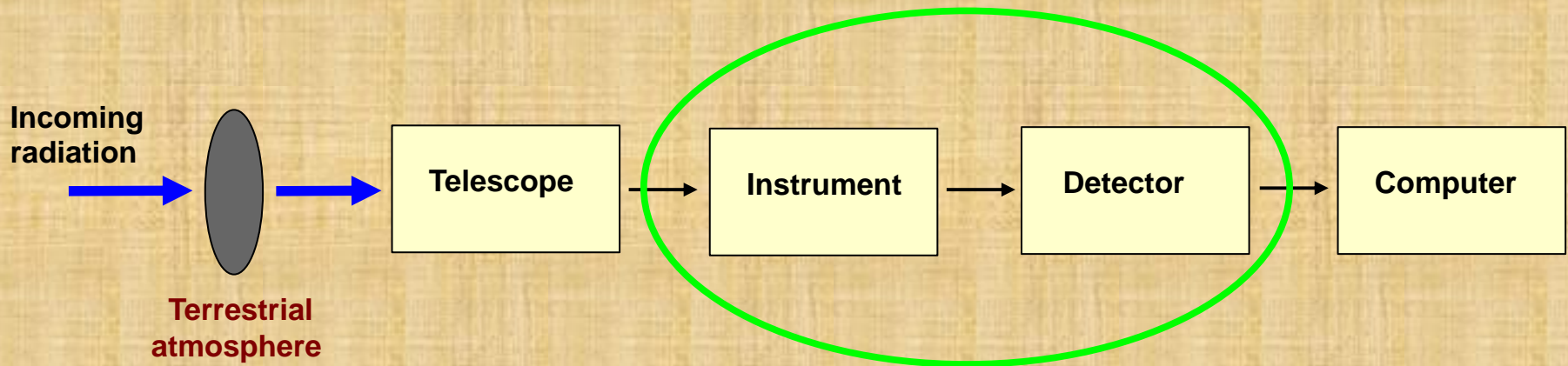
The **Telescope** has the purpose of collecting as much light as possible from the source, and of separating the light from nearby sources on the sky.

The **Instrument** has the purpose of forming an image or a spectrum, isolating photons of a given range of wavelengths. It is usually an imaging camera or a spectrograph.

The **Detector** (usually an optical CCD or a near-IR array) records and counts the photons that pass through the telescope + instrument.

The **Computer** controls the telescope & detector and stores the collected information.

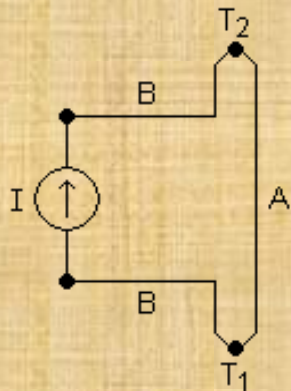
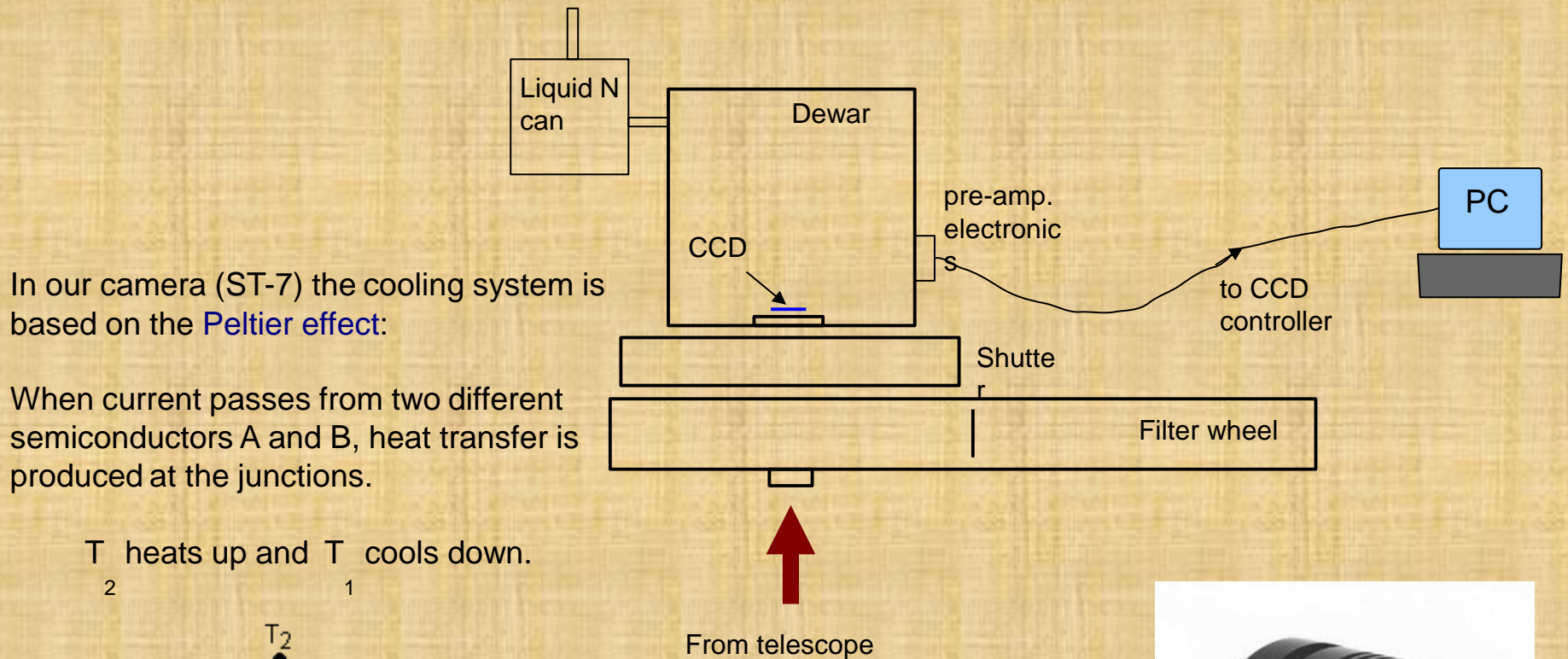
## Structure of an **observing system**



The **Instrument** has the purpose of forming an image or a spectrum, isolating photons of a given range of wavelengths. It is usually an imaging camera or a spectrograph.

The **Detector** (usually an optical CCD or a near-IR array) records and counts the photons that pass through the telescope + instrument.

# Most simple instrument: Imaging Camera



Our ST-7 camera



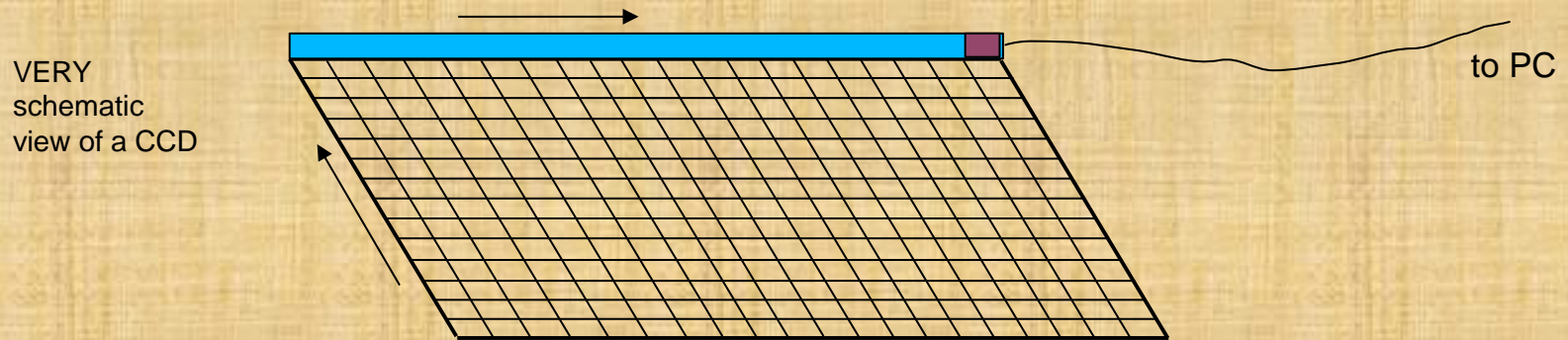
**Picture of a CCD Detector: (one of the 8 IMACS CCDs at Magellan Telescope)**





## Modern Astronomical Detectors: Charged Coupled Devices (CCD)

A CCD is a Digital Detector very similar to that of commercial Digital Photographic Cameras. It consists of an integrated circuit containing an array of pixels (*capacitors*), each one sensitive to photons, each one capable of recording how many photons have hit it.



The size of a CCD is normally  $\sim 1\text{--}4$  cm per side, and they normally have between  $\sim 1000 - 4000$  pixels per side (each pixel is then  $10\text{--}20$  microns large).



## The physics of a CCD:

**SEMICONDUCTOR:** material whose valence electrons cannot move (conduct) between one atom and the next. However, if the electrons acquire some extra energy, they can jump to the *conduction band*, where they can be transferred from one atom to the next. This extra-energy can be provided by a photon.

### DOPING OF A SEMICONDUCTOR:

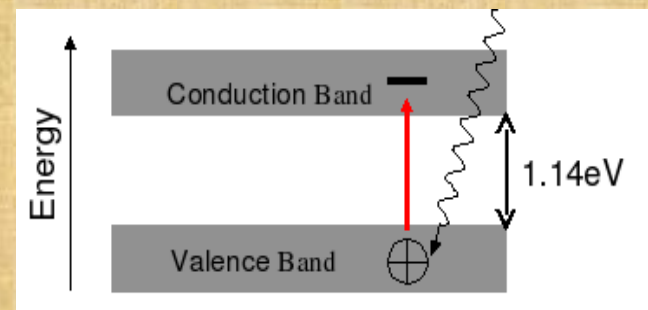
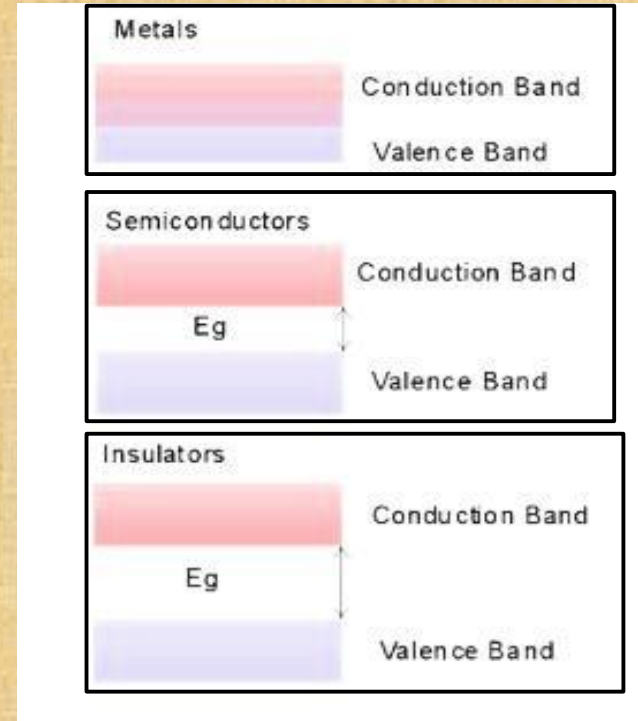
The electric properties of a semiconductor can be altered by adding some atoms to them.

**n doping:** atoms with more than 4 valence electrons are added.

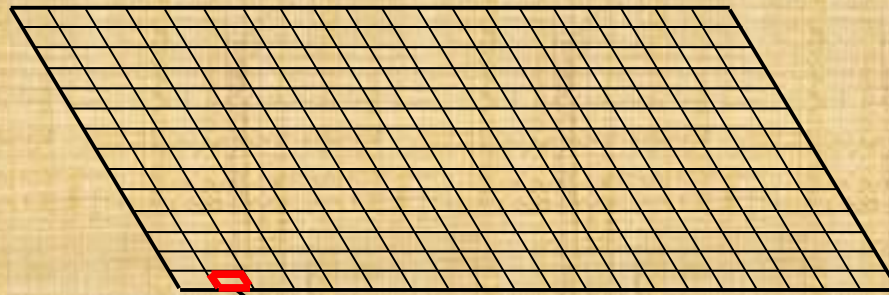
The extra electrons occupy the conduction band, creating a persistent set of negative charges.

**p doping:** atoms with less than 4 valence electrons are added.

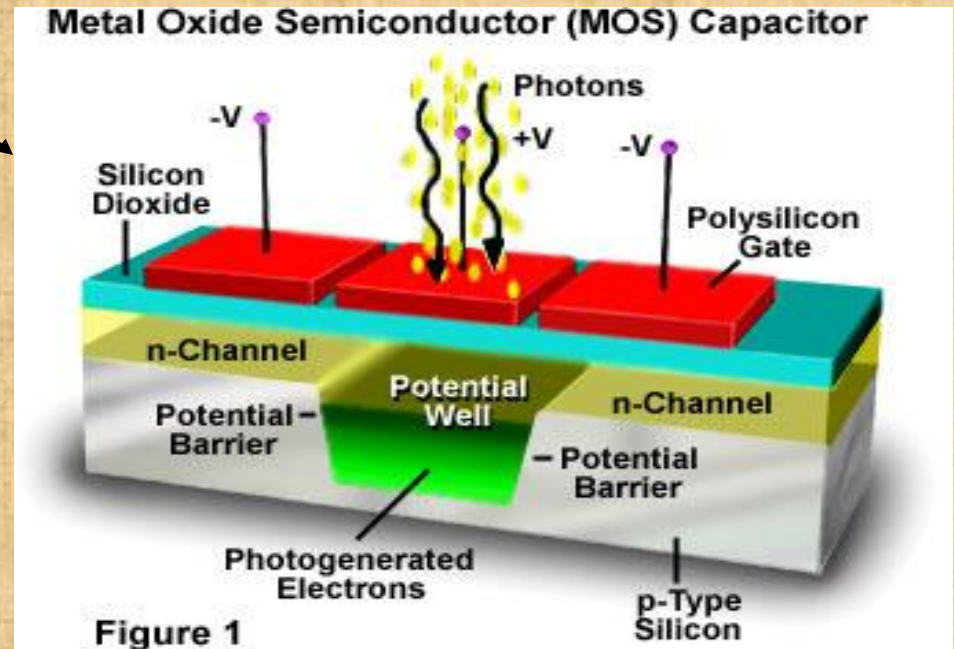
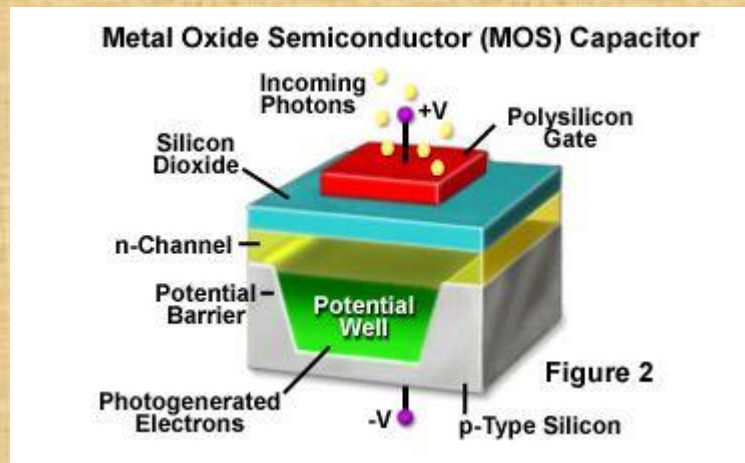
Electrons from the conducting bands go to occupy the extra *holes* in the valence band. This creates a persistent set of positive charges.



# Modern Astronomical Detectors: Charged Coupled Devices (CCD)

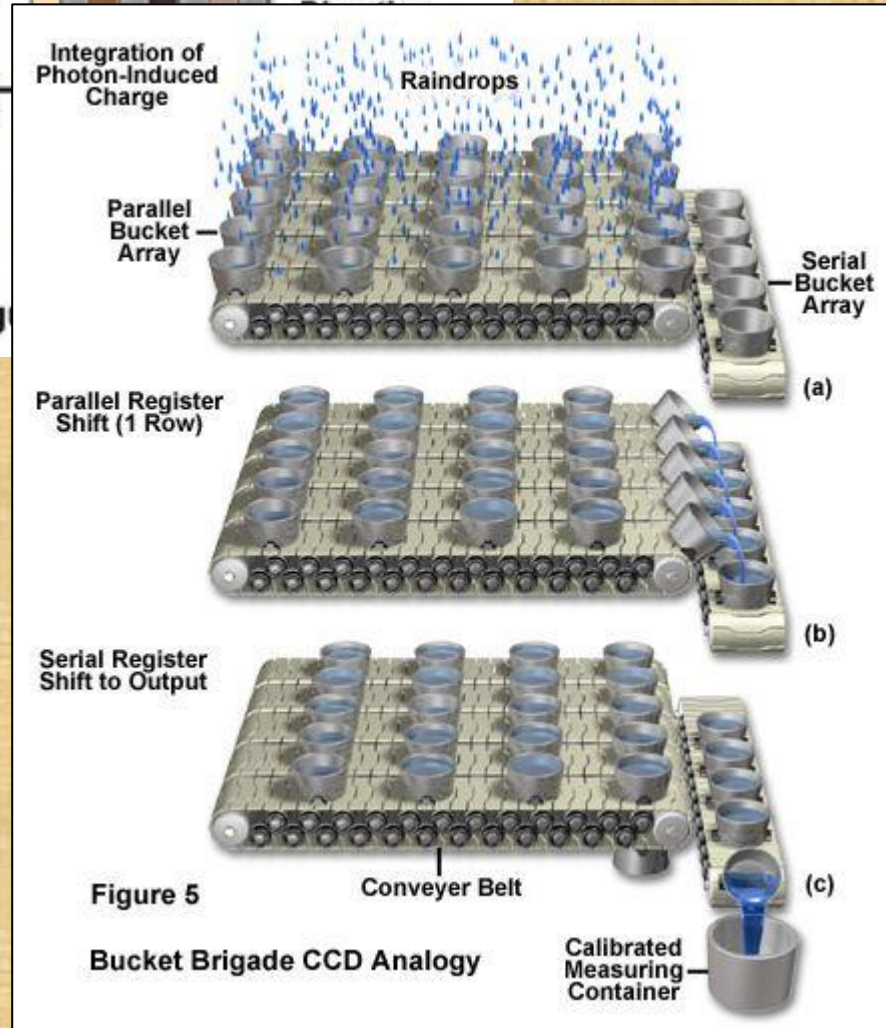
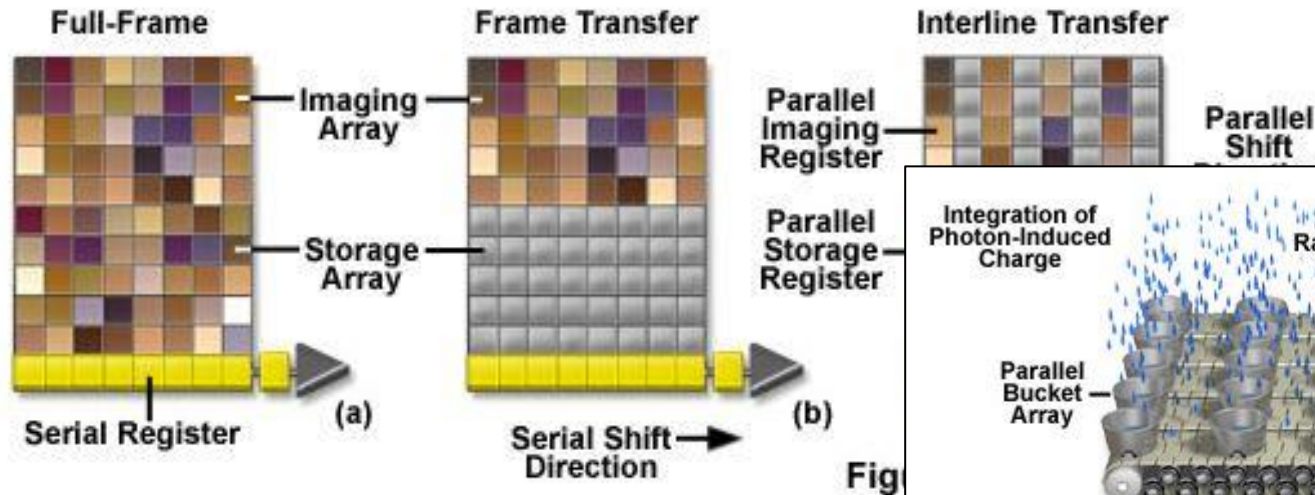


1 pixel



# Typical architecture of CCD Detectors

## Common Charge-Coupled Device (CCD) Architectures





# Main characteristics of a CCD

**Quantum Efficiency:** Ratio of incident energy to detected energy (as measurable charge).

Typical peak values:

|                     |         |
|---------------------|---------|
| Eye:                | 1-2 %   |
| Photographic plate: | 1-2 %   |
| CCDs :              | 70-90 % |
| Near-IR det. :      | 30-50 % |

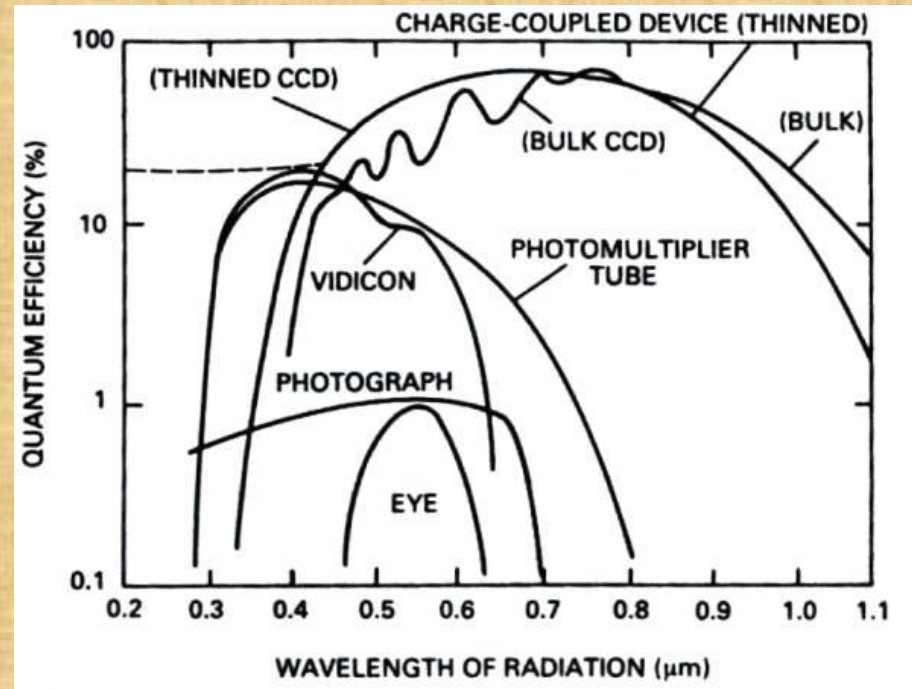
**Pixel Size:** The smaller the better (microns).

**Spectral range:** Range over which Q.E. is high enough for reasonable operation.

**Readout Noise (RON):** noise introduced by the electronics while reading each pixels (in electrons)

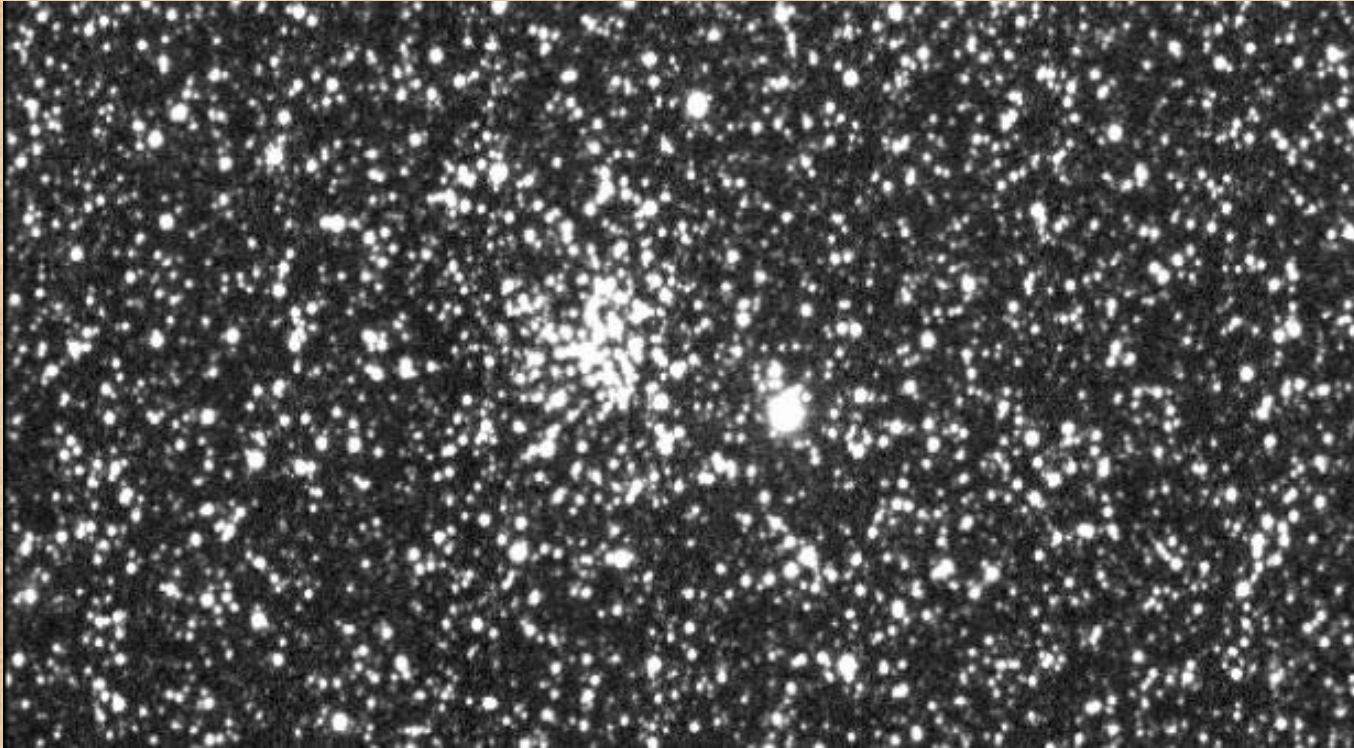
**Gain:** Conversion factor between incident photons and recorded Analog to Digital Units (ADUs). Given in electrons/ADU

**Dynamic range/saturation:** ratio of maximum to minimum detectable signal *within linear range* (given at times approximately as ADU of saturation)





# Imagen astronómica CCD “cruda”



Eventualmente obtenemos una imagen digital que podemos desplegar en un computador. Pero esa imagen NO es la que ingresó por la pupila del telescopio. Está contaminada con señales espurias, impresas por la óptica del telescopio y la electrónica del CCD (el ejemplo es una de las que usarán en la Tarea 4).

Fin de ppt de Clase 11